DES Waste Management Division
29 Hazen Drive; PO Box 95
Concord, NH 03302-0095

Type I-A Permit Modification to Solid Waste Management Facility Permit
Phase IV – Four Hills Landfill
Nashua, New Hampshire

NHDES Site #: 198403099
Project Number: 4905

Prepared For:
City of Nashua
Nashua Division of Public Works,
Solid Waste Division
840 West Hollis Street
Nashua, NH 03062
Phone Number (603) 589-3410
RP Contact Name: Kerry Converse
RP Contact Email: ConverseK@nashuanh.gov

Prepared By:
Sanborn, Head & Associates, Inc.
20 Foundry Street
Concord, NH 03301
Phone Number: (603) 415-6132
Contact Name: Edward A. Galvin
Contact Email: egalvin@sanbornhead.com

Sanborn, Head & Associates, Inc.
Digitally signed by Sanborn, Head & Associates, Inc.
Date: 2020.07.17 14:54:00 -04'00'

Date of Report: July 17, 2020

SANBORN HEAD

Building Trust. Engineering Success.

TYPE I-A PERMIT APPLICATION FOR SOLID WASTE MANAGEMENT FACILITY

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Nashua
NEW HAMPSHIRE'S GATE CITY

Prepared for the City of Nashua
File No. 3066.11
July 2020

SANBORN HEAD
Building Trust. Engineering Success.

20 Foundry Street
Concord, NH 03301

Jamie Colby
Solid Waste Management Bureau
NH Department of Environmental Services
29 Hazen Drive
Concord, NH 03302-0095

July 17, 2020
File No. 3066.11

Re: Type I-A Modification to Solid Waste Management Facility Permit Application
Phase IV – Four Hills Landfill
Nashua, New Hampshire
Permit No. DES-SW-SP-95-002

Dear Jaime:

On the behalf of the City of Nashua, Sanborn Head is submitting the enclosed application for a Type I-A Modification to Solid Waste Management Facility Permit (Type I-A PMA) for the Phase IV Expansion at the Four Hills Landfill (Landfill). The Type I-A PMA presents the design for a new lined disposal area at the Landfill, which will be located between the closed unlined landfill and Phases I and II.

The enclosed application was prepared in accordance with the New Hampshire Solid Waste Rules. The project includes the construction of liner, leachate collection and conveyance, landfill gas (LFG), and stormwater management systems. The approved project will secure approximately 30 years of safe and efficient solid waste disposal capacity for the City.

The City and Sanborn Head appreciate your timely review of this application. Please do not hesitate to contact Eddie at (603) 415-6132 or egalvin@sanbornhead.com should you require additional information.

Very truly yours,
SANBORN, HEAD & ASSOCIATES, INC.

Edward A. Galvin

Edward A. Galvin, PE
Project Manager

Eric S. Steinhauser

Eric S. Steinhauser, PE, CPESC, CPSWQ
Senior Vice President

ESS/EAG:ess

Enclosure: Type I-A Modification to Solid Waste Management Facility Permit Application

Copies to: Lisa Fauteux, City of Nashua w/o enclosure
Jeff Lafleur, City of Nashua w/o enclosure
Kerry Converse, City of Nashua

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NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Waste Management Division

For Office Use Only:
WMD Log #:_____________________________
Date Rec'd.:_____________________________
No. of Copies:___________________________
Fee: $______________/Check #_____________

APPLICATION FORM FOR

TYPE I MODIFICATION TO SOLID WASTE MANAGEMENT FACILITY PERMIT

pursuant to
RSA 149-M and New Hampshire Administrative Solid Waste Rule Env-Sw 315

SECTION I. FACILITY IDENTIFICATION

(1)	Facility name: Four Hills Landfill
(2)	Functional classification: ☐ collection/storage/transfer ☐ processing/treatment ☒ landfill
(3)	Mailing address: 840 West Hollis Street, Nashua, NH 03062
(4)	Permit number: DES-SW-SP-95-002
(5)	Location, by street address and municipality: 840 West Hollis Street, Nashua, NH 03062

SECTION II. PERMITTEE IDENTIFICATION

(1)	Permittee/applicant name: City of Nashua - Lisa M. Fauteux, Director Division of Public Works			
(2)	Mailing address: 9 Riverside Street, Nashua, NH 03062			
(3)	Telephone number: 603-589-3140			
(4)	If different than above, identify the individual associated with and designated by the permittee/applicant to be the contact individual for matters concerning this application:			
	(a) Name: Kerry Converse		(b)	Title: Environmental Engineer
	(c) Mailing address: 840 West Hollis Street, Nashua, NH 03062			
	(d) Telephone number: 603-589-3420	(e)	E-Mail: conversek@nashuanh.gov	

SECTION III. DESCRIPTION OF PROPOSED MODIFICATION

Describe the proposed modification by answering each of the following questions. Use additional paper as necessary.

(1) Provide a **BRIEF** description of the proposed modification. [Check box if response is provided on separate paper ☒]
Please see attached Additional Information

(2) Identify whether the proposed modification is a "type I-A" or "type I-B" modification. (If uncertain, use the worksheet provided with the instructions for this form): ☒ Type I-A ☐ Type I-B

(3) Identify, either below or on separate paper, each written permit condition that will require amendment to effect the proposed modification and provide draft language for the same. [Check box if response is provided on separate paper ☐]
This application does not seek an amendment to the existing permit.

(4) Identify, below, each "last approved plan of record" identified in the permit which will be affected by the proposed modification and will therefore require amendment/revision:

Check here if affected	**TYPE OF PLAN**	**DES APPROVAL DATE**	**WMD LOG #** **(Find this number on your copy of the approval)**
☒	Facility design plans/specifications	August 2, 2019	199700397, 199800059, 2019-43165-01, 2019-43165-02, 2019-43165-03
☒	Facility operating plan	April 10, 2020	2020-45245-01
☒	Facility closure plan	April 10, 2020	2020-45225-01
☒	Facility financial assurance plan	April 10, 2020	2020-45265-01
☐	Other plan (specify):		

(5)	Submit, on separate paper, the proposed amendments/revisions for each document identified pursuant to (4) above, based on the below listed instructions. (Note: The revisions may be presented in the form of replacement pages ready for substitution into the last approved plan of record, each page being clearly marked to show the date of revision. In the event there is no last approved plan of record for any of the following, you must prepare and submit a full plan, including the proposed modification(s), in accordance with the applicable cited <u>Rules</u>.)	
	☒	Facility design plans must be prepared in accordance with Env-Sw 1103.05.
	☒	Facility operating plans must be prepared in accordance with Env-Sw 1105.11.
	☒	Facility closure plans must be prepared in accordance with Env-Sw 1106.04.
	☒	Financial assurance plans must be prepared as specified in Env-Sw 1400 and must include all related draft financial assurance documents required to effect the proposed modification.
(6)	In order for DES to approve the proposed modification, the agency must be able to conclude from the information provided in this application that the proposed modification meets all applicable requirements of the Rules. Therefore, for any aspect of the proposed modification where it may not be self-evident that the proposed change meets all applicable requirements of the Rules, you should explicitly provide such information. Provide your response below and/or use separate paper as necessary. (Check box if response is attached on separate paper ☐)	
	Not applicable. This permit application is formated to explicity provide the required information.	

SECTION IV. SCHEDULE

Provide a proposed schedule for implementing the modification. Use separate paper if necessary. (Check box if response is attached on separate paper ☒)

Please see attached Additional Information

SECTION V. STATEMENT OF NEED

Provide a statement of need describing why the proposed change is necessary or desirable. Use separate paper if necessary. (Check box if response is attached on separate paper ☒)

Please see attached Additional Information

SECTION VI. IMPACT EVALUATION

On separate paper, identify all impacts, both positive and adverse, which the proposed modification will have, including each of the below listed considerations.

(1) The effect the modification will have on facility function, capacity, life expectancy, service type and service area.

(2) The effect the modification will have on the environment, public health and safety.

(3) The effect the modification will have on the state's ability to achieve the goals and objectives specified in RSA 149-M:2, namely achieving a 40% minimum weight reduction in the solid waste stream on a per capita basis by the year 2000 and avoiding the disposal of recyclable materials in a lined landfill with a leachate collection system.

(4) The effect the modification will have on establishing and maintaining integrated waste management systems consistent with the hierarchy of waste management methods in RSA 149-M:3 [the methods, in descending order of preference as specified in RSA 149-M:3, are: source reduction; recycling and reusing; composting; waste-to-energy technologies (including incineration), incineration without resource recovery; and landfilling].

(5) Consistency with the state solid waste management plan and the applicable district plan, pursuant to RSA 149-M:12,I(b). If necessary, contact the P&DRS at (603) 271-2925 for plan information.

SECTION VII. PUBLIC BENEFIT DEMONSTRATION

Provide a "demonstration of public benefit" based on the below listed instructions. Check which one of the listed instructions applies to your particular application.

☒	**For a type I-A modification of a standard permit**, provide a "demonstration of public benefit" in accordance with RSA 149-M:11 and in conformance with the provisions of Env-Sw 1005.05. Prepare and submit the demonstration on separate paper.
☐	**For a type I-A modification of an emergency permit or a research and development permit, or a permit-by-notification**, there is a presumption of public benefit, provided that the proposed modification meets all requirements of the Rules. Therefore, you may skip this section and go to Section VIII.
☐	**For a type I-B modification**, there is a presumption of public benefit, provided that the proposed modification meets all requirements of the Rules. Therefore, you may skip this section and go to Section VIII.

SECTION VIII. OTHER PERMITS

Complete the following table to identify and provide the status of all other permits or approvals necessary to effect the proposed modification.

Type of Permit/Approval Required	Date the Application was/will be Submitted	Status/Comments
Alteration of Terrain	July/August 2020	Being submitted shortly after this application
City Site Plan Approval	TBD	Application to be filed about one year prior to planned construction
Air Resources	TBD	Application to be filed about one year prior to planned construction

SECTION IX. LEGAL NOTICES

Submit proof of having provided certain legal notifications and filings, as follows:

(1) You must send by certified mail, or deliver in hand, a complete copy of this application to the host municipality, host solid waste management district and other affected entities, with a "notice of filing," as specified by Env-Sw 303.

(2) For a type I-A modification, you must send by certified mail, or deliver in hand, a "notice of filing" to each owner of property abutting the facility site, as specified by Env-Sw 303. If the applicant/permittee or the owner of the facility site owns any abutting parcel of land, the "notice of filing" must be sent to the owner(s) of the next parcel(s) not owned by the permittee/applicant or facility site owner.

(3) You must also provide a "notice of filing" to the New Hampshire Department of Justice/Office of the Attorney General (NH DoJ/AGO) if, pursuant to Section X(2) of this form, you are required to submit business and personal disclosure information.

(4) You must attach to this application "proof" that notification has been provided as required by (1) through (3) above. Therefore, attach a copy of the notice(s) of filing and the signature(s) of all required recipients, acknowledging receipt.

SECTION X. CERTIFICATION OF COMPLIANCE/COMPLIANCE REPORT

All applications for permit modification must be submitted with either certification of compliance or a compliance report, as follows:

(1) If you are ABLE to certify that each of the statements numbered (1) - (8) below are true, do so by your signature.

(2) If you are UNABLE to certify that each of the statements numbered (1) - (8) below are true, you must:

- ☐ Prepare and submit a separate Compliance Report as specified by Env-Sw 303.15; and
- ☐ If the proposed modification involves a change in organizational structure, or a change in individuals/entities holding 10% or more of the permittee's debt or equity, or a change in officers, directors, partners or key employees, none of which constitutes a change in operational control of the facility or a change in ownership per Env-Sw 315.02(f), also submit completed "business and personal disclosure forms" for each non-compliant individual and entity involved in the change. Obtain the required forms from the P&DRS at (603) 271-2925. Submit the completed forms, with the notice of filing referenced by Section IX(3) of this form and a copy of the Compliance Report, direct to the New Hampshire Department of Justice/Office of Attorney General, Environmental Protection Bureau, 33 Capitol Street, Concord, NH 03301-6397. [Note: Copies of the completed disclosure forms should NOT be attached to this application when it is submitted to DES or to the host municipality, host solid waste management district and other effected entities, pursuant to Section IX(1) above. Only the NH DoJ/AGO should receive copies of the disclosure forms].

COMPLIANCE STATEMENT

The applicant shall certify that each of the statements listed in (1)-(8) below are true for each of the following individuals and entities:

- ☒ **The applicant, and**
- ☒ **The facility owner, and**
- ☒ **The facility operator, and**
- ☒ **All individuals and entities holding 10% or more of the applicant's debt or equity, and**
- ☒ **All of the applicant's officers, directors, and partners, and**
- ☒ **All individuals and entities having managerial, supervisory or substantial decision making authority and responsibility for the management of the facility operations or the activity(s) for which approval is being sought.**

(1)	No individual or entity listed above has been convicted of or plead guilty or no contest to a felony in any state or federal court during the 5 years before the date of the application.
(2)	No individual or entity listed above has been convicted of or plead guilty or no contest to a misdemeanor for a violation of environmental statutes or rules in any state or federal court during the 5 years before the date of the application.
(3)	No individual or entity listed above has owned or operated any hazardous or solid waste facility which has been the subject of an administrative or judicial enforcement action for a violation of environmental statutes or rules during the 5 years before the date of the application.

(4) No individual or entity listed above has been the subject of any administrative or judicial enforcement action for a violation of environmental statutes and rules during the 5 years before the date of the application;

(5) All hazardous and solid waste facilities owned or operated in New Hampshire by any individual or entity listed above are in compliance with either.
- (a) All applicable environmental statutes, rules, and DES permit requirements; or
- (b) A DES approved schedule for achieving compliance therewith.

(6) All individuals and entities listed above are in compliance with all civil and criminal penalty provisions of any outstanding consent agreement, settlement, or court order to which DES is a party.

(7) All individuals and entities listed above have paid, or are in compliance with the payment schedule for any administrative fine assessed by DES.

(8) All individuals and entities listed above are in compliance with all terms and conditions under every administrative order, court order or settlement agreement relating to programs implemented by DES.

Signature of the permittee/applicant certifying the above statements are true:

Permittee/Applicant Name **(Print Clearly or Type)** Andrew Patrician, Asst. Director of Public Works, City of Nashua for Lisa Fauteux, Director of Public Works

Permittee/Applicant Signature

Date 7-15-2020

SECTION XI. PERMITTEE/APPLICANT SIGNATURE REQUIREMENTS

The permittee/applicant must sign the following statement prior to submitting this application. All copies of the application filed with DES must bear the permittee's/applicant's ORIGINAL signature. If the permittee/applicant is not an individual, an individual duly authorized by the permittee/applicant shall sign the application.

To the best of my knowledge and belief, the information and material submitted herewith is correct and complete. I understand that any approval granted by DES based on false and/or incomplete information shall be subject to revocation or suspension, and that administrative, civil or criminal penalties may also apply. I certify that this application is submitted on a complete and accurate form, as provided by DES, without alteration of the text.

Permittee/Applicant Name **(Print Clearly or Type)** Andrew Patrician, Asst. Director of Public Works, City of Nashua, for Lisa Fauteux, Director of Public Works

Permittee/Applicant Signature

Date 7-15-2020

SECTION XII. PROPERTY OWNER SIGNATURE

If the permittee and property owner are not the same, the property owner must also sign this form as follows. All copies of the application filed with DES must bear the property owner's ORIGINAL signature. If the property owner is not an individual, an individual duly authorized by the property owner shall sign the application.

(1) I hereby affirm that the permittee/applicant has the legal right to occupy and use the property on which the subject facility is or will be located for the purposes specified in this application.

(2) I hereby affirm that I shall grant access to the property for closure and post-closure monitoring of the subject facility and site as required by RSA 149-M and the New Hampshire Solid Waste Rules (Env-Sw 100 - 300 and Env-Sw 400 - 2000), as amended.

Property Owner Name **(Print Clearly or Type)** Andrew Patrician, Asst. Director of Public Works, City of Nashua, for Lisa Fauteux, Director of Public Works

Property Owner Signature

Date 7-15-2020

THE CITY OF NASHUA
Division of Public Works
Solid Waste Department

"The Gate City"

July 2020

ATTACHMENT

SECTION X. Certification of Compliance/ Compliance Report

Type I Modification to Solid Waste Management Facility Permit

Nashua Four Hills Landfill
Permit #DES-SW-SP-95-002

This report has been prepared and submitted pursuant to the requirements of Env-Sw 303.15 to address Compliance Statement Item 4 in Section X of the Type I Permit Modification Application dated July 15, 2020. This permit application requests approval for the siting and future construction of Phase IV of the Four Hills secure expansion landfill.

The City of Nashua was subject to an Administrative Order by Consent (AOC) No. AF-18-032 issued January 3, 2019 by the New Hampshire Department of Environmental Services (NHDES) concerning violations to landfill cover requirements at the City's Four Hills Phase I/II landfill. The violations were identified during inspections by NHDES staff in May and June 2017.

Pursuant to Items 7 and 8 of the Compliance Statement, the City has paid the administrative fine assessed by NHDES, and has fully complied with the provisions, terms and conditions of the AOC.

As required by the AOC, an updated facility Operating Plan that revised and clarified landfill daily and interim cover requirements was submitted under a Type IB permit modification to NHDES on January 28, 2019. The NHDES approved the updated Operating Plan on April 8, 2019. The operating plan was further modified in January 2020 to include operation of the newly constructed Phase III landfill. The NHDES approved this plan on April 10, 2020.

The City continues to maintain compliance with the cover requirements of the approved Operating Plan and AOC; therefore, the NHDES should not find the AOC grounds for denying this Type I permit application.

Additional Information
Type I-A Permit Modification to Solid Waste Management Facility Permit Application
Four Hills Landfill – Phase IV
Permit No. DES-SW-SP-95-002

The information below is provided in the order referenced in the application form for a Type I-A Permit Modification to Solid Waste Management Facility Permit (Type I-A PMA).

Section III. Description of Proposed Modification

(1) Brief Description of the proposed modification

The proposed Phase IV Secure Landfill Expansion (Phase IV expansion) includes the construction of a new double-lined disposal area at the City of Nashua's Four Hills Landfill (Facility). The Phase IV expansion will be located between the closed, unlined municipal solid waste (MSW) landfill and lined Phases I and II. The Phase IV expansion project includes the construction of liner, leachate collection and conveyance, landfill gas (LFG), and stormwater management systems. The Phase IV expansion project will secure approximately 30 years of additional safe and efficient solid waste disposal capacity for the City.

The Phase IV expansion was designed as double-lined facility in accordance with Env-Sw 805.05. The Phase IV expansion requires construction of new liner and leachate collection systems over the existing closed, unlined MSW landfill (herein referred to as the "overlay area") [pursuant to Env-Sw 805.17(a)(2)] and over the area between the closed, unlined MSW landfill, and the lined Phases I and II (herein referred to as the "base area"). The area over Phases I and II is considered a vertical expansion over a permitted lined disposal area [see Env-Sw 805.17(a)(1)] and, as such, there is no needed to construct additional liner or leachate collection systems over this area. Because Phases I and II have liner penetrations as part of their leachate collection system that do not meet the requirements of Env-Sw 805.05(j), an Application of Waiver to Env-Sw 805.05(j), which would allow for the vertical expansion to occur over Phases I and II, is provided in Appendix J.

Phase IV is proposed to be constructed in four stages (Stages I through IV) with the succeeding stage being constructed as waste is placed in the preceding stage. The first construction stage includes the following activities:

- Excavation of soil the base area to achieve the foundation on which the liner and leachate collection systems will be constructed;
- Decommission and/or removal of existing infrastructure located in the base area including: (i) groundwater monitoring wells[1]; (ii) landfill gas collection and conveyance infrastructure; and (iii) leachate cleanout pipes.
- Construction of the perimeter berm and access roads;

---

[1] Replacement groundwater monitoring wells will be installed prior to the Stage 1 construction.

- Construction of the liner and leachate collection systems in the base area, with a connection to like systems in Phase I; and
- Construction of a new leachate pumping system and associated infrastructure to transfer the liquid to the existing leachate management system.

As waste is placed in the base area of Phase IV, the liner and leachate collection systems, along with the perimeter berm, will be extended, over the course of Stages II through IV, up the sideslope of the existing closed, unlined MSW landfill (overlay area).

Existing infrastructure including groundwater monitoring wells, landfill gas collection and conveyance infrastructure, and leachate cleanout pipes will need to be decommissioned and/or relocated within the Phase IV expansion footprint of prior to construction.

(5) Facility Plans

Drawings that illustrate the Phase IV expansion design are provided as Appendix A to this Type I-A PMA.

A revised Operating Plan that incorporates the Phase IV expansion is provided as Appendix D to this Type I-A PMA.

A revised Closure Plan that incorporates the Phase IV expansion is provided as Appendix E to this Type I-A PMA.

A revised Financial Plan that incorporates the Phase IV expansion is provided as Appendix F to this Type I-A PMA.

Section V. Statement of Need

The City of Nashua has a well-developed and managed waste management program for the residents and businesses of the City. The City promotes recycling and provides for curbside recycling and maintains a recycling center and a composting operation at the Four Hills Landfill. Because not all waste materials can be reused, recycled, or composted, secure disposal facilities are needed.

In Nashua, the City owns and operates the Four Hills Landfill, an integrated waste material handling facility. Because the Facility only accepts waste generated within the City limits, it is an important City resource. Currently, the projected disposal capacity of the permitted disposal area is anticipated to be exhausted in 2030. The Phase IV expansion is intended to supplement this important City resource, providing this much needed service to the City for years to come.

Section IV. Schedule

Because the projected disposal capacity of the permitted disposal area is anticipated to be exhausted in 2030, Phase IV needs to be operation not later than 2028 to provide for a smooth transition in operations. Accordingly, the following implementation schedule is proposed:

- July 2020 – Submit Type I-A PMA
- July 2021 – Receive permit
- July 2021 through January 2025 – Capital budget process for the project
- January 2025 through January 2026 – Prepare construction bid and Type II PMA documents, City to appropriate funding, and bid and award construction project
- January 2026 – Issue Type II PMA for initial construction.
- May 2026 – Obtain authorization to construct.
- May 2026 – Begin initial construction of the first stage of the project
- June 2027 – Complete construction of the first stage and apply of operating approval.
- January 2028 – Begin operations.

Section VI. Impact Evaluation

(1) The effect the modification will have on facility function, capacity, life expectancy, service type and service area;

The Phase IV expansion does not impact the Facility's function, service type, nor the service area, which is limited to the residents and businesses of the City. The Phase IV expansion will increase the Facility's MSW disposal capacity disposal capacity and hence the Facility's life expectancy. The increase in disposal capacity supplements the existing City's waste management resource providing this much needed service to the City for years to come.

(2) The effect the modification will have on the environment, public health and safety;

The Phase IV expansion meets the requirements of the Federal Criteria for Municipal Solid Waste Landfills (40 CFR 258) and the New Hampshire Solid Waste Rules, specifically Env-Sw 315.05 and applicable portions of Env-Sw 803, 804.04, 805, 806.07, 1002, 1003, 1004, and 1102, and 1103. Because the Phase IV expansion is designed, and will be operated, in accordance with the applicable federal and state requirements, there should be no adverse impact on the environment, public health, and safety.

(3) The effect the modification will have on the state's ability to achieve the goals and objectives specified in RSA 149-M:2;

The Phase IV expansion does not impact the state's ability to achieve the goals and objectives specified in RSA 149-M:2. The Phase IV expansion provides the continued ability for the City to properly manage materials that cannot be composted, reused, or recycled.

(4) The effect the modification will have on establishing and maintaining integrated waste management systems consistent with the hierarchy of waste management methods in RSA 149-M:3;

The Phase IV expansion does not impact the hierarchy of waste management methods in RSA 149:M:3. The City of Nashua has a well-developed and managed waste management program for the residents and businesses of the City. The City promotes recycling and provides for curbside recycling and maintains a recycling center and a composting operation at the Facility. Because not all waste materials can be reused, recycled, or composted, secure disposal facilities are needed.

(5) Information that demonstrates that the facility, as modified, will be consistent with the state solid waste management plan and the applicable district plan, pursuant to RSA 149-M:12, 1(b);

The Phase IV expansion will not affect the state solid waste management plan or district plans as there are no proposed changes to accepted waste type or facility service area.

Section VII. Public Benefit Demonstration

The Public Benefit Demonstration for the Phase IV expansion project is provided as Appendix G to this Type I-A PMA.

Section IX. Legal Notices

Legal notices as required by Env-Sw 303 were issued to the City of Nashua City Clerk, Mayor, and City Council, as wells as the Nashua Regional Planning Commission. Copies of the notices are provided in Appendix H to this Type I-A PMA.

A “notice of filling” letter was not sent to the New Hampshire Department of Justice/Office of the Attorney General because the facility is able to complete the compliance statement in Section X of the application.

A “notice of filling” letter as required by Env-Sw 303 was sent to each owner of property abutting the facility site.

A copy of this application was sent to the host municipality and host solid waste management district by certified mail. Copies of the certified mail receipts and copies of the signed certified mail receipts are also included in Appendix H.

Notices to the Nashua Airport and the FAA are provided in Attachment D to the Design Report (Appendix A to this Type I-A PMA).

Closing

The contents of this application were prepared under the direction of Eric S. Steinhauser, a New Hampshire licensed Professional Engineer experienced in solid waste facility design. The drawings were prepared to meet the requirements of the New Hampshire Solid Waste Rules (Env-Sw 800) and are consistent with the current state of practice in the solid waste industry in New Hampshire.

ERIC SCOTT STEINHAUSER No. 11494

Eric Scott Steinhauser

Eric S. Steinhauser

Eric S. Steinhauser, PE, CPESC, CPSWQ

7/17/2020
Date

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APPENDIX A

DESIGN REPORT

SANBORN HEAD
Building Trust. Engineering Success.

ERIC
SCOTT
STEINHAUSER
No. 11494

Eric Scott Steinhauser

DESIGN REPORT

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Nashua
NEW HAMPSHIRE'S GATE CITY

Prepared for the City of Nashua
File No. 3066.11
July 2020

SANBORN, HEAD & ASSOCIATES, INC.

www.sanbornhead.com

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1.0 INTRODUCTION

1.1 Purpose

Sanborn Head prepared this Design Report as part of the application for a Type I-A Modification to Solid Waste Management Facility Permit (Type I-A PMA) for the Phase IV Secure Landfill Expansion (Phase IV expansion), a proposed double-lined disposal area at the Four Hills Landfill Facility (Facility) located in Nashua, New Hampshire.

This report describes the design for the proposed Phase IV expansion, which satisfies the design requirements of the Federal Criteria for Municipal Solid Waste (MSW) Landfills (40 CFR 258) and the New Hampshire Solid Waste Rules (NH SW Rules), specifically Env-Sw 315.05 and applicable portions of Env-Sw 803, 804.04, 805, 806.07, 1002, 1003, 1004, and 1102, and 1103. Supporting design calculations, technical specifications, and a Construction Quality Assurance (CQA) Plan, which complies with the requirements of Env-Sw 805.16, are provided as Attachments A, B, and C, respectively, to this report.

Additionally, this report refers to the following appendices of the Type I-A PMA:

- Appendix B – Drawings, which contains engineering drawings titled "Phase IV Design, Type I-A Permit Modification Application, Four Hills Landfill, City of Nashua, Nashua, New Hampshire," dated April 2020, prepared by Sanborn Head. The drawings were prepared in accordance with Env-Sw 314.11;
- Appendix C – Hydrogeologic Report, which contains a report that describes the hydrogeologic conditions and the site and addresses related siting criteria and groundwater monitoring, which address the requirements of Env-Sw 804.02, 804.03, and 804.05;
- Appendix D – Operating Plan, which provides information relative to operating the Facility and complies with the requirements of Env-Sw 806, 1005, and 1105;
- Appendix E – Closure Plan, which provides information relative to the closure and post-closure care of the Facility and addresses the requirements of Env-Sw 807, 1006, and 1106; and
- Appendix F – Financial Assurance Plan, which provides information relative to providing and maintain financial assurance and addresses the requirements of Env-Sw 1400

1.2 Location and Background

The 294-acre[1] Facility, located at 840 West Hollis Street (Parcel 0000D-00054-CI), is owned and operated by the City of Nashua, New Hampshire (City) under Solid Waste Permit No. DES-SW-95-002, issued on June 26, 1995 and last modified on February 27, 1998. The Facility includes: (i) two unlined landfills; (ii) the lined Secure Landfill (consisting of disposal areas Phases I, II, and III); (iii) a landfill gas to energy facility; (iv) a residential drop-off area; (v) a municipal operations and maintenance building; (vi) a leaf/yard waste compost area; and (vii) wooded areas.

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[1] http://assessing.gonashua.com/Summary.asp?AccountNumber=39412

Since 1971, the City has operated the Facility for the disposal of MSW and construction and demolition debris (C&D). The approximately 11-acre unlined C&D landfill was active until 1994 and was closed with a geomembrane cap system between 1997 and 1998. The approximately 60-acre unlined MSW landfill was operated until August 2003 and was closed with a geomembrane cap system in the fall of 2003. MSW disposal operations began in the lined Phase I area in 2000 and in the lined Phase II area in 2009. MSW disposal operations are anticipated to begin in the lined Phase III area in 2020.

1.3 Project Description

The Phase IV expansion covers approximately 32.4 acres including about 16.9 acres on the southwestern side of the closed, unlined MSW landfill, 11.3 acres on the northeastern side of Phases I and II, and the 4.2 acre area in between the two disposal areas, which currently consists of an existing access road between the and miscellaneous infrastructure (e.g., monitoring wells, gas wells, drainage features).

Env-Sw 805.12(a) requires that MSW landfills be designed as double-lined facilities in accordance with Env-Sw 805.05. As shown on Figure 1, the Phase IV expansion requires construction of new liner and leachate collection systems over the existing closed, unlined MSW landfill (herein referred to as the “overlay area”) [pursuant to Env-Sw 805.17(a)(2)] and over the area between the closed, unlined MSW landfill, and the lined Phases I and II (herein referred to as the “base area”). The area over Phases I and II is considered a vertical expansion over a permitted lined disposal area [see Env-Sw 805.17(a)(1)] and, as such, there is no needed to construct additional liner or leachate collection systems over this area.

Phase IV is proposed to be constructed in four stages (Stages I through IV) with the succeeding stage being constructed as waste is placed in the preceding stage. The first construction stage includes the following activities:

- Excavation of soil the base area to achieve the foundation on which the liner and leachate collection systems will be constructed;
- Decommission and/or removal of existing infrastructure located in the base area including: (i) groundwater monitoring wells[2]; (ii) landfill gas collection and conveyance infrastructure; and (iii) leachate cleanout pipes.
- Construction of the perimeter berm and access roads;
- Construction of the liner and leachate collection systems in the base area, with a connection to like systems in Phase I, and the overlay area; and
- Construction of a new leachate pumping system and associated infrastructure to transfer the liquid to the existing leachate management system.

As waste is placed in the base area of Phase IV, the liner and leachate collection systems, along with the perimeter berm, will be extended, over the course of Stages II through IV, up the sideslope of the existing closed, unlined MSW landfill (overlay area).

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[2] Replacement groundwater monitoring wells will be installed prior to the Stage 1 construction.

2.0 FEDERAL REQUIREMENTS (40 CFR 258)

2.1 Overview

Because the Facility will accept more than 100 tons of waste per day, according to Env-Sw 803.03(e), the design of the Phase IV expansion must comply with specific provisions of 40 CFR 258. Promulgated in 1991 and subsequently amended, 40 CFR 258 establishes the minimum criteria for the siting, design, construction, operation, and closure/post-closure for MSW landfills. According to Env-Sw 803.04, the following sections of 40 CFR 258 are applicable requirements specific to the Phase IV expansion:

- Location restrictions specified in 40 CFR 258.10 through 258.16, which are addressed in Sections 2.2 through 2.7 of this Design Report;
- Operating criteria specified in 40 CFR 258.20, 258.21, 258.23, 258.24, 258.28 and 258.29, which are addressed in the Operating Plan provided as Appendix D to the Type I-A PMA;
- Design criteria specified in 40 CFR 258.40, which are addressed in Section 2.8 of this Design Report;
- Groundwater monitoring and corrective action requirements specified in 40 CFR 258.53 through 258.58, which is addressed in the Facility groundwater management permit, GWP-198403099-N-005;
- Closure and post-closure requirements specified in 40 CFR 258.60(i) and 258.61, which is address in the Closure Plan provided as Appendix E to the Type I-A PMA and
- Financial assurance mechanisms specified in 40 CFR 258, subpart G, which is addressed in the Financial Assurance Plan provided as Appendix F of the Type I-A PMA.

2.2 Airport Safety (40 CFR 258.10)

40 CFR 258.10 is repeated below.

§258.10 Airport safety.

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that are located within 10,000 feet (3,048 meters) of any airport runway end used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway end used by only piston-type aircraft must demonstrate that the units are designed and operated so that the MSWLF unit does not pose a bird hazard to aircraft.

(b) Owners or operators proposing to site new MSWLF units and lateral expansions within a five-mile radius of any airport runway end used by turbojet or piston-type aircraft must notify the affected airport and the Federal Aviation Administration (FAA).

(c) The owner or operator must place the demonstration in paragraph (a) of this section in the operating record and notify the State Director that it has been placed in the operating record.

(d) For purposes of this section:

(1) Airport means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) Bird hazard means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

Note to §258.10: A prohibition on locating a new MSWLF near certain airports was enacted in Section 503 of the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (Ford Act), Pub. L. 106-181 (49 U.S.C. 44718 note). Section 503 prohibits the "construction or establishment" of new MSWLFs after April 5, 2000 within six miles of certain smaller public airports. The Federal Aviation Administration (FAA) administers the Ford Act and has issued guidance in FAA Advisory Circular 150/5200-34, dated August 26, 2000. For further information, please contact the FAA.

[56 FR 51016, Oct. 9, 1991, as amended at 68 FR 59335, Oct. 15, 2003]

Figure 2 depicts a five-mile radius around the Phase IV expansion footprint. As shown on Figure 2, the Phase IV expansion is located about 3.5 miles (18,480 feet) south of the Nashua Airport at Boire Field, a public-use airport that handles both piston-type and turbojet aircraft. Phase IV is also located about 2.5 miles (13,200 feet) northeast of the Pepperell Airport, a private-use airport. Because Phase IV is located within 5 miles of these airport, the required notifications to the airports and the FAA were issued, copies of which are provided in Attachment D to this Design Report.

2.3 Floodplains (40 CFR 258.11)

40 CFR 258.11 is repeated below.

§258.11 Floodplains.

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in 100-year floodplains must demonstrate that the unit will not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste so as to pose a hazard to human health and the environment. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For purposes of this section:

(1) Floodplain *means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, that are inundated by the 100-year flood.*

(2) 100-year flood *means a flood that has a 1-percent or greater chance of recurring in any given year or a flood of a magnitude equaled or exceeded once in 100 years on the average over a significantly long period.*

(3) Washout *means the carrying away of solid waste by waters of the base flood.*

Figure 3 depicts the Phase IV expansion area and the FEMA-mapped floodplains. As shown on Figure 3, the Phase IV expansion is not located in a 100-year floodplain and hence will not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste so as to pose a hazard to human health and the environment.

2.4 Wetlands (40 CFR 258.12)

40 CFR 258.12 is repeated below.

§258.12 Wetlands.

(a) New MSWLF units and lateral expansions shall not be located in wetlands, unless the owner or operator can make the following demonstrations to the Director of an approved State:

> *(1) Where applicable under section 404 of the Clean Water Act or applicable State wetlands laws, the presumption that practicable alternative to the proposed landfill is available which does not involve wetlands is clearly rebutted;*
>
> *(2) The construction and operation of the MSWLF unit will not:*
>
> > *(i) Cause or contribute to violations of any applicable State water quality standard,*
> >
> > *(ii) Violate any applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act,*
> >
> > *(iii) Jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of a critical habitat, protected under the Endangered Species Act of 1973, and*
> >
> > *(iv) Violate any requirement under the Marine Protection, Research, and Sanctuaries Act of 1972 for the protection of a marine sanctuary;*
>
> *(3) The MSWLF unit will not cause or contribute to significant degradation of wetlands. The owner or operator must demonstrate the integrity of the MSWLF unit and its ability to protect ecological resources by addressing the following factors:*
>
> > *(i) Erosion, stability, and migration potential of native wetland soils, muds and deposits used to support the MSWLF unit;*
> >
> > *(ii) Erosion, stability, and migration potential of dredged and fill materials used to support the MSWLF unit;*
> >
> > *(iii) The volume and chemical nature of the waste managed in the MSWLF unit;*
> >
> > *(iv) Impacts on fish, wildlife, and other aquatic resources and their habitat from release of the solid waste;*
> >
> > *(v) The potential effects of catastrophic release of waste to the wetland and the resulting impacts on the environment; and*
> >
> > *(vi) Any additional factors, as necessary, to demonstrate that ecological resources in the wetland are sufficiently protected.*
>
> *(4) To the extent required under section 404 of the Clean Water Act or applicable State wetlands laws, steps have been taken to attempt to achieve no net loss of wetlands (as defined by acreage and function) by first avoiding impacts to wetlands to the maximum extent practicable as required by paragraph (a)(1) of this section, then minimizing unavoidable impacts to the maximum extent practicable, and finally offsetting remaining unavoidable wetland impacts through all appropriate and practicable compensatory mitigation actions (e.g., restoration of existing degraded wetlands or creation of man-made wetlands); and*
>
> *(5) Sufficient information is available to make a reasonable determination with respect to these demonstrations.*

(b) For purposes of this section, wetlands means those areas that are defined in 40 CFR 232.2(r).

Figure 3 depicts the Phase IV expansion area and the mapped wetlands. As shown on Figure 3, the Phase IV expansion is not located in a wetland.

2.5 Fault Areas (40 CFR 258.13)

40 CFR 258.13 is repeated below.

§258.13 Fault areas.

(a) New MSWLF units and lateral expansions shall not be located within 200 feet (60 meters) of a fault that has had displacement in Holocene time unless the owner or operator demonstrates to the Director of an approved State that an alternative setback distance of less than 200 feet (60 meters) will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment.

(b) For the purposes of this section:

(1) Fault *means a fracture or a zone of fractures in any material along which strata on one side have been displaced with respect to that on the other side.*

(2) Displacement *means the relative movement of any two sides of a fault measured in any direction.*

(3) Holocene *means the most recent epoch of the Quaternary period, extending from the end of the Pleistocene Epoch to the present.*

Geologic features around the Phase IV expansion area are discussed in the Hydrogeologic Report (Appendix C to the Type I-A PMA). Based on the information presented in the Hydrogeologic Report, the Phase IV expansion area is not located within 200 feet of a fault that has had displacement in Holocene time.

2.6 Seismic Impact Zones (40 CFR 258.14)

40 CFR 258.13 is repeated below.

§258.14 Seismic impact zones.

(a) New MSWLF units and lateral expansions shall not be located in seismic impact zones, unless the owner or operator demonstrates to the Director of an approved State/Tribe that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record.

(b) For the purposes of this section:

(1) Seismic impact zone means an area with a ten percent or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in 250 years.

(2) Maximum horizontal acceleration in lithified earth material means the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment.

(3) Lithified earth material means all rock, including all naturally occurring and naturally formed aggregates or masses of minerals or small particles of older rock that formed by crystallization of magma or by induration of loose sediments. This term does not include man-made materials, such as fill, concrete, and asphalt, or unconsolidated earth materials, soil, or regolith lying at or near the earth surface.

According to Algermissen, et. al (1990)[3], the Phase IV expansion is located in a seismic zone. Because of this, the stability calculations performed for this project (see Attachment A) considered the mapped ground acceleration of 0.114g, and the Phase IV expansion was designed to accommodate this seismic potential.

2.7 Unstable Areas (40 CFR 258.15)

40 CFR 258.13 is repeated below.

§258.15 Unstable areas.

(a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in an unstable area must demonstrate that engineering measures have been incorporated into the MSWLF unit's design to ensure that the integrity of the structural components of the MSWLF unit will not be disrupted. The owner or operator must place the demonstration in the operating record and notify the State Director that it has been placed in the operating record. The owner or operator must consider the following factors, at a minimum, when determining whether an area is unstable:

> *(1) On-site or local soil conditions that may result in significant differential settling;*
> *(2) On-site or local geologic or geomorphologic features; and*
> *(3) On-site or local human-made features or events (both surface and subsurface).*

(b) For purposes of this section:

> *(1)* Unstable *area means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the landfill structural components responsible for preventing releases from a landfill. Unstable areas can include poor foundation conditions, areas susceptible to mass movements, and Karst terranes.*
>
> *(2)* Structural components *means liners, leachate collection systems, final covers, run-on/run-off systems, and any other component used in the construction and operation of the MSWLF that is necessary for protection of human health and the environment.*
>
> *(3)* Poor foundation conditions *means those areas where features exist which indicate that a natural or man-induced event may result in inadequate foundation support for the structural components of an MSWLF unit.*
>
> *(4)* Areas susceptible to mass movement *means those areas of influence (i.e., areas characterized as having an active or substantial possibility of mass movement) where the movement of earth material at, beneath, or adjacent to the MSWLF unit, because of natural or man-induced events, results in the downslope transport of soil and rock material by means of gravitational influence. Areas of mass movement include, but are not limited to, landslides, avalanches, debris slides and flows, soil fluction, block sliding, and rock fall.*
>
> *(5)* Karst terranes *means areas where karst topography, with its characteristic surface and subterranean features, is developed as the result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features present in karst terranes include, but are not limited to, sinkholes, sinking streams, caves, large springs, and blind valleys.*

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[3] Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., and Bender, B.L. (1990), *Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico*, Miscellaneous Field Studies Map MF-2120, Map C.-Horizontal Acceleration (90 Percent Probability of Not Being Exceeded in 250 Years), Department of the Interior, US Geological Survey.

Geologic features around the Phase IV expansion area are discussed in the Hydrogeologic Report (Appendix C to the Type I-A PMA). Based on the information presented in the Hydrogeologic Report, the Phase IV expansion area is not located within a geologic unstable area as defined above. However, the overlay area will be constructed over and existing closed, unlined MSW landfill. Because of this, the Phase IV expansion design accounts for related considerations such as differential settlement of the liner due to compression of the closed, unlined MSW landfill. The design considerations are addressed in Section 4.4 of this Design Report.

2.8 Design Criteria (40 CFR 258.40)

40 CFR 258.40(a)(1) states that a new MSW landfill or a lateral expansion must be constructed in accordance with the design approved by the "Director of and approved State." New Hampshire is an approved state and the NH SW Rules define the minimum requirements for a MSW landfill liner system. Section 4 of this Design Report describes how the proposed Phase IV expansion design complies with the NH SW Rules, and hence 40 CFR 258.40.

3.0 SITING REQUIREMENTS (ENV-SW 804, 1003, AND 1102)

3.1 Overview

Env-Sw 804 provides the siting requirements for MSW landfills. Because most of the siting requirements are related to hydrogeologic issues, please refer to Appendix C (Hydrogeologic Report) of the Type I-A PMA, which addresses the information required by following:

- Groundwater Protection Standards (Env-Sw 804.02);
- Surface Water Protection Standards (Env-Sw 804.03); and
- Geologic Siting Limitations (Env-Sw 804.05).

The following sections address the physical distance requirements of Env-Sw 804, 1003, and 1102.

3.2 Separation to Groundwater and Bedrock (Env-Sw 804.02(d))

The NH SW Rules require that the base of the bottom liner system be a minimum of 6 feet above the seasonal high groundwater table and the confirmed top of bedrock. Figures 4 and 5, which were prepared based on information presented in the Hydrogeologic Report, presents a comparison of the seasonal high groundwater table and the top of bedrock versus the proposed Phase IV expansion grades that represent the bottom of the secondary liner system. As shown in Figures 4 and 5, the bottom of the secondary liner system is at least 6 feet above the seasonal high groundwater table and the top of bedrock.

3.3 Separation to Surface Waters (Env-Sw 804.03)

The NH SW Rules require that:

- The footprint of a landfill not be located within 200 feet of a perennial surface water body, measured from the closest bank of a stream and closest shore of a lake, as applicable. [Env-Sw 804.03(d)]

- The footprint of a landfill not be located within 200 feet upgradient and 100 feet downgradient of a wetland within the jurisdiction of RSA 482-A, excluding any drainage appurtenances related to the site, that is not allowed to be filled under the authority of RSA 482-A. [Env-Sw 804.03(e)]
- The footprint of a landfill not be located within 1,000 feet upgradient of a surface water reservoir or intake used for a community drinking water supply. [Env-Sw 804.03(f)]
- The footprint of a landfill not be located within the 100-year flood hazard zone. [Env-Sw 804.03(g)]

Figure 3 depicts the relationship of the Phase IV expansion area with respect to the above. As shown in Figure 3, the Phase IV expansion area complies with the required setback distances listed above.

3.4 Set-back Requirement (Env-Sw 804.04)

The NH SW Rules require that the Phase IV expansion include:

- A minimum 100-foot buffer strip between the property line and the footprint of the landfill. [Env-Sw 804.04(a)]
- A minimum 300-foot buffer between Class I and Class II roads and a minimum 100-foot buffer between Class III through Class VI roads and the footprint of the landfill. [Env-Sw 804.04(b)]
- A minimum distance of 500 feet between existing residences not owned by the applicant and the footprint of the landfill. [Env-Sw 804.04(c)]
- A minimum distance of 10,000 feet from an airport runway used by turbojet aircraft or 5,000 feet of an airport runway used by only piston-type aircraft and the footprint of the landfill. [Env-Sw 804.04(e)]

Figure 3 depicts the relationship of the Phase IV expansion area with respect to the property line, roads, and residences; Figure 2 depicts the relationship with respect to airports. As shown in Figures 2 and 3, the Phase IV expansion area complies with the required setback distances listed above.

3.5 Distance to Other Facilities (Env-Sw 1003.01)

The proposed location of the Phase IV expansion was selected to best use the available space at the Facility. As presented herein and on the drawings (Appendix B to the Type I-A PMA), some of the existing Facility infrastructure will be modified to accommodate the expansion. As such, the Phase IV expansion will be not interfere with operation or closure of the Facility.

3.6 Easements and Right-of-Ways (Env-Sw 1003.02)

The Phase IV expansion is located on land owned by the City and is outside of right-of-ways and easements.

3.7 Property Ownership (Env-Sw 1003.03)

The Phase IV expansion is located on land owned by the City.

3.8 Groundwater and Surface Waters (Env-Sw 1003.04)

The Phase IV expansion is not located in an area that would violate state law with respect to the management and protection of rivers and groundwater (see Sections 3.2 and 3.3 above and the Hydrogeologic Report, Appendix C to the Type I-A PMA).

3.9 Wetlands (Env-Sw 1003.05)

The Phase IV expansion is not located in an area that would violate state law with respect to the protection of wetlands (see Section 2.4 above).

3.10 Shoreland Protection (Env-Sw 1003.06)

The Phase IV expansion is not located in an area that would violate state law with respect to the protection of shoreland as the development is greater than 250 feet from a regulated shoreland (see Section 3.3 above and the Hydrogeologic Report, Appendix C to the Type I-A PMA).

3.11 Designated Rivers (Env-Sw 1003.07)

The Phase IV expansion is not located in an area that would violate state law with respect to the protection of designated rivers as the development is greater than 250 feet from a river (see Section 3.3 above and the Hydrogeologic Report, Appendix C to the Type I-A PMA).

3.12 Compatibility (Env-Sw 1102.01)

The proposed Phase IV expansion was designed to be compatible with the NH SW Rules, as described herein.

3.13 Co-existence (Env-Sw 1102.02)

The proposed Phase IV expansion is located at a currently permitted solid waste facility and was designed to be compatible with the NH SW Rules, as described herein. The operation of Phase IV as a MSW landfill serves as the continuance of current operations, providing the City with a resource for its MSW disposal needs.

3.14 Other Siting Limitations (Env-Sw 804.06)

There are no other known siting limitations related to the Phase IV expansion project.

4.0 DESIGN AND CONSTRUCTION REQUIREMENTS (ENV-SW 805)

4.1 Overview

Pursuant to Env-Sw 805.02(a) the Phase IV expansion will include: (i) a double liner system that complies with the requirements of Env-Sw 805.04 and 805.05; (ii) a leachate collection and removal system that complies with Env-Sw 805.06; (iii) a leak detection and locations system with Env-Sw 805.07; (iv) a groundwater monitoring system that complies with the requirements of Env-Sw 805.08 (see Type I-A PMA Appendix C-Hydrogeologic Report); (v) a stormwater management system with Env-Sw 805.09; (vi) a landfill gas (LFG) collection and control system that complies with Env-Sw 806.07; (vii) a final cover system that complies with Env-Sw 805.10; and (viii) associated supporting infrastructure for power, leachate conveyance, and stormwater management. Because the Facility is an active, permitted MSW landfill, systems and structures are in place to accommodate the needs of facility personnel relative to shelter, sanitation and communication. In addition, as depicted in Figure 1, much of Phase IV is a vertical expansion, and, as such, the Phase I portion of the project is governed by Env-Sw 805.17(a)(1), and the overly portion (i.e., over the closed, unlined MSW landfill) is governed by Env-Sw 805.17(a)(2).

4.2 Landfill Subgrade and Base Grade Requirements (Env-Sw 805.03)

As discussed in Section 2 above and in the Hydrogeologic Report, the natural soil types in the Phase IV expansion area footprint are characterized as glacial till, glaciofluvial, and glaciolacustrine deposits. These soil types have supported the existing landfills and will support the Phase IV expansion. Subsurface data provided in the Hydrogeologic Report do not indicate the presence of variable soil conditions such as soft clay or organic soils within the Phase IV expansion footprint that could result in significant differential settlement.

As depicted in Figure 1, the Phase IV expansion is comprised of three different areas: (i) the vertical expansion over Phases I and II; (ii) the overlay area over the closed, unlined landfill ; and (iii) the base area. Pursuant to Env-Sw 805.17(a)(1), a liner system is not required for the Phase IV vertical expansion over Phases I and II. However, because Phases I and II have liner penetrations as part of their leachate collection system that do not meet the requirements of Env-Sw 805.05(j), an Application for Waiver from Env-Sw 805.05(j), to allow for the vertical expansion to occur over Phases I and II, is provided as Appendix J to this Type I_A PMA. Also, pursuant to Env-Sw 805.17(a)(2), for the overlay area, *a double liner system meeting the requirements of Env-Sw 805.05 over the existing landfill* is required. Furthermore, for the base area, a double liner system that also complies with 805.03 will be required.

Construction of the Phase IV expansion will begin in the base area following the decommissioning and removal of the existing groundwater monitoring wells and Facility infrastructure. The existing subgrade will be prepared (i.e., excavated, shaped, and proof rolled) to achieve the desired contours that promote drainage of leachate to a common sump. Structural Fill, as defined in the Technical Specifications (see Attachment B to this Design Report), will be used to construct the containment berms on the east and west ends of the base area and for general raises in grade.

Once the prepared subgrade is established, then the Landfill Subgrade, consisting of a 6-inch thick layer of Screened Till, will be placed and compacted to the grades depicted on the drawings (see Appendix B to the Type I-A PMA). The Landfill Subgrade grades represent the bottom of the liner system or top of the Landfill Subgrade. As previously noted, the Landfill Subgrade grades are at least 6 feet above the seasonal high groundwater table and the top of bedrock.

The materials properties, placement, and compaction requirements of the Screened Till are defined in the technical specifications; the CQA testing requirements for the Screened Till are addressed in the CQA Plan (see Attachment C to this Design Report).

For the overlay area, the double liner system will be constructed over the final cover system of the existing closed, unlined MSW landfill. The existing final cover system consists of the following components, listed from top to bottom:

- A 6-inch thick layer of topsoil;
- A 12-inch thick layer of drainage sand;
- A drainage geocomposite;
- A 40-mil thick, textured high-density polyethylene (HDPE) geomembrane;
- A 6-inch thick layer of buffer sand; and
- A 12-inch thick layer of cover material.

To construct the double liner system in the overlay area, the 6-inch thick layer of topsoil will be removed exposing the drainage sand layer, on which the Phase IV liner system will be constructed. Because the underlying components of the existing final cover system will remain, the requirements of Env-Sw 805.03 are met as follows.

(a) The subgrade surface (i.e., existing drainage sand layer) will be graded and prepared for landfill construction;

(b) The 40-mil thick HDPE geomembrane exhibits a hydraulic conductivity of less than $1{\times}10^{-4}$ cm/sec;

(c) The subgrade materials can support the facility under the anticipated loading conditions;

(d) The Phase IV expansion is stable, see Attachment A for calculations;

(e) The existing drainage sand layer, on which the secondary geomembrane will be installed:

  - Is uniform and consistent and stable under loading; and
  - Contains no stones greater than one inch in diameter, and no sharp or angular materials; and

(f) The base grades are sloped as required by Env-Sw 805.06 (see Section 4.5 of this report).

Also, when constructed, the soil layers of the existing final cover system were compacted to at least 90 percent of the maximum dry density as determined by ASTM D1557 (Modified Effort). To comply with Env-Sw 805.03(f)(3), additional testing will be performed to verify that the soil layer exhibits an in-place density of at least 95 percent of the maximum dry density as determined by ASTM D698 (Standard Effort). If needed, then the existing drainage sand layer will be subjected to additional compaction using a smooth drum roller until field tests confirm that the desired compaction is achieved.

4.3 Liner Material and Construction Requirements (Env-Sw 805.04)

The proposed double liner system for the Phase IV expansion is the same as the double liner systems constructed for Phases I through III. The Phase IV expansion double liner system includes two (primary and secondary) 60-mil thick, textured HDPE geomembranes. When first introduced, HDPE geomembranes were subjected to numerous chemical compatibility tests to document its appropriateness for use as a MSW landfill liner material. At present, HDPE geomembranes are commonly used as liner and cover materials for MSW landfills. The material properties and installation requirements for the 60-mil thick, textured HDPE geomembrane are defined in the technical specifications and the CQA testing requirements are addressed in the CQA Plan (Attachments B and C, respectively).

4.4 Liner System Design Standards (Env-Sw 805.05)

As indicated above, the double liner system will include primary and secondary 60-mil, textured HDPE geomembranes. Being a double liner system, a leachate collection and removal system (see Section 4.5) will be constructed above the primary geomembrane and a leak detection and location system (see Section 4.6) will be constructed above the secondary geomembrane. Specifically, the double liner system includes the following, listed from top to bottom:

- An 18-inch thick layer Drainage Sand;
- A drainage geocomposite (primary);
- A 60-mil thick, textured HDPE geomembrane (primary);
- A geosynthetic clay liner (GCL) (base area only, extends 10-feet up the sideslope);
- A 12-inch thick layer of Drainage Sand (base area only, not on sideslopes);
- A drainage geocomposite (secondary);
- A 60-mil thick, textured HDPE geomembrane (secondary);
- A 6-inch thick layer of Screened Till (Landfill Subgrade, see Section 4.2, in base area only); and
- The Prepared Subgrade.

Details illustrating the double liner system are provided in the drawings (Appendix B to the Type I-A PMA). The material properties and installation requirements for the components of the double liner system are defined in the technical specifications and the CQA testing requirements are addressed in the CQA Plan (Attachments B and C, respectively).

As noted above, the liner geomembranes will be overlain by a drainage geocomposite and 12 inches of Drainage Sand, except on the sideslopes. As described in Sections 4.5 and 4.6, the geotextile components of the primary and secondary drainage geocomposites will be selected to protect the underlying geomembrane from puncture. Furthermore, the drainage geocomposite and the overlying drainage aggregate material will be selected to transmit leachate to limit hydraulic head. See Attachment A for supporting calculations.

The double liner system will be constructed over slopes not exceeding 2 horizontal to 1 vertical (2H:1V), and there are no penetrations through the either the primary or secondary liner in areas where leachate may collect.

Stability calculations for the Phase IV expansion are presented in Attachment A and includes evaluations of global stability (full buildout of the expansion) and veneer stability of the liner system components. The results of these calculations indicate that the proposed double liner system meets or exceeds industry standard factors of safety (FS).

4.5 Leachate Collection and Removal System (Env-Sw 805.06)

Currently, leachate generated in Phases I, II, and III is conveyed, via gravity, through the leachate manhole to the Leachate Flow Control Building located to the north of the closed, unlined MSW Landfill. The Leachate Flow Control Building controls the flow of leachate from the Facility to an existing 12-inch diameter gravity connection to the City of Nashua's sewer system.

The Facility operates under an industrial discharge permit that was approved by the City of Nashua's wastewater treatment plant (WWTP), which allows the Facility to convey leachate up to 288,000 gallons per day (200 gallons per minute) to the WWTP. The City of Nashua's WWTP includes secondary treatment and has a design capacity of 16 million gallons per day (MGD). The current average flow at the City of Nashua's WWTP is in excess of 10 MGD. In the event that leachate generated at the Facility cannot be transferred to the City of Nashua's WWTP, commercial wastewater haulers will be contracted to dispose of leachate at wastewater treatment facilities in Massachusetts. (See also the Operating Plan, Appendix D to the Type I-A PMA.)

The Phase IV expansion will be constructed so that stormwater and leachate are hydraulically separated. To accomplish this, berms will be constructed on the east and west ends to isolate the disposal area from the surrounding area. Furthermore, the Phase IV expansion will be developed in stages and will include division berms to divert runon from the closed, unlined MSW landfill away from the disposal area. Anticipated staging is depicted on the drawings.

The leachate collection and removal system is designed to function in all weather conditions. The leachate will be collected in a sump located at the lowest spot in the base area and the piping will be protected from the overlying waste by the Drainage Sand and/or Crushed Stone. Leachate will be pumped from the sump to a Sump Riser Building, in which exposed piping will be insulated and heat traced. Below ground conveyance piping between the Phase IV Sump Riser Building and the existing leachate manhole, where leachate is directed to the City of Nashua wastewater treatment system, will be installed below the frost line or insulated.

Leachate generation rates were calculated for each development phase of the Phase IV expansion. The calculations were performed using the United States Environmental Protection Agency (USEPA) Hydrologic Evaluation of Landfill Performance (HELP) model, a quasi-two-dimensional hydrologic model for evaluating the water balance of landfills, cover systems, and other solid waste containment facilities. For the Phase IV expansion, the HELP model's weather data was updated using the precipitation data based on recent daily precipitation data collected at the Nashua Airport between 2010 and 2019[4]. Leachate recirculation was not considered in the HELP model. The HELP model incorporated various percent base slopes and considered the following development scenarios:

- Initial filling, assuming a 10-foot thick waste layer;
- 103.5-foot thick waste layer (50% total waste thickness); and
- 207-foot thick waste layer (100% waste thickness).

The results of the HELP model are provided in Attachment A and demonstrate that there will be less than 12 inches of leachate hydraulic head on the primary liner system. Also, calculations supporting the selection of the Drainage Geocomposite transmissivity, which can be either a geonet drainage geocomposite of a multilinear drainage geocomposite, are included in Attachment A.

Leachate generated in Phase IV will flow to an 8-inch diameter perforated HDPE collection pipe installed on the north side of the base area. The perforated leachate collection pipe will be surrounded by Crushed Stone covered with a nonwoven geotextile. The collection pipe flows to the Crushed Stone-filled sump (primary leachate sump) where a submersible pump will convey the leachate to through the Sump Riser building to the existing leachate manhole. Cleanouts will be provided for the collection pipe. The cleanouts provide access to the pipes for cleaning and video inspections, if necessary.
Calculations related to the selection of the nonwoven geotextiles and the flow capacity and physical strength of the 8-inch diameter perforated HDPE collection pipe are provided in Attachment A.

The primary leachate sump will be located at the low point in the western end of the Phase IV expansion. The primary leachate sump will be about 2.5 feet deep with 3H:1V sideslopes extending up from an 8-foot by 14-foot bottom area. As an additional measure, a 60-mil thick, textured HDPE geomembrane will be installed over the primary geomembrane. The additional 60-mil geomembrane will be welded to the primary geomembrane outside the limits of the sump. A nonwoven geotextile will be installed around the Crushed Stone to provide additional puncture protection to the underlying geomembrane and to maintain the integrity of the stone. Details of the primary leachate sump are presented on the drawings (see Appendix B to the Type I-A PMA).

Leachate will be removed from the primary leachate sump using submersible pumps installed in 18-inch and 24-inch diameter HDPE riser pipes, which extend from the base of the sump to a Sump Riser Building. In the base the primary leachate sump, the risers will be perforated to allow liquid to flow into the pipe. Details of the risers are presented on the drawings.

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[4] National Oceanic and Atmospheric Administration, Quality Controlled Local Climatological Data (2010-2019) for Boire Field Airport, Nashua, New Hampshire. (https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/quality-controlled-local-climatological-data-qclcd).

The leachate pumps will be controlled through the Facility's telemetry system. Each pump will be configured to operate when the leachate level in the sump reaches a pre-determined set point. Flow meters will monitor the volume of leachate pumped. Leachate controls will have readouts on the control panels that permit direct observation of leachate levels in the sumps. Details of piping, valves, and controls for the leachate pumping system are provided on the drawings and are consistent with the systems in place for Phase III.

The Phase IV expansion development stages were designed to limit the potential for runon from the closed, unlined MSW Landfill and the Phase I. Stormwater diversion berms will be constructed to divert stormwater runon away from the active disposal area. With these considerations, the Phase IV expansion development stages were configured to retain the liquid captured during a 100-year, 24-hour storm event (7.85 inches) (i.e., contingency event), which is calculated to be approximately 1,817,700 gallons for the critical development scenario. Because this liquid must be removed within seven (7) days the leachate collection sump will be equipped with a pump rated at 155 gallons per minute (gpm) in addition to a pump rated at 29 gpm to manage the routine leachate flow. Supporting calculations are provided in Attachment A.

As previously noted, the Facility is permitted to discharge leachate to the City's WWTP at a rate of approximately 288,000 gallons per day. Over a seven-day period, this amounts to approximately 2,016,000 gallons. Because the volume of the contingency event is 1,817,700 gallons, which less than 2,016,000-gallon limit, no additional on-site leachate storage is required. The expected operating leachate flow volume is also expected to be managed within the allowable range of the City's discharge limit.

The proposed components of the Phase IV leachate collection and removal system consist of HDPE materials as well as other materials commonly used in similar systems and meet or exceed the requirements of the NH SW Rules. The material properties and installation requirements for the components of the leachate collection and removal system are defined in the technical specifications and the CQA testing requirements are addressed in the CQA Plan (Attachments B and C, respectively).

4.6 Leak Detection and Location System Requirements (Env-Sw 805.07)

In addition to the leachate collection and removal system described in Section 4.5, the Phase IV expansion includes a leak detection and location system, otherwise known as the secondary leachate collection system. The secondary leachate collection system is located beneath the primary geomembrane liner and above the secondary 60-mil thick, textured HDPE geomembrane. The system consists of Drainage Geocomposite (geonet drainage geocomposite), which is overlain by a 12-inch thick layer of Drainage Sand in areas with slope less than 5 percent. An 8-inch diameter perforated HDPE collection pipe, installed on the north side of the base area, conveys the liquid to a Crushed Stone-filled sump (secondary leachate sump) located coincident with the primary leachate sump. The perforated secondary leachate collection pipe will be surrounded by Crushed Stone covered with a nonwoven geotextile. As with the primary leachate system, a submersible pump will convey the leachate to through the Sump Riser Building to the existing leachate manhole. Cleanouts will be provided for the collection pipe. The cleanouts provide access to the pipes for cleaning and video inspections, if necessary.

Calculations related to the selection of the nonwoven geotextiles and the flow capacity and physical strength of the 8-inch diameter perforated HDPE collection pipe are provided in Attachment A.

The secondary leachate sump will have a 4-foot by 9-foot bottom area. As an additional measure, a 60-mil thick, textured HDPE geomembrane will be installed over the secondary geomembrane. The additional geomembrane will be welded to the secondary geomembrane outside the limits of the sump. A nonwoven geotextile will be installed around the Crushed Stone to provide additional puncture protection to the underlying geomembrane and to maintain the integrity of the stone. Details of the sump are presented on the drawings (see Appendix B to the Type I-A PMA).

Leachate will be removed from the secondary collection sump using a submersible pump installed in an 18-inch diameter HDPE riser pipe, which extend from the base of the sump to a Sump Riser Building. In the base of each sump, the riser will be perforated to allow liquid to flow into the pipe. Details of the riser are presented on the drawings (see Appendix B to the Type I-A PMA).

The leachate pump will be controlled through the Facility's telemetry system. The pump will be configured to operate when the leachate level in the sump reaches a pre-determined set point. A flow meter will monitor the volume of leachate pumped. Leachate controls will have readouts on the control panels that permit direct observation of leachate levels in the sumps. Details of piping, valves, and controls for the leachate pumping system are provided on the drawings and are consistent with the systems in place for Phase III.

The transmissivity of the Drainage Geocomposite was selected so that liquids can be conveyed to the sump from the most hydraulically distant location in the system in less than 24 hours under saturated hydraulic conditions. Supporting calculations are provided in Attachment A.

4.7 Groundwater and Surface Water Monitoring System Requirements (Env-Sw 805.08)

The Hydrogeologic Report for the Phase IV expansion, provided as Appendix C to the Type I-A PMA, discusses the hydrogeologic conditions of the Facility and recommends a groundwater and surface water monitoring plan. The locations of the existing and proposed groundwater monitoring wells and surface water monitoring points are depicted on the drawings (see Appendix B to the Type I-A PMA). As noted on the monitoring plan drawing, there is no change to the surface water monitoring locations. The groundwater monitoring network will be modified to reflect the decommissioning of four groundwater monitoring locations within the footprint of the Phase IV expansion and the installation of four replacement groundwater release detection wells. The location of the groundwater monitoring wells provides for one (1) hydraulically upgradient and at least three (3) hydraulically downgradient locations.

The groundwater monitoring wells will be decommissioned or installed in accordance with NHDES requirements.

4.8 Stormwater Management System Requirements (Env-Sw 805.09)

Overview

The Phase IV expansion design was prepared considering the management of stormwater runoff and runon. Accordingly, the design incorporates features to:

- Divert runon around/away from the Phase IV disposal area;
- Control stormwater runoff from the Facility;
- Control erosion, sedimentation, siltation, and flooding; and
- Limit leachate generation.

The stormwater management system features were designed in consideration of the following criteria:

- Accommodate the considering the precipitation from a 25-year, 24-hour storm event;
- Accommodate the development phases of the Phase IV expansion from initial construction to closure and the post-closure period;
- Be hydraulically separate from the leachate collection and removal system – stormwater that contacts waste is to be managed as leachate unless representative analytical characterization performed in accordance with the Operating Plan (see Appendix D of the Type I-A PMA) demonstrates the liquid may be lawfully discharged to ground or surface waters without treatment;
- Function effectively during frozen ground conditions;
- Include permanent sedimentation ponds and detention ponds sized to handle the 25-year, 24-hour storm event with no less than one foot of freeboard below the emergency spillway invert;
- Limit the peak runoff from the 25-year, 24-hour storm event to no greater than the pre-development discharge rate;
- Provide appropriately sized perimeter drainage features to convey runoff around the disposal area during the operating and post-closure periods; and
- Incorporate appropriate erosion and sediment control measures to reduce the potential for erosion and capture sediment should erosion occur.

Because of the aerial extent of the Phase IV expansion, a NHDES Alteration of Terrain (AoT) permit is required. Although the AoT permit application will be filed separately, the Phase IV stormwater and erosion and sedimentation controls presented on the drawings (see Appendix B to the Type I-A PMA) and described below, incorporate the AoT Bureau design criteria.

Existing Conditions

There are six (6) stormwater detention basins at the Facility. These basins were designed and constructed to accommodate the stormwater runoff flows from the closed C&D landfill, the closed, unlined MSW landfill, Phases I, II, and III, and the compost area. Stormwater runoff is directed to the basins through drainage swales, culverts, and/or over land flow. The basins are designed to discharge the detained water in a controlled and non-erosive manner to on-site wetland areas and Trestle Brook at permitted locations.

Proposed Condition

Being located between existing landfill units, stormwater runoff from the Phase IV expansion will be directed to Detention Basins #2 and #4. The Phase IV expansion area is divided into drainage areas using diversion swales so that stormwater runoff is directed to specific basins in a controlled manner. The runoff to each basin is controlled to maintain the design functionality and performance of the existing basins. The stormwater management features proposed for the Phase IV expansion are depicted on the drawings (Appendix B to the Type I-A PMA) and support calculations are provided in Attachment A. Proposed erosion and sediment control measures are also depicted on the drawings and addressed in the Technical Specifications (Attachment B).

Perimeter Stormwater Control

A perimeter berm will be constructed on the west, north, and east sides of the Phase IV expansion area (the south side is bounded by Phase I). The perimeter berm serves as a stormwater runon barrier to the Phase IV expansion disposal area. A trapezoidal shaped drainage swale will be constructed in the perimeter berm outside of the limit of waste and the liner/cover system anchor trench. The swale is designed to handle the runoff from the Phase IV disposal area. Due to the slope, the west and east swales will be lined with gabions, while the flatter north swale will be grass-lined.

Gabions are rectangular baskets made of galvanized steel wire and filled with stone. Gabions are relatively flexible and can accommodate settlement normally associated with waste disposal facilities without adversely affecting channel performance or integrity. Gabion-lined swales have successfully been used numerous landfills including those in New Hampshire.

Stormwater in the perimeter swales will be conveyed to existing Basins #2 or #4 through existing stormwater management conveyances. The existing stormwater basins control the peak discharge flow and allow for sediment removal.

Phased Construction and Hydraulic Separation

The Phase IV expansion will be constructed in stages, which are depicted on the drawings (see Appendix B to the Type I-A PMA). As part of the staged development, temporary and permanent stormwater management features will be constructed to hydraulically separate stormwater from leachate, which will limit the volume of leachate generated in Phase IV.

During the initial construction, the lower portions of the east and west perimeter berms (permanent features) will be constructed, which, as previously described, will prevent stormwater runon into the active disposal area. In addition, temporary diversion berms will be constructed on the north and south sides of the initial construction area, which will prevent stormwater runon from the closed, unlined MSW landfill and Phase I, respectively.

As waste filling progresses, the perimeter berms, which include the gabion-lined drainage swales, will be extended up the slope of the closed, unlined MSW landfill, and new temporary diversion berms will be installed north and south of the Phase IV disposal area.

Erosion, Sediment, Silt, and Flood Control

Erosion and sediment control (ESC) best management practices (BMPs) are incorporated in the design and will be implemented during the construction and waste filling stages of the Phase IV expansion. The BMPs include: (i) planning; (ii) installing ESC measures downslope of earth disturbing activities; (iii) stabilizing disturbed ground (temporary and permanent); and (iv) observing site conditions. The purpose of these measures is to reduce the potential for soil erosion, limit the transport of eroded soil, and contain sediment and silt.

- Planning – Large-scale construction projects are successful when the construction activities are well planned and contingencies are considered. The construction of the Phase IV expansion is staged so that the construction limits are well-defined and perimeter controls can be installed prior to implementing large-scale earth moving. The staged development of Phase IV is depicted on the drawings as are the specific BMPs.
- Down slope measures – Soil-retaining BMPs (e.g., filter logs) will be installed down slope of earth disturbing activities and in front of stormwater conveyance features that may receive sediment-laden runoff. Down slope measures will be installed prior to initiating construction activities and will remain in place until after the contributing area is stabilized.
- Stabilization – Disturbed areas will be stabilized once the area is at final grade, or within 14 days of termination of activity. Acceptable temporary stabilization measures include mulch and tack, gravel cover, and vegetation. Acceptable permanent stabilization measures include gravel or paved roadway and permanent vegetation. Temporary and permanent vegetation may supplemented with an erosion blanket or turf reinforcing mat as needed. In addition, drainage swales should be lined with non-erosive materials based on the anticipated stormwater flows
- Observations – The performance of BMPs is dependent on routine maintenance, which is best evaluated through regular observation of the features. Observations should be performed on a regular basis based on season and weather and after significant precipitation events. The observations should be documented and needed maintenance and/or corrective action noted. Required BMP maintenance or replacement should be performed timely.

The Phase IV expansion is not located in a flood zone nor would the stormwater runoff from the Phase IV expansion cause flooding at the Facility or the surrounding area.

4.9 Landfill Gas Control Requirements (Env-Sw 806.07)

The closed, unlined MSW landfill and Phases I and II have active landfill gas (LFG) collection and control systems (GCCSs). LFG extracted from the GCCSs are conveyed to an on-site LFG-to-electricity plant or to an on-site flare. Because the Phase IV expansion will overlay some of the GCCS components (i.e., conveyance pipes, collection features), these components will be either decommissioned, relocated, or modified, as depicted on the drawings (Appendix B to the Type I-A PMA).

LFG generated in the Phase IV disposal area will be managed by GCCS components installed in the waste mass. The GCCS components will collection trenches, extraction wells, and conveyance pipe. The drawings depict the proposed final extraction well layout and a proposed LFG conveyance pipe network. Collection trenches will be installed on a regular frequently, perhaps every 12 to 18 months depending on waste type and volume. The location of the trenches will be based on the actual configuration of the waste fill at the time. Details of the GCCS components are depicted on the drawings.

4.10 Landfill Final Cover System Requirements (Env-Sw 805.10)

The Phase IV expansion will be filled with waste to the grades shown on the drawings (see Appendix B of the Type I-A PMA), with the top deck of having a slope of no less than five percent (5%); except for stormwater diversion swales and the average slope of the sideslopes will be no steeper than 3H:1V at closure. Once the proposed final grades of the Phase IV expansion are achieved, the disposal area will be capped with a final cover system that achieves the following performance standards (see also Env-Sw 807.04):

- Reduce the potential to generate leachate;
- Promote drainage of stormwater;
- Limit the potential for soil erosion and the transport of sediment;
- Reduce the potential to generate decomposition gases (LFG) and capture LFG that is generated;
- Settle without damaging the integrity of the final cover system;
- Not adversely impact to air, groundwater, or surface water; and
- Not otherwise pose a risk to human health or the environment (e.g., isolate the waste, limit attraction of vectors, limit odors, avoid potential for fire).

To achieve the above performance standards, the proposed Phase IV expansion final cover system will comply with the Env-Sw 805.10 (e) having the following components, listed from top to bottom:

- 4-inch thick layer of Topsoil (Layer 5);
- 12-inch thick layer of drainage sand (Layer 4b);
- A drainage geocomposite (Layer 4a);
- 40-mil thick geomembrane (Layer 3);
- 12-inch thick layer of sand (Layer 2); and

- 12-inch thick layer of soil overlying the waste (Layer 1).

Details of the final cover system and its termination at the perimeter berm is depicted on the drawings.

Stormwater runoff from the closed landfill will be collected in diversion swales constructed above the final cover system and conveyed to gabion-lined downchutes to the perimeter drainage system. The diversion swales are designed to convey runoff from the 25-year, 24-hour precipitation event. Location and configuration of the diversion swales are depicted on the drawings. Supporting calculations are provided in Attachment A.

The technical specifications and the CQA testing requirements for the above final system components are addressed in the CQA Plan (Attachments B and C, respectively). Calculations supporting the stability of the final cover system and the selection of the drainage geocomposite are provided in Attachment A. Following construction of the final cover system, the limits of the system will be identified with visible physical markers.

4.11 Other Design Requirements (Env-Sw 805.11)

Staging, stormwater, and leachate management

As depicted on the drawings and described above, the Phase IV expansion will be developed in stages. Depending on economic conditions and anticipated waste receipts, the stages may be subdivided into cells using berms that will hydraulically separate adjacent cells. The development of the stages, and the construction of diversion berms to divert stormwater runoff, are integral to limiting the generation of leachate. As Phase IV expansion area is developed, construction of the proposed stormwater features will be consistent with those required for final closure. The proposed stormwater management features were designed to safely convey stormwater in a non-erosive manner to the existing stormwater management features, which were evaluated to confirm their performance for the proposed Phase IV expansion.

Access and aesthetics

The Phase IV expansion area is located between two existing landfill units. As such, access to the disposal area is controlled and limited to one access point. The existing main access road will be used by authorized personnel to reach the disposal area. As with the other disposal areas, perimeter litter fencing will be provided.

As previously noted, the Phase IV expansion area is more than 500 feet from the property line and is nestled between two existing landfills. Considering that there is a treed area along the property line, it will be difficult to view Phase IV from offsite.

Stability

Stability evaluations of the Phase IV expansion are provided in Attachment A. The evaluations incorporated the contribution of the perimeter berm. The Phase IV expansion was design to exhibit a static factor of safety of at least 1.5.

4.12 Construction Quality Assurance/Quality Control (Env-Sw 805.16)

The liner and final cover systems will be constructed in accordance with the Phase IV expansion drawings (see Appendix B to the Type I-A PMA), technical specifications (Attachment B), and the CQA Plan (Attachment C). These documents were prepared based on the known site conditions, the planned operations (see Appendix D to the Type I-A PMA), and the supporting calculations (Attachment A). The technical specifications and CQA Plan prescribe the material testing requirements and frequencies and defines the responsibilities of the CQA personnel.

5.0 UNIVERSAL DESIGN REQUIREMENTS (ENV-SW 1004 AND 1103)

5.1 General Requirements (Env-Sw 1103.01)

The Phase IV expansion design incorporates proven technologies, previously used at the Facility and other NH landfills, and is based on industry-standard engineering practices that comply with the 40 CFR 258 and NH SW Rules. The design is compatible with the proposed operating and closure plans.

5.2 Roads and Traffic Control (Env-Sw 1004.02)

The existing entrance to the Facility will continue to be used during the operating life of Phase IV. The existing entrance controls access and provides for a safe flow of traffic into, out of, and within the entrance area. The Facility entrance provides adequate queuing for vehicles. A separate scale bypass allows passenger vehicles to access the citizen drop off area.

5.3 Drainage (Env-Sw 1004.03)

Site drainage is described in Section 4.8 above.

5.4 Protection of Landfill Closure Systems (Env-Sw 1004.04)

Currently, the closed, unlined MSW and the C&D landfills contain final closure systems. The Phase IV design will be constructed over a portion of the closed, unlined MSW and will incorporate new stormwater management features. Also, several existing groundwater monitoring locations with the base area will be decommission and replaced.

5.5 Wastewater Systems (Env-Sw 1004.05)

The Phase IV project does not impact the existing on-site wastewater collection and transmission features at the Facility.

5.6 Motor Vehicle Waste Collection (Env-Sw 1004.06)

Motor vehicle waste collection is not an permitted activity at the Facility.

5.7 Equipment (Env-Sw 1004.07 and (Env-Sw 1103.02))

Equipment proposed for the Phase IV expansion (e.g., pump, meters, etc.) were selected for the purpose specified. At the time of construction, other conforming equipment may be available, and a review of proposed changes to the equipment will be reviewed at that time. Equipment installed will conform with manufacturer's specifications and recommendations.

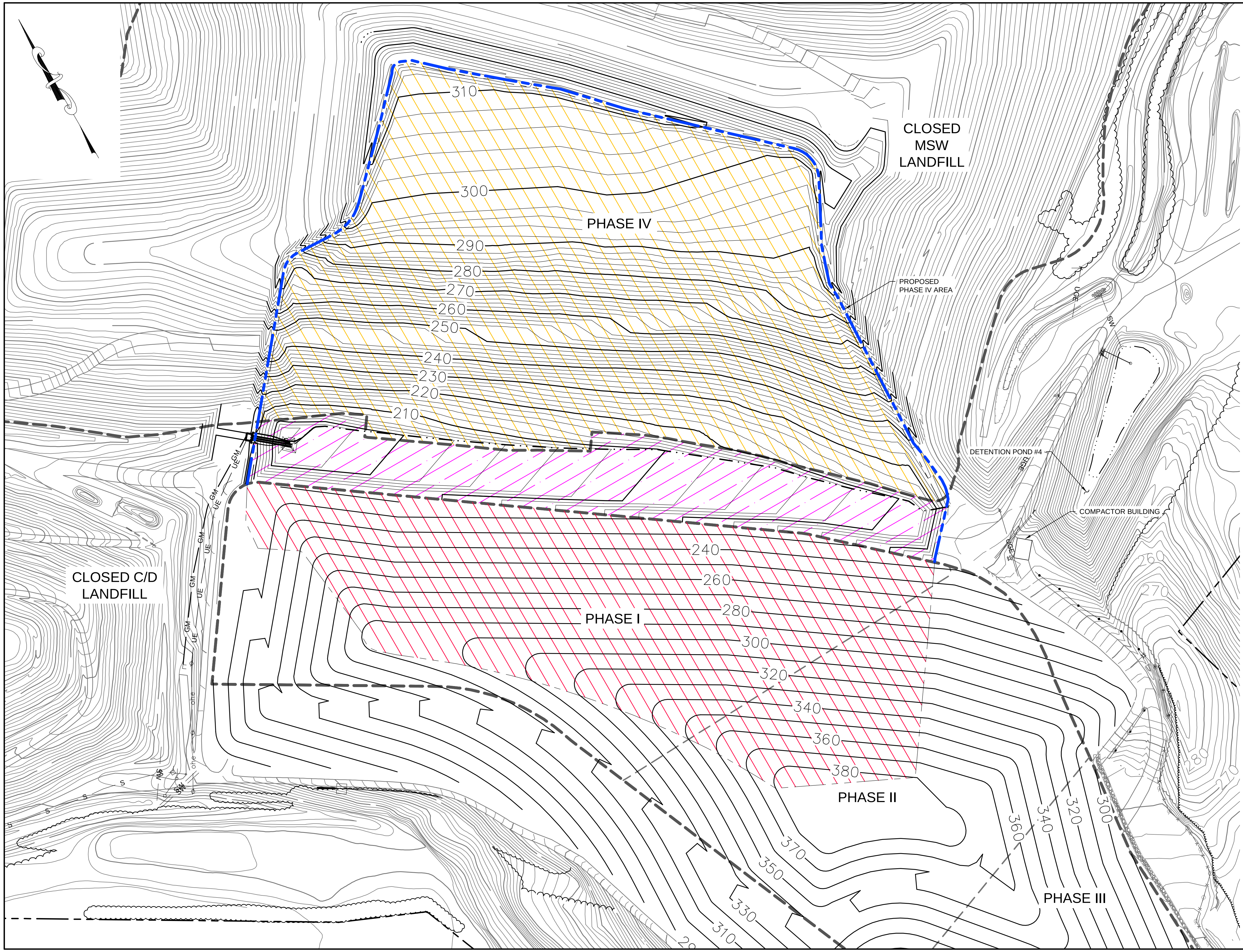
5.8 Access Control (Env-Sw 1103.03)

Access to Phase IV will be controlled and limited to one access point, which is locked during off hours. The Facility is surrounded by a perimeter fence and weather-resistance signs are posted along the perimeter.

5.9 Surrounding Properties (Env-Sw 1103.04)

The Phase IV expansion area is more than 500 feet from the property line and is nestled between two existing landfills. Considering that there is a treed area along the property line, it will be difficult to view Phase IV from offsite.

P:\3000s\3066.11\Source Files\Type I-A PMA\App A - Design\Design Report\Phase IV Design Report.docx



NOTES:

1. GRADES SHOWN IN PHASES I-III REPRESENT PROPOSED FINAL GRADES.
2. GRADES SHOWN WITHIN PHASE IV REPRESENT PROPOSED SECONDARY LINER GRADES.

LEGEND:

▬ ▬ ▬ (blue)	PROPOSED PHASE IV LIMIT OF WASTE
▬ ▬ ▬	EXISTING LIMIT OF WASTE
— — —	PHASE LIMIT
▨	VERTICAL EXPANSION OVER CLOSED, UNLINED LANDFILL
▨	BASE AREA
▨	VERTICAL EXPANSION OVER PHASES I AND II

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LINER SYSTEM SUMMARY PLAN

PROJECT NUMBER: 3066.11

FIGURE NUMBER: 1

IMAGES: P:\3000s\3066.11\Graphics Files\CAD\Design Report\Xrefs\MA_Pepperell_20180709_TM_geo.jpg
P:\3000s\3066.11\Graphics Files\CAD\Design Report\Xrefs\NH_Nashua_North_20180711_TM_geo.jpg
P:\3000s\3066.11\Graphics Files\CAD\Design Report\Xrefs\NH_Nashua_South_20180712_TM_geo.jpg
P:\3000s\3066.11\Graphics Files\CAD\Design Report\Xrefs\NH_South_Merrimack_20180709_TM_geo.jpg

XREFS: ..\XREFS\BORDER.dwg
P:\3000s\3066.11\Graphics Files\CAD\Design Report\Xrefs\LIMITS.dwg

FILE: P:\3000s\3066.11\Graphics Files\CAD\Design Report\02 - Airport Setback Plan.dwg
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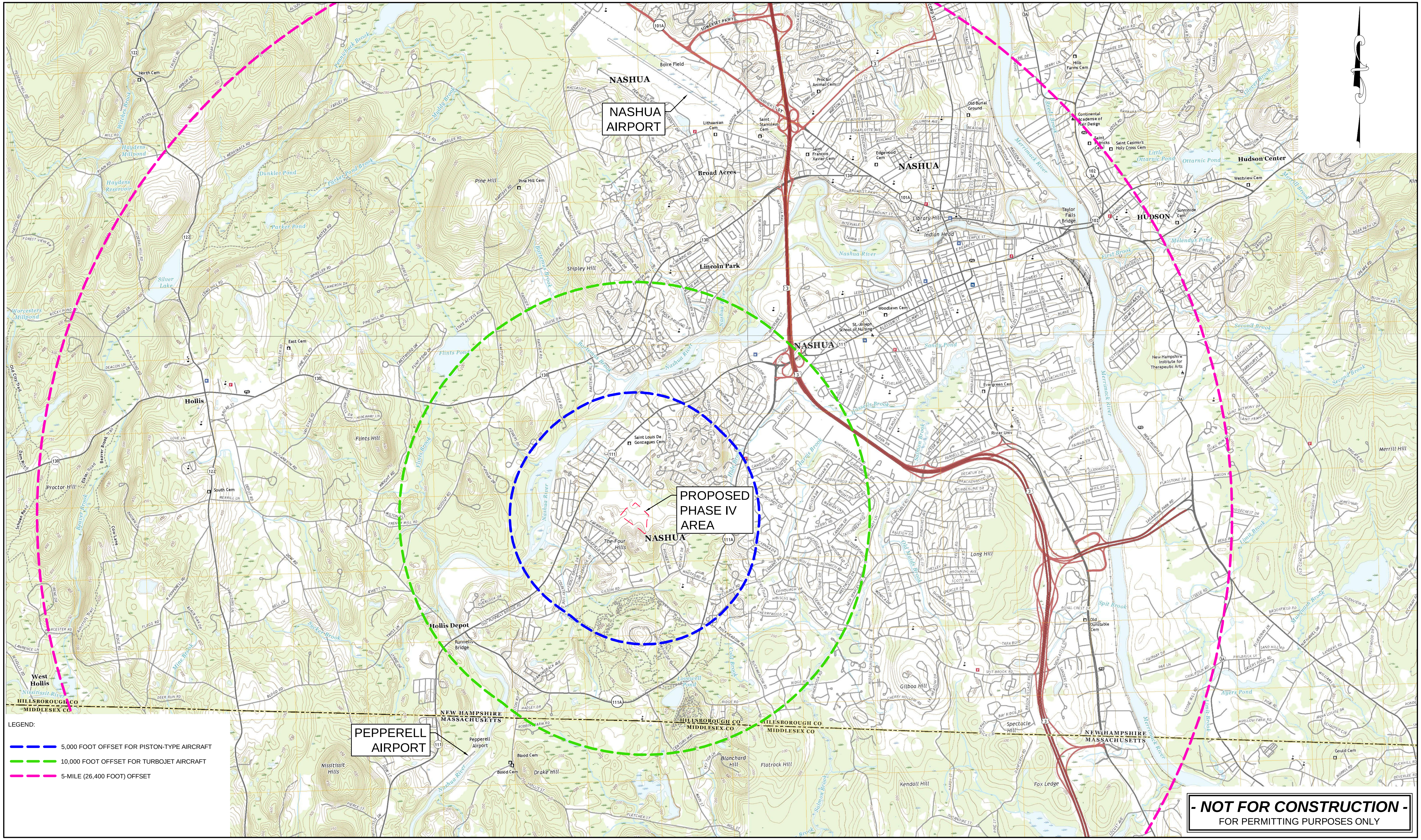
USER: ssantiago
PLOT DATE: 7-8-20 2:17 PM



LEGEND:

- 5,000 FOOT OFFSET FOR PISTON-TYPE AIRCRAFT
- 10,000 FOOT OFFSET FOR TURBOJET AIRCRAFT
- 5-MILE (26,400 FOOT) OFFSET

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN | HEAD

GRAPHICAL SCALE
2000' 1000' 0' 2000' 4000'

NO.	DATE	DESCRIPTION	BY

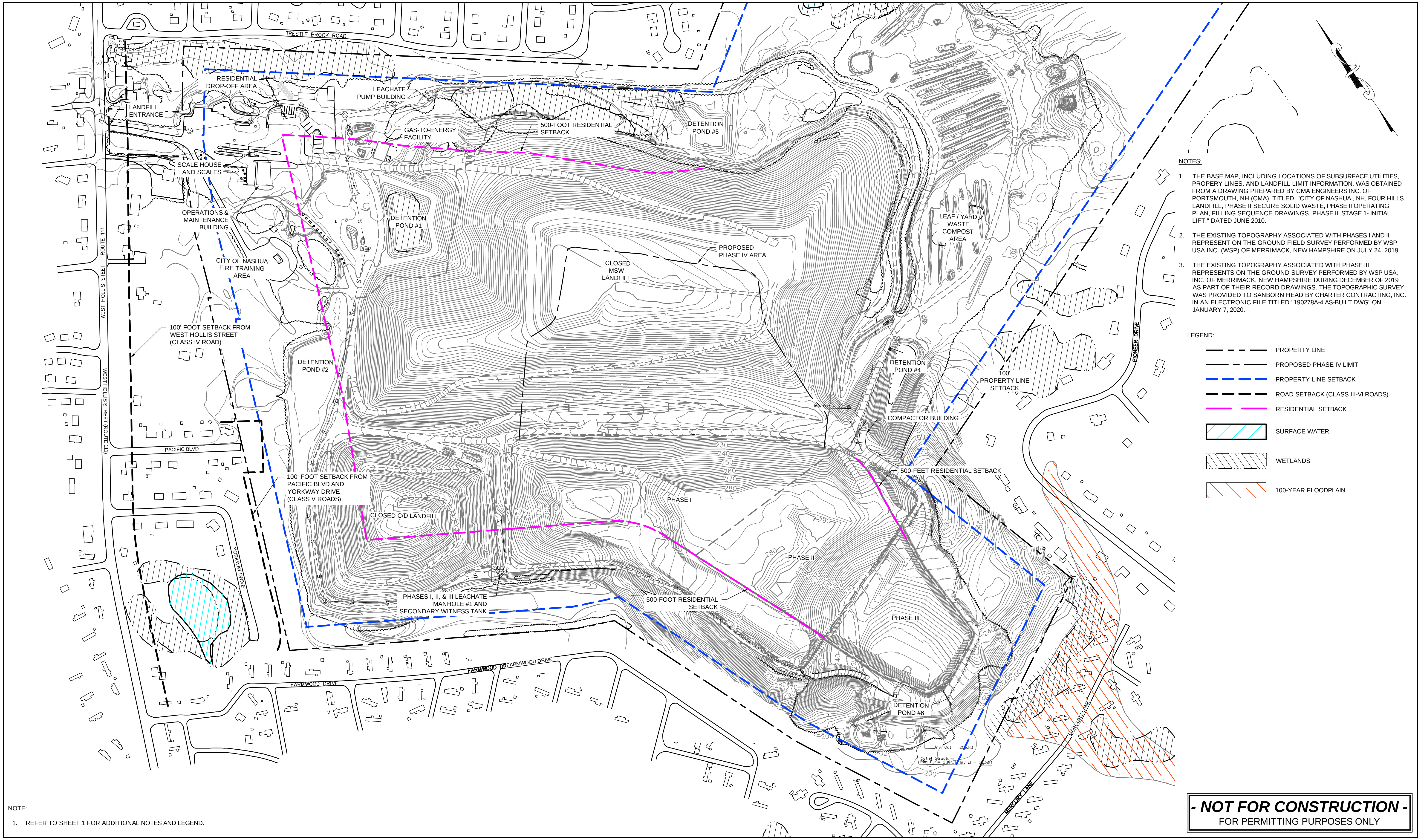
DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SETBACK PLAN - AIRPORTS

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
2



NOTES:

1. THE BASE MAP, INCLUDING LOCATIONS OF SUBSURFACE UTILITIES, PROPERY LINES, AND LANDFILL LIMIT INFORMATION, WAS OBTAINED FROM A DRAWING PREPARED BY CMA ENGINEERS INC. OF PORTSMOUTH, NH (CMA), TITLED, "CITY OF NASHUA , NH, FOUR HILLS LANDFILL, PHASE II SECURE SOLID WASTE, PHASE II OPERATING PLAN, FILLING SEQUENCE DRAWINGS, PHASE II, STAGE 1- INITIAL LIFT," DATED JUNE 2010.
2. THE EXISTING TOPOGRAPHY ASSOCIATED WITH PHASES I AND II REPRESENT ON THE GROUND FIELD SURVEY PERFORMED BY WSP USA INC. (WSP) OF MERRIMACK, NEW HAMPSHIRE ON JULY 24, 2019.
3. THE EXISTING TOPOGRAPHY ASSOCIATED WITH PHASE III REPRESENTS ON THE GROUND SURVEY PERFORMED BY WSP USA, INC. OF MERRIMACK, NEW HAMPSHIRE DURING DECEMBER OF 2019 AS PART OF THEIR RECORD DRAWINGS. THE TOPOGRAPHIC SURVEY WAS PROVIDED TO SANBORN HEAD BY CHARTER CONTRACTING, INC. IN AN ELECTRONIC FILE TITLED "190278A-4 AS-BUILT.DWG" ON JANUARY 7, 2020.

LEGEND:

PROPERTY LINE
PROPOSED PHASE IV LIMIT
PROPERTY LINE SETBACK
ROAD SETBACK (CLASS III-VI ROADS)
RESIDENTIAL SETBACK
SURFACE WATER
WETLANDS
100-YEAR FLOODPLAIN

NOTE:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.

- NOT FOR CONSTRUCTION -

FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
200' 100' 0' 200' 400'

NO.	DATE	DESCRIPTION	BY

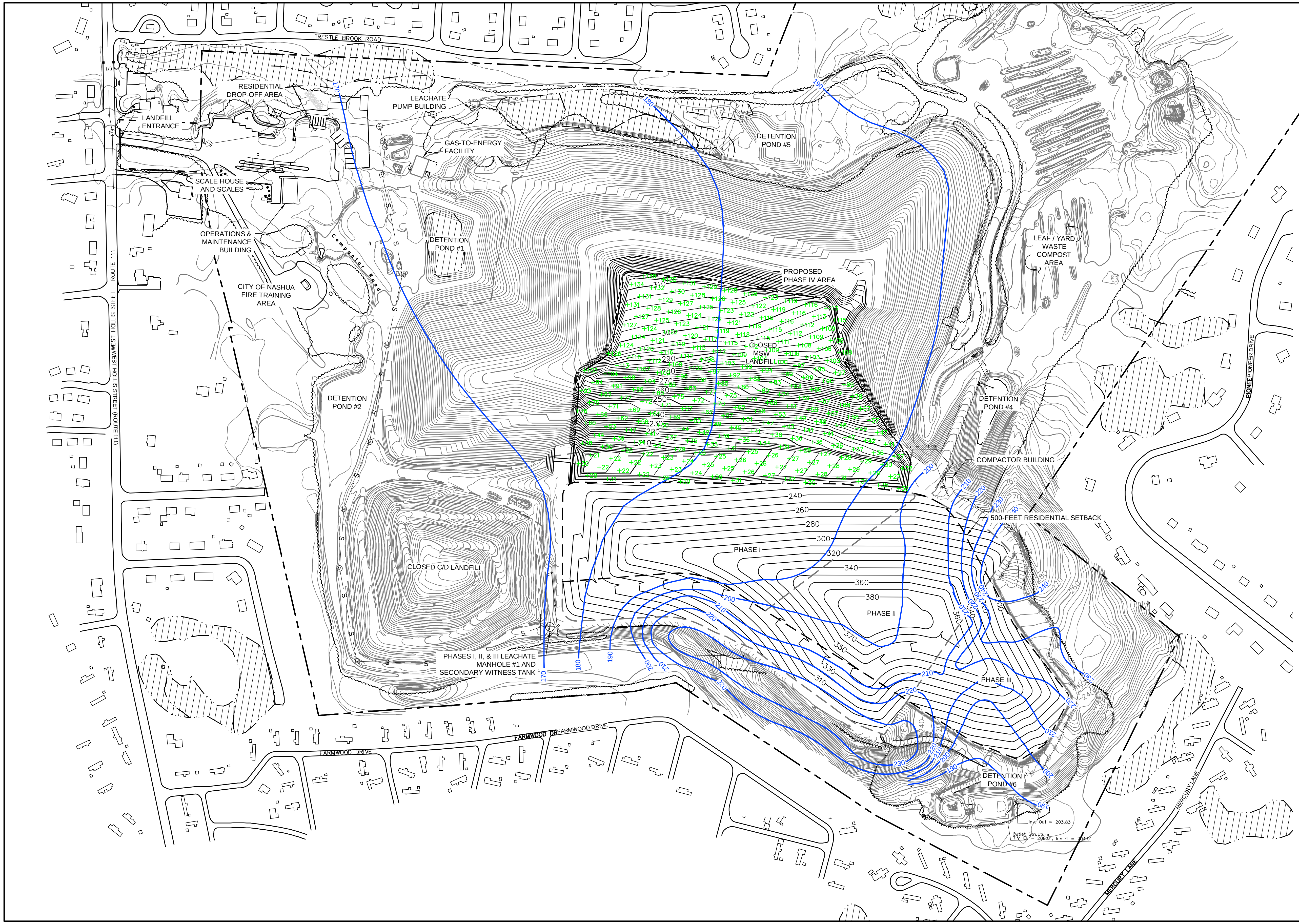
DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SETBACK PLAN - PROPERTY LINE, ROADS, FLOODPLAINS, WETLAND AREAS, AND SURFACE WATER

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
3



NOTES:

1. THE BASE MAP WAS OBTAINED FROM A DRAWING PREPARED BY CMA ENGINEERS INC. OF PORTSMOUTH, NH (CMA), TITLED, "CITY OF NASHUA, NH, FOUR HILLS LANDFILL, PHASE II SECURE SOLID WASTE, PHASE II OPERATING PLAN, FILLING SEQUENCE DRAWINGS, PHASE II, STAGE 1- INITIAL LIFT,", DATED JUNE 2010.

2. DEPTH TO GROUNDWATER TICKS ON THIS SHEET REPRESENT A COMPARISON OF SEASONAL HIGH GROUNDWATER ELEVATIONS WITH THE PROPOSED SECONDARY LINER GRADES.

LEGEND:

—250—	SECONDARY BASE 10-FOOT CONTOUR
——	SECONDARY BASE 2-FOOT CONTOUR
—250—	EXISTING 10-FOOT CONTOUR
——	EXISTING 2-FOOT CONTOUR
—320—	PHASES I-III FINAL GRADE CONTOUR
—190—	SEASONAL HIGH GROUNDWATER CONTOUR
— — — —	PROPERTY LINE
+27	DEPTH TO GROUNDWATER

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN ||| HEAD

GRAPHICAL SCALE
200' 100' 0' 200' 400'

NO.	DATE	DESCRIPTION	BY

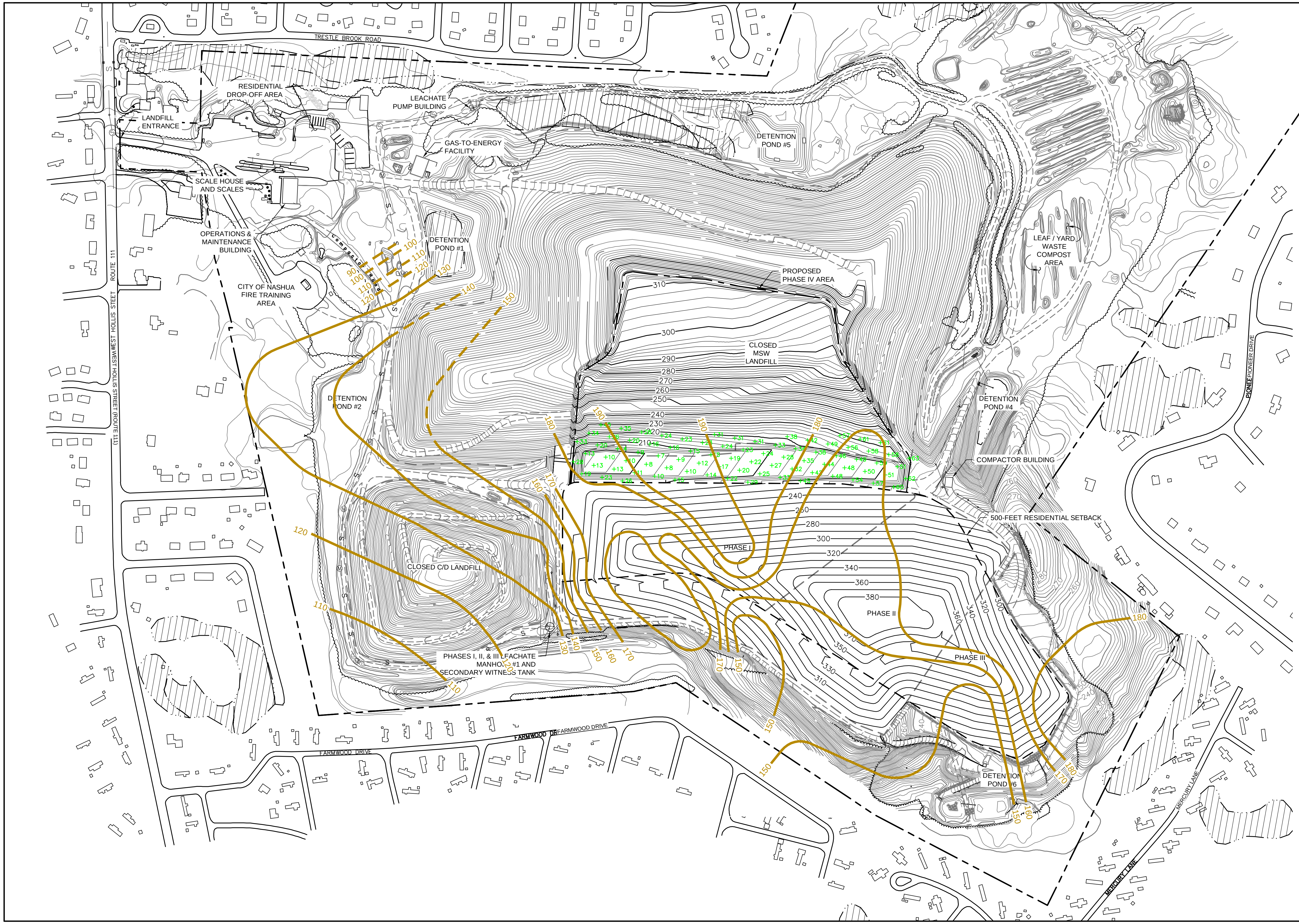
DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SEPARATION TO SEASONAL HIGH GROUNDWATER

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
4



NOTES:

1. DEPTH TO BEDROCK TICKS ON THIS SHEET REPRESENT A COMPARISON OF BEDROCK ELEVATIONS WITH THE PROPOSED SECONDARY LINER GRADES.

LEGEND:

250	SECONDARY BASE 10-FOOT CONTOUR
	SECONDARY BASE 2-FOOT CONTOUR
250	EXISTING 10-FOOT CONTOUR
	EXISTING 2-FOOT CONTOUR
350	PHASES I-III FINAL GRADE CONTOUR
190	BEDROCK ELEVATION CONTOUR
	PROPERTY LINE
+27	DEPTH TO BEDROCK

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
200' 100' 0' 200' 400'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SEPARATION TO BEDROCK

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
5

ATTACHMENT A

CALCULATIONS

CONTENTS
(Design Calculations)

A Global Stability

- A.1 Static and Seismic Stability

B Leachate Collection System

- B.1 Primary Drainage Geocomposite (Transmissivity)
- B.2 Geotextile Filter
- B.3 Leachate Collection Pipe Strength
- B.4 Leachate Collection Pipe Flow Capacity
- B.5 Secondary Travel Time (Transmissivity)

C Leachate Management System

- C.1 Phase IV Pump Sizing (Contingency)
- C.2 Leachate Sump Risers

D Liner System

- D.1 Geomembrane Puncture Resistance
- D.2 Anchor Trench Pullout
- D.3 Liner System Veneer Slope Stability

E Capping System

- E.1 Cap Geocomposite (Transmissivity)
- E.2 Cap Veneer Slope Stability

F Stormwater Management

- F.1 Stormwater Management Calculations

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A.1 STATIC AND SEISMIC STABILITY

PURPOSE:

To evaluate the global and liner stability of the proposed Phase IV grading for both static and seismic conditions at the Four Hills Landfill located in Nashua, New Hampshire.

METHOD:

- Identify cross-sections representing critical slope conditions for the proposed Phase IV liner system, perimeter berm, and final grades.
- Select strength properties for various materials associated with the cross-sections from published data, site-specific soil logs, and engineering experience.
- Estimate the horizontal acceleration for the site based on published data and mapping.
- Compute the minimum factor of safety (FS) for static and seismic conditions based on the selected cross-sections and material properties using Slide [Ref. 1]. The evaluation shall consider the potential for circular failure (stability of the foundation material) and block failure (stability of the liner system) modes. Slide is a two-dimensional slope stability program that uses vertical slice limit equilibrium methods to calculate the FS.

CROSS-SECTIONS:

The proposed secondary liner grades and final grades for Phase IV are presented on Sheets 5 and 10 of the Phase IV Design Drawings, respectively. Figure 1 depicts the location of the cross-sections selected for the analysis. The cross-sections were selected based on critical material interfaces, slopes, waste depth, and geometry.

MATERIAL PROPERTIES:

Strength properties are summarized in Table 1 below:

Table 1. Strength properties for modeled soils

Material	Unit Weight (pcf)	Friction Angle (deg.)	Cohesion (psf)
Glacial Till	140	33	0
Sand	120	28	0
MSW	85	33	0
MSW <750 psi	85	0	500
Existing MSW	85	33	0

The properties in Table 1 were taken from:

- the Naval Facilities Engineering Command (NAVFAC) design manual [Ref 2.];
- Peck et al. (1974) [Ref 3.];
- Technical Manual TM 5-818-1/AFM 88-3 [Ref. 4];
- Kavazanjian [via Qian et al. (2002), see Ref. 5]; and

- Stark et al. (2009) [Ref. 6].

The strength properties for the Phase III liner interfaces, in Table 2 below, were selected based on a direct shear database report prepared by the Geosynthetic Research Institute [Ref. 7] and engineering experience.

Table 2. Strength properties for modeled interfaces

Material	Unit Weight (pcf)	Friction Angle (deg.) (Peak)	Friction Angle (deg.) (Post Peak)	Cohesion (psf)
Liner System	120	15	8	0

HORIZONTAL ACCELERATION:

The selected slope cross-sections were evaluated using a horizontal acceleration to simulate a seismic event. According to EPA guidance [Ref. 8], the seismic analysis is to incorporate the expected maximum horizontal ground acceleration in lithified earth materials (bedrock), which relates to the horizontal acceleration with a 90 percent or greater probability of not being exceeded in 250 years. References 8 and 9 were used to select the horizontal acceleration in the area of Phase III. As shown in Attachment A, a peak ground acceleration (PGA) of 0.195 times the earth's gravitation pull (g) was obtained from the USGS [Ref. 9] for the evaluation.

It is noted that the industry practice is to adjust the PGA for slope-height effects when the depth to of the failure plane is greater than 20 feet. Using a conservative height of 60 feet (average thickness of waste within Phase IV) above the failure plane, the seismic acceleration is reduced to 0.114 g based on the procedure provided in Anderson et al. (2008) [Ref. 10].

$$\mathrm{K_{max}} = \alpha \times \mathrm{PGA} \qquad \text{[Ref. 10]}$$

Where:

$\mathrm{K_{max}}$ = Adjusted seismic acceleration (g);

α = Fill height-dependent reduction factor (dimensionless); and

= $1 + \frac{H}{100}(0.5\beta - 1)$

H = Average thickness of waste at the critical surface (ft) = 60 ft

β = $\frac{S_{D1}}{PGA} = \frac{0.120\ g}{0.195\ g} = 0.615$

= $1 + \frac{60}{100}(0.5 \times 0.615 - 1) = 0.585$

PGA = Peak ground acceleration (g) = 0.195 g.

Therefore,

$$\mathrm{K_{max}} = 0.585 \times 0.195\ g = 0.114\ g$$

CALCULATION AND RESULTS:

The FS for the selected cross-sections were calculated using Slide with the modeled slope, height, geometry, material, and interface properties. Global stability (i.e., circular and block failure modes) were evaluated using the Spencer's method of slices considering static and seismic conditions. The current state of practice for analyzing landfill liner systems under seismic loading is to model the liner system with post peak strengths, as the peak strengths typically mobilize after displacements greater than 20 mm according to Theil (2002) [Ref. 11]. The results are summarized in Table 3 and 4 below. Refer to Attachment B for the Slide output figures.

Table 3. Factors of Safety for Modeled Cross-Sections (Global)

Section	**Failure Direction**	**Failure Mode**	**Factor of Safety**	
			Static	**Seismic**
A-A'	L to R	Circular	2.3	1.6
		Block	2.4	1.7
	R to L	Circular	2.0	1.5
		Block	2.0	1.5
B-B'	L to R	Circular	2.2	1.6
		Block	2.4	1.7
	R to L	Circular	3.1	2.0
		Block	3.0	2.1

Table 4. Factors of Safety for Modeled Cross-Sections (Liner System)

Section	**Failure Direction**	**Factor of Safety**		
		Static		**Seismic**
		Peak	**Post Peak**	**Post Peak**
A-A'	L to R	2.1	2.0	1.3
	R to L	2.0	1.9	1.1
B-B'	L to R	2.1	2.0	1.4
	R to L	3.0	2.7	1.6

As summarized in Tables 3 and 4, the FS for the proposed slope cross sections is at least 1.5 for peak strengths and at least 1.0 for post peak strengths, considering static conditions. For seismic conditions, all scenarios result in a FS greater than the required 1.0. Because the FS for the post-peak seismic analyses are greater than 1.0, a pseudo-static analysis is not required according to Anderson et al. (2008) [Ref. 10].

CONCLUSIONS:

The global and liner stability of the Phase IV liner and perimeter berm meets the required FSs for the proposed conditions under static and seismic conditions.

REFERENCES:

[1] Rocscience Inc., 2016, Slide, version 6.039, Slope Stability and Groundwater Software, Toronto, Ontario.

[2] Naval Facilities Engineering Command (NAVFAC), 1982, Soil Mechanics, NAVFAC DM7.01 Design Manual, p. 7.1-22.

[3] Peck, B. Ralph, Hanson, E. Walter, and Thornburn, H. Thomas, Foundation Engineering, 2nd Edition, Wiley, Inc., 1974, p. 87.

[4] Joint Departments of the Army and Air Force, USA, 1983, "Technical Manual TM 5-818-1/AFM 88-3, Chapter 7, Soils and Geology, Procedures for Foundation Design of Buildings and Other Structures (Except Hydraulic Structures)," p. 3-3.

[5] Qian, X., Koerner, R. M., and Gray, D. H, 2002, Geotechnical Aspects of Landfill Design and Construction, Prentice-Hall, Inc., p. 184 & 202.

[6] Stark, T., Sarihan, N., and Li, G., 2009, Shear Strength of Municipal Waste for Stability Analyses, Environmental Geology, Vol. 57, Issue 8 p. 1911 & 1923.

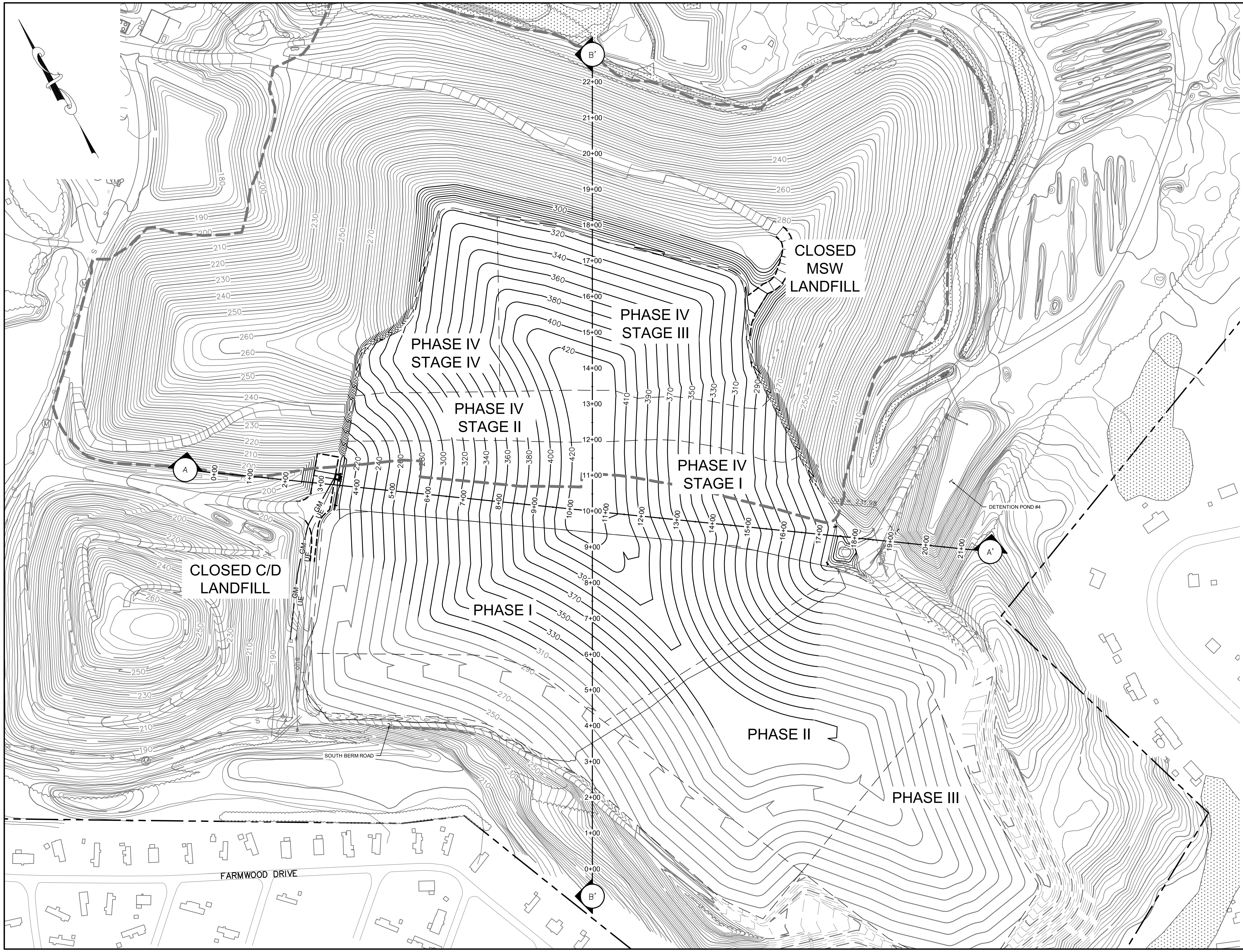
[7] Koerner, G., and Narejo, D., 2005, "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces," Geosynthetic Research Institute, GRI Report #30.

[8] USEPA (1995), RCRA Subtitle D (40 CFR Part 258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, Washington, DC, 156 pp.

[9] USGS, U.S. Seismic Design Maps, earthquake.usgs.gov/designmaps/us/application.php.

[10] Anderson, D., et al., 2008, "Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments," National Cooperative Highway Research Program, Report 611.

[11] Thiel, R., 2002, "Peak vs. Residual Shear Strength for Landfill Bottom Liner Stability Analyses," Proceedings of the 15th Annual GRI Conference, Hot Topics in Geosynthetics – II, Houston, TX, Geosynthetics Institute, Folsum, PA, pp. 40-70.



NOTES:

1. THE BASE MAP, INCLUDING LOCATIONS OF SUBSURFACE UTILITIES, PROPERTY LINES, AND LANDFILL INFORMATION, WAS OBTAINED FROM A DRAWING PREPARED BY CMA ENGINEERS INC. OF PORTSMOUTH, NH (CMA), TITLED: "CITY OF NASHUA, NH, FOUR HILLS LANDFILL, PHASE III SECURE SOLID WASTE, PHASE II OPERATING PLAN, FILLING SEQUENCE DRAWINGS, PHASE II STAGE 1- INITIAL LIFT," DATED JUNE 2010.

HORIZONTAL DATUM:	NAD83 (2001)
HORIZONTAL PROJECTION:	NH STATE PLANE
VERTICAL DATUM:	NGVD 1929

2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARATION OF THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED ACCORDING TO THE PERMITTED LIMIT OF WASTE AS NECESSARY .

3. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.

LEGEND:

———	EXISTING 2-FOOT ELEVATION CONTOUR
—270—	EXISTING 10-FOOT ELEVATION CONTOUR
———	PROPOSED 2-FOOT ELEVATION CONTOUR
—320—	PROPOSED 10-FOOT ELEVATION CONTOUR
— — —	PHASE LIMIT

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
140' 70' 0' 140' 280'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO / O. HERNANDEZ
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

PROJECT NUMBER:
3066.11

STABILITY CROSS SECTIONS

FIGURE NUMBER:
1

ATTACHMENT A

Design Maps Detailed Report

2009 NEHRP Recommended Seismic Provisions (42.73305°N, 71.52497°W)

Site Class D – “Stiff Soil”, Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters and Risk Coefficients

Note: Ground motion values contoured on Figures 22-1, 2, 5, & 6 below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_{SUH} and S_{SD}) and 1.3 (to obtain S_{1UH} and S_{1D}). Maps in the Proposed 2015 NEHRP Provisions are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

Figure 22–1: Uniform–Hazard (2% in 50–Year) Ground Motions of 0.2-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B

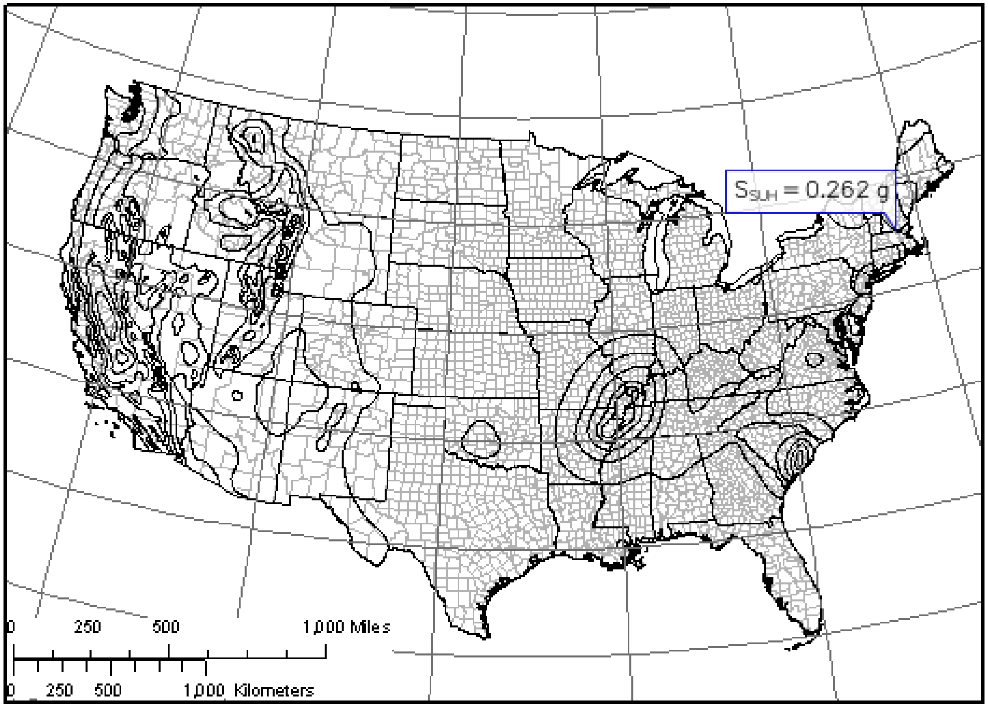
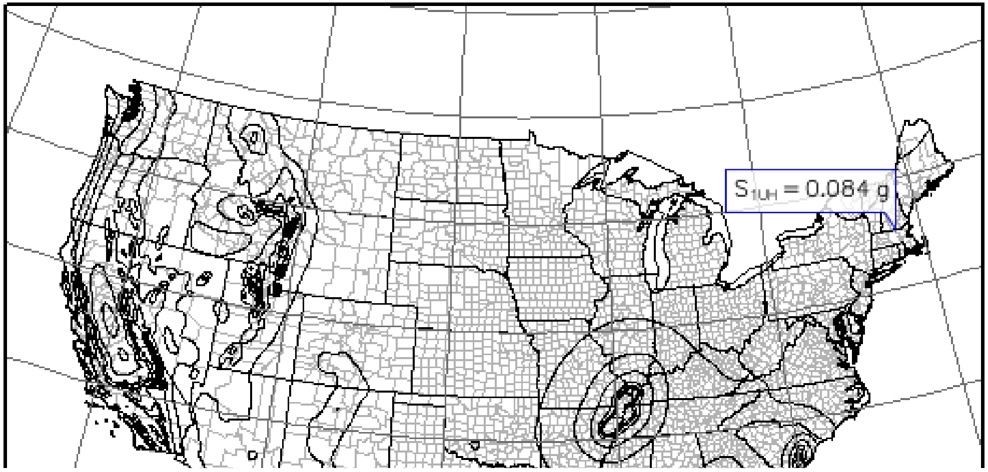


Figure 22–2: Uniform–Hazard (2% in 50–Year) Ground Motions of 1.0-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B



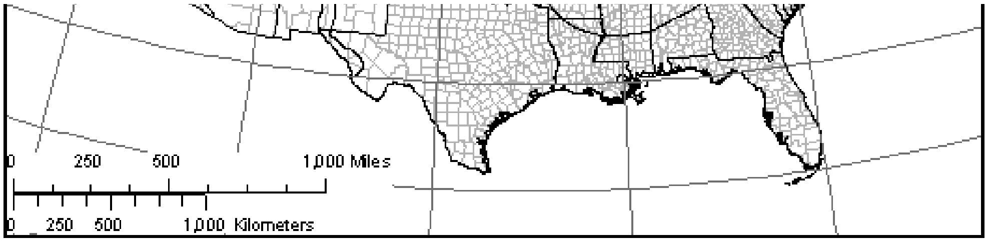

0 250 500 1,000 Miles
0 250 500 1,000 Kilometers

Figure 22–3: Risk Coefficient at 0.2-Second Spectral Response Period

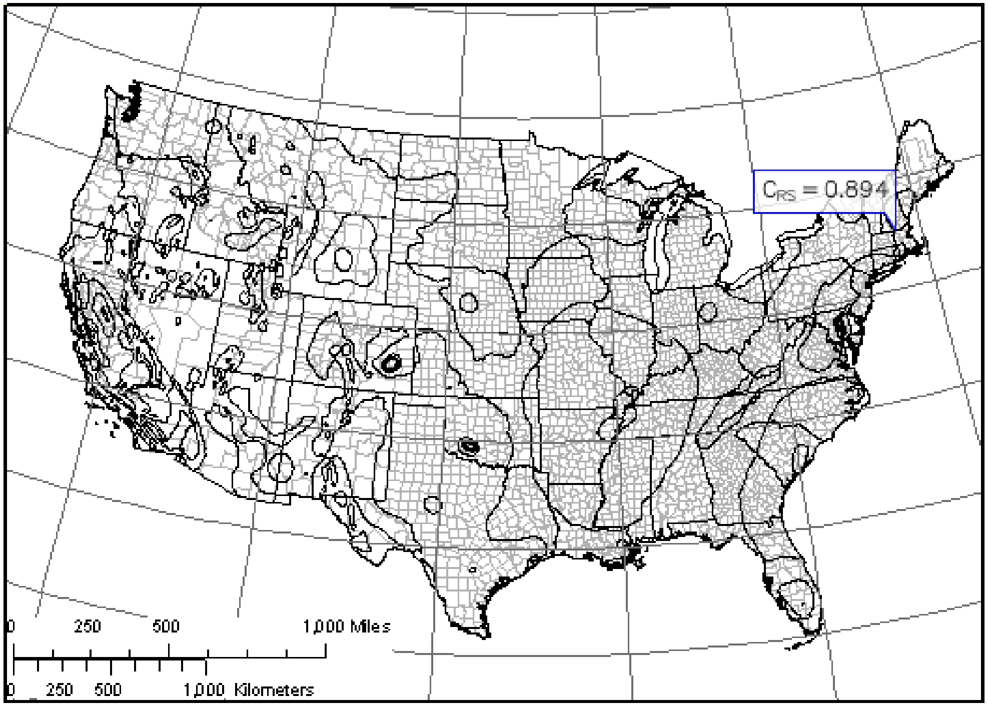


Figure 22–4: Risk Coefficient at 1.0-Second Spectral Response Period

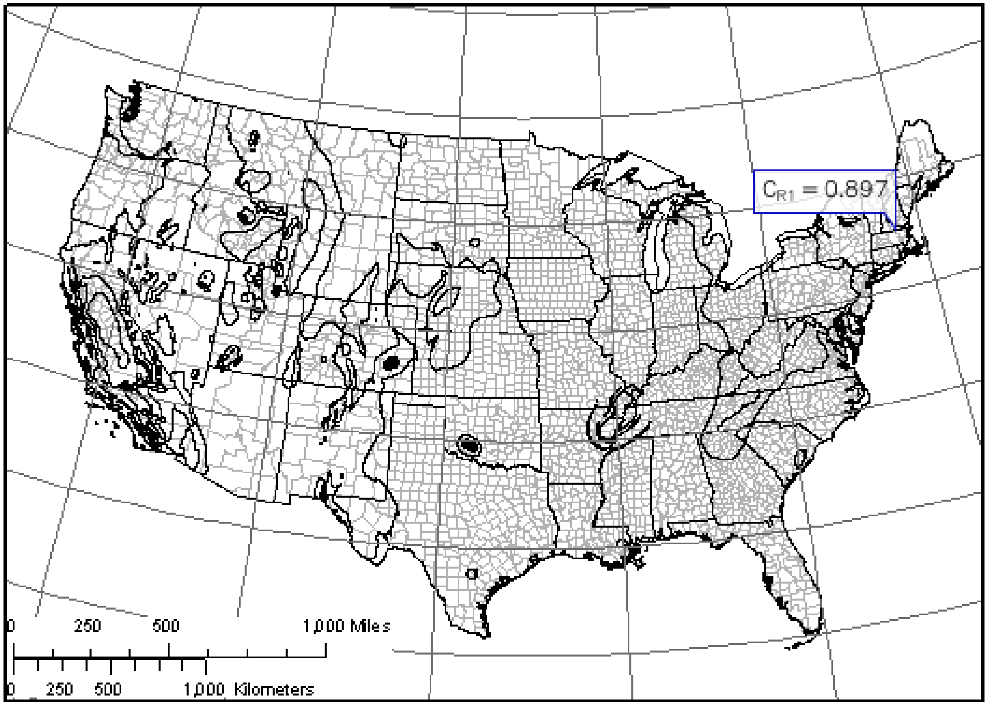


Figure 22–5: Deterministic Ground Motions of 0.2-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B

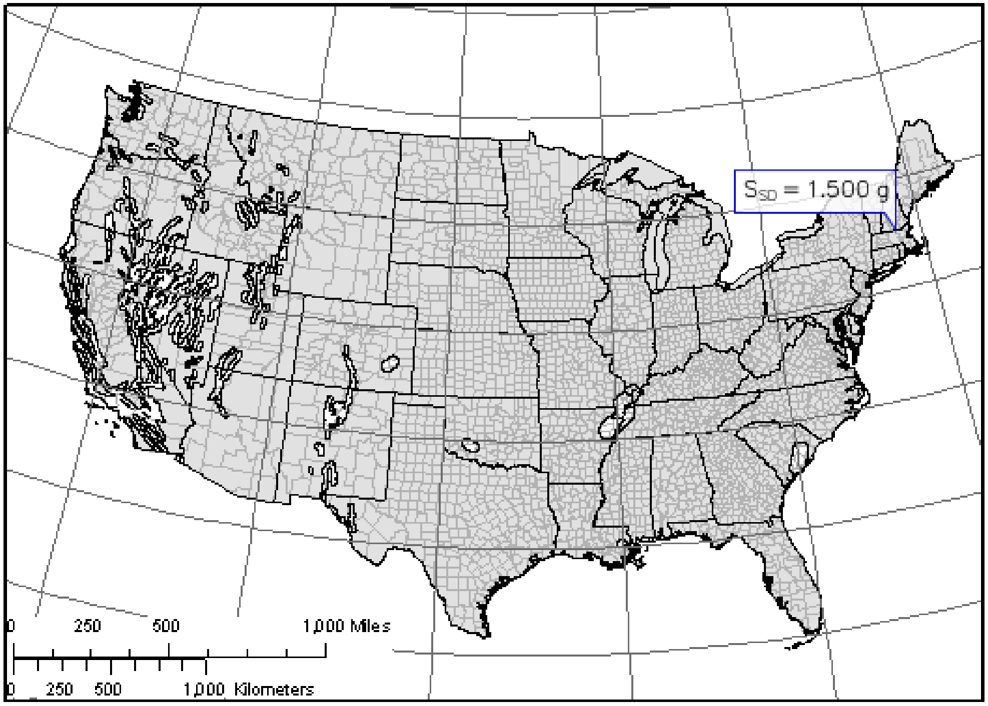
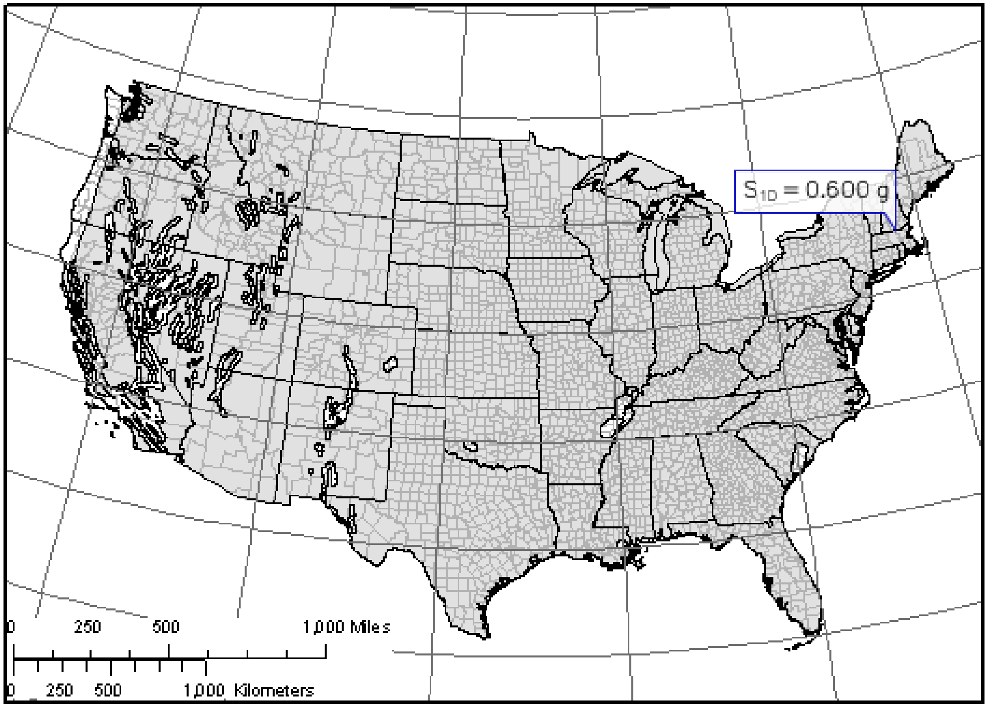


Figure 22–6: Deterministic Ground Motions of 1.0-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B



Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class D, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index *PI* > 20, • Moisture content *w* ≥ 40%, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients, Risk Coefficients, and Risk–Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Equation (11.4–1): $C_{RS}S_{SUH}$ = 0.894 x 0.262 = 0.234 g

Equation (11.4–2): S_{SD} = 1.500 g

S_S ≡ "Lesser of values from Equations (11.4–1) and (11.4–2)" = 0.234 g

Equation (11.4–3): $C_{R1}S_{1UH}$ = 0.897 x 0.084 = 0.075 g

Equation (11.4–4): S_{1D} = 0.600 g

S_1 ≡ "Lesser of values from Equations (11.4–3) and (11.4–4)" = 0.075 g

Table 11.4–1: Site Coefficient F_a

Site Class	Spectral Response Acceleration Parameter at Short Period				
	$S_S \le 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	$\boxed{1.6}$	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = D and S_S = 0.234 g, F_a = 1.600

Table 11.4–2: Site Coefficient F_v

Site Class	Spectral Response Acceleration Parameter at 1–Second Period				
	$S_1 \le 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \ge 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	$\boxed{2.4}$	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = D and S_1 = 0.075 g, F_v = 2.400

Equation (11.4–5): $S_{MS} = F_a S_S = 1.600 \times 0.234 = 0.375$ g

Equation (11.4–6): $S_{M1} = F_v S_1 = 2.400 \times 0.075 = 0.180$ g

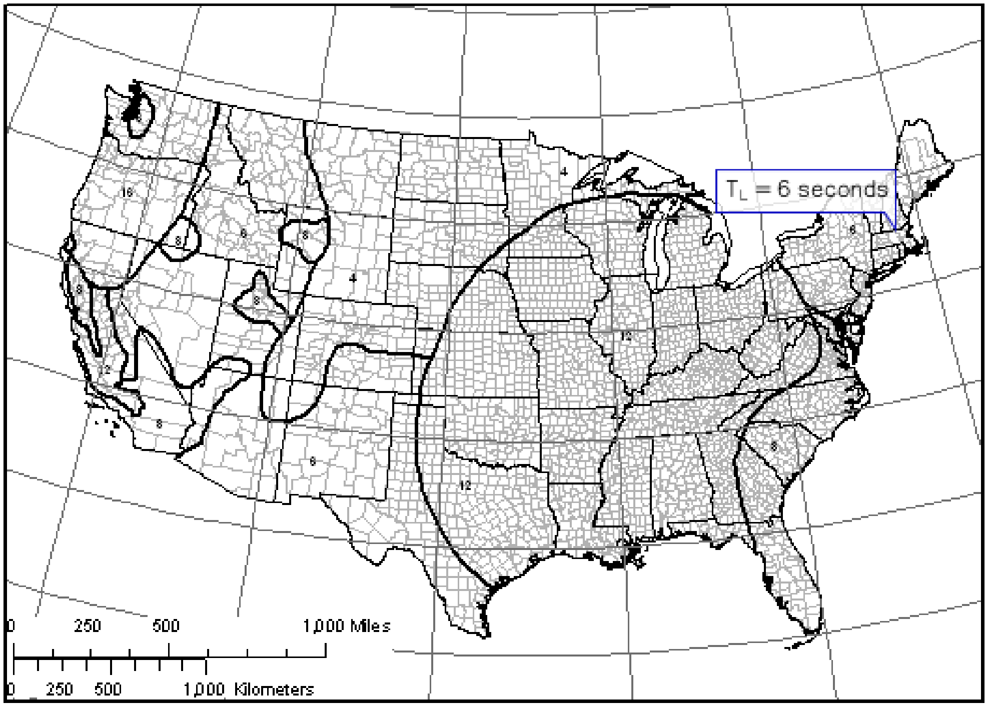
Section 11.4.4 — Design Spectral Acceleration Parameters

Equation (11.4–7): $S_{DS} = ⅔\, S_{MS} = ⅔ \times 0.375 = 0.250$ g

Equation (11.4–8): $S_{D1} = ⅔\, S_{M1} = ⅔ \times 0.180 = \boxed{0.120 \text{ g}}$

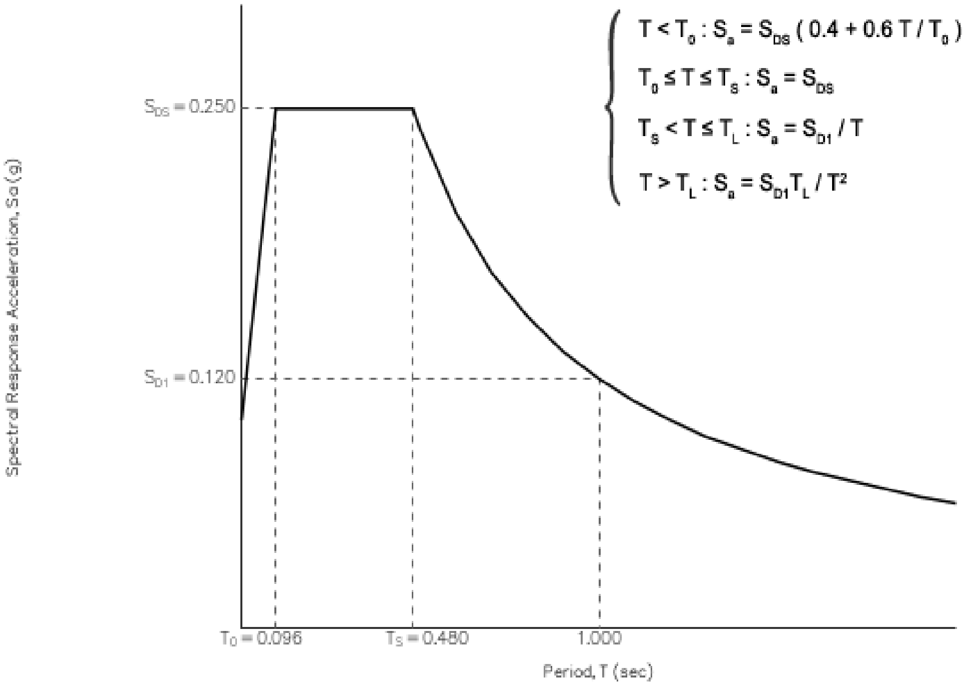
Section 11.4.5 — Design Response Spectrum

Figure 22–7: Long–period Transition Period, T_L (s)



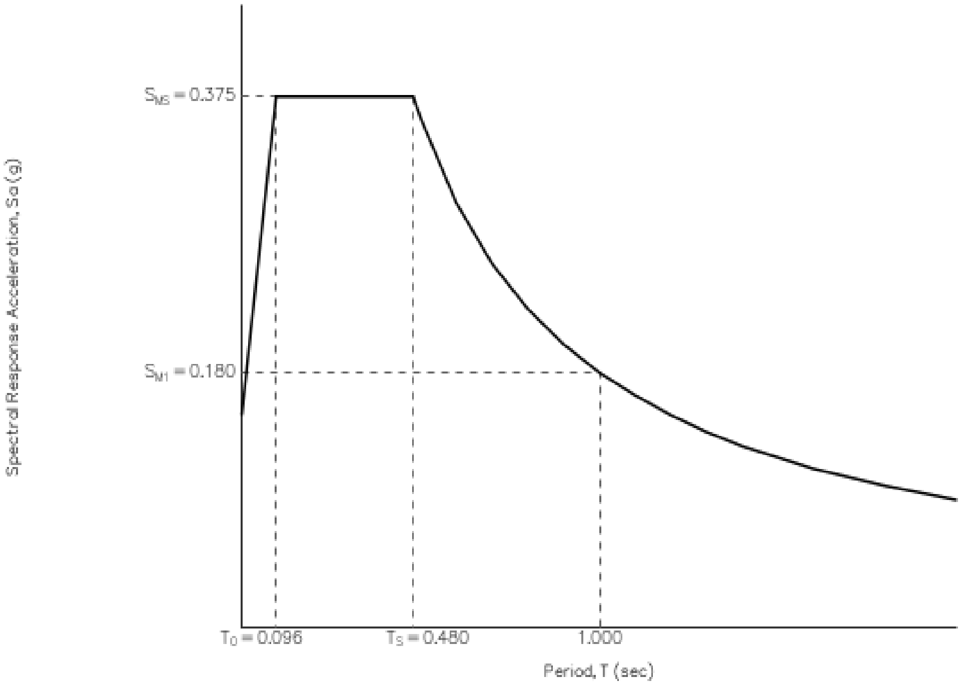
$T_L = 6$ seconds

Figure 11.4–1: Design Response Spectrum



Section 11.4.6 — MCE_R Response Spectrum

The MCE_R response spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

Table 11.8–1: Site Coefficient F_{PGA}

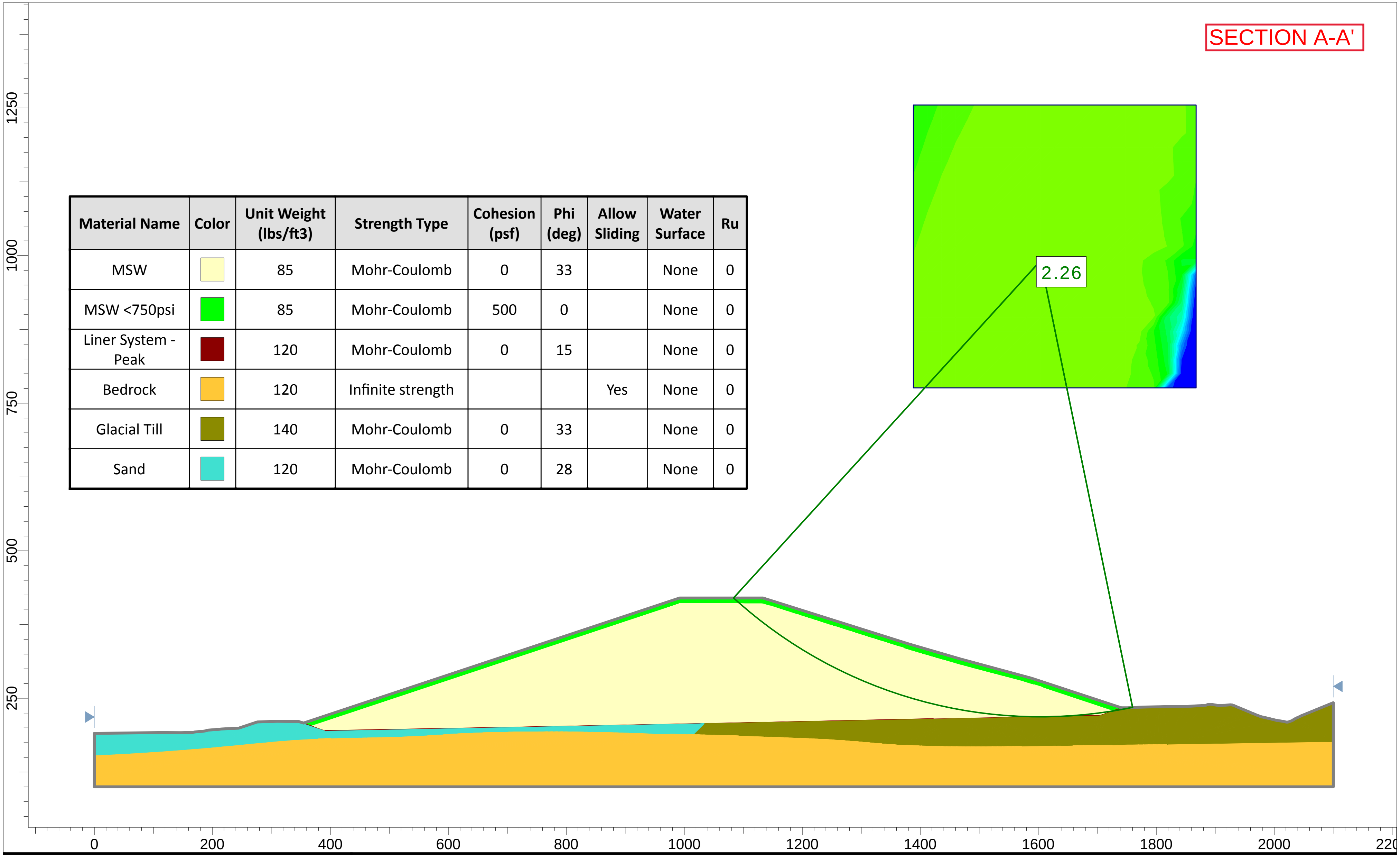
Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of PGA

For Site Class = D and PGA = 0.126 g, F_{PGA} = 1.547

Mapped PGA PGA = 0.126 g

Equation (11.8–1): $PGA_M = F_{PGA}PGA = 1.547 \times 0.126 = \boxed{0.195\ g}$



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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Project
NASHUA PHASE IV STABILITY ANALYSIS

Analysis Description
LINER STABILITY

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Scale 1:2700

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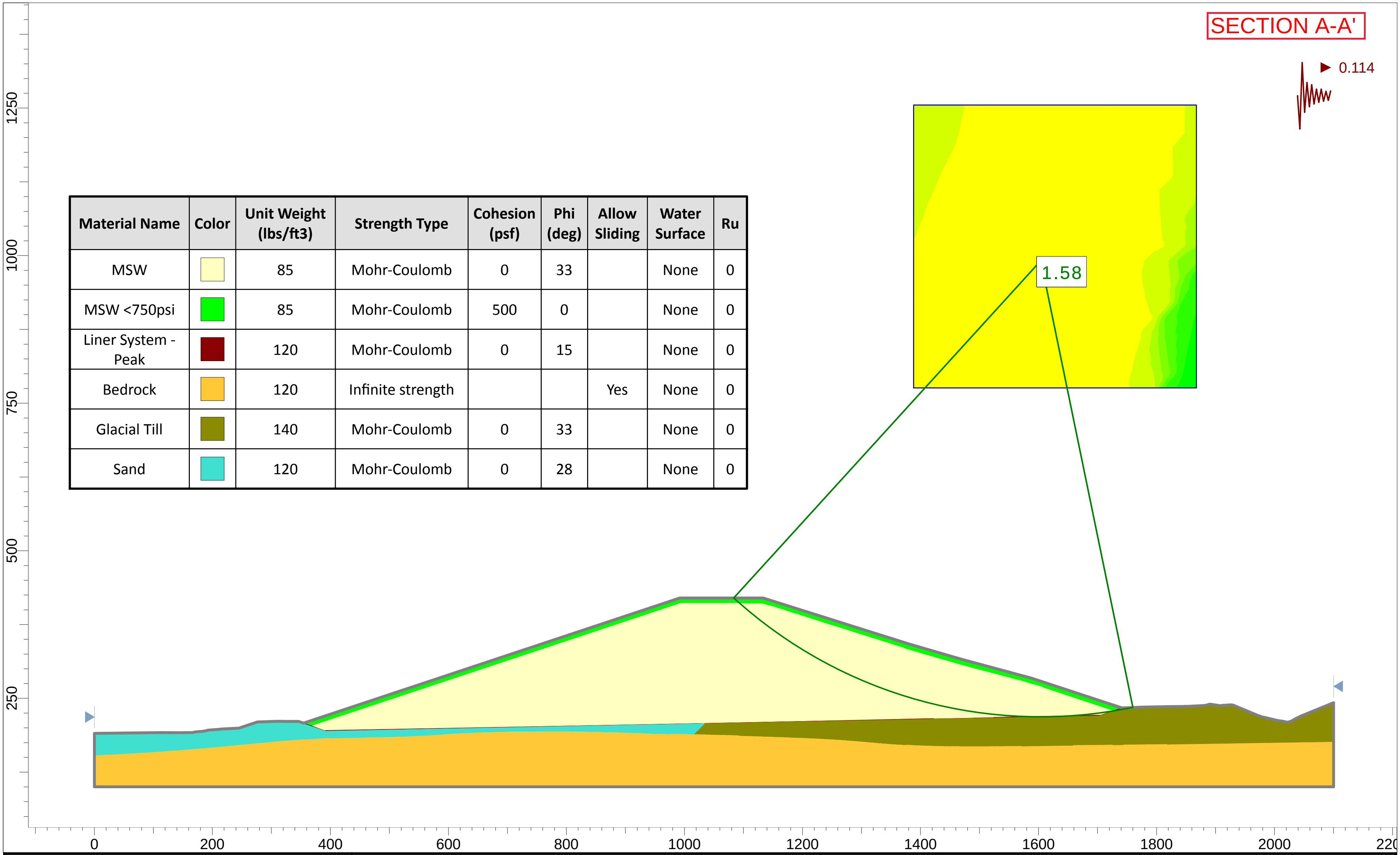
SECTION A-A'



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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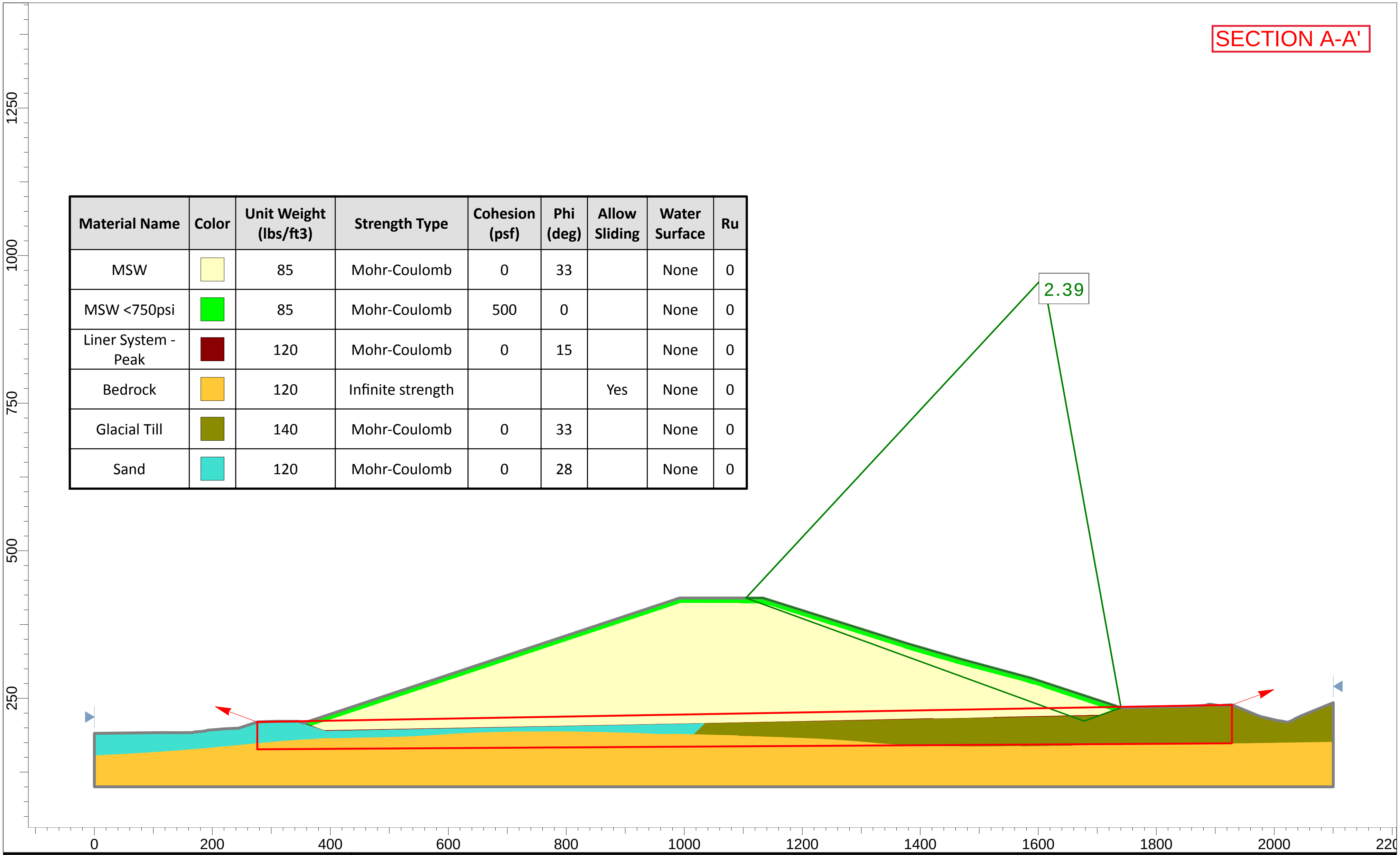

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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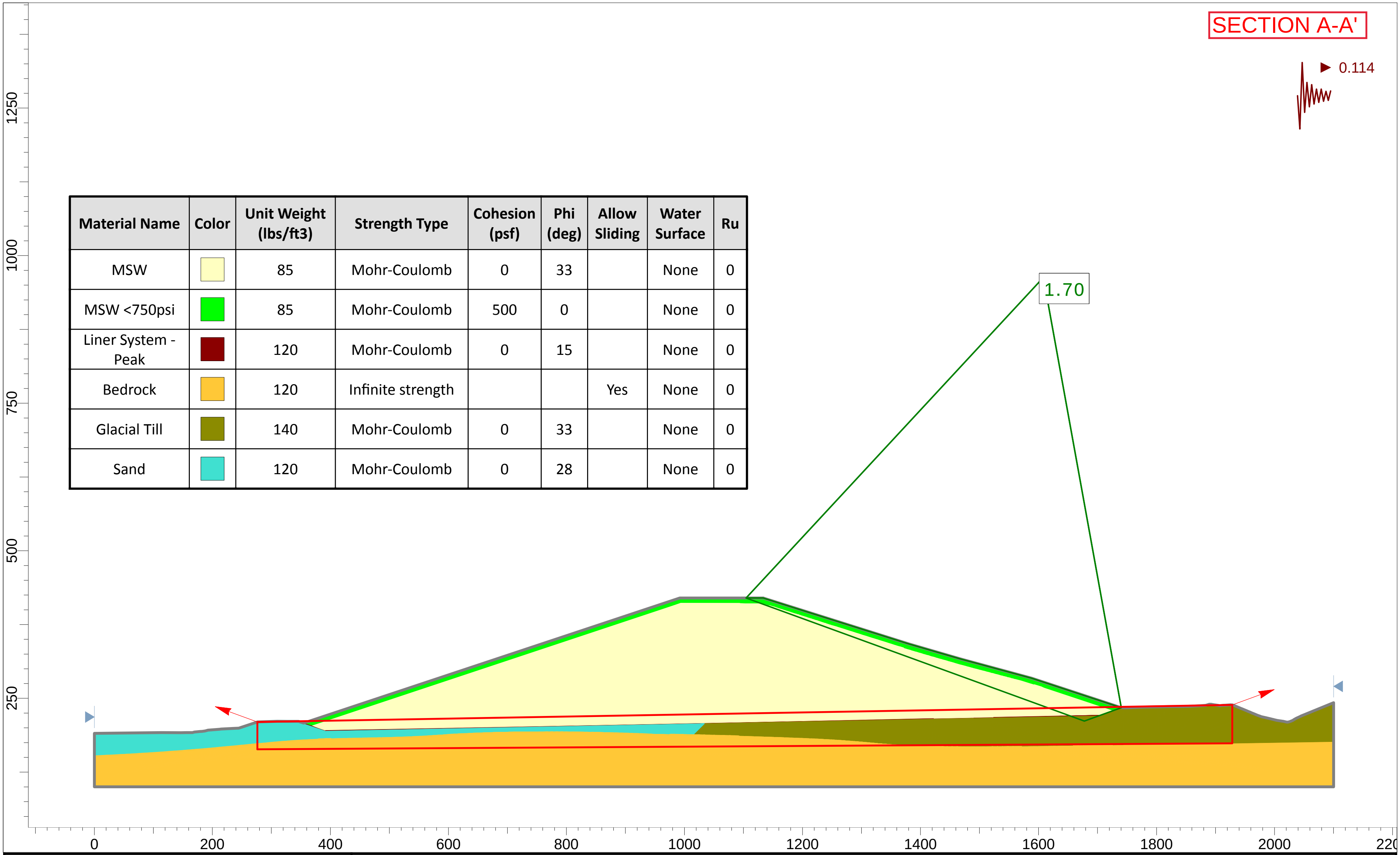

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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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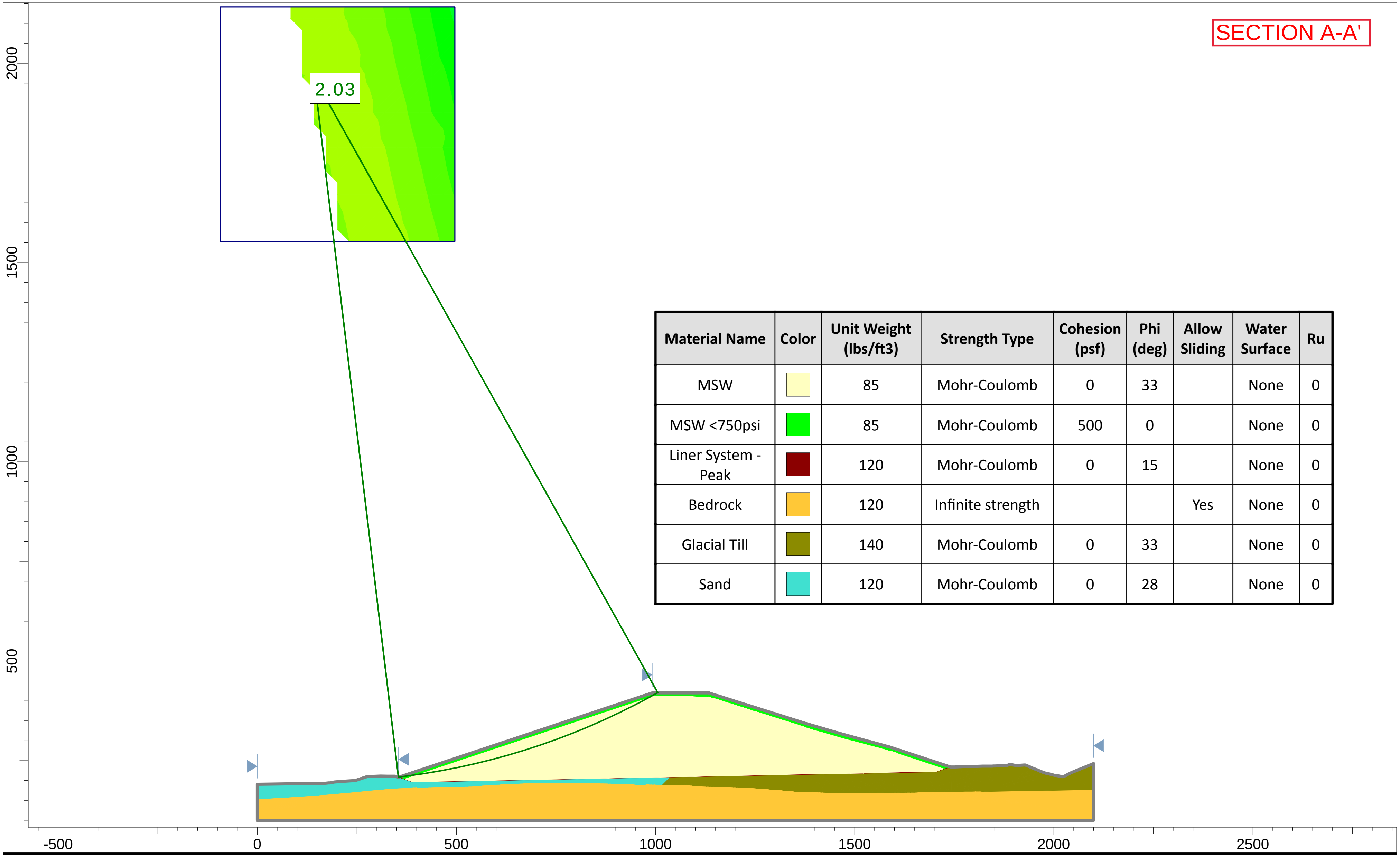

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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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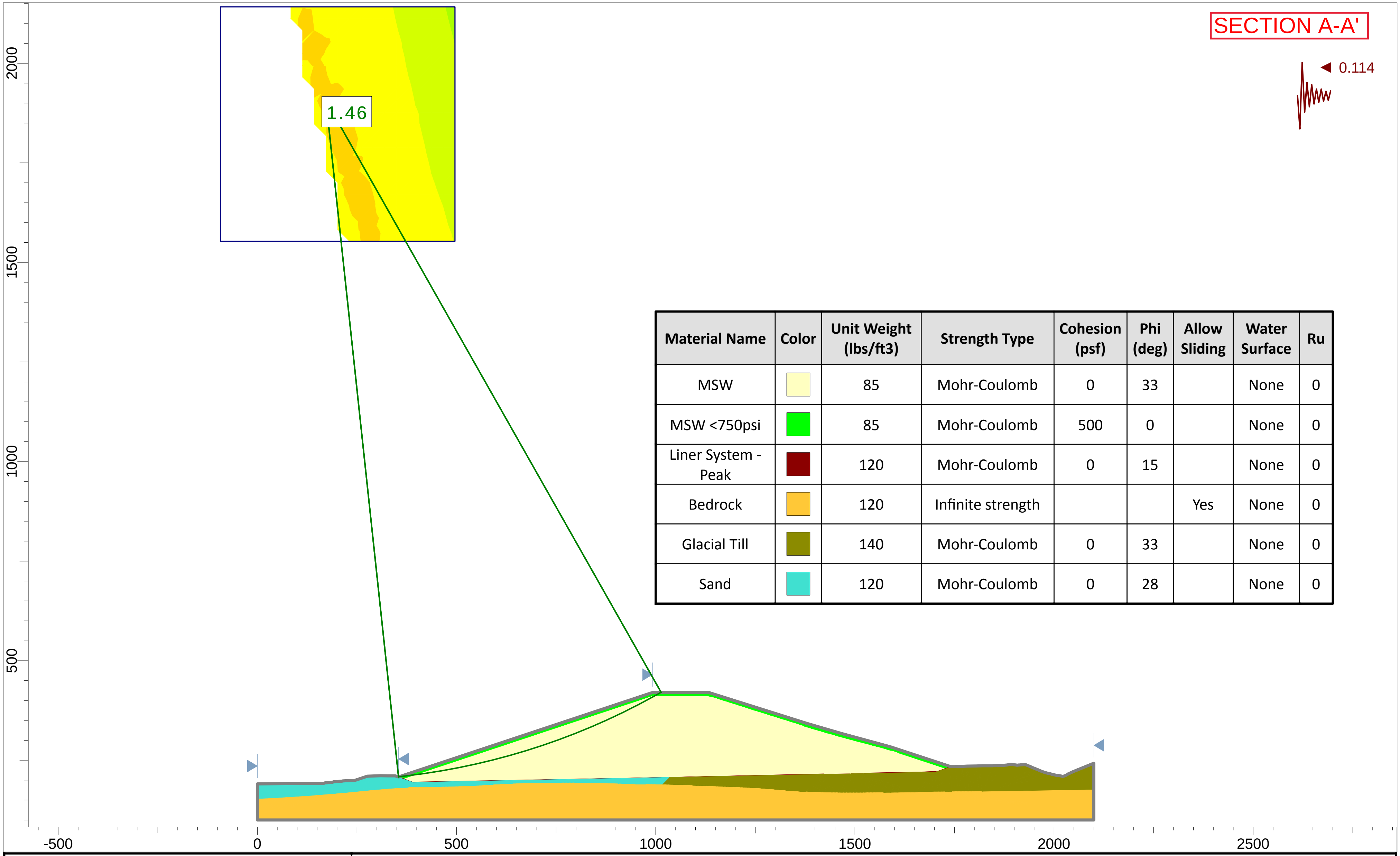

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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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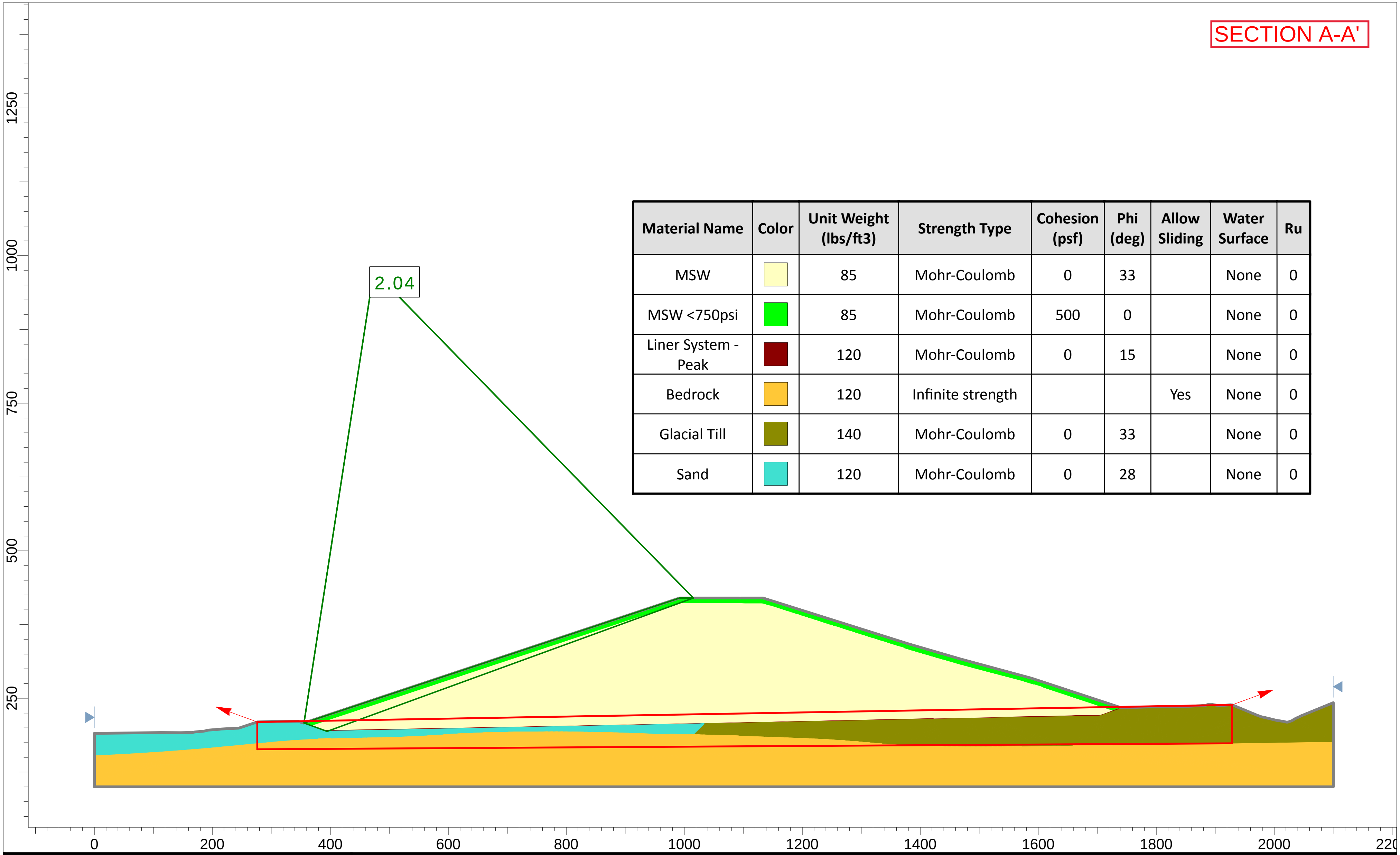

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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
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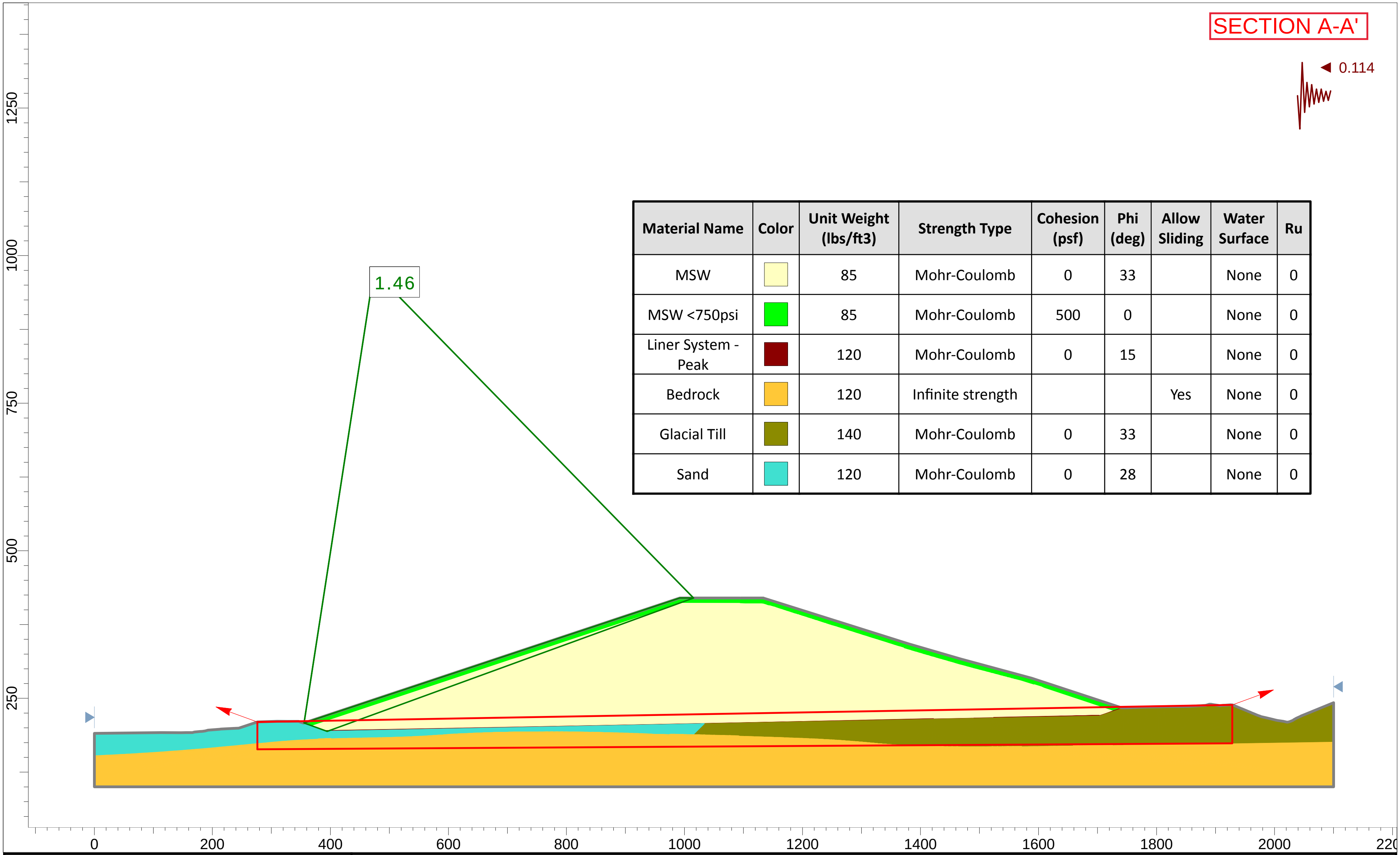

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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
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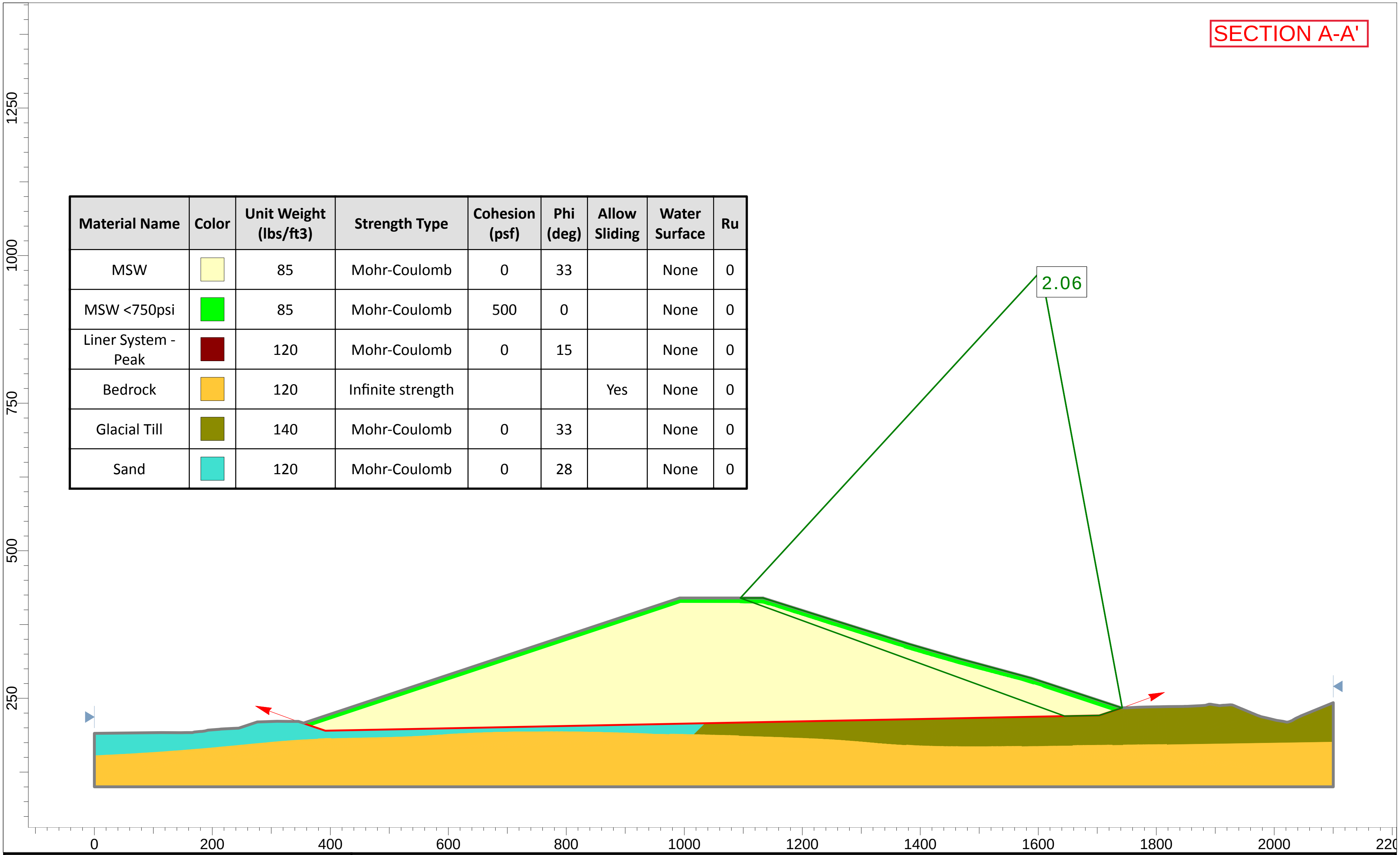

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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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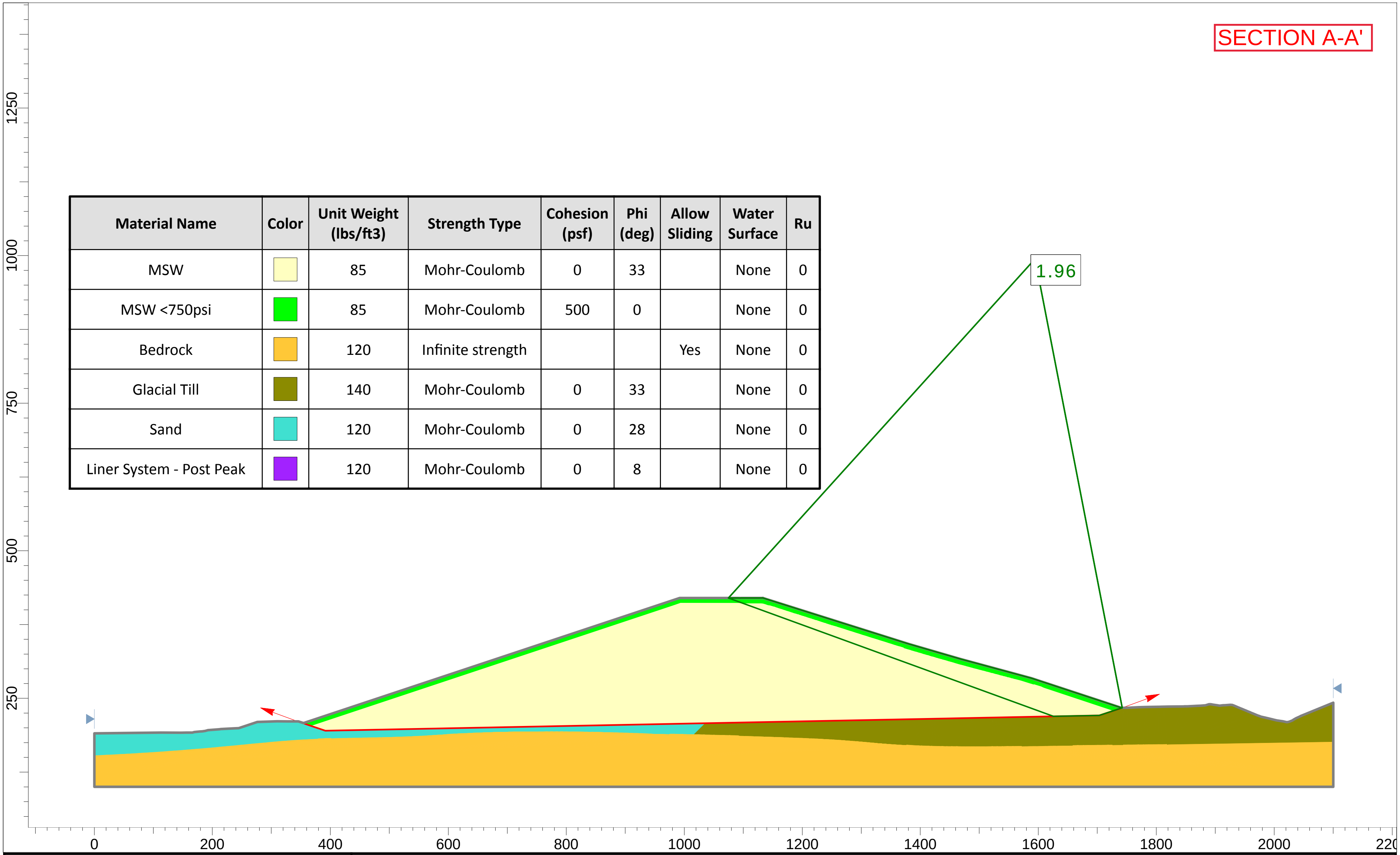

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟪	120	Mohr-Coulomb	0	8		None	0

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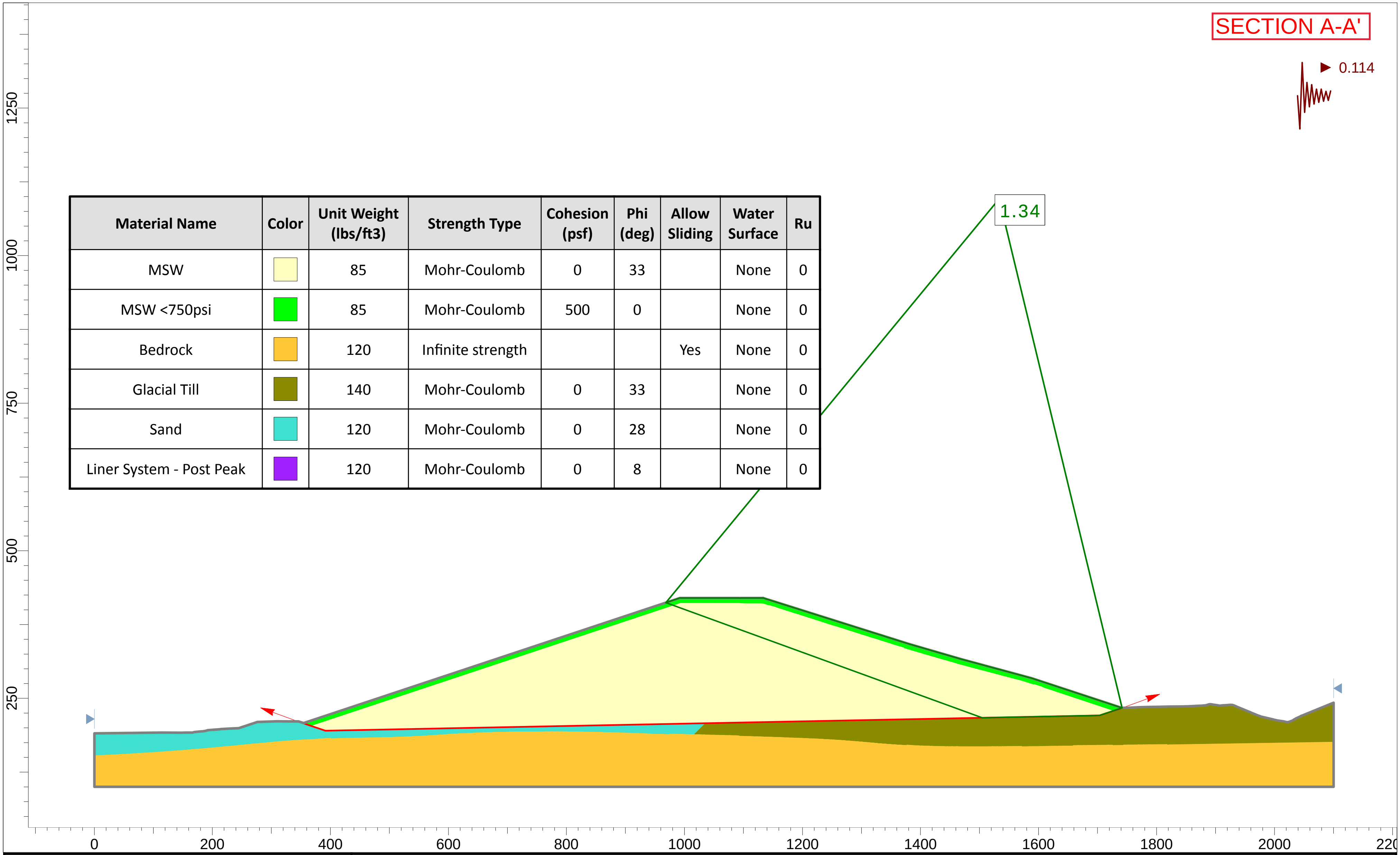

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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟪	120	Mohr-Coulomb	0	8		None	0

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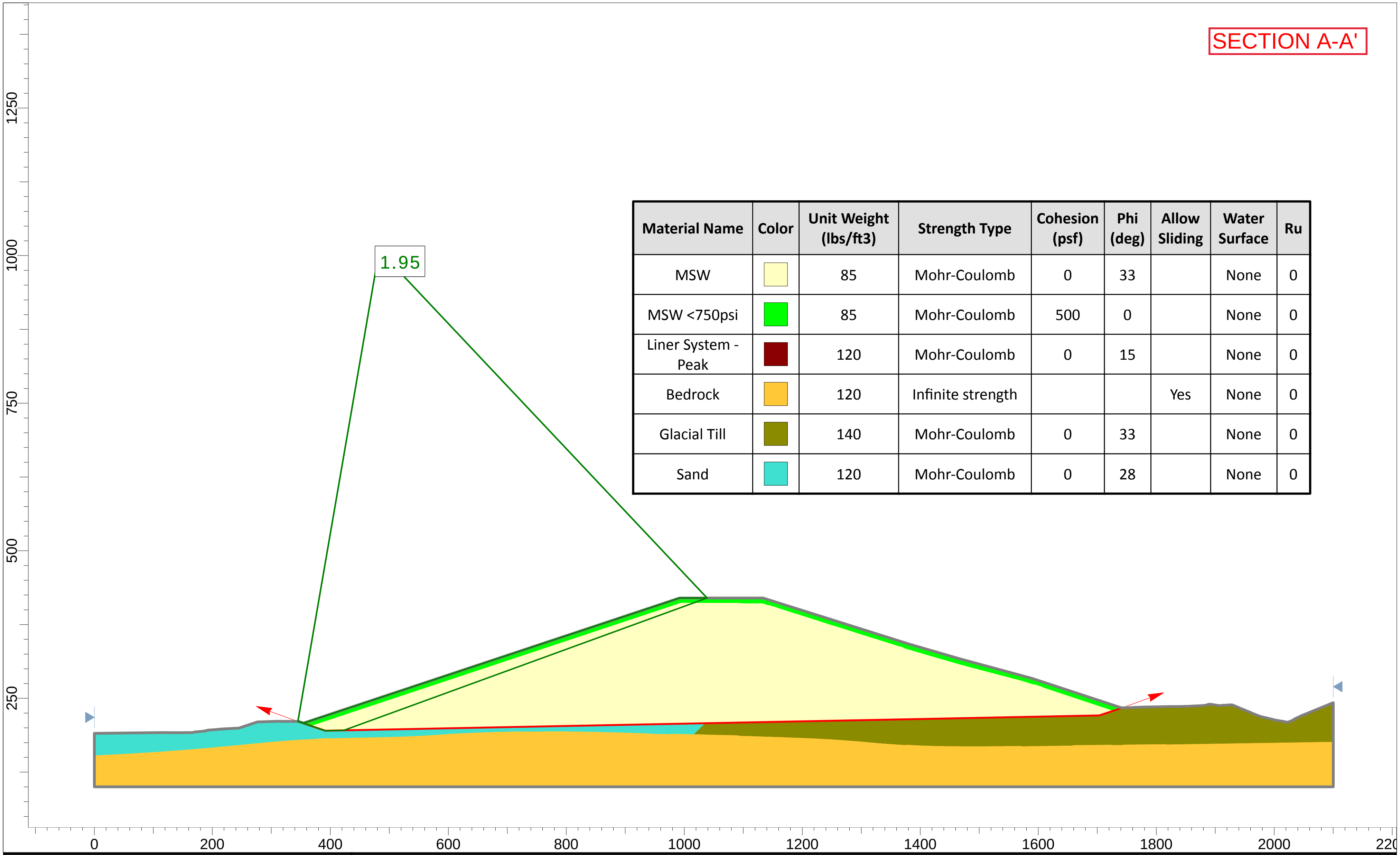

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0

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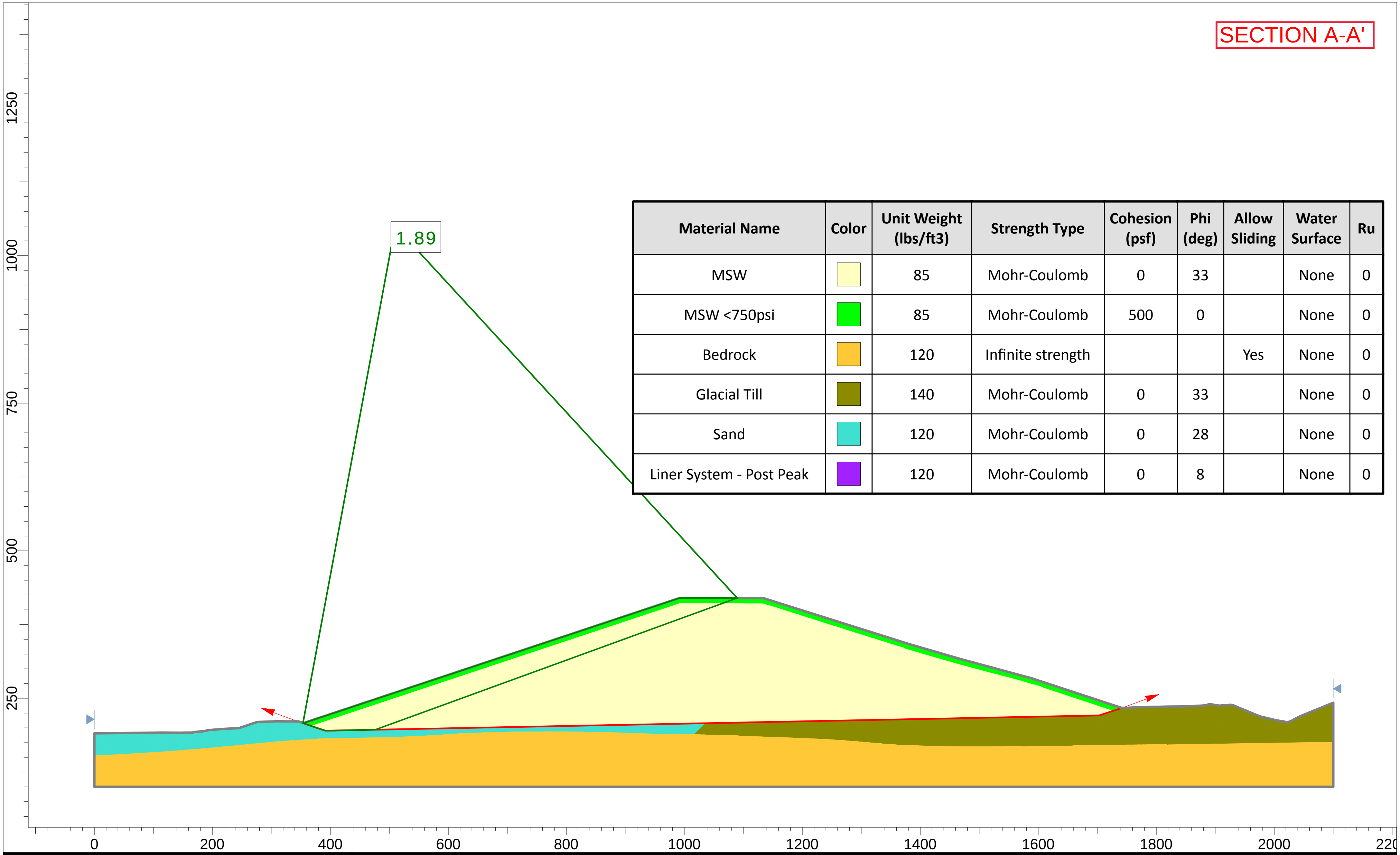

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟪	120	Mohr-Coulomb	0	8		None	0

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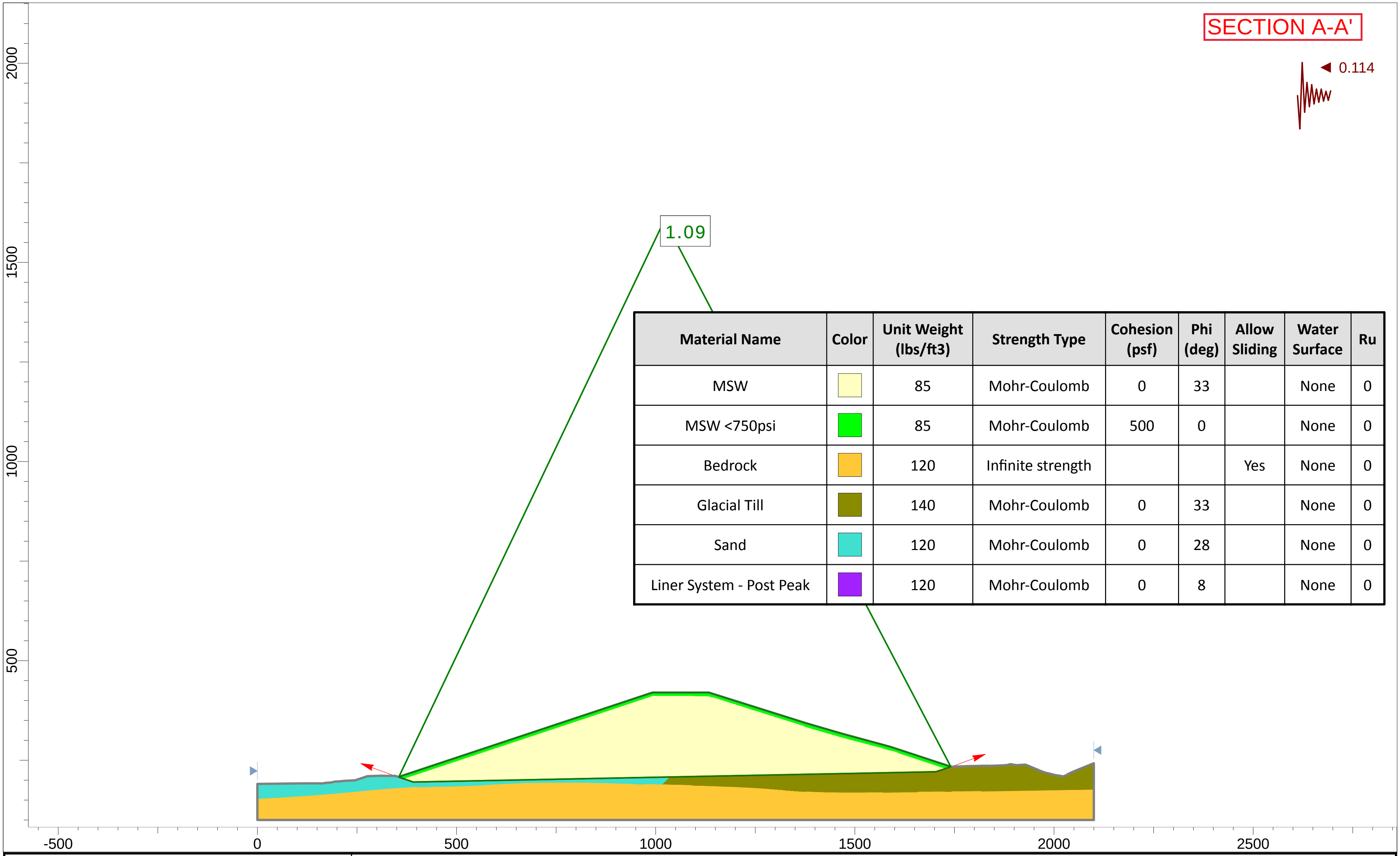

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟪	120	Mohr-Coulomb	0	8		None	0

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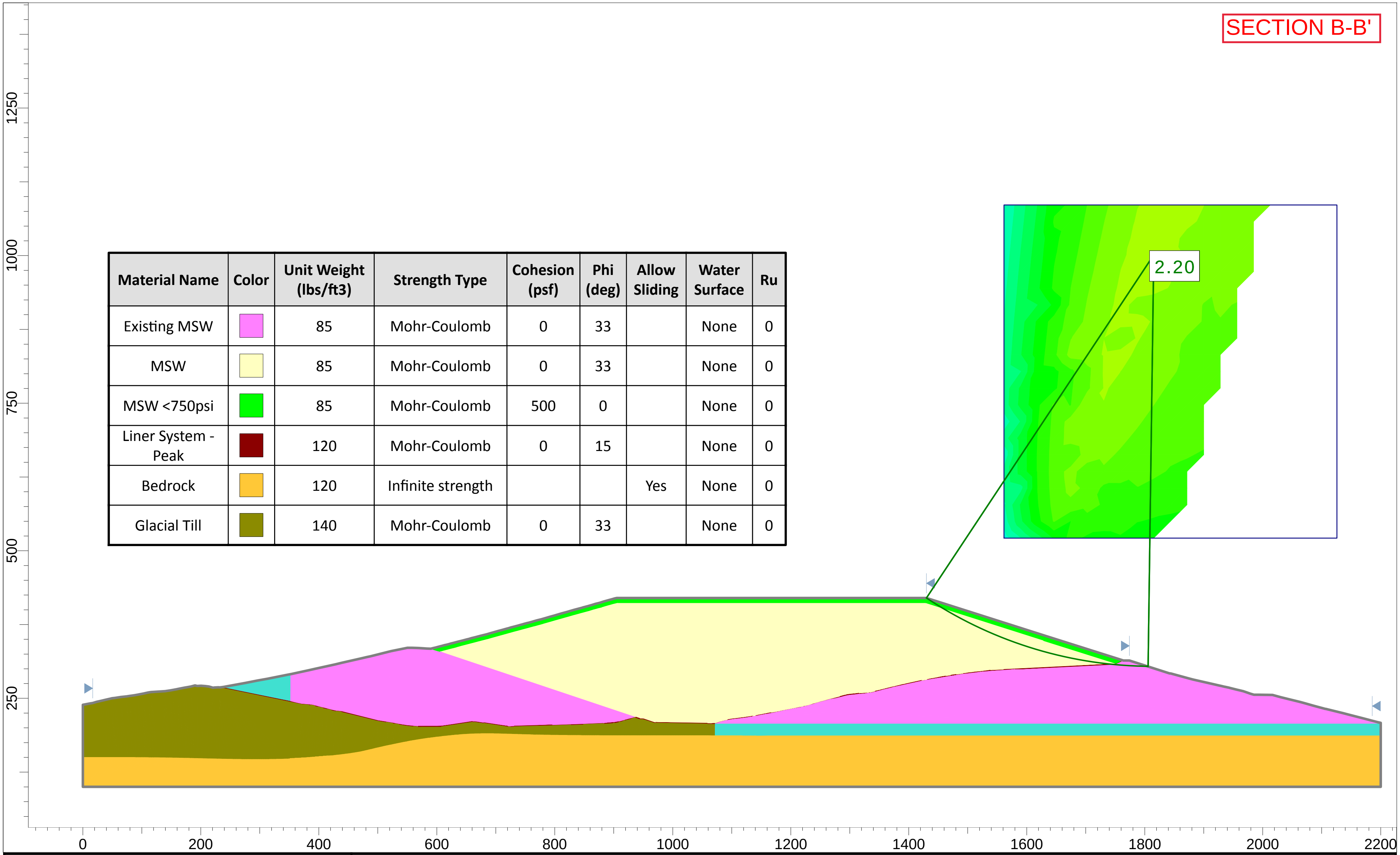

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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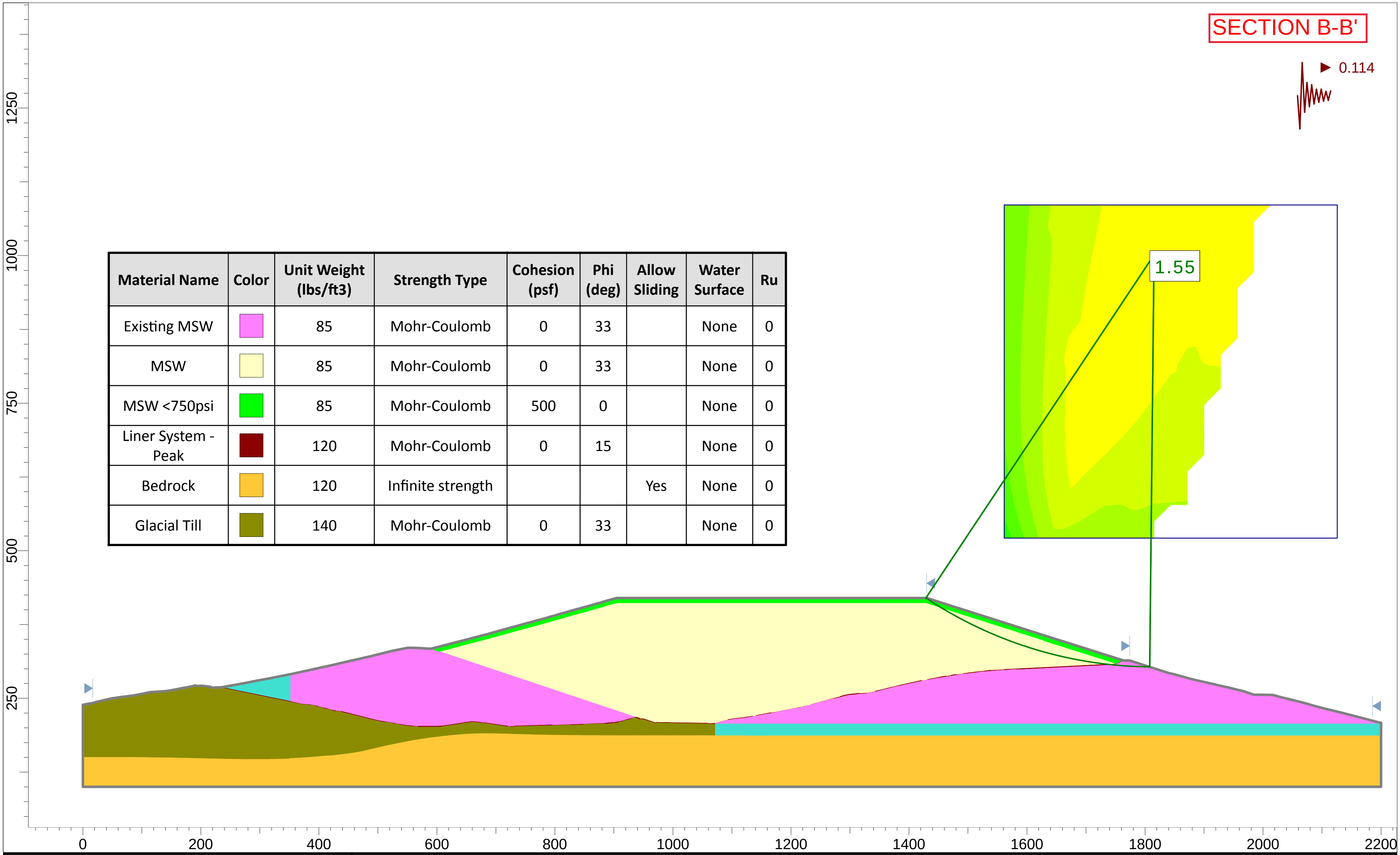

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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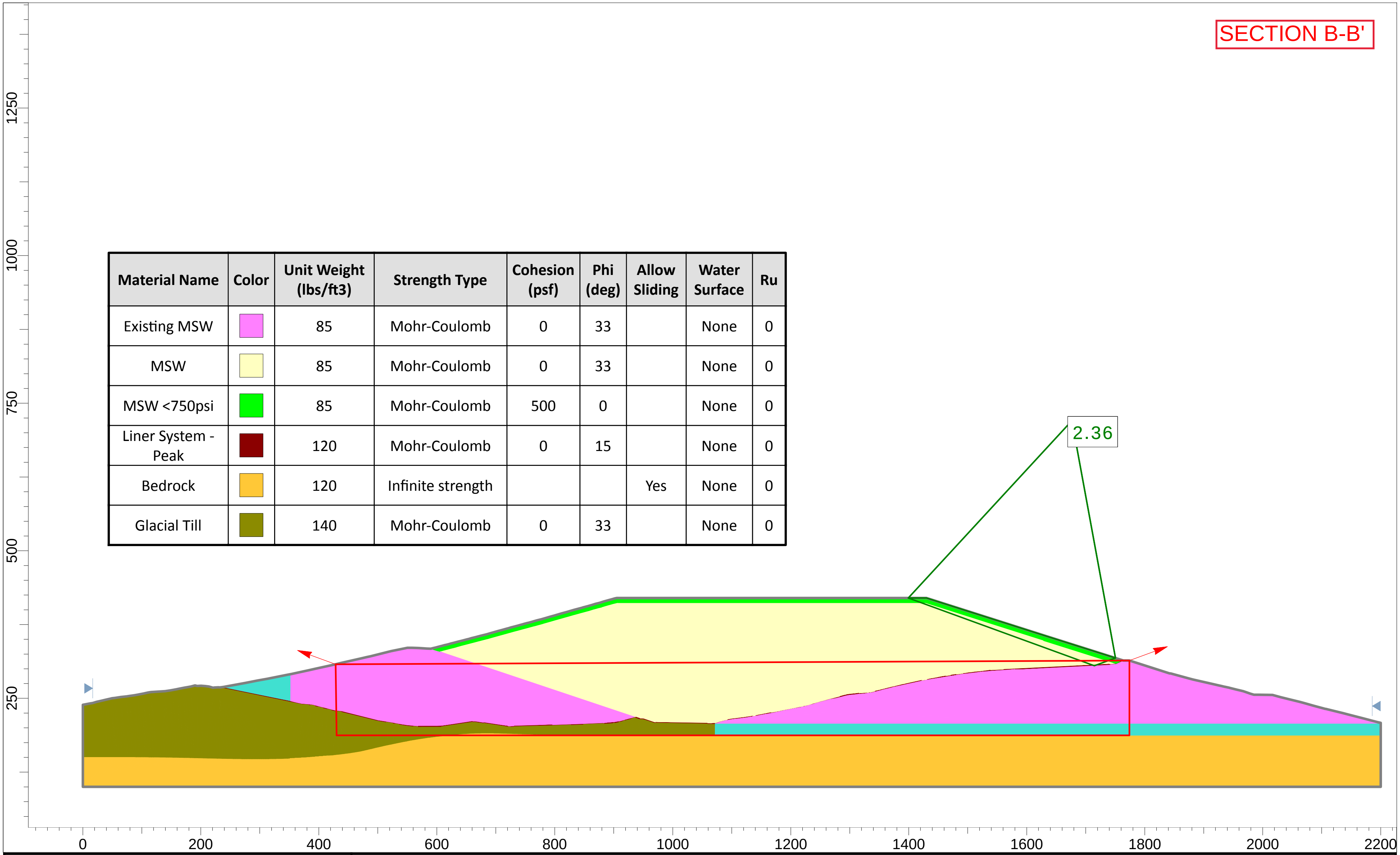
Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
File Name	Circular - L to R - Seismic



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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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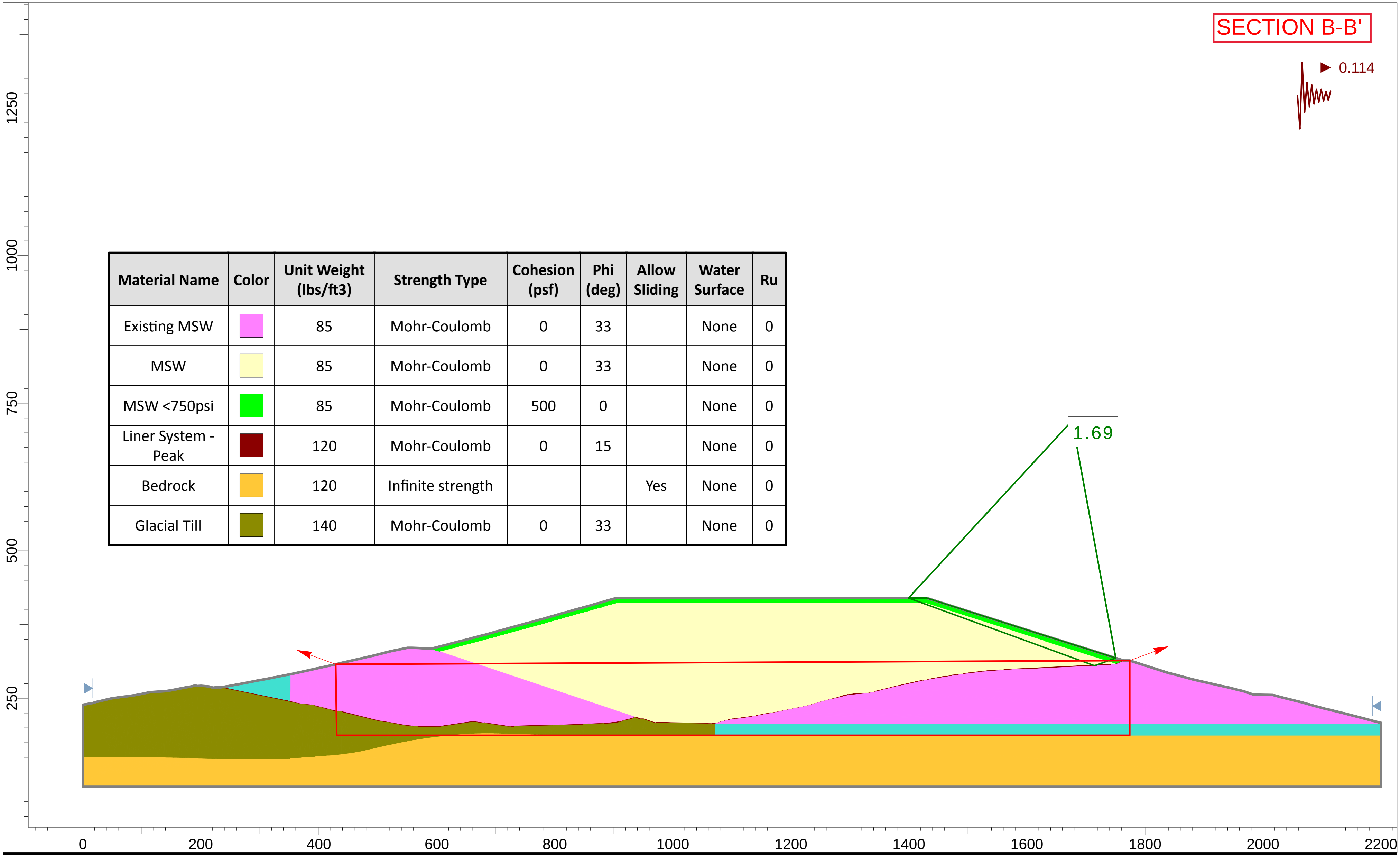
Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
File Name	Block - L to R - Static



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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
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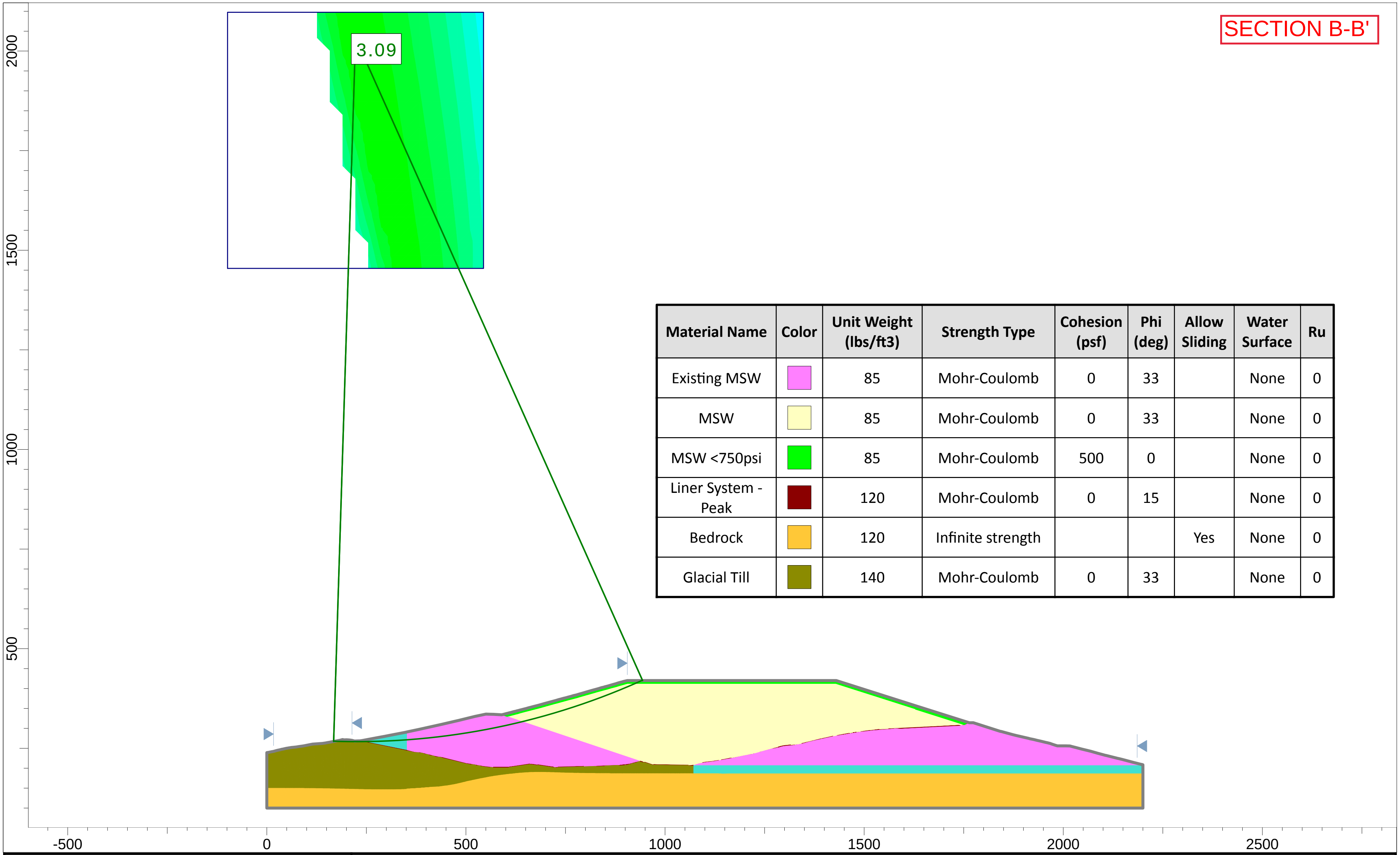

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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:4000
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
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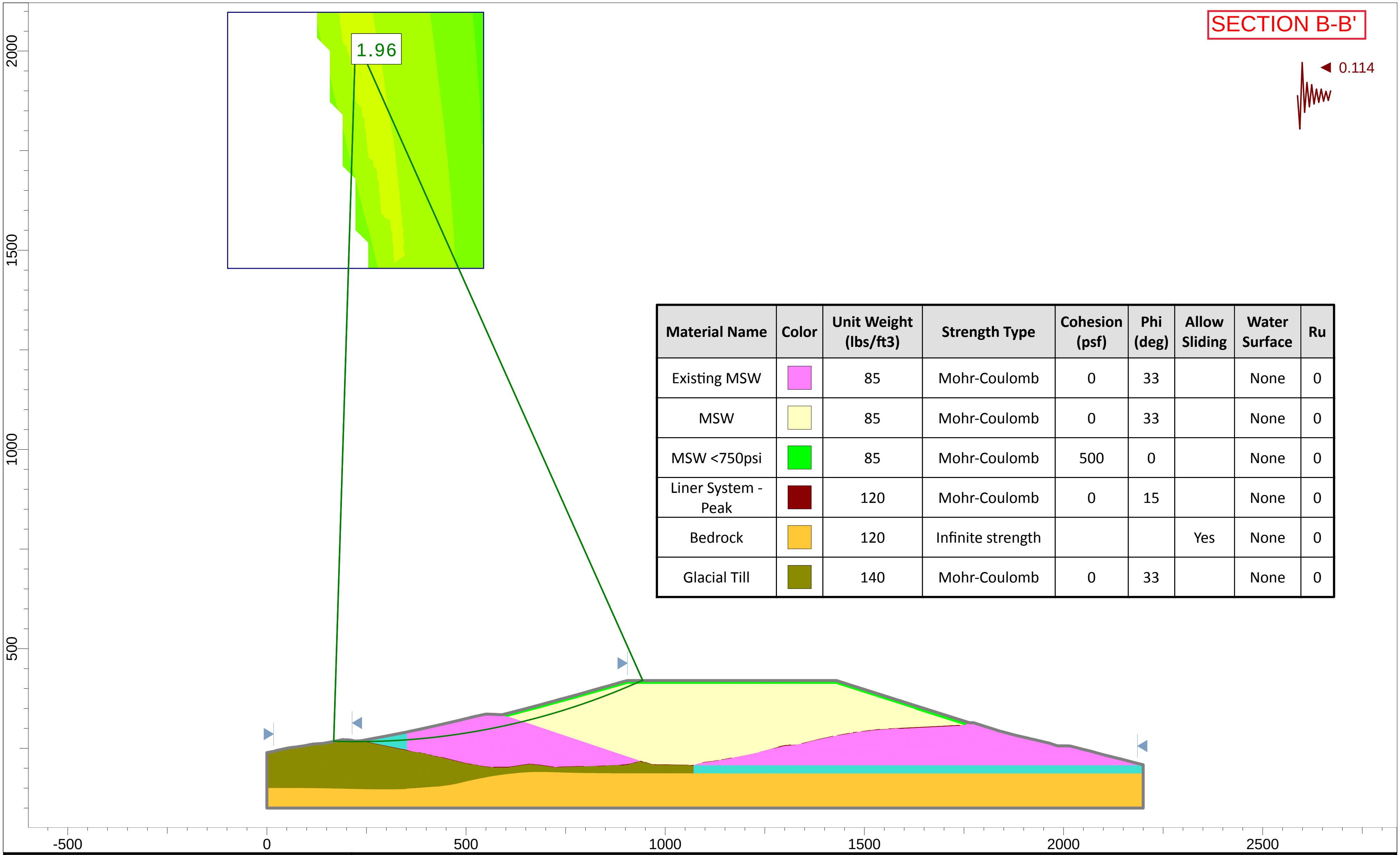

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:4000
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
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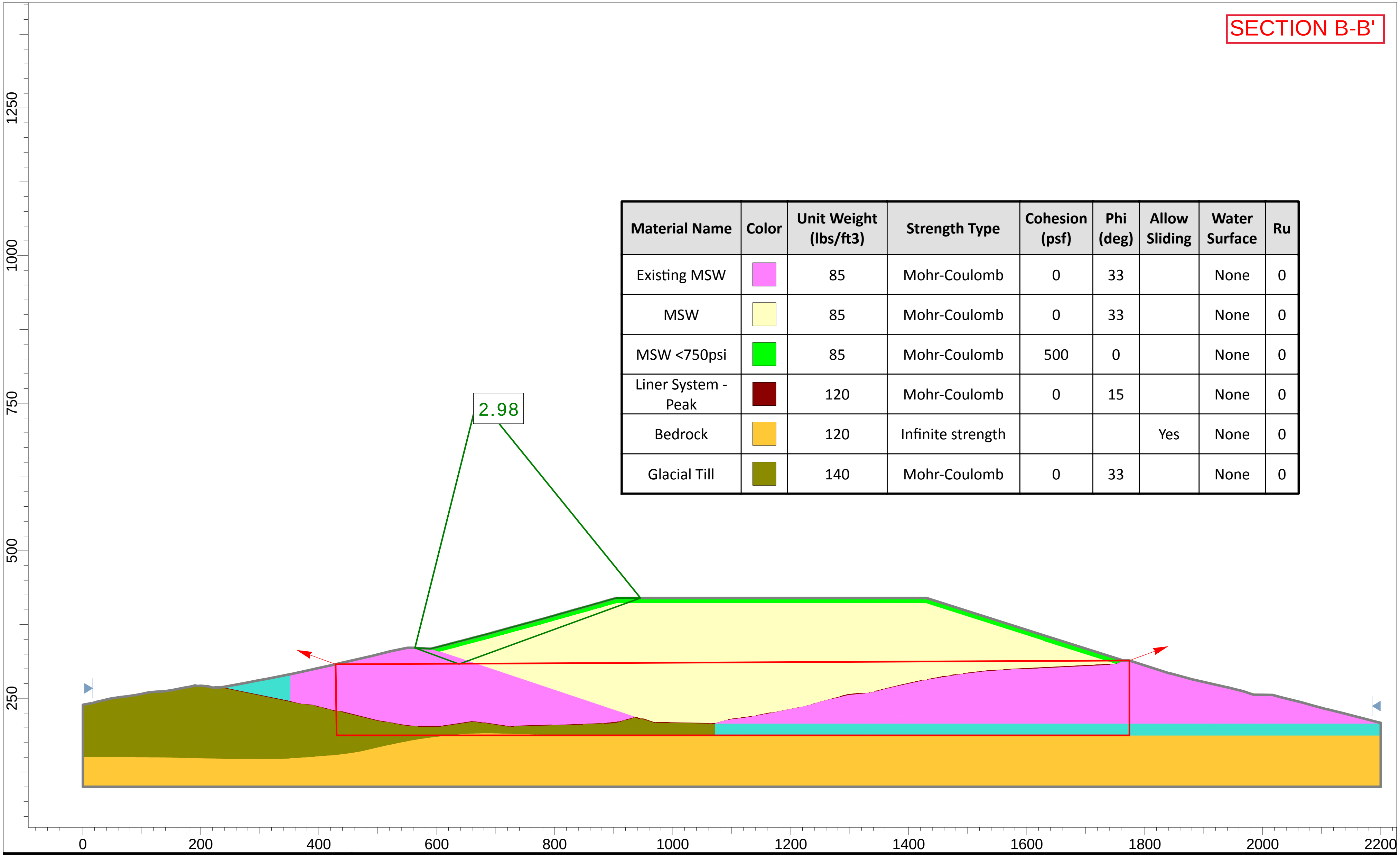

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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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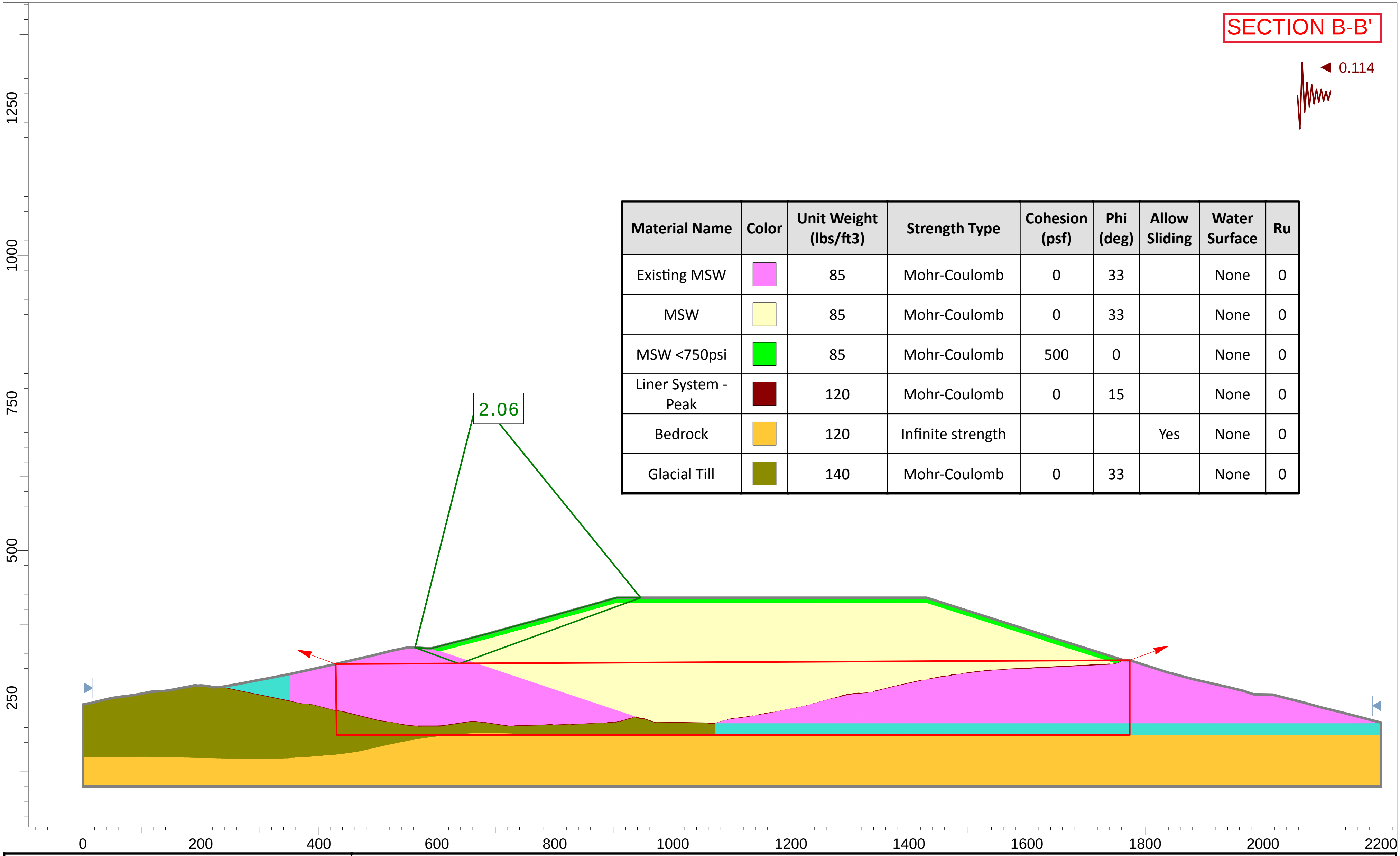
Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
File Name	Block - R to L - Static



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
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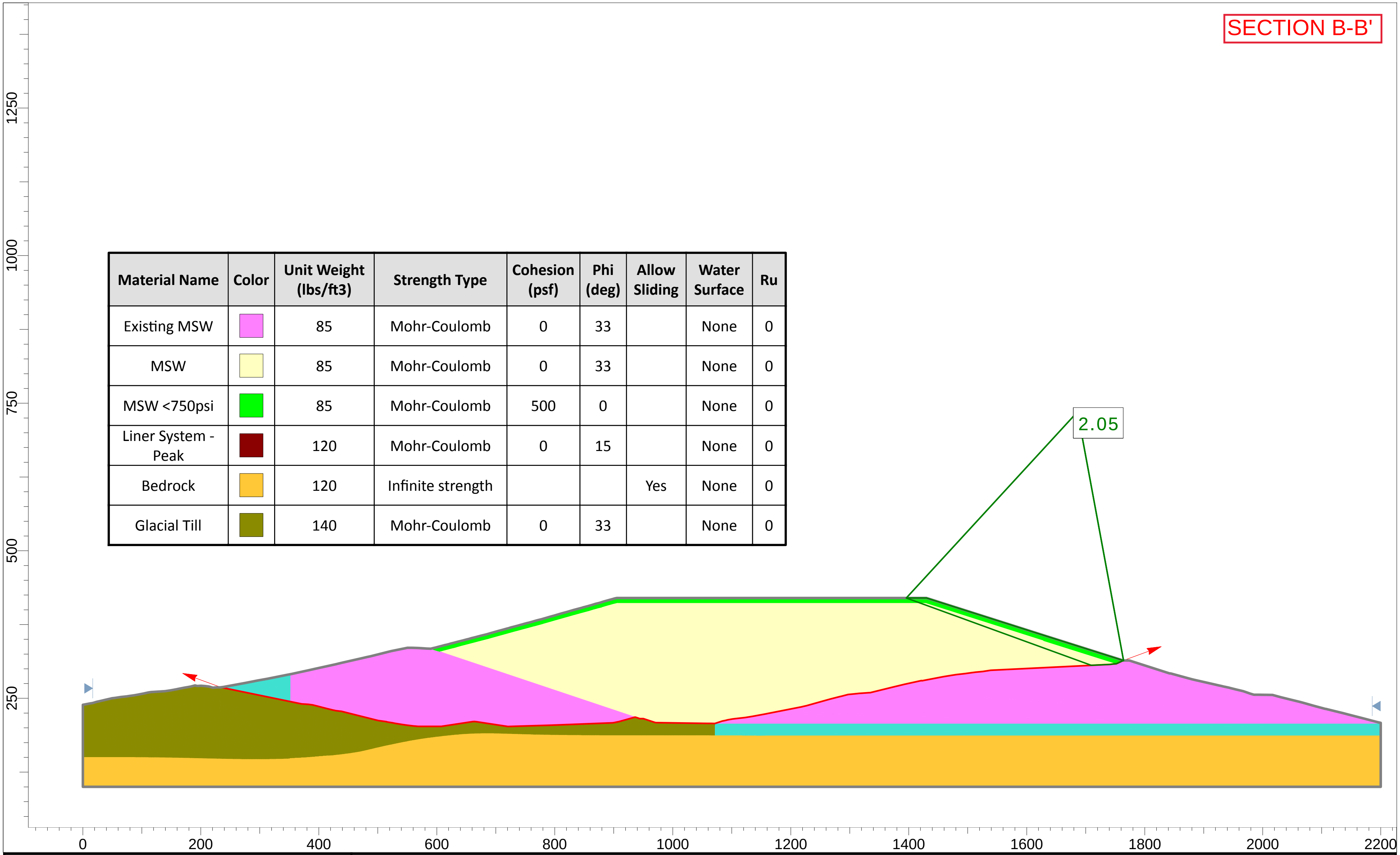

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
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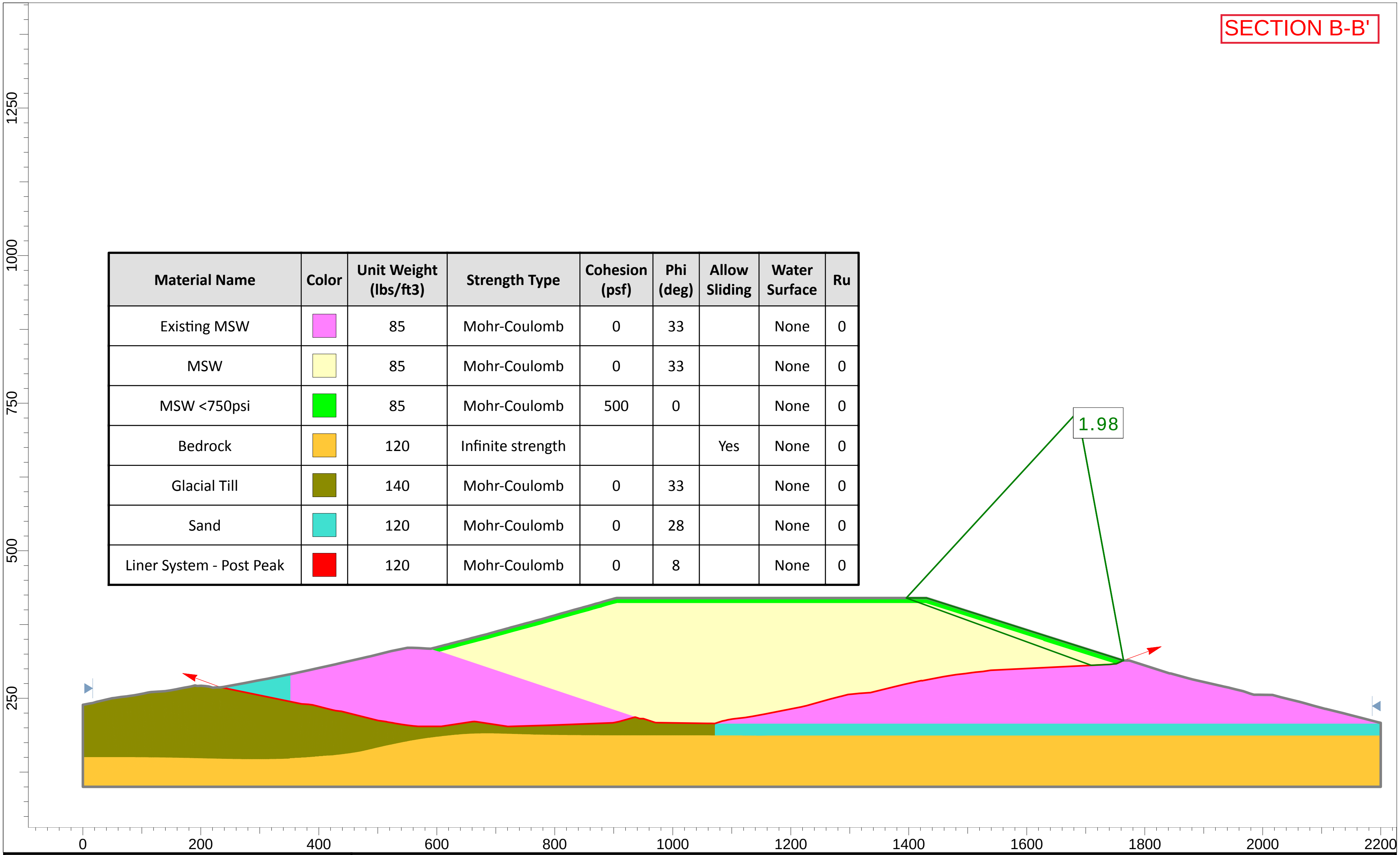

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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟥	120	Mohr-Coulomb	0	8		None	0

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Project NASHUA PHASE IV STABILITY ANALYSIS

Analysis Description LINER STABILITY

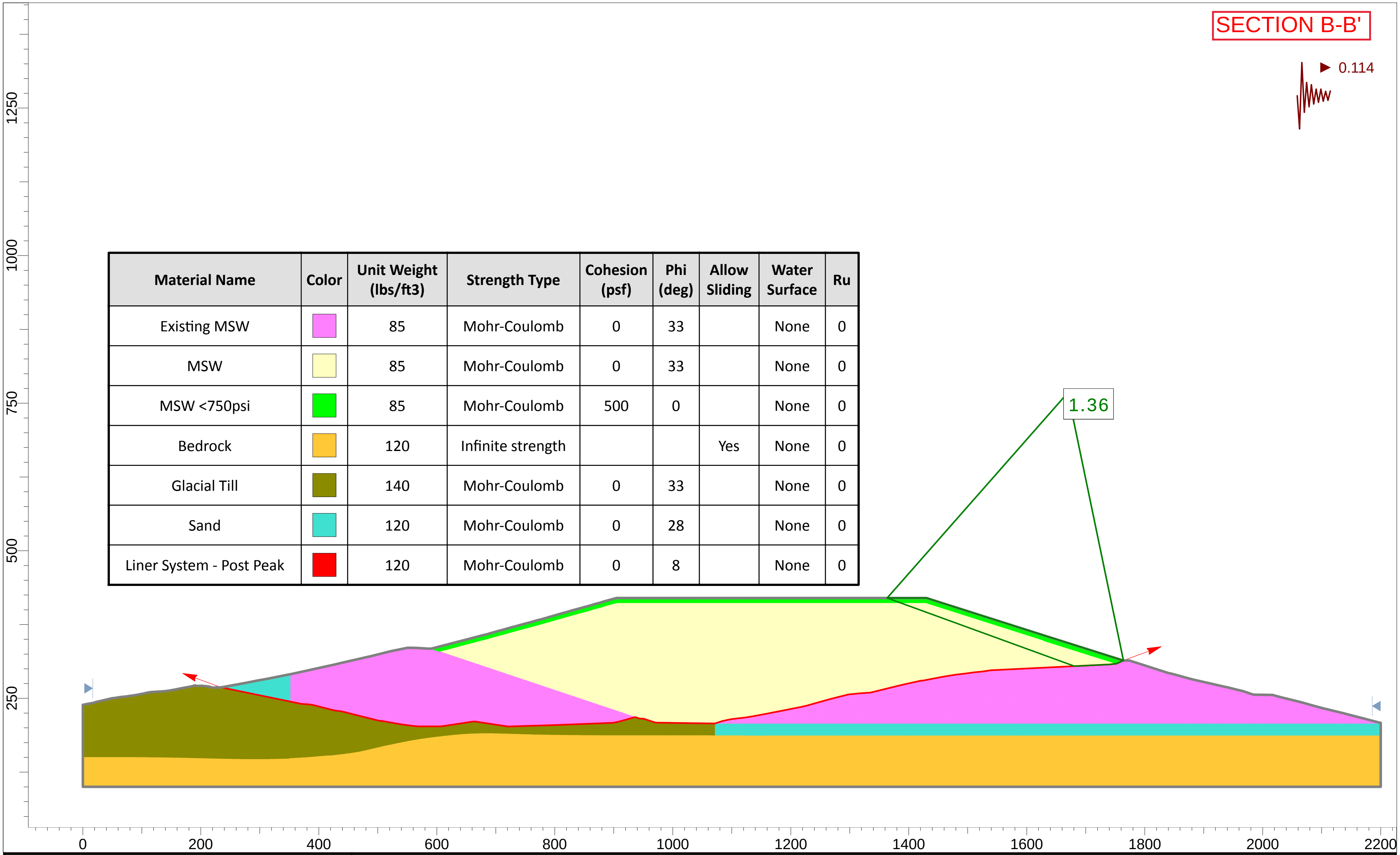
Drawn By O. HERNANDEZ

Scale 1:2700

Company SANBORN, HEAD & ASSOCIATES, INC.

Date 6/25/2020, 2:06:12 PM

File Name Liner - L to R - Static - Post Peak



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟥	120	Mohr-Coulomb	0	8		None	0

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Project NASHUA PHASE IV STABILITY ANALYSIS

Analysis Description LINER STABILITY

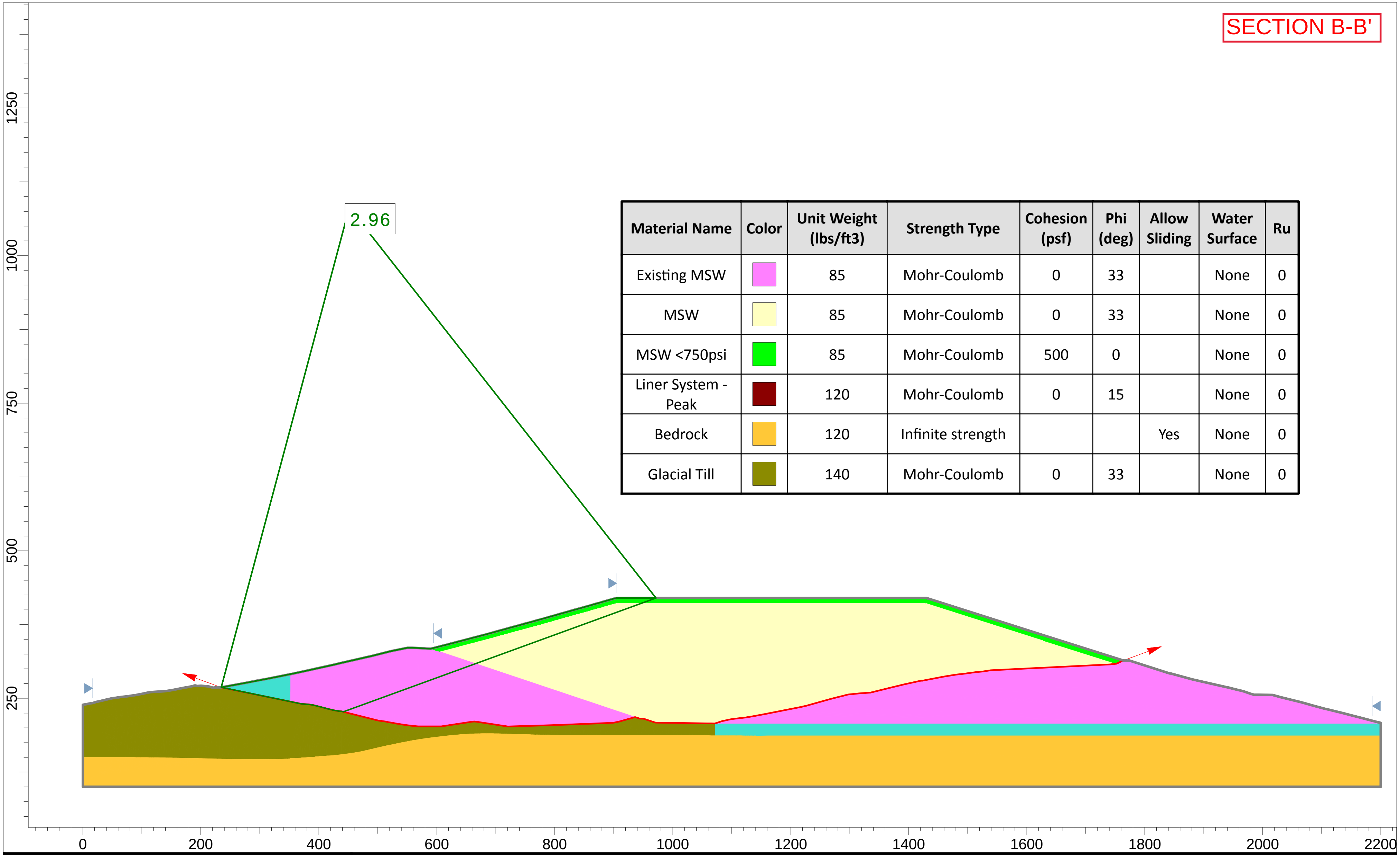
Drawn By O. HERNANDEZ

Scale 1:2700

Company SANBORN, HEAD & ASSOCIATES, INC.

Date 6/25/2020, 2:06:12 PM

File Name Liner - L to R - Seismic - Post Peak



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Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Liner System - Peak	🟥	120	Mohr-Coulomb	0	15		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0

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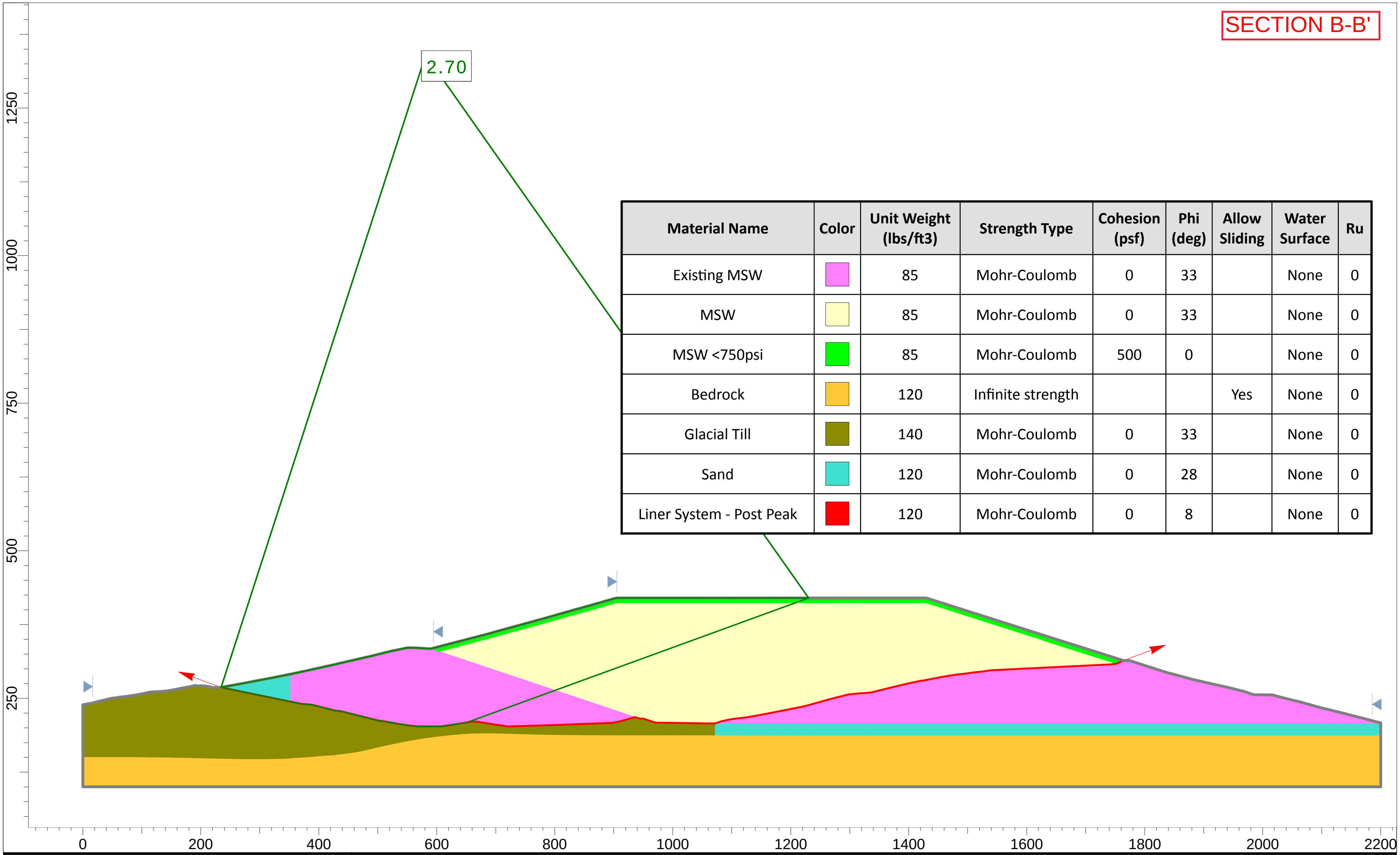
Project	NASHUA PHASE IV STABILITY ANALYSIS		
Analysis Description	LINER STABILITY		
Drawn By O. HERNANDEZ	*Scale* 1:2700	*Company*	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM	*File Name*	Liner - R to L - Static - Peak



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MSW	🟨	85	Mohr-Coulomb	0	33		None	0
MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟥	120	Mohr-Coulomb	0	8		None	0

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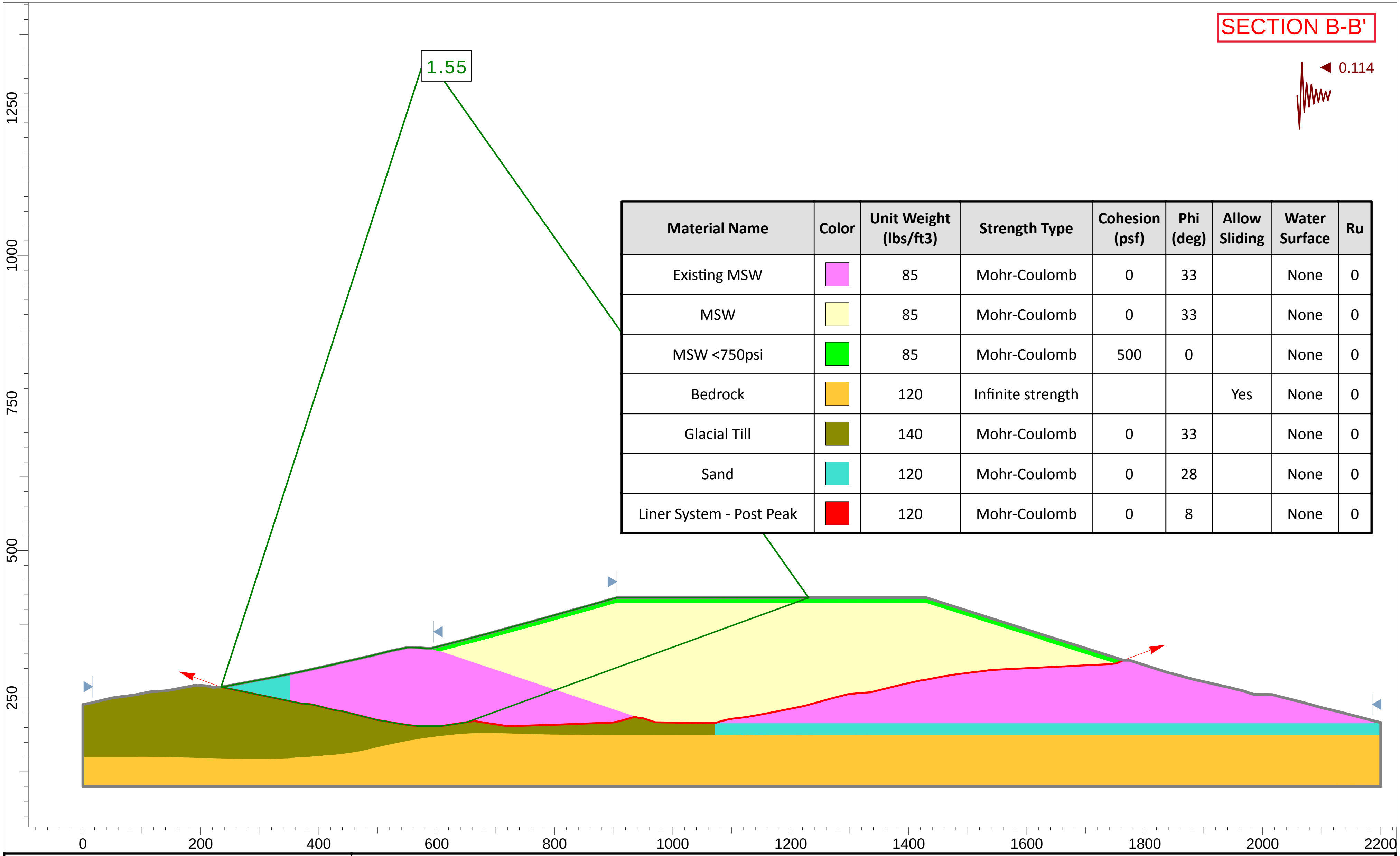
Project	NASHUA PHASE IV STABILITY ANALYSIS
Analysis Description	LINER STABILITY
Drawn By	O. HERNANDEZ
Scale	1:2700
Company	SANBORN, HEAD & ASSOCIATES, INC.
Date	6/25/2020, 2:06:12 PM
File Name	Liner - R to L - Static - Post Peak



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Ru
Existing MSW	🟪	85	Mohr-Coulomb	0	33		None	0
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MSW <750psi	🟩	85	Mohr-Coulomb	500	0		None	0
Bedrock	🟧	120	Infinite strength			Yes	None	0
Glacial Till	🟫	140	Mohr-Coulomb	0	33		None	0
Sand	🟦	120	Mohr-Coulomb	0	28		None	0
Liner System - Post Peak	🟥	120	Mohr-Coulomb	0	8		None	0

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Project
NASHUA PHASE IV STABILITY ANALYSIS

Analysis Description
LINER STABILITY

Drawn By O. HERNANDEZ
Scale 1:2700
Company SANBORN, HEAD & ASSOCIATES, INC.

Date 6/25/2020, 2:06:12 PM
File Name Liner - R to L - Seismic - Post Peak

B.1 Primary Drainage Geocomposite

PURPOSE:

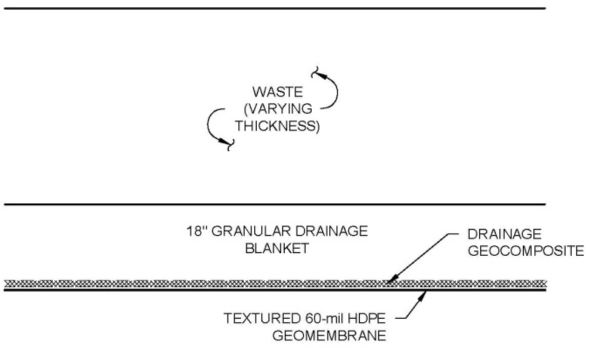
Calculate the flow capacity required for the drainage geocomposite during the initial operation (10ft of waste placed), active operation (50% of waste placed), and full buildout (100% of waste placed) of the landfill for the various slopes and drainage length combinations within the base and sideslope areas of Phase IV. Specify the minimum required transmissivity of the drainage geocomposite for Phase IV.

DATA:

The following table summarizes the differing slope (β) and associated drainage lengths (L) in the base and overlay areas:

Area Designation	Slope, β		Drainage Length, L	
	%	Degrees	Feet	Meters
Base area	2.4	1.37	182	55.5
Overlay area with slope ≤ 5%	5	2.86	339	103
Overlay area with slope > 5%	22.6	12.73	409	125

See Attachment A for a plan that shows the location of the slopes and associated drainage lengths described in the above table. See Attachment B for a plan that shows the location of the maximum waste thickness. The HELP Model (Enhanced Version 3.95.1.7) [Ref. 1] was utilized to evaluate the performance requirements of the primary liner system drainage geocomposite and is based on the following cross-section:



See below for additional HELP Model inputs:

- Model the waste using default material texture (18), vertical percolation layer for 10 ft.

- Model the drainage sand as default material texture (2) modified with the hydraulic conductivity for Drainage Sand equal to 1 x 10^{-4} cm/sec, and a thickness of 1.5 ft.

- Model the drainage geocomposite as default material texture (20) modified for a saturated hydraulic conductivity of 7.87 cm/sec and a thickness of 250 mil.

- Model the geomembrane as default material texture (35) for 60 mil.

- Use daily precipitation data for Nashua, New Hampshire from 2010 through 2019 obtained from the National Oceanic and Atmospheric Administration (NOAA) website, modified by adding the 25-year, 24-hour storm event, 5.55 inches (Attachment E).

- Use synthetically generated evapotranspiration, temperature, and solar radiation data for Nashua, New Hampshire.

- Assume bare ground conditions and no runoff allowed.

- Assume an evaporative zone depth of 8 inches and a maximum leaf area index of 0.

METHOD:

1. Perform additional HELP Model evaluations to calculate the peak daily drainage collected from the drainage geocomposite layer in inches per day (in/day) for each of the following critical phases of waste placement, slope, and drainage length combination:

   a. Initial Operation (10 ft of waste placed)
   b. Active Operation (50% of waste placed, about 103.5 feet of waste)
   c. Full Buildout (100% of waste placed, about 207 feet of waste)

   Convert the peak daily drainage collected from the drainage geocomposite layer obtained from each HELP Model output to an impingement rate in meters per second (q_i).

$$q_i, \frac{m}{sec} = Peak\ Daily\ Drainage, \frac{in}{day}\, x\, \frac{0.0254\ m}{in}\, x\, \frac{1\ day}{24\ hr}\, x\, \frac{1\ hr}{60\ min}\, x\, \frac{1\ min}{60\ sec} \qquad (1)$$

2. Calculate the design transmissivity (θ_{Design}) for the drainage geocomposite based on the impingement rate, drainage length, and slope.

$$\theta_{Design} = \frac{q_i L}{\sin\beta} \qquad (2)$$

3. Select reduction factors based on Table 1 on Page 297 of Reference 2 (see Attachment C) that are applicable to the Phase IV leachate collection system. Calculate the product of all the reduction factors.

$$\Pi(\mathrm{RF}) = \mathrm{RF}_{in} \times \mathrm{RF}_{cr} \times \mathrm{RF}_{cc} \times \mathrm{RF}_{bc} \qquad (3)$$

Where:

$\Pi(\mathrm{RF})$ = product of all reduction factors (dimensionless);
RF_{in} = reduction factor for intrusion of the adjacent geotextiles into the drainage core;
RF_{cr} = reduction factor for creep deformation of the drainage core;
RF_{cc} = reduction factor for chemical clogging; and
RF_{bc} = reduction factor for biological clogging.

Select a desired factor of safety, FS_d, based on engineering literature and judgment. Calculate the required hydraulic transmissivity (θ_{req}) for the drainage geocomposite based on the design transmissivity, the product of all reduction factors, and the desired factor of safety.

$$\theta_{req} = FS_d \text{ x } \Pi(\mathrm{RF}) \text{ x } \theta_{Design} \qquad (4)$$

Where:

θ_{req} = Required drainage geocomposite hydraulic transmissivity (m^2/s);
FS_d = Factor of Safety (specify based on the phase of waste placement)
$\Pi(\mathrm{RF})$ = Product of all reduction factors (dimensionless)
θ_{Design} = Design transmissivity (m^2/s);

CALCULATION:

See Table 1 for a summary of the calculations for each of the waste placement scenarios mentioned above. Below is an example calculation based on the initial operation of Phase IV (18 inches of the granular drainage blanket material above the primary liner system, 10 feet of waste placed, and a slope of 2.4 percent.

1. Based on the initial operation of Phase IV and a base area liner system slope of 2.4 percent, a peak daily drainage collected from the drainage geocomposite layer of 0.63834 in/day was calculated utilizing the HELP Model. Therefore, Equation 1 becomes:

$$q_i = 0.63834 \frac{in}{day} x \frac{0.0254\, m}{in} x \frac{1\, day}{24\, hr} x \frac{1\, hr}{60\, min} x \frac{1\, min}{60\, sec} = 1.88\ x\ 10^{-7} \frac{m}{sec}$$

2. Using Equation 2, calculate the design transmissivity (θ_{Design}) for the drainage geocomposite based on the impingement rate, drainage length, and slope.

$$\theta_{Design} = \frac{1.88\ x\ 10^{-7}\,\frac{m}{sec}\,x\ 55.5\ m}{\sin 1.37°} = 4.36\ x\ 10^{-4}\,\frac{m^2}{sec}$$

3. Select appropriate reduction factors based on the full buildout scenario[1].

   Assume:
   RF_{in} = 1.2
   RF_{cr} = 1.2
   RF_{cc} = 1.5
   RF_{bc} = 1.2
   Therefore, Equation 3 becomes:

   $$\Pi(RF) = 1.2 \times 1.2 \times 1.5 \times 1.2 = \underline{2.59}$$

4. Assuming a desired factor of safety (FS_d) of 1.5, utilize Equation (4) to calculate the required hydraulic transmissivity (θ_{req}) for the drainage geocomposite based on the design transmissivity, the product of all reduction factors, and the desired factor of safety:

   $$\theta_{req} = 1.5\ x\ 2.59\ x\ 4.36\ x\ 10^{-4} m^2/s$$

   $$\theta_{req} = \underline{1.69 \times 10^{-3}\ m^2/s}$$

Table 1 also summarizes the maximum head on the liner system calculated by the HELP Model for each scenario. Based on the HELP Model results, the maximum head on the liner system will not exceed 12 inches using 330 mil drainage geocomposite at the required minimum transmissivity values.

CONCLUSION:

An acceptable drainage geocomposite for Phase IV should exhibit a minimum transmissivity of:

$$1.7 \times 10^{-3}\ m^2/s$$

For example, GSE PermaNet 330 mil Drainage Geocomposite will meet these transmissivity requirements (see Attachment D).

The HELP Model results for each of the slopes and drainage length scenarios are provided in Attachment F.

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[1] The reduction factors are intended to account for burial depth and long-term material performance due to clogging and deformation, and serve to increase the factor of safety. The reduction factors and calculation are based on generally accepted industry design practices, and the values chosen are based on engineering and site experience.

REFERENCES:

[1] USEPA, *The Hydrologic Evaluation of Landfill Performance (HELP) Model*, Enhanced Version 3.95.1.7, August 2012.

[2] Giroud, J.P. Zornberg, J.G., Zhao, A., 2000, "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers," *Geosynthetics International*, Special Issue on Liquid Collection Systems, Vol. 7, Nos. 4-6, pp. 285-380.

TABLES:

Table 1	Drainage Geocomposite Evaluation

ATTACHMENTS:

Attachment A	Drainage Lengths Worksheet
Attachment B	Phase IV Design Maximum Waste Thickness Worksheet
Attachment C	Reduction Factors
Attachment D	Extreme Precipitation Tables
Attachment E	GSE PermaNet 330 mil Drainage Geocomposite Product Data Sheet
Attachment F	HELP Model Results

Table 1 - Drainage Geocomposite Evaluation
Phase IV Landfill Expansion Project
Four Hills Landfill - Nashua, New Hampshire

Phase of Waste Placement	Modeled Saturated Hydraulic Conductivity, k	Area Designation	Slope Angle		Peak Head on the Primary Liner	Leachate Impingement Rate, q_i		Drainage Length, L	Design Transmissivity, θ_{Design}	Maximum Applied Stress, σ_{100}	Intrusion Reduction Factor, RF_{in}	Creep Reduction Factor, RF_{cr}	Chemical Clogging Reduction Factor, RF_{cc}	Biological Clogging Reduction Factor, RF_{bc}	Product of All Reduction Factors, $\Pi(RF)$	Desired Factor of Safety, FS_d	Required Transmissivity, θ_{req}
	cm/sec		%	Deg.	in	in/day	m/sec	m	m^2/sec	psf							m^2/sec
Initial Operation[1] (10 ft waste placed)	7.87	Base Area	2.4	1.37	0.17	0.638	1.88E-07	55.5	4.36E-04	850	1.2	1.2	1.5	1.2	2.59	1.5	1.69E-03
	7.87	Overlay (less than or equal to 5%)	5.0	2.86	0.15	0.638	1.87E-07	103	3.87E-04	850	1.2	1.2	1.5	1.2	2.59	1.5	1.50E-03
	7.87	Overlay (greater than 5%)	22.6	12.73	0.21	0.642	1.89E-07	125	1.07E-04	850	1.2	1.2	1.5	1.2	2.59	1.5	4.20E-04
Active Operation (50% of waste placed, about 103.5 feet of waste)	7.87	Base Area	2.4	1.37	0.05	0.191	5.62E-08	55.5	1.30E-04	8797.5	1.5	1.5	1.6	1.2	4.32	1.5	8.46E-04
	7.87	Overlay (less than or equal to 5%)	5.0	2.86	0.06	0.191	5.63E-08	103	1.16E-04	8797.5	1.5	1.5	1.6	1.2	4.32	1.5	7.53E-04
	7.87	Overlay (greater than 5%)	22.6	12.73	0.20	0.191	5.62E-08	125	3.19E-05	8797.5	1.5	1.5	1.6	1.2	4.32	1.5	2.06E-04
Full Buildout (100% of waste placed, about 207 feet of waste)	7.87	Base Area	2.4	1.37	0.05	0.187	5.49E-08	55.5	1.28E-04	17595	1.7	1.7	1.7	1.2	5.90	1.5	1.13E-03
	7.87	Overlay (less than or equal to 5%)	5.0	2.86	0.06	0.187	5.50E-08	103	1.13E-04	17595	1.7	1.7	1.7	1.2	5.90	1.5	1.00E-03
	7.87	Overlay (greater than 5%)	22.6	12.73	0.20	0.187	5.50E-08	125	3.12E-05	17595	1.7	1.7	1.7	1.2	5.90	1.5	2.76E-04

Max: **1.69E-03**

1 - The desired factor of safety is lower during initial operations because it is an interim condition of relatively short duration where the drainage geocomposite is relatively "new". Furthermore, there is limited chemical and biological impacts during initial operations, so it is not necessary to be as conservative as the active operation or full buildout calculations. As more waste is placed in the landfill and chemical and biological impacts increase, the desired factor of safety is increased.

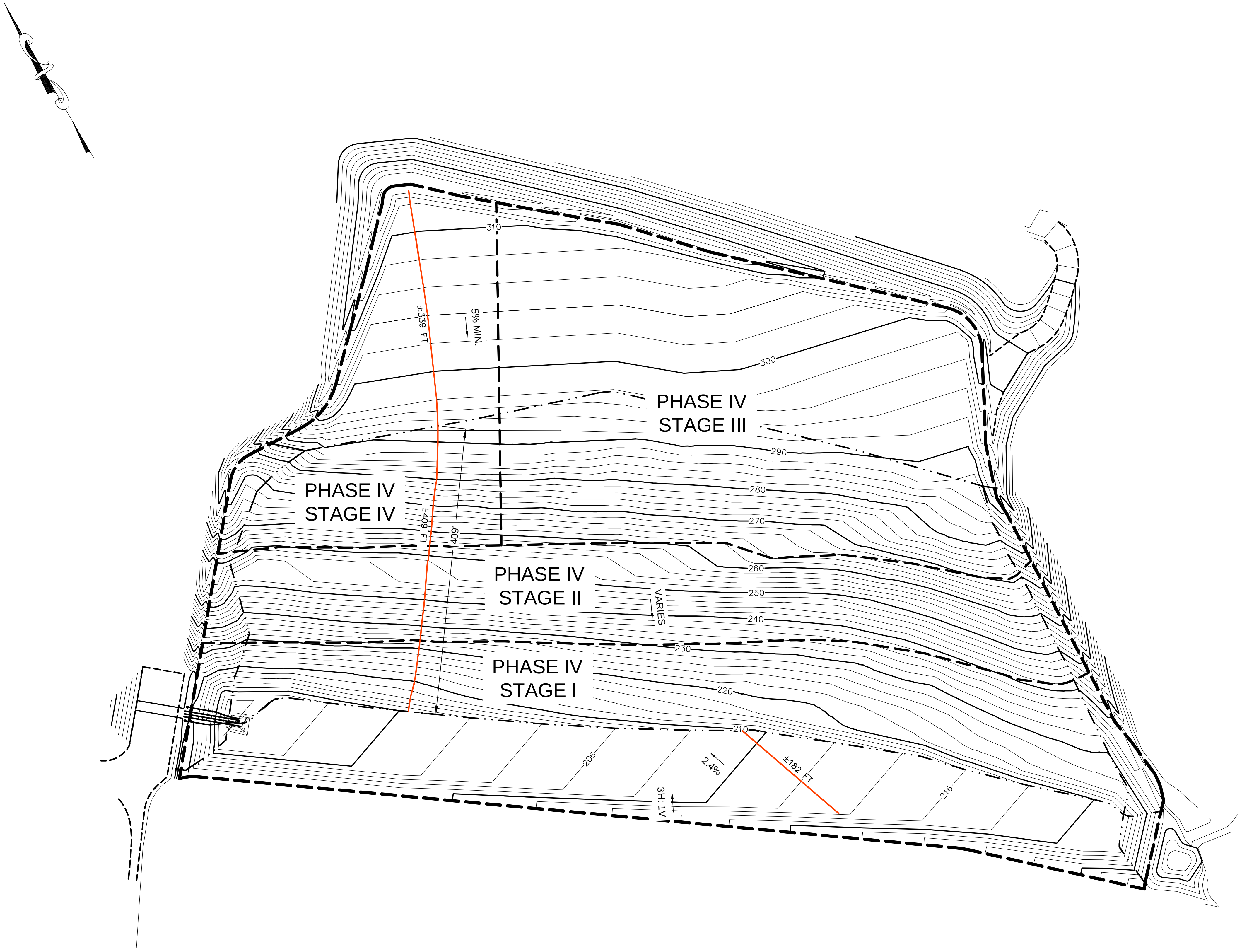
Attachment A

NOTES:

1. BASE GRADES REPRESENT THE SECONDARY LINER GRADES.

LEGEND:

—210—	PROPOSED 10-FOOT CONTOUR
——	PROPOSED 2-FOOT CONTOUR
━ ━ ━	LIMIT OF WASTE
— · — · —	PERFORATED LEACHATE COLLECTION PIPE
——	SOLID LEACHATE RISER PIPE
115 FT	CRITICAL LEACHATE FLOW PATH AND LENGTH



- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
80' 40' 0 80' 160'

DRAFT

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

DRAINAGE LENGTHS WORKSHEET

PROJECT NUMBER:
3066.11

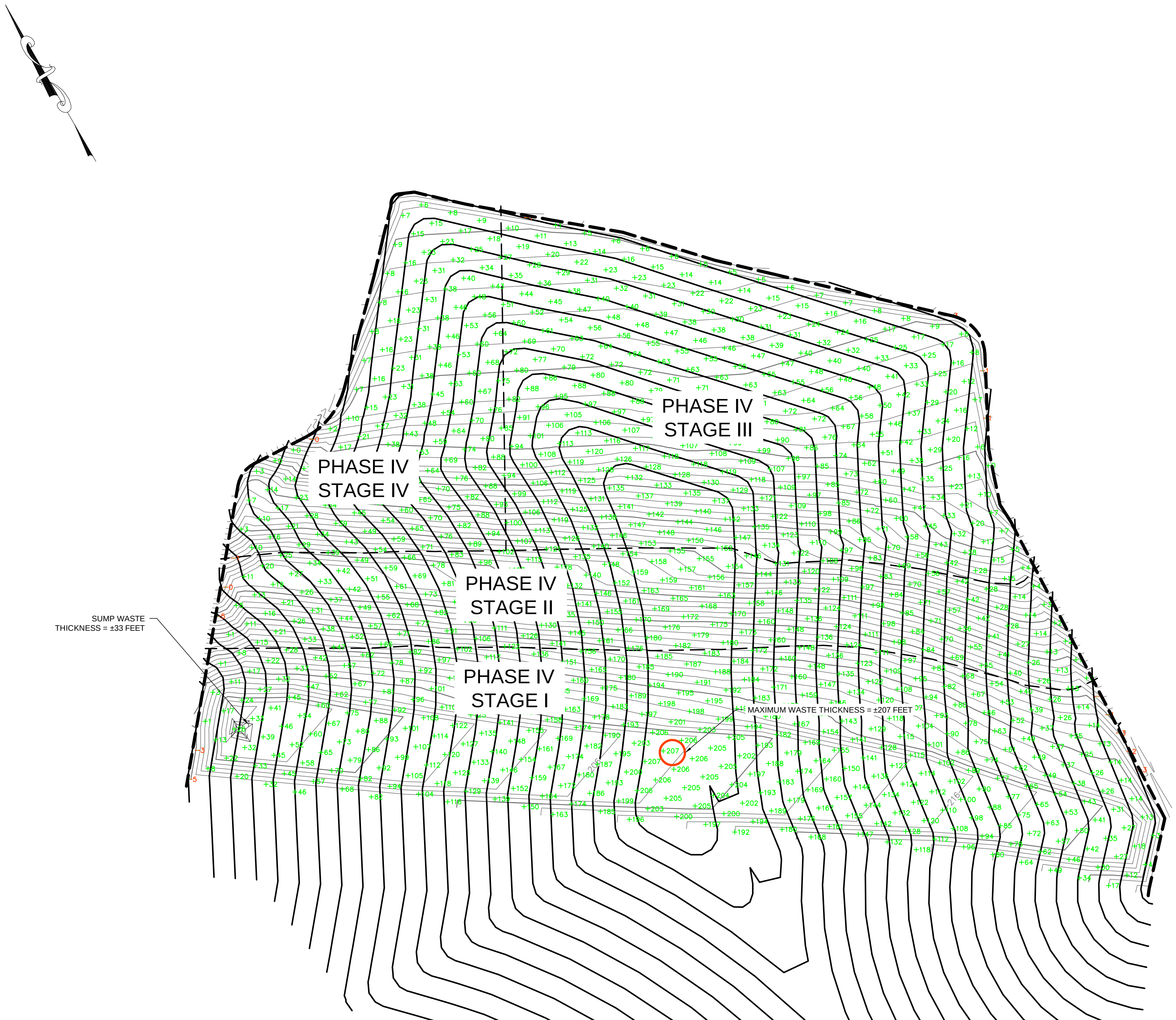
FIGURE NUMBER:
1

IMAGES:

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\Proposed Secondary Liner Grades.dwg

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\Calculations\Drainage Lengths Worksheet.dwg
LAYOUT: 1
USER: ssantiago
PLOT DATE: 6-12-20 2:53 PM

Attachment B



NOTES:

GRADES SHOWN REPRESENT THE SECONDARY LINER GRADES AND FINAL GRADES. SECONDARY LINER GRADES WERE RAISED BY 2.5 FEET AND FINAL GRADES WERE LOWERED BY 3.5 FEET TO CALCULATE WASTE THICKNESS.

LEGEND:

—210—	10-FOOT PHASE IV SECONDARY LINER CONTOUR
——	2-FOOT PHASE IV SECONDARY LINER CONTOUR
—420—	10-FOOT FINAL GRADE CONTOUR
▬ ▬ ▬ ▬	LIMIT OF WASTE
— — — —	STAGE LIMIT
+102	DEPTH OF WASTE (FEET)

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
80' 40' 0 80' 160'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

WASTE THICKNESS WORKSHEET

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
1 OF 1

IMAGES:

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\Proposed Secondary Liner Grades.dwg

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\Calculations\Depth Worksheet.dwg
LAYOUT: 1
USER: ssantiago
PLOT DATE: 7-9-20 8:54 AM

Attachment C

RF_{CR} = reduction factor for creep deformation of the drainage core itself and/or creep intrusion of the adjacent geotextile into the drainage core space,

RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals onto the geotextile or within the drainage core space, and

RF_{BC} = reduction factor for biological clogging of the geotextile or within the drainage core space.

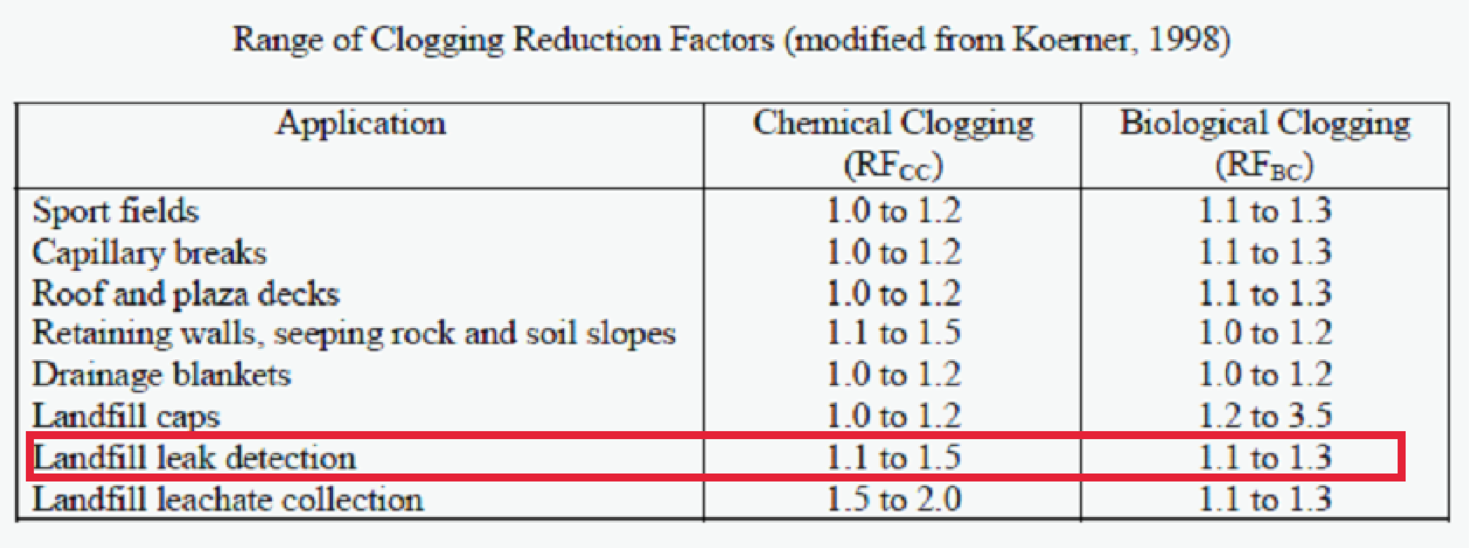
TABLE 8.5 RECOMMENDED REDUCTION FACTORS FOR EQ. (8.12) TO DETERMINE ALLOWABLE FLOW RATE OF DRAINAGE GEOCOMPOSITES [SHEET DRAINS (most applications), WICK DRAINS AND EDGE DRAINS]

Application Area	RF_{IN}	RF_{CR}*	RF_{CC}	RF_{BC}
Sport fields	1.0 to 1.2	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.3 to 1.5	1.2 to 1.4	1.1 to 1.5	1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill caps	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.2 to 1.5
Secondary leachate collection (landfill)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Primary leachate collection (landfill)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Wick drains (or PVDs)†	1.5 to 2.5	1.0 to 2.5	1.0 to 1.2	1.0 to 1.2
Highway edge drains	1.2 to 1.8	1.5 to 3.0	1.1 to 5.0	1.0 to 1.2

* These values assume that the ultimate value was obtained using an applied normal pressure of approximately 1.5 times the field anticipated maximum value. If not, the values must be increased.

† An additional term for kinking, or crimping, should be included, where $RF_{KG} = 1.0$ to 4.0.

Attachment C



Range of Clogging Reduction Factors (modified from Koerner, 1998)

Application	Chemical Clogging (RF_{CC})	Biological Clogging (RF_{BC})
Sport fields	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.0 to 1.2	1.1 to 1.3
Roof and plaza decks	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.1 to 1.5	1.0 to 1.2
Drainage blankets	1.0 to 1.2	1.0 to 1.2
Landfill caps	1.0 to 1.2	1.2 to 3.5
Landfill leak detection	1.1 to 1.5	1.1 to 1.3
Landfill leachate collection	1.5 to 2.0	1.1 to 1.3

Modified recommended reduction factors taken from page 9 of GRI-GC8 dated April 17, 2001.

Attachment D

PRODUCT DATA SHEET

GSE PermaNet 330 mil Geocomposite

GSE PermaNet 330 mil geocomposite is manufactured with a GSE PermaNet geonet core heat-bonded on one or both sides with a nonwoven needlepunched geotextile. The round strand, creep resistant structure of this product ensures continuous flow performance and durability under rigorous environmental conditions and is ideal for extremely demanding applications.

[*]

AT THE CORE:
The product's structure provides superior performance under demanding conditions.

Product Specifications

Tested Property	Test Method	Frequency	Minimum Average Roll Value		
Geocomposite			6 oz/yd^2	8 oz/yd^2	10 oz/yd^2
Transmissivity(2), gal/min/ft (m^2/sec) Double-Sided Composite Single-Sided Composite	ASTM D 4716	1/540,000 ft^2	 9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})	 9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})	 9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})
Ply Adhesion, lb/in	ASTM D 7005	1/50,000 ft^2	1.0	1.0	1.0
Geonet Core(1,3) – GSE PermaNet					
Geonet Core Thickness, mil	ASTM D 5199	1/50,000 ft^2	330	330	330
Transmissivity(2), gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	28.8 (6 x 10^{-3})	28.8 (6 x 10^{-3})	28.8 (6 x 10^{-3})
Compressive Strength, lb/ft^2	ASTM D 6364	1/540,000 ft^2	60,000	60,000	60,000
Creep Reduction Factor	ASTM D 7361	per formulation	1.3 @ 25,000 psf	1.3 @ 25,000 psf	1.3 @ 25,000 psf
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94
Tensile Strength (MD), lb/in	ASTM D 7179	1/50,000 ft^2	100	100	100
Carbon Black Content, %	ASTM D 4218	1/50,000 ft^2	2.0	2.0	2.0
Geotextile(1,3)					
Mass per Unit Area, oz/yd^2	ASTM D 5261	1/90,000 ft^2	6	8	10
Grab Tensile, lb	ASTM D 4632	1/90,000 ft^2	160	220	260
Grab Elongation	ASTM D 4632	1/90,000 ft^2	50%	50%	50%
CBR Puncture Strength, lb	ASTM D 6241	1/540,000 ft^2	435	575	725
Trapezoidal Tear Strength	ASTM D 4533	1/90,000 ft^2	65	90	100
AOS, US Sieve, (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)	80 (0.180)	100 (0.150)
Permittivity, sec^{-1}	ASTM D 4491	1/540,000 ft^2	1.5	1.3	1.0
Water Flow Rate, gpm/ft^2	ASTM D 4491	1/540,000 ft^2	110	95	75
UV Resistance, % Retained	ASTM D 4355 (after 500 hours)	per formulation	70	70	70
NOMINAL ROLL DIMENSIONS(4)					
Roll Width, ft			15	15	15
Roll Length, ft	Double-Sided Composite Single-Sided Composite		150 150	140 150	130 140
Roll Area, ft^2	Double-Sided Composite Single-Sided Composite		2,250 2,250	2,100 2,250	1,950 2,100

NOTES:

- (1) All geotextile properties are minimum average roll values except AOS which is maximum average roll value and UV resistance is typical value. Geonet core thickness is nominal value.
- (2) Gradient of 0.1, normal load of 25,000 psf, water at 70° F between steel plates for 15 minutes. Contact GSE for performance transmissivity data for use in design.
- (3) Component properties prior to lamination.
- (4) Roll widths and lengths have a tolerance of ±1%.

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

GSE
ENVIRONMENTAL™

[**DURABILITY RUNS DEEP**] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

Attachment E

Extreme Precipitation Tables

Northeast Regional Climate Center

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

Smoothing	Yes
State	New Hampshire
Location	
Longitude	71.522 degrees West
Latitude	42.732 degrees North
Elevation	0 feet
Date/Time	Mon, 24 Jul 2017 14:26:49 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.28	0.42	0.53	0.69	0.86	1.08	**1yr**	0.74	1.02	1.25	1.57	1.98	2.50	2.76	**1yr**	2.21	2.66	3.08	3.79	4.40	**1yr**
2yr	0.33	0.51	0.64	0.84	1.06	1.33	**2yr**	0.92	1.22	1.54	1.92	2.39	2.97	3.31	**2yr**	2.63	3.19	3.69	4.42	5.03	**2yr**
5yr	0.40	0.62	0.77	1.03	1.32	1.68	**5yr**	1.14	1.53	1.94	2.42	3.01	3.72	4.20	**5yr**	3.29	4.04	4.67	5.55	6.26	**5yr**
10yr	0.44	0.70	0.88	1.20	1.56	2.00	**10yr**	1.35	1.80	2.32	2.90	3.59	4.42	5.02	**10yr**	3.91	4.83	5.59	6.60	7.39	**10yr**
25yr	0.53	0.84	1.07	1.47	1.95	2.51	**25yr**	1.68	2.26	2.93	3.66	4.53	5.55	6.38	**25yr**	4.91	6.13	7.09	8.31	9.21	**25yr**
50yr	0.59	0.95	1.22	1.71	2.31	3.01	**50yr**	2.00	2.67	3.51	4.39	5.41	6.60	7.65	**50yr**	5.84	7.35	8.49	9.88	10.88	**50yr**
100yr	0.68	1.10	1.42	2.01	2.74	3.58	**100yr**	2.37	3.17	4.19	5.24	6.45	7.85	9.17	**100yr**	6.95	8.81	10.17	11.76	12.86	**100yr**
200yr	0.78	1.27	1.64	2.35	3.25	4.28	**200yr**	2.81	3.75	5.01	6.27	7.70	9.34	11.00	**200yr**	8.27	10.57	12.19	14.01	15.20	**200yr**
500yr	0.93	1.53	2.00	2.91	4.08	5.40	**500yr**	3.52	4.71	6.34	7.94	9.74	11.77	14.00	**500yr**	10.41	13.46	15.49	17.65	18.98	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.22	0.34	0.41	0.55	0.68	0.79	1yr	0.59	0.77	1.04	1.34	1.68	2.33	2.51	1yr	2.06	2.41	2.69	3.44	4.04	1yr
2yr	0.32	0.49	0.60	0.82	1.01	1.21	2yr	0.87	1.18	1.37	1.79	2.29	2.87	3.22	2yr	2.54	3.10	3.58	4.27	4.88	2yr
5yr	0.36	0.56	0.69	0.95	1.21	1.42	5yr	1.04	1.39	1.63	2.12	2.71	3.42	3.97	5yr	3.03	3.82	4.33	5.08	5.80	5yr
10yr	0.40	0.61	0.76	1.06	1.36	1.59	10yr	1.18	1.56	1.80	2.40	3.06	3.90	4.52	10yr	3.45	4.35	5.00	5.78	6.61	10yr
25yr	0.45	0.69	0.85	1.22	1.60	1.86	25yr	1.38	1.82	2.10	2.84	3.58	4.66	5.49	25yr	4.12	5.28	6.10	6.88	7.83	25yr
50yr	0.49	0.74	0.92	1.33	1.79	2.10	50yr	1.54	2.06	2.36	3.23	4.04	5.34	6.38	50yr	4.72	6.14	7.10	7.85	8.93	50yr
100yr	0.53	0.80	1.00	1.45	1.98	2.37	100yr	1.71	2.32	2.65	3.34	4.56	6.13	7.45	100yr	5.43	7.16	8.28	8.96	10.21	100yr
200yr	0.58	0.87	1.10	1.59	2.22	2.67	200yr	1.92	2.61	2.96	3.75	5.18	7.07	8.71	200yr	6.26	8.38	9.66	10.21	11.71	200yr
500yr	0.65	0.96	1.24	1.80	2.56	3.15	500yr	2.21	3.08	3.46	4.35	6.16	8.53	10.75	500yr	7.55	10.34	11.91	12.20	13.99	500yr

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.31	0.48	0.59	0.79	0.97	1.14	1yr	0.84	1.12	1.29	1.68	2.11	2.66	2.99	1yr	2.36	2.87	3.37	4.12	4.71	1yr
2yr	0.36	0.55	0.68	0.92	1.13	1.32	2yr	0.98	1.29	1.50	1.94	2.49	3.10	3.44	2yr	2.74	3.31	3.84	4.60	5.23	2yr
5yr	0.44	0.67	0.83	1.15	1.46	1.69	5yr	1.26	1.65	1.90	2.43	3.05	4.07	4.42	5yr	3.60	4.25	5.05	5.98	6.70	5yr
10yr	0.52	0.80	0.99	1.39	1.79	2.07	10yr	1.55	2.02	2.35	2.91	3.62	5.02	5.63	10yr	4.44	5.42	6.23	7.31	8.11	10yr
25yr	0.67	1.02	1.26	1.80	2.37	2.70	25yr	2.05	2.64	3.05	3.68	4.52	6.64	7.43	25yr	5.87	7.15	8.23	9.54	10.43	25yr
50yr	0.80	1.22	1.52	2.19	2.95	3.30	50yr	2.54	3.22	3.73	4.41	5.35	8.20	9.16	50yr	7.26	8.81	10.13	11.66	12.62	50yr
100yr	0.97	1.47	1.84	2.66	3.65	4.04	100yr	3.15	3.95	4.56	5.70	6.33	10.10	11.29	100yr	8.93	10.86	12.47	14.24	15.24	100yr
200yr	1.18	1.77	2.24	3.25	4.53	4.94	200yr	3.91	4.83	5.56	6.91	7.50	12.43	13.90	200yr	11.00	13.36	15.34	17.41	18.43	200yr
500yr	1.52	2.27	2.92	4.24	6.03	6.42	500yr	5.20	6.28	7.25	8.92	9.38	16.36	18.27	500yr	14.48	17.57	20.15	22.71	23.70	500yr

Powered by ACIS
Northeast Regional
Climate Center

Attachment F

Initial Operation - Base Area

```
****************************************************************************
****************************************************************************
**                                              **
**                                              **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE          **
**                                              **
**          HELP Version 3.95 D        (10 August 2012)          **
**                   developed at                    **
**      Institute of Soil Science, University of Hamburg, Germany       **
**                    based on                    **
**          US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)           **
**            DEVELOPED BY ENVIRONMENTAL LABORATORY              **
**              USAE WATERWAYS EXPERIMENT STATION               **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY          **
**                                              **
**                                              **
****************************************************************************
****************************************************************************


 TIME:  14.54    DATE:  10.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
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Rate)\Help files\Site Data\Phase IV 2010-2020.d4
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Rate)\Help files\Site Data\Phase IV.d13
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Rate)\Help files\Site Data\Phase IV.d11
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Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Initial Operation.out
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Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Initial Operation.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
   1    DATE (yyyymmdd)
   2    AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
   3    FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
   4    PRECIPITATION (INCH)
   5    RUNOFF (INCH)
   6    POTENTIAL EVAPOTRANSPIRATION (INCH)
   7    ACTUAL EVAPOTRANSPIRATION (INCH)
   8    WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
   9    HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
  10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
  11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


************************************************************************************************

   TITLE:  Four Hills Landfill - Phase IV Design

************************************************************************************************


                  WEATHER DATA SOURCES
---------------------------------------------------------------------------



      NOTE:  PRECIPITATION DATA FOR     Nashua            New Hampshire
             WAS ENTERED FROM A TEXT FILE.



      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE

         NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    22.60       24.50       33.60       44.90       55.50       64.80
    69.80       67.70       59.50       49.10       38.70       26.60


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE
              AND STATION LATITUDE  =  42.70 DEGREES
```

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******************************************************************************

                    LAYER DATA   1
------------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                      LAYER  1
                      --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
      THICKNESS                  =   120.00   INCHES
      POROSITY                   =     0.6710 VOL/VOL
      FIELD CAPACITY             =     0.2920 VOL/VOL
      WILTING POINT              =     0.0770 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0.3123 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-02 CM/SEC


                      LAYER  2
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   2
      THICKNESS                  =    18.00   INCHES
      POROSITY                   =     0.4370 VOL/VOL
      FIELD CAPACITY             =     0.0620 VOL/VOL
      WILTING POINT              =     0.0240 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0.1500 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=     0.5800E-02 CM/SEC


                      LAYER  3
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  20
```

```
    THICKNESS                 =      0.25   INCHES
    POROSITY                  =     0.8500 VOL/VOL
    FIELD CAPACITY            =     0.0100 VOL/VOL
    WILTING POINT             =     0.0050 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.0364 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      10.00     CM/SEC
    SLOPE                     =      2.40   PERCENT
    DRAINAGE LENGTH           =     182.0    FEET


                    LAYER  4
                    --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
    THICKNESS                 =      0.06   INCHES
    EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
    FML PINHOLE DENSITY       =      0.00   HOLES/ACRE
    FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
    FML PLACEMENT QUALITY       =  3 - GOOD


*******************************************************************************

          GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
-----------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
          A SLOPE LENGTH OF  390. FEET.

   SCS RUNOFF CURVE NUMBER            =     79.55
   FRACTION OF AREA ALLOWING RUNOFF     =      0.0    PERCENT
   AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
   EVAPORATIVE ZONE DEPTH             =     8.0    INCHES
   INITIAL WATER IN EVAPORATIVE ZONE   =      2.278  INCHES
   UPPER LIMIT OF EVAPORATIVE STORAGE  =      5.368  INCHES
   FIELD CAPACITY OF EVAPORATIVE ZONE  =      2.336  INCHES
   LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.616  INCHES
   SOIL EVAPORATION ZONE DEPTH         =      8.000  INCHES
   INITIAL SNOW WATER                  =      0.000  INCHES
```

```
     INITIAL INTERCEPTION WATER          =      0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS    =     40.188  INCHES
     TOTAL INITIAL WATER                 =     40.188  INCHES
     TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


******************************************************************************

               EVAPOTRANSPIRATION DATA   1
----------------------------------------------------------------------------

                  VALID FOR  10 YEARS


     NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
            NASHUA           NEW HAMPSHIRE
        STATION LATITUDE                    =  42.70 DEGREES
        MAXIMUM LEAF AREA INDEX             =   0.00
        START OF GROWING SEASON (JULIAN DATE)  =    128
        END OF GROWING SEASON (JULIAN DATE)    =    277
        EVAPORATIVE ZONE DEPTH              =   8.0  INCHES
        AVERAGE ANNUAL WIND SPEED           =  10.94 MPH
        AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
        AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
        AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
        AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************



******************************************************************************

           FINAL WATER STORAGE AT END OF YEAR 2019
----------------------------------------------------------------------------

              LAYER       (INCHES)       (VOL/VOL)
              -----       --------       ---------
                1         35.3511         0.2946

                2          3.0894         0.1716

                3          0.0134         0.0535

                4          0.0000         0.0000
```

```
    TOTAL WATER IN LAYERS       38.454

    SNOW WATER               5.244

    INTERCEPTION WATER          0.000

    TOTAL FINAL WATER         43.698

***********************************************************************




***********************************************************************

            PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
-------------------------------------------------------------------------

                                (INCHES)     (CU. FT.)
                               ----------   -------------
     PRECIPITATION                          5.55       20146.502

     RUNOFF                           0.000         0.0000

     DRAINAGE COLLECTED FROM LAYER  3        0.63834      2317.17261

     PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000000        0.00004

     AVERAGE HEAD ON TOP OF LAYER  4          0.085

     MAXIMUM HEAD ON TOP OF LAYER  4          0.168

     LOCATION OF MAXIMUM HEAD IN LAYER  3
          (DISTANCE FROM DRAIN)              2.7 FEET

     SNOW WATER                             10.15       36858.2344

     MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.6710

     MINIMUM VEG. SOIL WATER (VOL/VOL)              0.1075


     ***  Maximum heads are computed using McEnroe's equations.  ***

          Reference:  Maximum Saturated Depth over Landfill Liner
                    by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Initial Operation - Overlay (less than or equal to 5%)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D        (10 August 2012)                 **
**                         developed at                                     **
**      Institute of Soil Science, University of Hamburg, Germany           **
**                           based on                                       **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:   9.41     DATE:  12.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Initial Operation Overlay less than or equal to 5%.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Initial Operation Overlay less than or equal to 5%.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Initial Operation Overlay less than or equal to 5%.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
   1   DATE (yyyymmdd)
   2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
   3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
   4   PRECIPITATION (INCH)
   5   RUNOFF (INCH)
   6   POTENTIAL EVAPOTRANSPIRATION (INCH)
   7   ACTUAL EVAPOTRANSPIRATION (INCH)
   8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
   9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
  10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
  11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


******************************************************************************

   TITLE:  Four Hills Landfill - Phase IV Design

******************************************************************************


                  WEATHER DATA SOURCES
------------------------------------------------------------------------------



      NOTE:  PRECIPITATION DATA FOR     Nashua            New Hampshire
             WAS ENTERED FROM A TEXT FILE.



      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE

          NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    22.60       24.50       33.60       44.90       55.50       64.80
    69.80       67.70       59.50       49.10       38.70       26.60



      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE
              AND STATION LATITUDE  =  42.70 DEGREES
```

```
******************************************************************************

                         LAYER DATA   1
------------------------------------------------------------------------------

                       VALID FOR  10 YEARS


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                           LAYER  1
                           --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  18
         THICKNESS                =    120.00   INCHES
         POROSITY                 =     0.6710 VOL/VOL
         FIELD CAPACITY           =     0.2920 VOL/VOL
         WILTING POINT            =     0.0770 VOL/VOL
         INITIAL SOIL WATER CONTENT  =     0.3123 VOL/VOL
         EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-02 CM/SEC



                           LAYER  2
                           --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   2
         THICKNESS                =     18.00   INCHES
         POROSITY                 =     0.4370 VOL/VOL
         FIELD CAPACITY           =     0.0620 VOL/VOL
         WILTING POINT            =     0.0240 VOL/VOL
         INITIAL SOIL WATER CONTENT  =     0.1500 VOL/VOL
         EFFECTIVE SAT. HYD. CONDUCT.=     0.5800E-02 CM/SEC



                           LAYER  3
                           --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER  20
```

```
         THICKNESS                  =     0.25   INCHES
         POROSITY                   =     0.8500 VOL/VOL
         FIELD CAPACITY             =     0.0100 VOL/VOL
         WILTING POINT              =     0.0050 VOL/VOL
         INITIAL SOIL WATER CONTENT =     0.0336 VOL/VOL
         EFFECTIVE SAT. HYD. CONDUCT.=     10.00     CM/SEC
         SLOPE                      =     5.00   PERCENT
         DRAINAGE LENGTH            =    339.0    FEET


                          LAYER  4
                          --------

               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
         THICKNESS                  =     0.06   INCHES
         EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
         FML PINHOLE DENSITY        =     0.00   HOLES/ACRE
         FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
         FML PLACEMENT QUALITY      =  3 - GOOD


******************************************************************************

            GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
----------------------------------------------------------------------------

                    VALID FOR  10 YEARS


        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
               SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
               GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
               A SLOPE LENGTH OF  390. FEET.

       SCS RUNOFF CURVE NUMBER            =     79.55
       FRACTION OF AREA ALLOWING RUNOFF   =      0.0    PERCENT
       AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
       EVAPORATIVE ZONE DEPTH             =      8.0    INCHES
       INITIAL WATER IN EVAPORATIVE ZONE  =      2.278  INCHES
       UPPER LIMIT OF EVAPORATIVE STORAGE =      5.368  INCHES
       FIELD CAPACITY OF EVAPORATIVE ZONE =      2.336  INCHES
       LOWER LIMIT OF EVAPORATIVE STORAGE =      0.616  INCHES
       SOIL EVAPORATION ZONE DEPTH        =      8.000  INCHES
       INITIAL SNOW WATER                 =      0.000  INCHES
```

```
      INITIAL INTERCEPTION WATER         =      0.000  INCHES
      INITIAL WATER IN LAYER MATERIALS   =     40.187  INCHES
      TOTAL INITIAL WATER                =     40.187  INCHES
      TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


******************************************************************************

                EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                  VALID FOR  10 YEARS


       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
              NASHUA           NEW HAMPSHIRE
          STATION LATITUDE                   =  42.70 DEGREES
          MAXIMUM LEAF AREA INDEX            =   0.00
          START OF GROWING SEASON (JULIAN DATE)  =    128
          END OF GROWING SEASON (JULIAN DATE)    =    277
          EVAPORATIVE ZONE DEPTH             =   8.0  INCHES
          AVERAGE ANNUAL WIND SPEED          =  10.94 MPH
          AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
          AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
          AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
          AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************



******************************************************************************

             FINAL WATER STORAGE AT END OF YEAR 2019
------------------------------------------------------------------------------

              LAYER       (INCHES)       (VOL/VOL)
              -----       --------       ---------
                1         35.3511         0.2946

                2          3.0894         0.1716

                3          0.0122         0.0489

                4          0.0000         0.0000
```

```
   TOTAL WATER IN LAYERS      38.453

   SNOW WATER                5.244

   INTERCEPTION WATER         0.000

   TOTAL FINAL WATER         43.697

*******************************************************************************



*******************************************************************************

          PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
----------------------------------------------------------------------------

                              (INCHES)     (CU. FT.)
                              ----------   -------------
    PRECIPITATION                        5.55       20146.502

    RUNOFF                          0.000        0.0000

    DRAINAGE COLLECTED FROM LAYER  3        0.63762      2314.56641

    PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000000        0.00003

    AVERAGE HEAD ON TOP OF LAYER  4         0.076

    MAXIMUM HEAD ON TOP OF LAYER  4         0.152

    LOCATION OF MAXIMUM HEAD IN LAYER  3
       (DISTANCE FROM DRAIN)            0.6 FEET

    SNOW WATER                          10.15       36858.2344

    MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.6710

    MINIMUM VEG. SOIL WATER (VOL/VOL)             0.1075


     ***  Maximum heads are computed using McEnroe's equations.  ***

        Reference:  Maximum Saturated Depth over Landfill Liner
               by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Initial Operation - Overlay (greater than 5%)

```
****************************************************************************
****************************************************************************
**                                              **
**                                              **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE           **
**                                              **
**          HELP Version 3.95 D        (10 August 2012)           **
**                   developed at                        **
**       Institute of Soil Science, University of Hamburg, Germany       **
**                    based on                         **
**          US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)           **
**            DEVELOPED BY ENVIRONMENTAL LABORATORY              **
**              USAE WATERWAYS EXPERIMENT STATION              **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                              **
**                                              **
****************************************************************************
****************************************************************************


 TIME:   9.52    DATE:  12.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:    P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Initial Operation Overlay greater than 5%.d10
 OUTPUT DATA FILE:             P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Initial Operation Overlay greater than 5%.out
 DAILY OUTPUT DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Initial Operation Overlay greater than 5%.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
    1   DATE (yyyymmdd)
    2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
    3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
    4   PRECIPITATION (INCH)
    5   RUNOFF (INCH)
    6   POTENTIAL EVAPOTRANSPIRATION (INCH)
    7   ACTUAL EVAPOTRANSPIRATION (INCH)
    8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
    9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
   10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
   11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


******************************************************************************

    TITLE:  Four Hills Landfill - Phase IV Design

******************************************************************************


                    WEATHER DATA SOURCES
-----------------------------------------------------------------------------



        NOTE:  PRECIPITATION DATA FOR     Nashua             New Hampshire
               WAS ENTERED FROM A TEXT FILE.



        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
               COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE

           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
     22.60       24.50       33.60       44.90       55.50       64.80
     69.80       67.70       59.50       49.10       38.70       26.60



        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
               COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE
                AND STATION LATITUDE  =  42.70 DEGREES
```

```
******************************************************************************

                    LAYER DATA   1
------------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                      LAYER  1
                      --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
       THICKNESS                 =    120.00   INCHES
       POROSITY                  =     0.6710 VOL/VOL
       FIELD CAPACITY            =     0.2920 VOL/VOL
       WILTING POINT             =     0.0770 VOL/VOL
       INITIAL SOIL WATER CONTENT  =     0.3121 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-02 CM/SEC



                      LAYER  2
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   2
       THICKNESS                 =     18.00   INCHES
       POROSITY                  =     0.4370 VOL/VOL
       FIELD CAPACITY            =     0.0620 VOL/VOL
       WILTING POINT             =     0.0240 VOL/VOL
       INITIAL SOIL WATER CONTENT  =     0.1521 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=     0.5800E-02 CM/SEC



                      LAYER  3
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  20
```

```
        THICKNESS                =     0.25   INCHES
        POROSITY                 =     0.8500 VOL/VOL
        FIELD CAPACITY           =     0.0100 VOL/VOL
        WILTING POINT            =     0.0050 VOL/VOL
        INITIAL SOIL WATER CONTENT  =     0.0174 VOL/VOL
        EFFECTIVE SAT. HYD. CONDUCT.=     10.00    CM/SEC
        SLOPE                    =    22.60   PERCENT
        DRAINAGE LENGTH          =    409.0    FEET


                     LAYER  4
                     --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
        THICKNESS                =     0.06   INCHES
        EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
        FML PINHOLE DENSITY       =     0.00   HOLES/ACRE
        FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
        FML PLACEMENT QUALITY      =  3 - GOOD


******************************************************************************

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
-----------------------------------------------------------------------------

                  VALID FOR  10 YEARS


       NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
              SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
              GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
              A SLOPE LENGTH OF  390. FEET.

      SCS RUNOFF CURVE NUMBER           =    79.55
      FRACTION OF AREA ALLOWING RUNOFF   =     0.0    PERCENT
      AREA PROJECTED ON HORIZONTAL PLANE  =     1.000  ACRES
      EVAPORATIVE ZONE DEPTH            =    8.0    INCHES
      INITIAL WATER IN EVAPORATIVE ZONE   =     2.281  INCHES
      UPPER LIMIT OF EVAPORATIVE STORAGE  =     5.368  INCHES
      FIELD CAPACITY OF EVAPORATIVE ZONE  =     2.336  INCHES
      LOWER LIMIT OF EVAPORATIVE STORAGE  =     0.616  INCHES
      SOIL EVAPORATION ZONE DEPTH        =     8.000  INCHES
      INITIAL SNOW WATER                =     0.000  INCHES
```

```
    INITIAL INTERCEPTION WATER         =     0.000  INCHES
    INITIAL WATER IN LAYER MATERIALS   =    40.195  INCHES
    TOTAL INITIAL WATER                =    40.195  INCHES
    TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR


******************************************************************************

               EVAPOTRANSPIRATION DATA   1
-----------------------------------------------------------------------------

                 VALID FOR  10 YEARS


      NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
             NASHUA            NEW HAMPSHIRE
         STATION LATITUDE                   =  42.70 DEGREES
         MAXIMUM LEAF AREA INDEX             =   0.00
         START OF GROWING SEASON (JULIAN DATE)  =    128
         END OF GROWING SEASON (JULIAN DATE)    =    277
         EVAPORATIVE ZONE DEPTH              =   8.0  INCHES
         AVERAGE ANNUAL WIND SPEED            =  10.94 MPH
         AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
         AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
         AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
         AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************




******************************************************************************

            FINAL WATER STORAGE AT END OF YEAR 2019
-----------------------------------------------------------------------------

            LAYER      (INCHES)      (VOL/VOL)
            -----      --------      ---------
              1        35.3851        0.2949

              2         3.0969        0.1720

              3         0.0053        0.0210

              4         0.0000        0.0000
```

```
   TOTAL WATER IN LAYERS        38.487

   SNOW WATER                5.244

   INTERCEPTION WATER          0.000

   TOTAL FINAL WATER          43.731

***************************************************************************



***************************************************************************

        PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
---------------------------------------------------------------------------

                          (INCHES)    (CU. FT.)
                          ----------   -------------
    PRECIPITATION                      5.55       20146.502

    RUNOFF                          0.000        0.0000

    DRAINAGE COLLECTED FROM LAYER  3         0.64248      2332.20923

    PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000000       0.00002

    AVERAGE HEAD ON TOP OF LAYER  4          0.022

    MAXIMUM HEAD ON TOP OF LAYER  4          0.205

    LOCATION OF MAXIMUM HEAD IN LAYER  3
       (DISTANCE FROM DRAIN)            0.0 FEET

    SNOW WATER                        10.15       36858.2344

    MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.6710

    MINIMUM VEG. SOIL WATER (VOL/VOL)             0.1089


     ***  Maximum heads are computed using McEnroe's equations.  ***

        Reference:  Maximum Saturated Depth over Landfill Liner
              by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Active Operation - Base Area

```
****************************************************************************
****************************************************************************
**                                                                        **
**                                                                        **
**         HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**                                                                        **
**         HELP Version 3.95 D        (10 August 2012)                    **
**                       developed at                                     **
**      Institute of Soil Science, University of Hamburg, Germany         **
**                          based on                                      **
**          US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                USAE WATERWAYS EXPERIMENT STATION                       **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                        **
**                                                                        **
****************************************************************************
****************************************************************************


 TIME:  15.03    DATE:  10.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Active Operation.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Active Operation.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Active Operation.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
     1   DATE (yyyymmdd)
     2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
     3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
     4   PRECIPITATION (INCH)
     5   RUNOFF (INCH)
     6   POTENTIAL EVAPOTRANSPIRATION (INCH)
     7   ACTUAL EVAPOTRANSPIRATION (INCH)
     8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
     9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
    10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
    11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


******************************************************************************

    TITLE:  Four Hills Landfill - Phase IV Design

******************************************************************************


                    WEATHER DATA SOURCES
----------------------------------------------------------------------------



      NOTE:  PRECIPITATION DATA FOR     Nashua           New Hampshire
             WAS ENTERED FROM A TEXT FILE.



      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA          NEW HAMPSHIRE

         NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
    -------    -------    -------    -------    -------    -------
     22.60      24.50      33.60      44.90      55.50      64.80
     69.80      67.70      59.50      49.10      38.70      26.60



      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA          NEW HAMPSHIRE
              AND STATION LATITUDE  =  42.70 DEGREES
```

```
******************************************************************************

                        LAYER DATA   1
------------------------------------------------------------------------------

                     VALID FOR  10 YEARS


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                          LAYER  1
                          --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  18
        THICKNESS                  =  1242.00   INCHES
        POROSITY                   =    0.6710 VOL/VOL
        FIELD CAPACITY             =    0.2920 VOL/VOL
        WILTING POINT              =    0.0770 VOL/VOL
        INITIAL SOIL WATER CONTENT  =    0.2954 VOL/VOL
        EFFECTIVE SAT. HYD. CONDUCT.=    0.1000E-02 CM/SEC


                          LAYER  2
                          --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   2
        THICKNESS                  =    18.00   INCHES
        POROSITY                   =    0.4370 VOL/VOL
        FIELD CAPACITY             =    0.0620 VOL/VOL
        WILTING POINT              =    0.0240 VOL/VOL
        INITIAL SOIL WATER CONTENT  =    0.1540 VOL/VOL
        EFFECTIVE SAT. HYD. CONDUCT.=    0.5800E-02 CM/SEC


                          LAYER  3
                          --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER  20
```

```
          THICKNESS                 =     0.25   INCHES
          POROSITY                  =     0.8500 VOL/VOL
          FIELD CAPACITY            =     0.0100 VOL/VOL
          WILTING POINT             =     0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT  =     0.0431 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      10.00     CM/SEC
          SLOPE                     =     2.40   PERCENT
          DRAINAGE LENGTH           =    182.0    FEET


                      LAYER  4
                      --------

                 TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
          THICKNESS                 =     0.06   INCHES
          EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
          FML PINHOLE DENSITY       =     0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS  =     0.00   HOLES/ACRE
          FML PLACEMENT QUALITY     =  3 - GOOD


******************************************************************************

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                     VALID FOR  10 YEARS


        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
               SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
               GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
               A SLOPE LENGTH OF  390. FEET.

        SCS RUNOFF CURVE NUMBER            =     79.55
        FRACTION OF AREA ALLOWING RUNOFF   =      0.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH             =      8.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE   =      2.278  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE  =      5.368  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE  =      2.336  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.616  INCHES
        SOIL EVAPORATION ZONE DEPTH        =      8.000  INCHES
        INITIAL SNOW WATER                 =      0.000  INCHES
```

```
      INITIAL INTERCEPTION WATER          =      0.000  INCHES
      INITIAL WATER IN LAYER MATERIALS    =    369.628  INCHES
      TOTAL INITIAL WATER                 =    369.628  INCHES
      TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


******************************************************************************

                 EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                   VALID FOR  10 YEARS


       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
              NASHUA            NEW HAMPSHIRE
          STATION LATITUDE                     =  42.70 DEGREES
          MAXIMUM LEAF AREA INDEX              =   0.00
          START OF GROWING SEASON (JULIAN DATE)  =    128
          END OF GROWING SEASON (JULIAN DATE)    =    277
          EVAPORATIVE ZONE DEPTH               =   8.0  INCHES
          AVERAGE ANNUAL WIND SPEED            =  10.94 MPH
          AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
          AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
          AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
          AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************



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             FINAL WATER STORAGE AT END OF YEAR 2019
------------------------------------------------------------------------------

               LAYER        (INCHES)       (VOL/VOL)
               -----        --------       ---------
                 1         366.6122         0.2952

                 2           3.0589         0.1699

                 3           0.0121         0.0482

                 4           0.0000         0.0000
```

```
   TOTAL WATER IN LAYERS       369.683

   SNOW WATER                5.244

   INTERCEPTION WATER          0.000

   TOTAL FINAL WATER         374.927

*************************************************************************



*************************************************************************

          PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
--------------------------------------------------------------------------

                               (INCHES)     (CU. FT.)
                              ----------   -------------
    PRECIPITATION                        5.55        20146.502

    RUNOFF                          0.000          0.0000

    DRAINAGE COLLECTED FROM LAYER  3         0.19121       694.08722

    PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000000        0.00002

    AVERAGE HEAD ON TOP OF LAYER  4          0.026

    MAXIMUM HEAD ON TOP OF LAYER  4          0.051

    LOCATION OF MAXIMUM HEAD IN LAYER  3
        (DISTANCE FROM DRAIN)             0.0 FEET

    SNOW WATER                          10.15        36858.2344

    MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.6710

    MINIMUM VEG. SOIL WATER (VOL/VOL)             0.1075


     ***  Maximum heads are computed using McEnroe's equations.  ***

        Reference:  Maximum Saturated Depth over Landfill Liner
                by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Active Operation - Overlay (less than or equal to 5%)

```
****************************************************************************
****************************************************************************
**                                                                        **
**                                                                        **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**                                                                        **
**          HELP Version 3.95 D        (10 August 2012)                   **
**                      developed at                                      **
**       Institute of Soil Science, University of Hamburg, Germany        **
**                        based on                                        **
**          US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**               USAE WATERWAYS EXPERIMENT STATION                        **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                        **
**                                                                        **
****************************************************************************
****************************************************************************


 TIME:  9.55    DATE:  12.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Active Operation Overlay less than or equal to 5%.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Active Operation Overlay less than or equal to 5%.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Active Operation Overlay less than or equal to 5%.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
   1   DATE (yyyymmdd)
   2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
   3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
   4   PRECIPITATION (INCH)
   5   RUNOFF (INCH)
   6   POTENTIAL EVAPOTRANSPIRATION (INCH)
   7   ACTUAL EVAPOTRANSPIRATION (INCH)
   8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
   9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
  10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
  11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


******************************************************************************

   TITLE:  Four Hills Landfill - Phase IV Design

******************************************************************************


                WEATHER DATA SOURCES
------------------------------------------------------------------------------



      NOTE:  PRECIPITATION DATA FOR    Nashua           New Hampshire
             WAS ENTERED FROM A TEXT FILE.



      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR   NASHUA           NEW HAMPSHIRE

         NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
   -------    -------    -------    -------    -------    -------
    22.60      24.50      33.60      44.90      55.50      64.80
    69.80      67.70      59.50      49.10      38.70      26.60



      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR   NASHUA           NEW HAMPSHIRE
              AND STATION LATITUDE  =  42.70 DEGREES
```

```
***************************************************************************

                    LAYER DATA   1
---------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                      LAYER  1
                      --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
      THICKNESS                 =   1242.00   INCHES
      POROSITY                  =     0.6710 VOL/VOL
      FIELD CAPACITY            =     0.2920 VOL/VOL
      WILTING POINT             =     0.0770 VOL/VOL
      INITIAL SOIL WATER CONTENT  =     0.2954 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-02 CM/SEC



                      LAYER  2
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   2
      THICKNESS                 =     18.00   INCHES
      POROSITY                  =     0.4370 VOL/VOL
      FIELD CAPACITY            =     0.0620 VOL/VOL
      WILTING POINT             =     0.0240 VOL/VOL
      INITIAL SOIL WATER CONTENT  =     0.1540 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=     0.5800E-02 CM/SEC



                      LAYER  3
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  20
```

```
            THICKNESS                 =      0.25   INCHES
            POROSITY                  =     0.8500 VOL/VOL
            FIELD CAPACITY            =     0.0100 VOL/VOL
            WILTING POINT             =     0.0050 VOL/VOL
            INITIAL SOIL WATER CONTENT  =     0.0396 VOL/VOL
            EFFECTIVE SAT. HYD. CONDUCT.=      10.00     CM/SEC
            SLOPE                     =      5.00   PERCENT
            DRAINAGE LENGTH           =    339.0    FEET


                            LAYER  4
                            --------

                     TYPE 4 - FLEXIBLE MEMBRANE LINER
                       MATERIAL TEXTURE NUMBER  35
            THICKNESS                 =      0.06   INCHES
            EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
            FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
            FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  3 - GOOD


***********************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
-----------------------------------------------------------------------

                       VALID FOR  10 YEARS


          NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                 SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
                 GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
                 A SLOPE LENGTH OF  390. FEET.

          SCS RUNOFF CURVE NUMBER            =     79.55
          FRACTION OF AREA ALLOWING RUNOFF    =      0.0    PERCENT
          AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
          EVAPORATIVE ZONE DEPTH             =     8.0    INCHES
          INITIAL WATER IN EVAPORATIVE ZONE   =      2.278  INCHES
          UPPER LIMIT OF EVAPORATIVE STORAGE  =      5.368  INCHES
          FIELD CAPACITY OF EVAPORATIVE ZONE  =      2.336  INCHES
          LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.616  INCHES
          SOIL EVAPORATION ZONE DEPTH        =      8.000  INCHES
          INITIAL SNOW WATER                 =      0.000  INCHES
```

```
     INITIAL INTERCEPTION WATER         =      0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS    =    369.627  INCHES
     TOTAL INITIAL WATER                 =    369.627  INCHES
     TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


******************************************************************************

             EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

               VALID FOR  10 YEARS


     NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           NASHUA            NEW HAMPSHIRE
       STATION LATITUDE                   =  42.70 DEGREES
       MAXIMUM LEAF AREA INDEX            =   0.00
       START OF GROWING SEASON (JULIAN DATE)  =    128
       END OF GROWING SEASON (JULIAN DATE)    =    277
       EVAPORATIVE ZONE DEPTH             =   8.0  INCHES
       AVERAGE ANNUAL WIND SPEED          =  10.94 MPH
       AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
       AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
       AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
       AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************




******************************************************************************

           FINAL WATER STORAGE AT END OF YEAR 2019
------------------------------------------------------------------------------

            LAYER      (INCHES)      (VOL/VOL)
            -----      --------      ---------
              1       366.6122        0.2952

              2         3.0589        0.1699

              3         0.0111        0.0443

              4         0.0000        0.0000
```

```
  TOTAL WATER IN LAYERS       369.682

  SNOW WATER               5.244

  INTERCEPTION WATER          0.000

  TOTAL FINAL WATER        374.926

***************************************************************************


***************************************************************************

          PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
--------------------------------------------------------------------------

                              (INCHES)     (CU. FT.)
                              ----------   -------------
   PRECIPITATION                     5.55       20146.502

   RUNOFF                        0.000         0.0000

   DRAINAGE COLLECTED FROM LAYER  3         0.19143       694.89240

   PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000000       0.00002

   AVERAGE HEAD ON TOP OF LAYER  4          0.023

   MAXIMUM HEAD ON TOP OF LAYER  4          0.061

   LOCATION OF MAXIMUM HEAD IN LAYER  3
       (DISTANCE FROM DRAIN)              0.0 FEET

   SNOW WATER                        10.15       36858.2344

   MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.6710

   MINIMUM VEG. SOIL WATER (VOL/VOL)              0.1075


    ***  Maximum heads are computed using McEnroe's equations.  ***

       Reference:  Maximum Saturated Depth over Landfill Liner
               by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Active Operation - Overlay (greater than 5%)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**                                                                          **
**          HELP Version 3.95 D        (10 August 2012)                     **
**                         developed at                                     **
**       Institute of Soil Science, University of Hamburg, Germany          **
**                           based on                                       **
**          US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                   **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**               USAE WATERWAYS EXPERIMENT STATION                          **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:   9.58    DATE:  12.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Active Operation Overlay greater than 5%.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Active Operation Overlay greater than 5%.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Active Operation Overlay greater than 5%.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
  1   DATE (yyyymmdd)
  2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
  3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
  4   PRECIPITATION (INCH)
  5   RUNOFF (INCH)
  6   POTENTIAL EVAPOTRANSPIRATION (INCH)
  7   ACTUAL EVAPOTRANSPIRATION (INCH)
  8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
  9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
 10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
 11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


******************************************************************************

  TITLE:  Four Hills Landfill - Phase IV Design

******************************************************************************


                    WEATHER DATA SOURCES
------------------------------------------------------------------------------



      NOTE:  PRECIPITATION DATA FOR     Nashua            New Hampshire
             WAS ENTERED FROM A TEXT FILE.



      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE

         NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
  -------    -------    -------    -------    -------    -------
   22.60      24.50      33.60      44.90      55.50      64.80
   69.80      67.70      59.50      49.10      38.70      26.60



      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE
              AND STATION LATITUDE  =  42.70 DEGREES
```

```
****************************************************************************

                    LAYER DATA   1
----------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                      LAYER  1
                      --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
      THICKNESS                =   1242.00   INCHES
      POROSITY                 =     0.6710 VOL/VOL
      FIELD CAPACITY           =     0.2920 VOL/VOL
      WILTING POINT            =     0.0770 VOL/VOL
      INITIAL SOIL WATER CONTENT  =     0.2953 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=     0.1000E-02 CM/SEC



                      LAYER  2
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   2
      THICKNESS                =     18.00   INCHES
      POROSITY                 =     0.4370 VOL/VOL
      FIELD CAPACITY           =     0.0620 VOL/VOL
      WILTING POINT            =     0.0240 VOL/VOL
      INITIAL SOIL WATER CONTENT  =     0.1575 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=     0.5800E-02 CM/SEC



                      LAYER  3
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  20
```

```
    THICKNESS                =     0.25   INCHES
    POROSITY                 =     0.8500 VOL/VOL
    FIELD CAPACITY           =     0.0100 VOL/VOL
    WILTING POINT            =     0.0050 VOL/VOL
    INITIAL SOIL WATER CONTENT  =     0.0199 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=     10.00     CM/SEC
    SLOPE                    =    22.60   PERCENT
    DRAINAGE LENGTH          =    409.0    FEET


                  LAYER  4
                  --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
    THICKNESS                =     0.06   INCHES
    EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
    FML PINHOLE DENSITY      =     0.00   HOLES/ACRE
    FML INSTALLATION DEFECTS    =     0.00   HOLES/ACRE
    FML PLACEMENT QUALITY       =  3 - GOOD


******************************************************************************

           GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                 VALID FOR  10 YEARS


   NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
          A SLOPE LENGTH OF  390. FEET.

   SCS RUNOFF CURVE NUMBER           =    79.55
   FRACTION OF AREA ALLOWING RUNOFF    =     0.0    PERCENT
   AREA PROJECTED ON HORIZONTAL PLANE  =     1.000  ACRES
   EVAPORATIVE ZONE DEPTH            =    8.0    INCHES
   INITIAL WATER IN EVAPORATIVE ZONE   =     2.281  INCHES
   UPPER LIMIT OF EVAPORATIVE STORAGE  =     5.368  INCHES
   FIELD CAPACITY OF EVAPORATIVE ZONE  =     2.336  INCHES
   LOWER LIMIT OF EVAPORATIVE STORAGE  =     0.616  INCHES
   SOIL EVAPORATION ZONE DEPTH         =     8.000  INCHES
   INITIAL SNOW WATER                  =     0.000  INCHES
```

```
      INITIAL INTERCEPTION WATER         =      0.000  INCHES
      INITIAL WATER IN LAYER MATERIALS   =    369.634  INCHES
      TOTAL INITIAL WATER                =    369.634  INCHES
      TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


******************************************************************************

               EVAPOTRANSPIRATION DATA   1
----------------------------------------------------------------------------

                 VALID FOR  10 YEARS


      NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
             NASHUA            NEW HAMPSHIRE
        STATION LATITUDE                      =  42.70 DEGREES
        MAXIMUM LEAF AREA INDEX               =   0.00
        START OF GROWING SEASON (JULIAN DATE) =    128
        END OF GROWING SEASON (JULIAN DATE)   =    277
        EVAPORATIVE ZONE DEPTH                =   8.0  INCHES
        AVERAGE ANNUAL WIND SPEED             =  10.94 MPH
        AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
        AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
        AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
        AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************




******************************************************************************

            FINAL WATER STORAGE AT END OF YEAR 2019
----------------------------------------------------------------------------

              LAYER        (INCHES)       (VOL/VOL)
              -----        --------       ---------
                1          366.7928        0.2953

                2            3.0638        0.1702

                3            0.0049        0.0196

                4            0.0000        0.0000
```

```
    TOTAL WATER IN LAYERS       369.861

    SNOW WATER                  5.244

    INTERCEPTION WATER          0.000

    TOTAL FINAL WATER         375.105

***************************************************************************




***************************************************************************

         PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
----------------------------------------------------------------------------

                              (INCHES)    (CU. FT.)
                              ----------  -------------
    PRECIPITATION                  5.55       20146.502

    RUNOFF                        0.000          0.0000

    DRAINAGE COLLECTED FROM LAYER  3      0.19101      693.35846

    PERCOLATION/LEAKAGE THROUGH LAYER  4    0.000000      0.00002

    AVERAGE HEAD ON TOP OF LAYER  4        0.006

    MAXIMUM HEAD ON TOP OF LAYER  4        0.200

    LOCATION OF MAXIMUM HEAD IN LAYER  3
        (DISTANCE FROM DRAIN)         0.0 FEET

    SNOW WATER                       10.15      36858.2344

    MAXIMUM VEG. SOIL WATER (VOL/VOL)          0.6710

    MINIMUM VEG. SOIL WATER (VOL/VOL)          0.1089


     ***  Maximum heads are computed using McEnroe's equations.  ***

         Reference:  Maximum Saturated Depth over Landfill Liner
                by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Full Buildout - Base Area

```
****************************************************************************
****************************************************************************
**                                       **
**                                       **
**         HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE          **
**                                       **
**         HELP Version 3.95 D        (10 August 2012)          **
**                    developed at                     **
**      Institute of Soil Science, University of Hamburg, Germany       **
**                     based on                      **
**         US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)           **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY             **
**            USAE WATERWAYS EXPERIMENT STATION              **
**         FOR USEPA RISK REDUCTION ENGINEERING LABORATORY          **
**                                       **
**                                       **
****************************************************************************
****************************************************************************


 TIME:  15.11    DATE:  10.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Full Buildout.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Full Buildout.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Base Full Buildout.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
   1   DATE (yyyymmdd)
   2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
   3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
   4   PRECIPITATION (INCH)
   5   RUNOFF (INCH)
   6   POTENTIAL EVAPOTRANSPIRATION (INCH)
   7   ACTUAL EVAPOTRANSPIRATION (INCH)
   8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
   9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
  10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
  11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


*******************************************************************************

   TITLE:  Four Hills Landfill - Phase IV Design

*******************************************************************************


                  WEATHER DATA SOURCES
-----------------------------------------------------------------------------



      NOTE:  PRECIPITATION DATA FOR     Nashua            New Hampshire
             WAS ENTERED FROM A TEXT FILE.



      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE

         NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
   -------    -------    -------    -------    -------    -------
    22.60      24.50      33.60      44.90      55.50      64.80
    69.80      67.70      59.50      49.10      38.70      26.60



      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE
              AND STATION LATITUDE  =  42.70 DEGREES
```

```
******************************************************************************

                    LAYER DATA   1
------------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                        LAYER  1
                        --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  18
        THICKNESS                =  2484.00   INCHES
        POROSITY                 =    0.6710 VOL/VOL
        FIELD CAPACITY           =    0.2920 VOL/VOL
        WILTING POINT            =    0.0770 VOL/VOL
        INITIAL SOIL WATER CONTENT  =    0.2937 VOL/VOL
        EFFECTIVE SAT. HYD. CONDUCT.=    0.1000E-02 CM/SEC



                        LAYER  2
                        --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   2
        THICKNESS                =    18.00   INCHES
        POROSITY                 =    0.4370 VOL/VOL
        FIELD CAPACITY           =    0.0620 VOL/VOL
        WILTING POINT            =    0.0240 VOL/VOL
        INITIAL SOIL WATER CONTENT  =    0.1535 VOL/VOL
        EFFECTIVE SAT. HYD. CONDUCT.=    0.5800E-02 CM/SEC



                        LAYER  3
                        --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER  20
```

```
          THICKNESS                =     0.25   INCHES
          POROSITY                 =     0.8500 VOL/VOL
          FIELD CAPACITY           =     0.0100 VOL/VOL
          WILTING POINT            =     0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT  =     0.0422 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      10.00     CM/SEC
          SLOPE                    =     2.40   PERCENT
          DRAINAGE LENGTH          =    182.0    FEET


                        LAYER  4
                        --------

                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                   MATERIAL TEXTURE NUMBER  35
          THICKNESS                =     0.06   INCHES
          EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
          FML PINHOLE DENSITY        =     0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS    =     0.00   HOLES/ACRE
          FML PLACEMENT QUALITY      =  3 - GOOD


******************************************************************************

            GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                  VALID FOR  10 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
                GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
                A SLOPE LENGTH OF  390. FEET.

        SCS RUNOFF CURVE NUMBER          =    79.55
        FRACTION OF AREA ALLOWING RUNOFF    =     0.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE  =     1.000  ACRES
        EVAPORATIVE ZONE DEPTH           =    8.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE   =     2.278  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE  =     5.368  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE  =     2.336  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE  =     0.616  INCHES
        SOIL EVAPORATION ZONE DEPTH        =     8.000  INCHES
        INITIAL SNOW WATER               =     0.000  INCHES
```

```
     INITIAL INTERCEPTION WATER        =     0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS   =   732.418  INCHES
     TOTAL INITIAL WATER              =   732.418  INCHES
     TOTAL SUBSURFACE INFLOW           =     0.00   INCHES/YEAR


******************************************************************************

              EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                VALID FOR  10 YEARS


      NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           NASHUA             NEW HAMPSHIRE
        STATION LATITUDE                   =  42.70 DEGREES
        MAXIMUM LEAF AREA INDEX              =   0.00
        START OF GROWING SEASON (JULIAN DATE)  =    128
        END OF GROWING SEASON (JULIAN DATE)    =    277
        EVAPORATIVE ZONE DEPTH               =   8.0  INCHES
        AVERAGE ANNUAL WIND SPEED            =  10.94 MPH
        AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
        AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
        AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
        AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************



******************************************************************************

           FINAL WATER STORAGE AT END OF YEAR 2019
------------------------------------------------------------------------------

             LAYER      (INCHES)      (VOL/VOL)
             -----      --------      ---------
               1       732.6277       0.2949

               2         3.0542       0.1697

               3         0.0119       0.0477

               4         0.0000       0.0000
```

```
   TOTAL WATER IN LAYERS       735.694

   SNOW WATER                5.244

   INTERCEPTION WATER          0.000

   TOTAL FINAL WATER         740.938

***********************************************************************




***********************************************************************

           PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
-------------------------------------------------------------------------

                              (INCHES)     (CU. FT.)
                              ----------   -------------
    PRECIPITATION                       5.55       20146.502

    RUNOFF                          0.000         0.0000

    DRAINAGE COLLECTED FROM LAYER  3         0.18690       678.44983

    PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000000        0.00002

    AVERAGE HEAD ON TOP OF LAYER  4          0.025

    MAXIMUM HEAD ON TOP OF LAYER  4          0.051

    LOCATION OF MAXIMUM HEAD IN LAYER  3
        (DISTANCE FROM DRAIN)             0.0 FEET

    SNOW WATER                         10.15       36858.2344

    MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.6710

    MINIMUM VEG. SOIL WATER (VOL/VOL)              0.1075


    ***  Maximum heads are computed using McEnroe's equations.  ***

        Reference:  Maximum Saturated Depth over Landfill Liner
                by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Full Buildout - Overlay (less than or equal to 5%)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D        (10 August 2012)                 **
**                              developed at                                **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                               based on                                   **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.02    DATE:  12.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Full Buildout Overlay less than or equal to 5%.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Full Buildout Overlay less than or equal to 5%.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Full Buildout Overlay less than or equal to 5%.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
    1   DATE (yyyymmdd)
    2   AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
    3   FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
    4   PRECIPITATION (INCH)
    5   RUNOFF (INCH)
    6   POTENTIAL EVAPOTRANSPIRATION (INCH)
    7   ACTUAL EVAPOTRANSPIRATION (INCH)
    8   WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
    9   HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
   10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
   11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


******************************************************************************

    TITLE:  Four Hills Landfill - Phase IV Design

******************************************************************************


                     WEATHER DATA SOURCES
-----------------------------------------------------------------------------



       NOTE:  PRECIPITATION DATA FOR     Nashua            New Hampshire
              WAS ENTERED FROM A TEXT FILE.



       NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
              COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE

          NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
     22.60       24.50       33.60       44.90       55.50       64.80
     69.80       67.70       59.50       49.10       38.70       26.60



       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
              COEFFICIENTS FOR    NASHUA            NEW HAMPSHIRE
               AND STATION LATITUDE  =  42.70 DEGREES
```

```
******************************************************************************

                    LAYER DATA   1
--------------------------------------------------------------------------

                  VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                      LAYER  1
                      --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  18
       THICKNESS                 =  2484.00   INCHES
       POROSITY                  =    0.6710 VOL/VOL
       FIELD CAPACITY            =    0.2920 VOL/VOL
       WILTING POINT             =    0.0770 VOL/VOL
       INITIAL SOIL WATER CONTENT  =    0.2937 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=    0.1000E-02 CM/SEC



                      LAYER  2
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   2
       THICKNESS                 =    18.00   INCHES
       POROSITY                  =    0.4370 VOL/VOL
       FIELD CAPACITY            =    0.0620 VOL/VOL
       WILTING POINT             =    0.0240 VOL/VOL
       INITIAL SOIL WATER CONTENT  =    0.1535 VOL/VOL
       EFFECTIVE SAT. HYD. CONDUCT.=    0.5800E-02 CM/SEC



                      LAYER  3
                      --------

              TYPE 2 - LATERAL DRAINAGE LAYER
```

```
              MATERIAL TEXTURE NUMBER 20
     THICKNESS                    =     0.25   INCHES
     POROSITY                     =     0.8500 VOL/VOL
     FIELD CAPACITY               =     0.0100 VOL/VOL
     WILTING POINT                =     0.0050 VOL/VOL
     INITIAL SOIL WATER CONTENT  =     0.0388 VOL/VOL
     EFFECTIVE SAT. HYD. CONDUCT.=     10.00     CM/SEC
     SLOPE                        =     5.00   PERCENT
     DRAINAGE LENGTH              =    339.0    FEET


                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER 35
     THICKNESS                    =     0.06   INCHES
     EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
     FML PINHOLE DENSITY          =     0.00   HOLES/ACRE
     FML INSTALLATION DEFECTS     =     0.00   HOLES/ACRE
     FML PLACEMENT QUALITY        =  3 - GOOD


******************************************************************************

           GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                   VALID FOR  10 YEARS


      NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
             SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
             GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
             A SLOPE LENGTH OF  390. FEET.

     SCS RUNOFF CURVE NUMBER              =    79.55
     FRACTION OF AREA ALLOWING RUNOFF     =     0.0    PERCENT
     AREA PROJECTED ON HORIZONTAL PLANE   =     1.000  ACRES
     EVAPORATIVE ZONE DEPTH               =     8.0    INCHES
     INITIAL WATER IN EVAPORATIVE ZONE    =     2.278  INCHES
     UPPER LIMIT OF EVAPORATIVE STORAGE   =     5.368  INCHES
     FIELD CAPACITY OF EVAPORATIVE ZONE   =     2.336  INCHES
     LOWER LIMIT OF EVAPORATIVE STORAGE   =     0.616  INCHES
     SOIL EVAPORATION ZONE DEPTH          =     8.000  INCHES
```

```
      INITIAL SNOW WATER                =      0.000  INCHES
      INITIAL INTERCEPTION WATER         =      0.000  INCHES
      INITIAL WATER IN LAYER MATERIALS    =    732.417  INCHES
      TOTAL INITIAL WATER               =    732.417  INCHES
      TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


******************************************************************************

                   EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                      VALID FOR  10 YEARS


        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
               NASHUA              NEW HAMPSHIRE
           STATION LATITUDE                     =  42.70 DEGREES
           MAXIMUM LEAF AREA INDEX               =   0.00
           START OF GROWING SEASON (JULIAN DATE)  =    128
           END OF GROWING SEASON (JULIAN DATE)    =    277
           EVAPORATIVE ZONE DEPTH                =   8.0  INCHES
           AVERAGE ANNUAL WIND SPEED              =  10.94 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************




******************************************************************************

                FINAL WATER STORAGE AT END OF YEAR 2019
------------------------------------------------------------------------------

              LAYER        (INCHES)       (VOL/VOL)
              -----        --------       ---------
                1         732.6277         0.2949

                2           3.0542         0.1697

                3           0.0109         0.0437
```

```
            4        0.0000      0.0000

    TOTAL WATER IN LAYERS       735.693

    SNOW WATER                  5.244

    INTERCEPTION WATER          0.000

    TOTAL FINAL WATER           740.937

***************************************************************************



***************************************************************************

        PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
-------------------------------------------------------------------------

                                  (INCHES)    (CU. FT.)
                                 ----------  -------------
    PRECIPITATION                     5.55      20146.502

    RUNOFF                           0.000         0.0000

    DRAINAGE COLLECTED FROM LAYER  3       0.18697     678.69788

    PERCOLATION/LEAKAGE THROUGH LAYER  4     0.000000      0.00002

    AVERAGE HEAD ON TOP OF LAYER  4        0.022

    MAXIMUM HEAD ON TOP OF LAYER  4        0.061

    LOCATION OF MAXIMUM HEAD IN LAYER  3
      (DISTANCE FROM DRAIN)            0.0 FEET

    SNOW WATER                       10.15      36858.2344

    MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.6710

    MINIMUM VEG. SOIL WATER (VOL/VOL)              0.1075

     ***  Maximum heads are computed using McEnroe's equations.  ***

       Reference:  Maximum Saturated Depth over Landfill Liner
```

by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Full Buildout - Overlay (greater than 5%)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**                                                                          **
**          HELP Version 3.95 D        (10 August 2012)          **
**                    developed at                      **
**      Institute of Soil Science, University of Hamburg, Germany       **
**                      based on                      **
**          US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)             **
**            DEVELOPED BY ENVIRONMENTAL LABORATORY                **
**              USAE WATERWAYS EXPERIMENT STATION                 **
**         FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.03     DATE:  12.06.2020


 PRECIPITATION DATA FILE:       P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV 2010-2020.d4
 TEMPERATURE DATA FILE:         P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d7
 SOLAR RADIATION DATA FILE:     P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d13
 EVAPOTRANSPIRATION DATA F. 1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A
- Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Site Data\Phase IV.d11
 SOIL AND DESIGN DATA FILE  1: P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Full Buildout Overlay greater than 5%.d10
 OUTPUT DATA FILE:              P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Full Buildout Overlay greater than 5%.out
 DAILY OUTPUT DATA FILE:        P:\3000s\3066.11\Source Files\Type I-A PMA\App A -
Design\Calculations\B - Leachate Collection System\B.1 - Help Model (Impingement
Rate)\Help files\Full Buildout Overlay greater than 5%.DAY

 COLUMNS OF DAILY OUTPUT DATA FILE:
```

```
   1    DATE (yyyymmdd)
   2    AIR TEMPERATURE  (* INDICATES FREEZING TEMPERATURES)
   3    FROZEN SOIL STATE (* INDICATES FROZEN SOIL)
   4    PRECIPITATION (INCH)
   5    RUNOFF (INCH)
   6    POTENTIAL EVAPOTRANSPIRATION (INCH)
   7    ACTUAL EVAPOTRANSPIRATION (INCH)
   8    WATER CONTENT OF THE EVAPORATIVE ZONE (INCH)
   9    HEAD  #1: AVERAGE HEAD ON TOP OF LAYER  4 (INCH)
  10    DRAIN #1: LATERAL DRAINAGE FROM LAYER  3 (INCH)
  11    LEAK  #1: PERCOLATION/LEAKAGE THROUGH LAYER  4 (INCH)


*****************************************************************************

   TITLE:  Four Hills Landfill - Phase IV Design

*****************************************************************************


                    WEATHER DATA SOURCES
----------------------------------------------------------------------------



     NOTE:  PRECIPITATION DATA FOR     Nashua             New Hampshire
            WAS ENTERED FROM A TEXT FILE.



     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    NASHUA             NEW HAMPSHIRE

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    22.60       24.50       33.60       44.90       55.50       64.80
    69.80       67.70       59.50       49.10       38.70       26.60



     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    NASHUA             NEW HAMPSHIRE
             AND STATION LATITUDE  =  42.70 DEGREES
```

```
*******************************************************************************

                      LAYER DATA   1
----------------------------------------------------------------------------

                    VALID FOR  10 YEARS


   NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.



                        LAYER  1
                        --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER  18
      THICKNESS                  =   2484.00   INCHES
      POROSITY                   =     0.6710 VOL/VOL
      FIELD CAPACITY             =     0.2920 VOL/VOL
      WILTING POINT              =     0.0770 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0.2937 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=    0.1000E-02 CM/SEC


                        LAYER  2
                        --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER   2
      THICKNESS                  =     18.00   INCHES
      POROSITY                   =     0.4370 VOL/VOL
      FIELD CAPACITY             =     0.0620 VOL/VOL
      WILTING POINT              =     0.0240 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0.1569 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=    0.5800E-02 CM/SEC


                        LAYER  3
                        --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER  20
```

```
    THICKNESS                 =     0.25   INCHES
    POROSITY                  =     0.8500 VOL/VOL
    FIELD CAPACITY            =     0.0100 VOL/VOL
    WILTING POINT             =     0.0050 VOL/VOL
    INITIAL SOIL WATER CONTENT  =     0.0196 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      10.00     CM/SEC
    SLOPE                     =    22.60   PERCENT
    DRAINAGE LENGTH           =    409.0    FEET


                      LAYER  4
                      --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
    THICKNESS                 =     0.06   INCHES
    EFFECTIVE SAT. HYD. CONDUCT.=     0.2000E-12 CM/SEC
    FML PINHOLE DENSITY       =     0.00   HOLES/ACRE
    FML INSTALLATION DEFECTS  =     0.00   HOLES/ACRE
    FML PLACEMENT QUALITY     =  3 - GOOD


******************************************************************************

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                    VALID FOR  10 YEARS


     NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
            SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
            GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
            A SLOPE LENGTH OF  390. FEET.

    SCS RUNOFF CURVE NUMBER              =    79.55
    FRACTION OF AREA ALLOWING RUNOFF     =     0.0    PERCENT
    AREA PROJECTED ON HORIZONTAL PLANE   =     1.000  ACRES
    EVAPORATIVE ZONE DEPTH               =     8.0    INCHES
    INITIAL WATER IN EVAPORATIVE ZONE    =     2.281  INCHES
    UPPER LIMIT OF EVAPORATIVE STORAGE   =     5.368  INCHES
    FIELD CAPACITY OF EVAPORATIVE ZONE   =     2.336  INCHES
    LOWER LIMIT OF EVAPORATIVE STORAGE   =     0.616  INCHES
    SOIL EVAPORATION ZONE DEPTH          =     8.000  INCHES
    INITIAL SNOW WATER                   =     0.000  INCHES
```

```
     INITIAL INTERCEPTION WATER         =     0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS   =   732.425  INCHES
     TOTAL INITIAL WATER                =   732.425  INCHES
     TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR


******************************************************************************

            EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

              VALID FOR  10 YEARS


        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
               NASHUA            NEW HAMPSHIRE
           STATION LATITUDE                    =  42.70 DEGREES
           MAXIMUM LEAF AREA INDEX             =   0.00
           START OF GROWING SEASON (JULIAN DATE)  =    128
           END OF GROWING SEASON (JULIAN DATE)    =    277
           EVAPORATIVE ZONE DEPTH              =   8.0  INCHES
           AVERAGE ANNUAL WIND SPEED           =  10.94 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  66.0  %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.0  %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************



******************************************************************************

            FINAL WATER STORAGE AT END OF YEAR 2019
------------------------------------------------------------------------------

              LAYER       (INCHES)      (VOL/VOL)
              -----       --------      ---------
                1        732.8394        0.2950

                2          3.0582        0.1699

                3          0.0049        0.0195

                4          0.0000        0.0000
```

```
  TOTAL WATER IN LAYERS       735.903

  SNOW WATER                  5.244

  INTERCEPTION WATER          0.000

  TOTAL FINAL WATER           741.146

***************************************************************************



***************************************************************************

          PEAK DAILY VALUES FOR YEARS 2010 THROUGH 2019
-------------------------------------------------------------------------

                              (INCHES)    (CU. FT.)
                              ----------  -------------
   PRECIPITATION                  5.55      20146.502

   RUNOFF                        0.000         0.0000

   DRAINAGE COLLECTED FROM LAYER  3        0.18703       678.93170

   PERCOLATION/LEAKAGE THROUGH LAYER  4     0.000000       0.00002

   AVERAGE HEAD ON TOP OF LAYER  4          0.006

   MAXIMUM HEAD ON TOP OF LAYER  4          0.201

   LOCATION OF MAXIMUM HEAD IN LAYER  3
      (DISTANCE FROM DRAIN)              0.0 FEET

   SNOW WATER                    10.15      36858.2344

   MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.6710

   MINIMUM VEG. SOIL WATER (VOL/VOL)             0.1089


    ***  Maximum heads are computed using McEnroe's equations.  ***

       Reference:  Maximum Saturated Depth over Landfill Liner
               by Bruce M. McEnroe, University of Kansas
```

ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

Project Phase IV Expansion Project
Location Four Hills Landfill, Nashua New Hampshire
Subject Geotextile Apparent Opening Size
Calculated By S. Santiago Date 5/12/2020
Checked By J. Grace/ E. Galvin Date 7/7/2020
P:\3000s\3066.11\Source Files\Type I-A PMA\App A - Design\Att A - Calcs\B - Leachate Collection System\B.2 - Geotextile Apparent Opening Size\Geotextiles.docx

B.2 GEOTEXTILES

PURPOSE:

Evaluate whether the geotextile component of the drainage geocomposite will retain the fine particles of the Drainage Sand without clogging.

DATA:

- Particle size distribution data for the Drainage Sand is below.

Sieve Size	Sieve Size (mm)	Percent Passing (%)
1/2-inch	12.5	100
No. 4	4.75	60-100
No. 10	2	40-95
No. 40	0.42	5-50
No. 100	0.15	0-17
No. 200	0.075	0-10

METHOD:

Calculate the required apparent opening size (AOS or O_{95}) of the geotextile component of the drainage geocomposite based on the particle size distribution of the Drainage Sand (Attachments A and B) and compare to the physical properties of a commercially available drainage geocomposite (Attachment C). Use the evaluation methods proposed by Koerner [Ref 1].

CALCULATIONS:

Calculate the maximum AOS for the geotextile filter using the following flow diagram. The proposed Drainage Sand has less than 10 percent (%) fines and less than 90% gravel and based upon the particle distribution (see Attachment A).

SEC. 2.2 GEOTEXTILE FUNCTIONS AND MECHANISMS 111

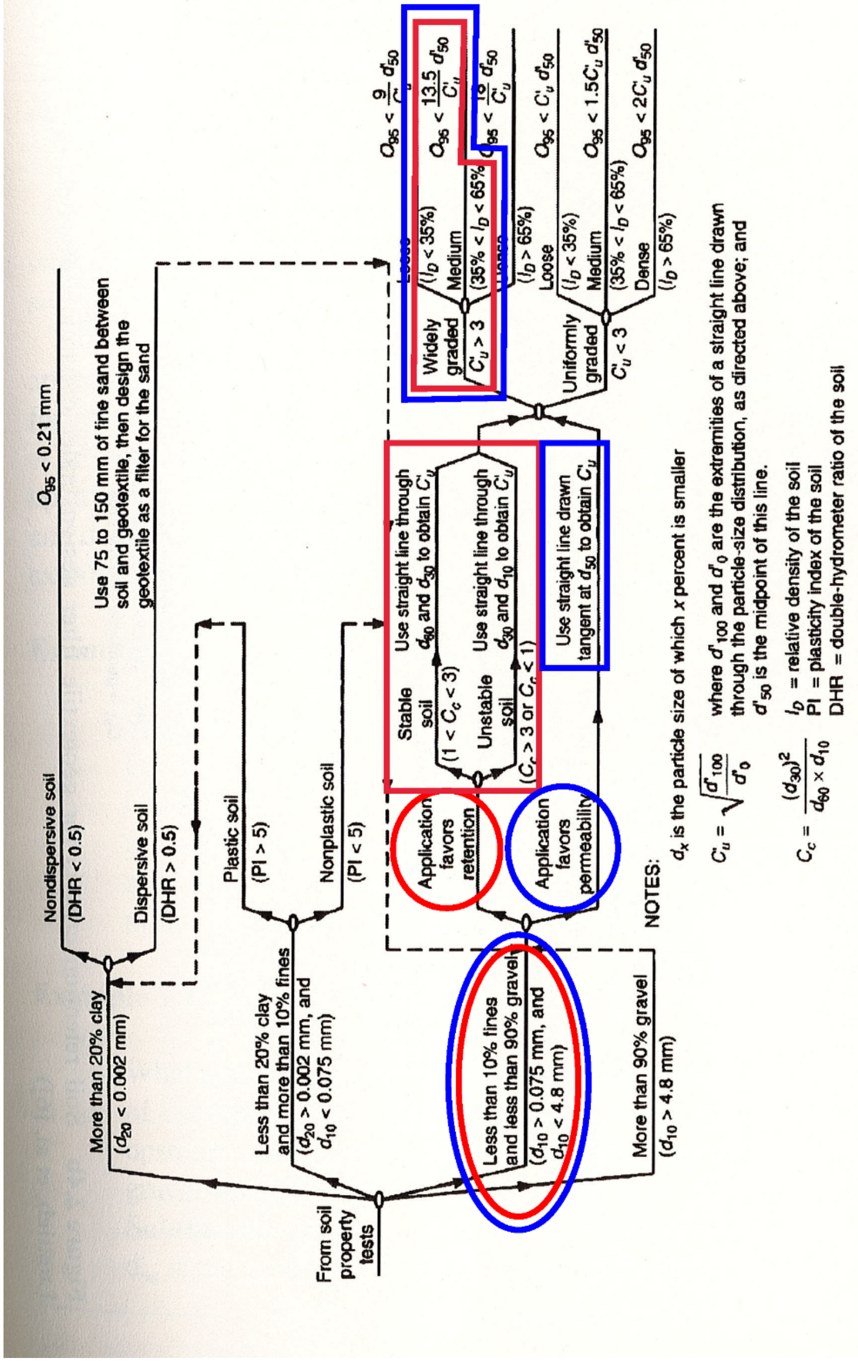


Figure 2.4a Soil retention criteria for geotextile filter design using steady-state flow conditions (After Luettich, et al. [6]).

Figure 2.4a: Soil Retention Criteria for geotextile filter design using steady-state flow conditions [Ref 1].

For an application favoring retention:

$$C_c = \frac{(d_{30})^2}{d_{60} \times d_{10}} \qquad \text{[Figure 2.4a, Ref 1]}$$

Where:

d_{10} = Particle size at which 10% of the material is finer = 0.075 (lower) to 0.58 (upper) mm (Attachment A)

d_{30} = Particle size at which 30% of the material is finer = 0.25 (lower) to 1.5 (upper) mm (Attachment A)

d_{60} = Particle size at which 60% of the material is finer = 0.56 (lower) to 4.8 (upper) mm (Attachment A)

Lower Particle Size	Upper Particle Size
$C_c = \frac{(0.25)^2}{0.56 \times 0.075}$	$C_c = \frac{(1.5)^2}{4.8 \times 0.58}$
$C_c = 1.49$	$C_c = 0.81$

For the lower particle size distribution, $1 < C_c < 3$, use a straight line through d_{60} and d_{30} to obtain d'_{100} and d'_0 to solve for C'_u. For the upper particle size distribution, $C_c < 1$, use a straight line through d_{30} and d_{10} to obtain C'_u. (Attachment A).

Therefore,

$$C'_u = \sqrt{\frac{d'_{100}}{d'_0}}$$

Where:

C'_u = coefficient of uniformity (dimensionless)

d'_{100} = based on the lines drawn on the particle size distribution included as Attachment A, the particle size at which 100% of the material is coarser = 2.0 (lower) to 30 (upper) mm

d'_0 = based on the lines drawn on the particle size distribution included as Attachment A, the particle size at which 0% of the material is finer = 0.09 (lower) to 0.38 (upper) mm

Lower Particle Size	Upper Particle Size
$C'_u = \sqrt{\frac{2.0\text{ mm}}{0.09\text{ mm}}} = 4.7$	$C'_u = \sqrt{\frac{30\text{ mm}}{0.38\text{ mm}}} = 8.9$
$C'_u = 4.7$	$C'_u = 8.9$

Based on an assumed relative density of the soil, I_D, of between 35% and 65% and because $C'_u > 3$ in both cases:

$$\text{AOS} < \frac{13.5}{C'_u} \times d'_{50}$$

Where:

AOS = Apparent opening size of the geotextile component of the drainage geocomposite.
C'_u = 4.7 (lower) and 8.9 (upper).
d'_{50} = Particle size at which 50% of the material is finer = 0.42 (lower) to 3.0 (upper) mm.

Lower Particle Size	Upper Particle Size
$\frac{13.5}{4.7} \times 0.42\text{ mm} = \underline{\underline{1.2\text{ mm}}}$	$\frac{13.5}{8.9} \times 3.0\text{ mm} = \underline{\underline{4.6\text{ mm}}}$

From Attachment C, AOS = 0.18 mm< 1.2 (lower) or 4.6 (upper) mm ∴ OK

For an application favoring permeability:

Use a straight line drawn tangent at d_{50} to obtain d'_{100} and d'_0 to solve for C'_u (Attachment B):

$$C'_u = \sqrt{\frac{d'_{100}}{d'_0}}$$

Where:

C'_u = Coefficient of uniformity (dimensionless)

d'_{100} = Particle size at which 100% of the material is coarser = 2.0 (lower) to 25 (upper) mm (Attachment B)

d'_0 = Particle size at which 0% of the material is finer = 0.09 (lower) to 0.425 (upper) mm (Attachment B)

<u>Lower Particle Size</u>	<u>Upper Particle Size</u>
$C'_u = \sqrt{\frac{2.0\text{ mm}}{0.09\text{ mm}}} = 4.7$	$C'_u = \sqrt{\frac{25\text{ mm}}{0.425\text{ mm}}} = 7.7$
$C'_u = 4.7$	$C'_u = 7.7$

Based on an assumed relative density of the soil, I_D, of between 35% and 65% and because $C'_u > 3$ in both cases:

$$\text{AOS} < \frac{13.5}{C'_u} \times d_{50}$$

Where:

AOS = Apparent opening size of the geotextile component of the drainage geocomposite

C'_u = 4.7 (lower) and 7.7 (upper)

d'_{50} = Particle size at which 50% of the material is finer = 0.42 (lower) to 3.0 (upper) mm (Attachment B)

<u>Lower Particle Size</u>	<u>Upper Particle Size</u>
$\frac{13.5}{4.7} \times 0.42\text{ mm} < \underline{\underline{1.2\text{ mm}}}$	$\frac{13.5}{7.7} \times 3.0\text{ mm} < \underline{\underline{5.3\text{ mm}}}$

From Attachment C, AOS = 0.15 mm< 1.2 (lower) or 5.3 (upper) mm ∴ OK

CONCLUSION:

The geotextile component of the proposed drainage geocomposite with an AOS no greater that 1.2 mm provides acceptable performance.

REFERENCES:

[1] Koerner, Robert M. (2012), *Designing with Geosynthetics*, 6th ed. Vol. 1. Xlibris Corporation, p. 111.

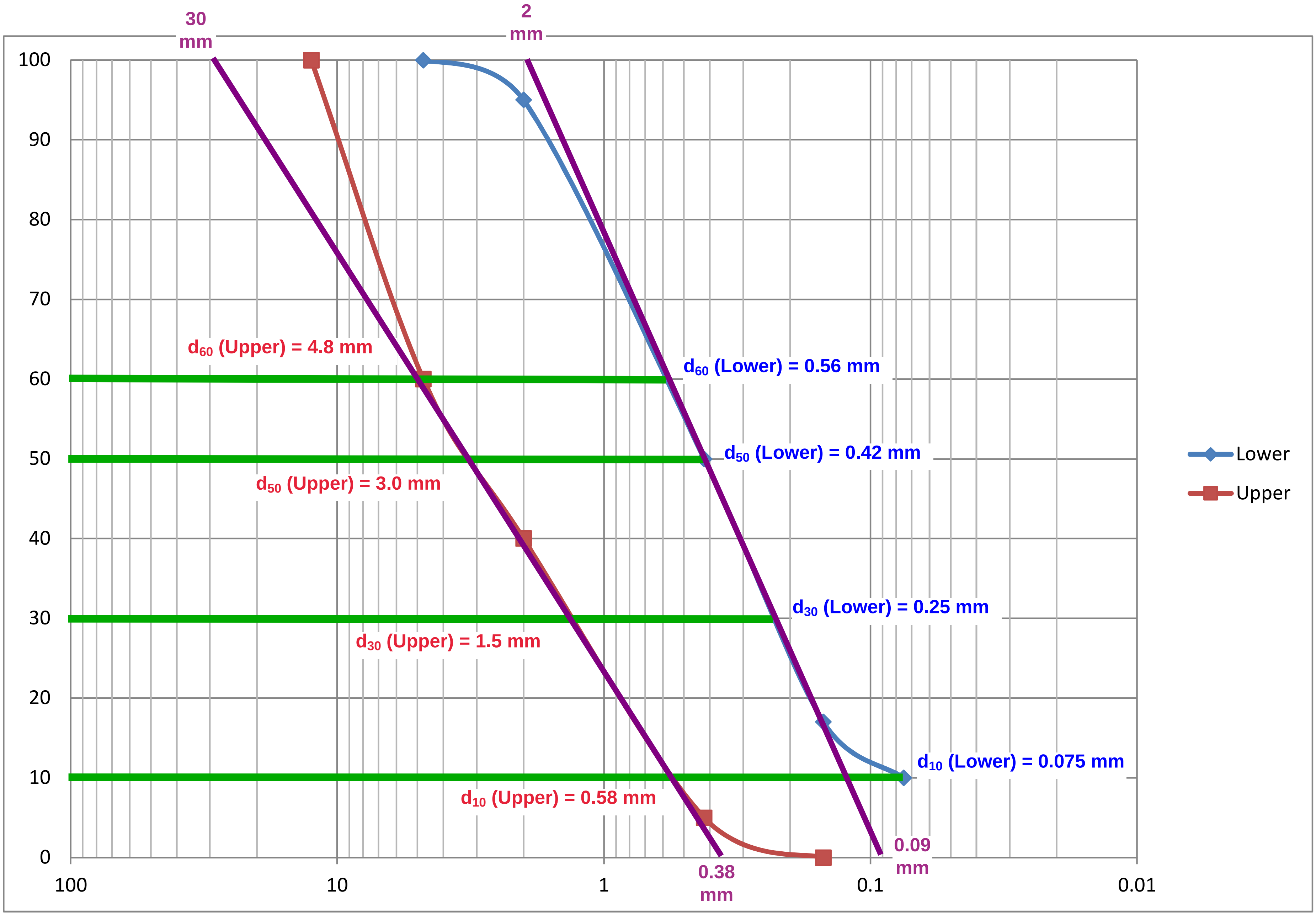
[2] Koerner, Robert M. (2012), *Designing with Geosynthetics*. 6th ed. Vol. 2, Xlibris Corporation, pp 872-873.

ATTACHMENTS:

Attachments A & B: Drainage Sand Grain Size Distribution Charts
Attachment C: GSE PermaNet 330 mil Geocomposite Specification Sheet

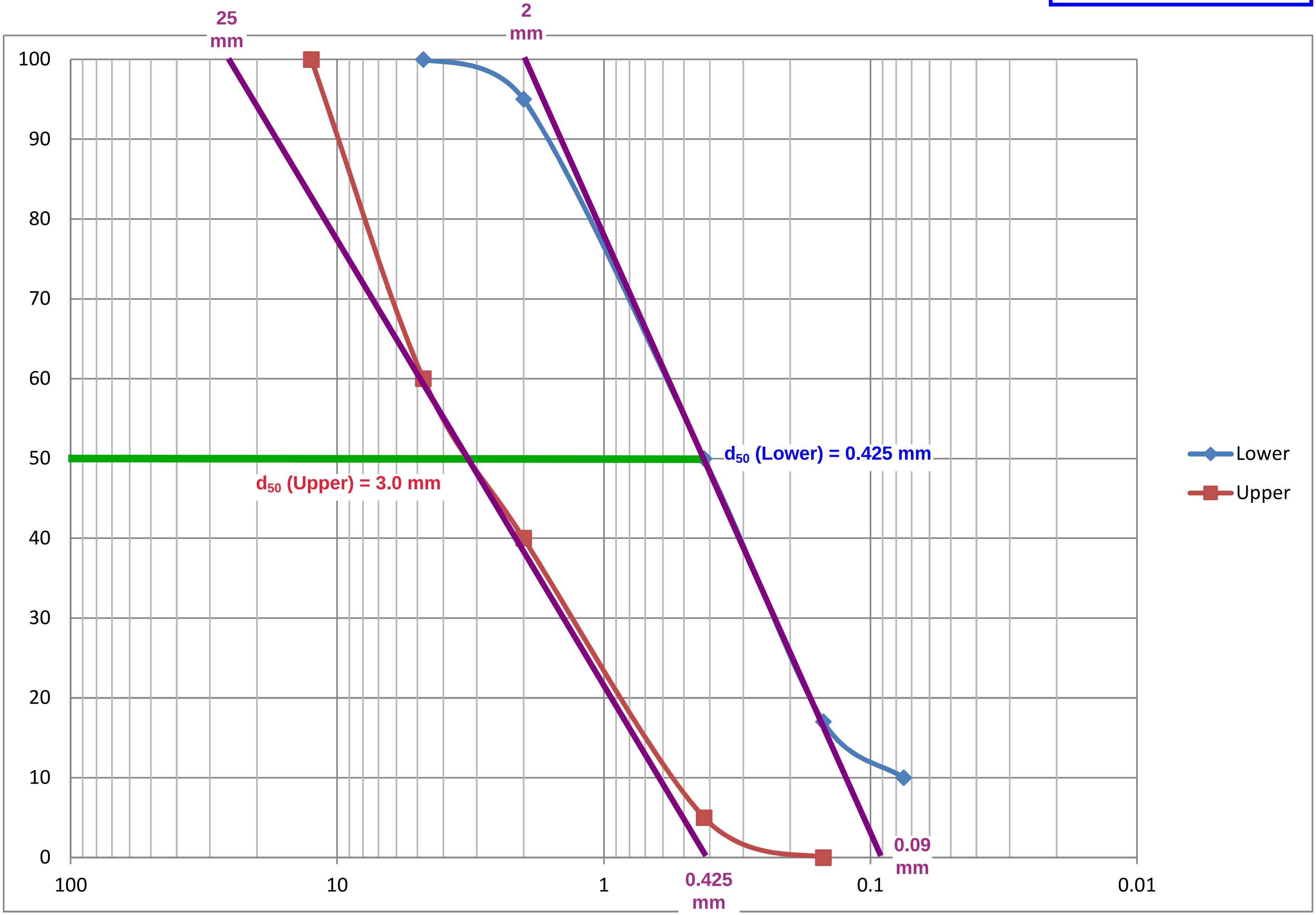
Application that Favors Retention

Attachment A



Attachment B

Application that Favors Retention



Attachment C

PRODUCT DATA SHEET

GSE PermaNet 330 mil Geocomposite

GSE PermaNet 330 mil geocomposite is manufactured with a GSE PermaNet geonet core heat-bonded on one or both sides with a nonwoven needlepunched geotextile. The round strand, creep resistant structure of this product ensures continuous flow performance and durability under rigorous environmental conditions and is ideal for extremely demanding applications.

AT THE CORE:
The product's structure provides superior performance under demanding conditions.

Product Specifications

Tested Property	Test Method	Frequency	Minimum Average Roll Value		
Geocomposite			6 oz/yd^2	8 oz/yd^2	10 oz/yd^2
Transmissivity(2), gal/min/ft (m^2/sec) Double-Sided Composite Single-Sided Composite	ASTM D 4716	1/540,000 ft^2	9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})	9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})	9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})
Ply Adhesion, lb/in	ASTM D 7005	1/50,000 ft^2	1.0	1.0	1.0
Geonet Core(1,3) – GSE PermaNet					
Geonet Core Thickness, mil	ASTM D 5199	1/50,000 ft^2	330	330	330
Transmissivity(2), gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	28.8 (6 x 10^{-3})	28.8 (6 x 10^{-3})	28.8 (6 x 10^{-3})
Compressive Strength, lb/ft^2	ASTM D 6364	1/540,000 ft^2	60,000	60,000	60,000
Creep Reduction Factor	ASTM D 7361	per formulation	1.3 @ 25,000 psf	1.3 @ 25,000 psf	1.3 @ 25,000 psf
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94
Tensile Strength (MD), lb/in	ASTM D 7179	1/50,000 ft^2	100	100	100
Carbon Black Content, %	ASTM D 4218	1/50,000 ft^2	2.0	2.0	2.0
Geotextile(1,3)					
Mass per Unit Area, oz/yd^2	ASTM D 5261	1/90,000 ft^2	6	8	10
Grab Tensile, lb	ASTM D 4632	1/90,000 ft^2	160	220	260
Grab Elongation	ASTM D 4632	1/90,000 ft^2	50%	50%	50%
CBR Puncture Strength, lb	ASTM D 6241	1/540,000 ft^2	435	575	725
Trapezoidal Tear Strength	ASTM D 4533	1/90,000 ft^2	65	90	100
AOS, US Sieve, (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)	80 (0.180)	100 (0.150)
Permittivity, sec^{-1}	ASTM D 4491	1/540,000 ft^2	1.5	1.3	1.0
Water Flow Rate, gpm/ft^2	ASTM D 4491	1/540,000 ft^2	110	95	75
UV Resistance, % Retained	ASTM D 4355 (after 500 hours)	per formulation	70	70	70
NOMINAL ROLL DIMENSIONS(4)					
Roll Width, ft			15	15	15
Roll Length, ft	Double-Sided Composite Single-Sided Composite		150 150	140 150	130 140
Roll Area, ft^2	Double-Sided Composite Single-Sided Composite		2,250 2,250	2,100 2,250	1,950 2,100

NOTES:
- (1) All geotextile properties are minimum average roll values except AOS which is maximum average roll value and UV resistance is typical value. Geonet core thickness is nominal value.
- (2) Gradient of 0.1, normal load of 25,000 psf, water at 70° F between steel plates for 15 minutes. Contact GSE for performance transmissivity data for use in design.
- (3) Component properties prior to lamination.
- (4) Roll widths and lengths have a tolerance of ±1%.

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

[DURABILITY RUNS DEEP] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

GSE ENVIRONMENTAL™

B.3 LEACHATE COLLECTION PIPE STRENGTH

PURPOSE:

Verify that an 8-inch (in.) diameter SDR 17 HDPE leachate collection pipe set in a 24-in. wide trench will withstand the anticipated live and dead loads. Evaluate the leachate collection pipe in the secondary liner system as it is located at a lower elevation and subjected to higher loads.

METHOD:

1. Calculate the static and live vertical loads that may be applied to the leachate collection pipe.

- Short-Term Conditions: Under short-term conditions, calculate the loads on the leachate collection pipe for the combined loading scenarios: (i) 1.5 feet (ft) of Crushed Stone and a 10-ft thick lift of waste (vertical static load); and (ii) a landfill waste compactor (Caterpillar 826K) (vertical live load)
- Long-Term Conditions: Under long-term conditions, calculate the load on the leachate collection pipe for the combined loading scenario of the liner system, the waste, and the final cover system. Calculate the radial earth pressure due to arching of materials over a deep buried pipe.

2. Calculate the maximum ring deflection and verify that it is within the allowable limits for a SDR 17 HDPE pipe.

3. Calculate the maximum compressive stress (crushing) of the pipe wall and verify that it is within allowable limits for an SDR 17 HDPE pipe.

4. Evaluate buckling of the pipe wall and verify that it is within the allowable limits for: (i) short-term loading by calculating the allowable constrained buckling pressure and verifying that it is greater than the combined vertical static load and live load; and (ii) long-term loading by calculating the critical constrained buckling pressure and verifying that it is greater than the radial direct earth pressure (P_{RD}) on the pipe.

DATA AND ASSUMPTIONS:

- 8-in. diameter SDR 17 HDPE pipe (Attachment A):
    - Inside diameter (ID) = 7.550 in. (nominal)
    - Outside diameter (OD) = 8.625 in. (nominal)
    - Wall thickness (t) = 0.507 in. (minimum)
- Apparent modulus of elasticity of a HDPE PE3XXX pipe:

  Short-Term Conditions, E = 27,000 lb/in^2 at 73.4°F and a duration of 100 years, [Ref 1, Ch. 3, Tables B.1.1 and B.1.2., pp. 99 – 100].

Long-Term Conditions, E = 11,610 lb/in^2 at 140°F and a duration of 100 years, [Ref 1, Ch. 3, Tables B.1.1 and B.1.2., pp. 99 – 100].

- Modulus of soil reaction for Crushed Stone around the pipe, E' = 3,000 lb/in^2 [Ref 1, Ch. 6, Table 3-7, p. 214].
- One-dimensional modulus of stone around pipe, M_S = 7,000 lb/in^2, by extrapolation based on the vertical soil stress = 120 lb/in^2 [Ref 1, Ch. 6, Table 3-12, p. 228].
- Waste height over secondary leachate collection pipe: ranges from 10 ft in first lift of waste to 207 ft at final grade (Attachment B).
- Waste has an estimated in-place unit weight of 85 pounds per cubic foot (lb/ft^3).
- Liner system thickness above the secondary leachate collection pipe: 18 in. (1.5 ft) of Crushed Stone in the primary leachate collection system and 16 in. (1.33 ft) of Crushed Stone in the secondary leachate collection system. Total 34 in. (2.83 ft).
- Crushed Stone has a unit weight of 130 lb/ft^3.
- Final cover system thickness = 42 in. (3.5 ft), including 6 in. of topsoil, 6 in. moisture retention layer, 12 in. of drainage sand, 6 in. of sand, and 12 in. of subgrade soil.
- Cover system soil has a unit weight of 125 lb/ft^3.
- The gross weight of a waste compactor is 90,207 lbs. with a maximum wheel load weight of 22,552 lbs. and a contact area of approximately 3.92 ft^2 (Attachment C).

CALCULATIONS:

1. Calculate the static and live vertical loads that may be applied to the leachate collection pipe.

Short-Term Conditions: Assume that the soil and waste is 12.83 ft thick (10 ft of waste and 2.83 ft of crushed stone), and the maximum wheel load weight of a waste compactor is 22,552 lbs. with a contact area of approximately 564 in^2 (3.92 ft^2) (Attachment C).

Vertical Static Load (P_E):

$$P_E = \gamma_{material} H$$ [Ref 1, Ch. 6, p. 196]

Where:

P_E = Vertical static load (lb/ft^2)
$\gamma_{material}$ = Unit weight of material (lb/ft^3)
H = Height of material (ft)

[Crushed Stone] [First lift of waste]

$$P_E = (2.83\text{ ft} \times 130\text{ lb/ft}^3) + (10\text{ ft} \times 85\text{ lb/ft}^3) = \underline{\underline{1{,}218\text{ lb/ft}^2}}$$

Vertical Live Load (P_L):

$$P_L = \frac{I_f \times W_W}{a_c}\left(1 - \frac{H^3}{\left(r_T^2 + H^2\right)^{1.5}}\right) \qquad \text{[Ref 1, Ch. 6, p. 202]}$$

Where:

P_L = vertical live load (lb/ft^2)

I_f = impact factor (dimensionless), ranges from 2.0 to 3.0 = Assume 3.0

W_w = wheel load = 22,552 lbs (Attachment C)

a_c = contact area (ft^2) = 3.92 ft^2 (Attachment C)

H = height of waste and stone (ft) = 12.83 ft

r_T = equivalent radius (ft) = $\sqrt{\frac{a_c}{\pi}}$ = 1.12 ft

$$P_L = \frac{3.0 \times 22{,}552\text{ lbs}}{3.92\text{ ft}^2}\left(1 - \frac{(12.83\text{ ft})^3}{\left((1.12\text{ ft})^2 + (12.83\text{ ft})^2\right)^{1.5}}\right) = \underline{\underline{195\text{ lbs/ft}^2}}$$

Long-Term Conditions: Assuming the live load is negligible under greatest waste thickness

Vertical Static Load (P_E):

[Crushed Stone] [Final waste thickness] [Final cover thickness]

$$P_E = (2.83\text{ ft} \times 130\text{ lb/ft}^3) + (207\text{ ft} \times 85\text{ lb/ft}^3) + (3.5\text{ ft} \times 125\text{ lb/ft}^3)$$

$$= \underline{\underline{18{,}400\text{ lb/ft}^2}}$$

Radial Directed Earth Pressure (P_{RD}):

For deep buried pipe, arching of the materials above the pipe will reduce the loading to the pipe. Calculate the radial directed earth pressure as follows:

$$P_{RD} = VAF \times P_E \qquad \text{[Ref 1, Ch. 6, p. 228]}$$

Where:

P_{RD} = Radial directed earth pressure (lb/ft^2)

P_E = Vertical static load (lb/ft^2) = $\underline{\underline{18{,}400\text{ lb/ft}^2}}$

VAF = Vertical arching factor (dimensionless) = $0.88 - 0.71\left(\frac{S_A - 1}{S_A + 2.5}\right)$

S_A = Hoop stress stiffness factor (dimensionless) = $\frac{1.43\,M_S\,r_{CENT}}{E\,t}$

M_S = One-dimensional modulus of soil (lb/in^2) = 7,000 lbs/in^2 [Ref 1]

r_{CENT} = Radius to centroidal axis of pipe (in.) = $\frac{ID+t}{2}$

E = 11,610 lb/in^2

t = Pipe wall thickness = 0.507 in.

ID = Inside pipe diameter = 7.550 in.

Therefore,

$$VAF = 0.88 - 0.71\left(\frac{S_A - 1}{S_A + 2.5}\right)$$

$$S_A = \frac{1.43\, M_S\, r_{CENT}}{E\, t}$$

$$r_{CENT} = \frac{7.550 + 0.507}{2} = 4.03 \text{ in.}$$

$$S_A = \frac{1.43\ (7{,}000\ \text{lb/in}^2)\ (\ 4.03\ \text{in.})}{(11{,}610\ \ \text{lb/in}^2)\ (0.507\ \text{in.})} = 6.85$$

$$VAF = 0.88\ -\ 0.71\ \left(\frac{6.85 - 1}{6.85 + 2.5}\right) = 0.44$$

$$P_{RD} = 0.44 \times 18{,}400\ \text{lb/ft}^2 = \underline{\underline{8{,}096\ \text{lb/ft}^2}}$$

2. Calculate the ring deflection and verify it is within the allowable limits.

Ring deflection refers to the pipe flattening due to the applied load. The allowable limit of ring deflection for a SDR 17 pipe is 7.5 percent [Ref 1, Ch. 6, p 218].

Modified Iowa Formula:

$$\frac{\Delta x}{D_M} = \frac{1}{144}\left[\frac{K_{BED}L_{DL}P_E + K_{BED}P_L}{\frac{2\,E}{3}\left(\frac{1}{DR-1}\right)^3 + 0.061\,F_S E'}\right]$$ [Ref 1, Ch. 6, p. 211]

Where:

$\frac{\Delta x}{D_M}$ = Percent deflection

Δx = Horizontal deflection (in.)

D_M = Mean pipe diameter (in.) = outside pipe diameter – pipe wall thickness = 8.12 in.

K_{BED} = Bedding factor (dimensionless), typically 0.1
L_{DL} = Deflection lag factor (dimensionless), assume 1.0 for no arching
P_E = Vertical static load (lb/ft^2)
P_L = Vertical live load (lb/ft^2)
E = Apparent modulus of elasticity of pipe for long-term conditions (100-years at 140°F) 11,610 lb/in^2 [Ref 1, Ch. 3, Tables B.1.1 and B.1.2., pp. 99 – 100].
E' = Modulus of soil reaction (lb/in^2) = 3,000 lb/in^2
F_S = Soil support factor (dimensionless), assume 1.0 (this assumes that the modulus of soil reaction, E', is equal to the native soil modulus of soil reaction, E'$_N$. This generally assumes the native soils are slightly compact granular soils or stiff cohesive soils) [Ref 1, Ch. 6, Tables 3-9 and 3-10, p. 216]
DR = Dimension ratio (dimensionless) = 17

The above reduces to:

$$\frac{\Delta x}{D_M} = \frac{1}{144}\left[\frac{0.1P_E + 0.1P_L}{185}\right]$$

Therefore:

Condition	**P_E (lb/ft^2)**	**P_L (lb/ft^2)**	**$\frac{\Delta x}{D_M}$**	**Deflection (%)**	**Recommended Limit***
Short Term	1,218	195	0.0052	0.53	7.5% => OK
Long Term	18,400	0	0.069	6.9	7.5% => OK

*Ref 1, Ch. 6, p. 217

3. Evaluate crushing of the leachate collection pipe wall and verify it is within the allowable limits.

Pipe wall crushing occurs when the compressive stress in the pipe wall exceeds the yield stress of the pipe material. The allowable compressive strength of a PE3XXX pipe is 1,000 lb/in^2 [Ref 1, Ch. 3, Table C.1, p. 102].

Pipe wall compressive stress (S):

$$S = \frac{(P_E + P_L) \times DR}{288}$$ [Ref 1, Ch. 6, p. 219]

Where:
P_E = Vertical Static Load (Short term) (lb/ft^2) = P_{RD} (Long term) [Ref 1, Ch. 6, p. 228]
P_L = Vertical Live Load (Long and Short term) (lb/ft^2)
DR = 17

Condition	**P_E (lb/ft^2)**	**P_L (lb/ft^2)**	**S (lb/in^2)**	**Allowable Compressive Strength (lb/in^2)**
Short Term	1,218	195	83	1,000 => OK
Long Term	8,096	0	478	1,000 => OK

4. Evaluate buckling of the leachate collection pipe wall for short-term and long-term conditions and verify that it is within the allowable limits.

Short-Term Conditions:

$$P_{WC} = \frac{5.65}{FS}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$$

[Ref 1, Ch. 6, p. 221]

Where:

P_{WC} = Allowable constrained buckling pressure (lb/in^2)
FS = Factor of Safety (dimensionless) = 2
R = Buoyancy reduction factor (dimensionless)
$= 1 - 0.33\left(\frac{H_{GW}}{H}\right)$
    H = Depth of cover (ft) = 12.83 ft
    H_{GW} = Height of groundwater above pipe (ft) = 1 ft, maximum allowable depth of leachate
$=1 - 0.33\left(\frac{1\text{ ft}}{12.83\text{ ft}}\right) = 0.974$
B′ = Soil support factor (dimensionless) = $\frac{1}{1+4e^{-0.065H}}$
$= \frac{1}{1+4e^{-0.065(12.83\text{ ft})}} = 0.365$
E′ = Modulus of soil reaction (lb/in^2) = 3,000 lb/in^2
E = apparent modulus of elasticity of pipe for short-term conditions (lb/in^2) = 27,000 lb/in^2
DR = 17

Therefore,

$$P_{WC} = \frac{5.65}{2}\sqrt{0.974 \times 0.365 \times 3{,}000\text{ lb/in}^2 \times \frac{27{,}000\text{ lb/in}^2}{12(17-1)^3}} = 68.4\text{ lb/in}^2 = 9{,}850\text{ lb/ft}^2$$

9,850 lb/ft^2 >> $P_E + P_L$ = 1,413 lb/ft^2 => OK

Long-Term Conditions:

$$P_{CR} = \frac{2.4\,\varphi R_H}{D_M}(EI)^{1/3}\left(E_S^*\right)^{2/3}$$

[Ref 1, Ch. 6, p. 233]

Where:

P_{CR} = Critical constrained buckling pressure (lb/in^2)
φ = Calibration factor (dimensionless) = 0.55 for granular soils
R_H = Geometry factor (dimensionless) = 1.0 for deep burials in uniform fills
D_M = Outside pipe diameter – pipe wall thickness = 8.625 in. – 0.507 in. = 8.118 in.
E = Apparent modulus of elasticity of pipe for long-term conditions (100-years at 140°F) (lb/in^2) = 11,610 lb/in^2.

I = Pipe wall moment of inertia (in^4/in) = $t^3/12$ for solid wall construction
$(0.507\text{ in})^3/12 = 0.0109\text{ in}^3$

M_s = One-dimensional modulus of soil (lb/in^2) = 7,000 lb/in^2

E_S = Secant modulus (lb/in^2) = $M_S \frac{(1+\mu)(1-2\mu)}{(1-\mu)}$ [Ref 1, Ch. 6, p. 230]

μ = Poisson's ratio = 0.15 [Ref 1, Ch. 6, Table 3-13, p. 230]

$7{,}000\ \text{lb/in}^2 \left(\frac{(1+0.15)(1-2(0.15))}{(1-0.15)}\right) = 6{,}629\ \text{lb/in}^2$

$E_s{}^*$ = $E_S/(1-\mu)$ (lb/in^2) =(6,629 lb/in^2)/(1-0.15) = 7,799 lb/in^2

Therefore,

$$P_{CR} = \frac{2.4\ (0.55)(1.0)}{8.118\ \text{in.}}\left(11{,}610\ \ \text{lb/in}^2 \times 0.0109\ \text{in.}^3\right)^{1/3}\left(7{,}799\ \text{lb/in}^2\right)^{2/3}$$

$$= 322\ \text{lb/in}^2 = \underline{46{,}368\ \text{lb/ft}^2}$$

$$\underline{46{,}368\ \text{lb/ft}^2 > P_{RD} = 8{,}084\ \text{lb/ft}^2;\ \text{and} > P_E\ \text{long term} = 19{,}647\ \text{lb/ft}^2 \Rightarrow \text{OK}}$$

CONCLUSIONS:

For the leachate collection system, an 8-in. diameter, SDR 17 HDPE pipe located in the primary or secondary liner system, the compressive (crushing) stress, buckling stress, and pipe deflections found are within the allowable limits for the proposed short-term and long-term conditions.

REFERENCES:

[1] Plastic Pipe Institute, *Handbook of Polyethylene Pipe*, Second Edition, 2007. Retrieved from www.plasticpipe.org , last accessed October 9, 2017.

ATTACHMENTS:

Attachment A	PE4710 (PE3408) Pipe Data Table
Attachment B	Waste Thickness Worksheet
Attachment C	826K Landfill Compactor Specifications and Wheel Load/Contact Area Calculation

Attachment A

PERFORMANCE PIPE
A DIVISION OF CHEVRON PHILLIPS CHEMICAL COMPANY LP

PE 4710 (PE3408)
Energy - DriscoPlex® 6400 Series
PE4710 IPS Pipe Data

Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter calculated using nominal OD and minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimensions and tolerances in applicable pipe specifications. Pressure Ratings are for water at 73.4ÅF. For other fluid and service temperature, ratings may differ. Refer to Engineering Manual for Chemical and Environmental Considerations.

Pressure		400 psi			335 psi			250 psi			200 psi			160 psi			125 psi			
Rating		DR 6.0			DR 7.0			DR 9.0			DR 11.0			DR 13.5			DR 17			
IPS Pipe Size	Nom OD (in)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	IPS Pipe Size
1"	1.315	0.219	0.851	0.33	0.180	0.933	0.29													
1 1/4"	1.660	0.277	1.073	0.52	0.227	1.179	0.46	0.184	1.270	0.37	0.151	1.340	0.31	0.123	1.399	0.26				1 1/4"
1 1/2"	1.900	0.317	1.228	0.69	0.260	1.349	0.61	0.211	1.453	0.49	0.173	1.533	0.41	0.141	1.601	0.34				1 1/2"
2"	2.375	0.396	1.535	1.07	0.325	1.686	0.95	0.264	1.815	0.77	0.216	1.917	0.64	0.176	2.002	0.53	0.140	2.078	0.43	2"
3"	3.500	0.583	2.264	2.33	0.479	2.485	2.06	0.389	2.675	1.66	0.318	2.826	1.39	0.259	2.951	1.16	0.206	3.063	0.94	3"
4"	4.500	0.750	2.910	3.85	0.616	3.194	3.40	0.500	3.440	2.75	0.409	3.633	2.31	0.333	3.794	1.92	0.265	3.938	1.55	4"
6"	6.625	1.104	4.285	8.35	0.908	4.700	7.37	0.736	5.065	5.96	0.602	5.349	5.00	0.491	5.584	4.15	0.390	5.798	3.36	6"
8"	8.625	1.438	5.576	14.15	1.182	6.119	12.50	0.958	6.594	10.11	0.784	6.963	8.47	0.639	7.270	7.04	0.507	7.550	5.69	8"
10"	10.750	1.792	6.951	21.98	1.473	7.627	19.42	1.194	8.219	15.70	0.977	8.679	13.16	0.796	9.062	10.93	0.632	9.416	8.83	10"
12"	12.750	2.125	8.245	30.92	1.747	9.046	27.31	1.417	9.746	22.08	1.159	10.293	18.51	0.944	10.749	15.38	0.750	11.160	12.43	12"
14"	14.000				1.918	9.934	32.93	1.556	10.701	26.63	1.273	11.301	22.32	1.037	11.802	18.54	0.824	12.253	14.98	14"
16"	16.000				2.192	11.353	43.01	1.778	12.231	34.78	1.455	12.915	29.15	1.185	13.488	24.22	0.941	14.005	19.57	16"
18"	18.000				2.466	12.772	54.43	2.000	13.760	44.02	1.636	14.532	36.89	1.333	15.174	30.65	1.059	15.755	24.77	18"
20"	20.000				2.740	14.191	67.20	2.222	15.289	54.34	1.818	16.146	45.54	1.481	16.860	37.84	1.176	17.507	30.58	20"
22"	22.000				3.014	15.610	81.32	2.444	16.819	65.75	2.000	17.760	55.10	1.630	18.544	45.79	1.294	19.257	37.00	22"
24"	24.000				3.288	17.029	96.77	2.667	18.346	78.25	2.182	19.374	65.58	1.778	20.231	54.49	1.412	21.007	44.03	24"
26"	26.000							2.889	19.875	91.84	2.364	20.988	76.96	1.926	21.917	63.95	1.529	22.759	51.67	26"
28"	28.000							3.111	21.405	106.51	2.545	22.605	89.26	2.074	23.603	74.17	1.647	24.508	59.93	28"
30"	30.000							3.333	22.934	122.27	2.727	24.219	102.47	2.222	25.289	85.14	1.765	26.258	68.80	30"
32"	32.000										2.909	25.833	116.58	2.370	26.976	96.87	1.882	28.010	78.28	32"
34"	34.000										3.091	27.447	131.61	2.519	28.660	109.36	2.000	29.760	88.37	34"
36"	36.000										3.273	29.061	147.55	2.667	30.346	122.60	2.118	31.510	99.07	36"

Pressure ratings are calculated using 0.63 design factor for HDS at 73ÅF as listed in PPI TR-4 for PE4710 materials. Temperature, chemical and environmental use considerations may require use of additional design factors.

Other Sizes and Dimensions Available

Bulletin: PP 155-4710 (PE 3408)
Page 1 of 1

April 2009 supersedes all previous publications

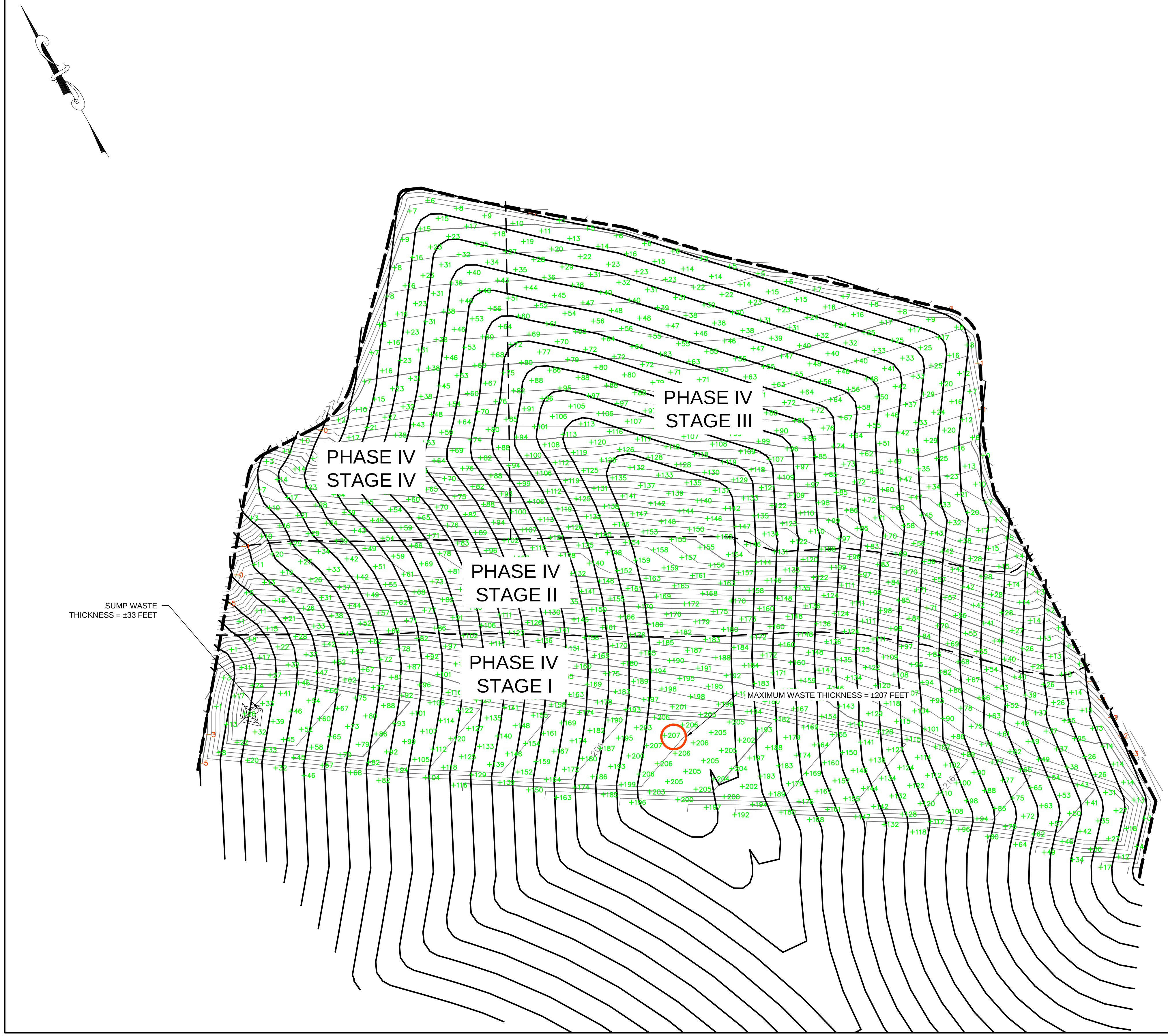
www.performancepipe.com

Performance Pipe, a division of
Chevron Phillips Chemical Company LP

PO Box 269006
Plano, TX 75026-9006

Phone: 800-527-0662
Fax: 972-599-7348

Attachment B



NOTES:

GRADES SHOWN REPRESENT THE SECONDARY LINER GRADES AND FINAL GRADES. SECONDARY LINER GRADES WERE RAISED BY 2.5 FEET AND FINAL GRADES WERE LOWERED BY 3.5 FEET TO CALCULATE WASTE THICKNESS.

LEGEND:

——210——	10-FOOT PHASE IV SECONDARY LINER CONTOUR
————	2-FOOT PHASE IV SECONDARY LINER CONTOUR
——420——	10-FOOT FINAL GRADE CONTOUR
▬ ▬ ▬ ▬	LIMIT OF WASTE
— — — —	STAGE LIMIT
+102	DEPTH OF WASTE (FEET)

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN | HEAD

GRAPHICAL SCALE
80' 40' 0 80' 160'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

WASTE THICKNESS WORKSHEET

PROJECT NUMBER: 3066.11

FIGURE NUMBER: 1 OF 1

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\Proposed Secondary Liner Grades.dwg
IMAGES:

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\Calculations\Depth Worksheet.dwg
LAYOUT: 1
USER: ssantiago
PLOT DATE: 7-9-20 8:54 AM

826K Landfill Compactor Specifications

Attachment C

Engine

Engine Model	Cat C15 ACERT	
Emissions	Tier 4 Final/Stage IV or Tier 3/Stage IIIA equivalent	
Rated Power (Net SAE J1349)	302 kW	405 hp
Rated Power (Net ISO 9249)	302 kW	405 hp
Gross Power	324 kW	435 hp
Net Power		
Direct Drive – Gross Power	307 kW	412 hp
Direct Drive – Torque Rise	33%	
Converter Drive – Gross Power	324 kW	435 hp
Converter Drive – Torque Rise	8.5%	
Maximum Net Torque @ 1,300 rpm	2005 N·m	1,478.8 lbf-ft
Maximum Altitude without Derating (Tier 4 Final/Stage IV)	2834 m	9,298 ft
Maximum Altitude without Derating (Tier 3/Stage IIIA)	2773 m	9,098 ft
Bore	137.2 mm	5.4 in
Stroke	171.4 mm	6.7 in
Displacement	15.2 L	927.6 in³
High Idle Speed	2,300 rpm	
Low Idle Speed	800 rpm	

Operating Specifications

Maximum Operating Weight (Tier 4 Final/Stage IV) – Multiple Blade and Wheel Offerings	40 917 kg	90,207 lb
Maximum Operating Weight – (Tier 3 Final/Stage IIIA equivalent) Multiple Blade and Wheel Offerings	40 454 kg	89,186 lb

Transmission

Transmission Type	Planetary – Powershift – ECPC	
Travel Speeds		
Forward – Maximum Eco Mode	6.9 km/h	4.3 mph
Forward – Maximum 1st	6 km/h	3.7 mph
Forward – Maximum 2nd	10.6 km/h	6.6 mph
Reverse – Maximum Eco Mode	7.4 km/h	4.6 mph
Reverse – Maximum 1st	6.9 km/h	4.3 mph
Reverse – Maximum 2nd	12.2 km/h	7.6 mph

Hydraulic System

Pump Flow at 1,950 rpm	117 L/min	30.9 gal/min
Main Relief Pressure	24 100 kPa	3,495 psi
Maximum Supply Pressure	24 100 kPa	3,495 psi
Lift System	Double Acting Cylinder	
Bore	120 mm	4.7 in
Stroke	1070 mm	42.1 in

Service Refill Capacities

Cooling System	116 L	30.6 gal
Engine Crankcase	34 L	9.0 gal
Transmission	66 L	17.4 gal
Fuel Tank	782 L	206.6 gal
Diesel Exhaust Fluid Tank (Tier 4 Final/Stage IV)	32 L	8.5 gal
Differentials and Final Drives – Front	100 L	26.4 gal
Differentials and Final Drives – Rear	110 L	29.1 gal
Hydraulic Tank Only	134 L	35.4 gal

- All non-road Tier 4 Final and Stage IV diesel engines are required to use:
  - Ultra Low Sulfur Diesel (ULSD) fuels containing 15 ppm (mg kg) sulfur or less. Biodiesel blends up to B20 are acceptable when blended with 15 ppm (mg/kg) sulfur or less ULSD and when the biodiesel feedstock meets ASTM D7467 specifications.
  - Cat DEO-ULS™ or oils that meet the Cat ECF-3, API CJ-4, and ACEA E9 specifications are required.
  - Diesel Exhaust Fluid (DEF) that meets all requirements defined in ISO 22241-1.

Axles

Front	Planetary – Fixed
Rear	Planetary – Oscillating
Oscillation Angle	±5°

Brakes

Parking Brake	Drum and Shoe, Spring Applied, Hydraulic Released

Cab

	Standard	Suppression
Operator Sound Pressure Level (ISO 6396)	73 dB(A)	72 dB(A)
Machine Sound Power Level (ISO 6395)	113 dB(A)	110 dB(A)

Hydraulic System – Steering

Steering System – Circuit	Double Acting – End Mounted	
Bore	114.3 mm	4.5 in
Stroke	576 mm	22.7 in
Steering System – Pump	Piston – Variable Displacement	
Maximum System Flow	170 L/min @ 1,950 rpm	44.9 gal/min @ 1,950 rpm
Steering Pressure Limited	24 000 kPa	3,481 psi
Vehicle Articulation Angle	86 degrees	

Wheels and Tips

Attachment – Wheels: 1200 mm (47.25 in) Paddle and Plus Tips

Weight	9582 kg	21,125 lb
Outside Diameter	1971 mm	6 ft 6 in
Drum Diameter	1610 mm	5 ft 3 in
Drum Width	1200 mm	3 ft 11 in
Tips per Wheel	30	
Width over Drums	3800 mm	12 ft 6 in

Attachment – Wheels: 1200 mm (47.25 in) Plus Tips

Weight	9980 kg	22,002 lb
Outside Diameter	1971 mm	6 ft 6 in
Drum Diameter	1610 mm	5 ft 3 in
Drum Width	1200 mm	3 ft 11 in
Tips per Wheel	30	
Width over Drums	3800 mm	12 ft 6 in

Attachment – Wheels: 1200 mm (47.25 in) Paddle Tips

Weight	9317 kg	20,540 lb
Outside Diameter	1971 mm	6 ft 6 in
Drum Diameter	1610 mm	5 ft 3 in
Drum Width	1200 mm	3 ft 11 in
Tips per Wheel	30	
Width over Drums	3800 mm	12 ft 6 in

File No. 3066.11 Page 1 of 1
Project Phase IV Expansion Project
Location Four Hills Landfill, Nashua, NH
Subject Attachment C – Wheel Load/Contact Area Caclulation
Calculated By L. Tracy Date 3/4/19
Checked By J. Grace Date 4/17/19
P:\3000s\3066.11\Source Files\Type I-A PMA\App A - Design\Att A - Calcs\B - Leachate Collection System\B.3 - Pipe Strength\Attachments\Compactor Load.docx

COMPACTOR WHEEL LOAD AND CONTACT AREA

PURPOSE:

Calculate the wheel load and contact area of the wheels of a Caterpillar 826K Landfill Compactor for use in calculating the vertical live load (P_L) that may be applied to the leachate collection pipe.

GIVEN:

- Weight of the compactor is 90,207 lbs
- Wheel Width is 3 ft 11 in. (47 in.)

METHOD:

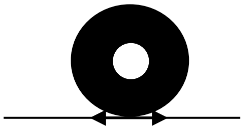
Wheel Load

$$\text{Wheel Load} = \frac{\text{Weight of Compactor}}{\text{4 wheels}}$$

$$\text{Wheel Load} = \frac{\text{90,207 lbs}}{4} = \text{22,552 lbs}$$

Contact Area

Conservatively assume contact over 12 in.



$$\text{Contact Area} = \text{47 in.} \times \text{12 in.} = \text{564 in.}^2 = \text{3.92 ft}^2$$

SANBORN ||| HEAD

File No. 3066.11 Page 1 of 4
Project Phase IV Expansion Project
Location Four Hills Landfill, Nashua New Hampshire
Subject Leachate Collection Pipe Flow Capacity
Calculated By L. Tracy/S. Santiago Date 06/12/2020
Checked By T. Petit/E. Galvin Date 7/7/2020
File: P:\3000s\3066.11\Source Files\Type I-A PMA\App A - Design\Att A - Calcs\B - Leachate Collection System\B.4 - Pipe Capacity\Pipe Flow Capacity.docx

B.4 LEACHATE COLLECTION PIPE FLOW CAPACITY

PURPOSE:

Evaluate the adequacy of an 8-inch diameter SDR 17 HDPE leachate collection pipe based on flow capacity and check that the proposed perforation pattern will permit sufficient flow into the pipe.

DATA:

- Inside diameter of an 8-inch diameter SDR 17 HDPE pipe, d = 7.55 inches (Attachment A);
- Conservatively assume a roughness coefficient for HDPE pipe, n =layer 0.011 (Attachment B);
- Conservatively assume a pipe slope, S = 1.0 percent;
- Conservatively assume full pipe flow (near full pipe conveys more liquid)
- Leachate Generation Rate from HELP model for the base area , q_i = 2,317 cubic feet per acre per day. Leachate Generation Rate from HELP model for the overlay areas with slopes of 5% or less, and slopes greater than 5%, q_i = 2,315 cubic feet per acre per day and q_i = 2,332 cubic feet per acre per day, respectively (See Calculation B-1);
- Conservatively assume a tributary area of 3.6 and 17.5 acres, the approximate traditionally lined and overlay areas of Phase IV, respectively.

METHOD:

Use Manning's Equation to estimate the capacity of the proposed 8-inch diameter SDR 17 HDPE leachate collection pipe. Estimate leachate flow based on HELP model results and compare to the flow capacity provided by the pipe. Confirm that the proposed perforation pattern permits sufficient flow into the leachate collection pipe.

CALCULATION:

Pipe Capacity:

Calculate the leachate collection pipe capacity using Manning's equation:

$$Q_{pipe} = \frac{1.486}{n} A\, R^{2/3}\, S^{1/2}$$

Where:

Q_{pipe} = flow (cfs)
n = Manning's roughness coefficient, use 0.011 for smooth pipe
A = pipe cross-sectional area (ft^2)
R = Hydraulic radius (ft)
S = Slope (ft/ft)

The cross-sectional area of the pipe is calculated using the inside diameter, which for SDR 17 HDPE pipe is 7.55 inches or 0.629 feet.

$$A = \frac{\pi d^2}{4} = \frac{\pi(0.629)^2}{4} = 0.311\ \text{ft}^2$$

For a pipe flowing full, the hydraulic radius is 25% of the pipe inner diameter = 0.157 ft

$$Q_{\text{pipe}} = \frac{1.486}{0.011} \times 0.311 \times 0.157^{2/3}\ 0.01^{1/2}$$

$$Q_{\text{pipe}} = 1.22\ \text{cfs}$$

Leachate Generation:

According to the HELP model results from Calculation B.1, the leachate generation rate is expected to be 2,317 cubic feet per acre per day for the base section of Phase IV. Applying this rate to the traditionally lined area of Phase IV, 3.6 acres, and converting to units of cubic feet per second (cfs):

$$Q_{\text{design}} = \frac{2{,}317\ \text{ft}^3}{\text{acre} \times \text{day}} \times 3.6\ \text{acres} \times \frac{\text{day}}{86{,}400\ \text{sec}} = 0.10\ \text{cfs}\ \ (\text{base area})$$

According to the HELP model results from Calculation B-1, the leachate generation rate is expected to be 2,315 cubic feet per acre per day for the overlay section of Phase IV with slopes of 5% or less. Applying this rate to the overlay area with slopes of 5% or less, 6.4 acres, and converting to units of cubic feet per second (cfs):

$$Q_{\text{design}} = \frac{2{,}315\ \text{ft}^3}{\text{acre} \times \text{day}} \times 6.4\ \text{acres} \times \frac{\text{day}}{86{,}400\ \text{sec}} = 0.17\ \text{cfs}\ \ (\text{overlay area with slopes} \leq 5\%)$$

According to the HELP model results from Calculation B-1, the leachate generation rate is expected to be 2,332 cubic feet per acre per day for the overlay section of Phase IV with slopes greater than 5%. Applying this rate to the overlay area with slopes greater than 5%, 11.1 acres, and converting to units of cubic feet per second (cfs):

$$Q_{\text{design}} = \frac{2{,}332\ \text{ft}^3}{\text{acre} \times \text{day}} \times 11.1\ \text{acres} \times \frac{\text{day}}{86{,}400\ \text{sec}} = 0.30\ \text{cfs}\ \ (\text{overlay area with slopes} > 5\%)$$

Compare the pipe capacity with the combined estimated flows of leachate:

$$FS = \frac{Q_{\text{pipe}}}{Q_{\text{design}}} = \frac{1.22\ \text{cfs}}{(0.10\ \text{cfs} + 0.17\ \text{cfs} + 0.30\ \text{cfs})} = 2.14$$

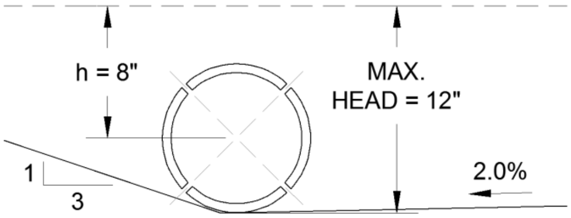
Pipe Perforations:

Confirm that the proposed perforation pattern permits sufficient flow into the leachate collection pipes by comparing the expected leachate flow over an assumed length of pipe (say 100 feet).

Use the orifice equation to estimate the inlet capacity provided by the perforations over a length of 100 feet.

$$Q = C_d\ a\ \sqrt{2gh}$$

Where: Q = flow (cfs)
C_d = discharge coefficient (use 0.6)
a = submerged area (ft^2)
g = gravitational constant (32.2 ft/sec^2)
h = effective head = 8 in = 0.67 ft



The proposed perforation pattern provides 8, ½-inch diameter holes per foot of pipe. The area of the perforations over a length of 100 feet is:

$$a = \frac{\pi d^2}{4} \times 8\ \text{holes/ft} \times 100\ \text{ft}$$

Where: d = perforation diameter = ½ in = 0.042 ft

$$a = \frac{\pi(0.042)^2}{4} \times 8\ \text{holes/ft} \times 100\ \text{ft}$$

$$a = 1.11\ \text{ft}^2$$

$$Q = 0.6 \times 1.11\ \text{ft}^2 \sqrt{2 \times 32.2\ \frac{\text{ft}}{\text{sec}^2} \times 0.67\ \ \text{ft}}$$

$$Q = 4.34\ \text{cfs}$$

$$\frac{Q_{\text{perf}}}{Q_{\text{design}}} = \frac{4.34\ \text{cfs}}{0.57\ \text{cfs}} = 8$$

CONCLUSIONS:

Comparing the expected flows with the calculated pipe capacities, the pipes have sufficient capacity to convey the expected flows to the leachate sump. Therefore, the perforations will not inhibit the flow of leachate into the leachate collection pipes.

ATTACHMENTS

Attachment A	PE4710 (PE3408) Pipe Data Table
Attachment B	Table 8 – Values of n For Use with Manning Equation taken from Performance Pipe Field Handbook

Attachment A

PE 4710 (PE3408)
Energy - DriscoPlex$^{®}$ 6400 Series
PE4710 IPS Pipe Data

Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter calculated using nominal OD and minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimensions and tolerances in applicable pipe specifications. Pressure Ratings are for water at 73.4ÁF. For other fluid and service temperature, ratings may differ. Refer to Engineering Manual for Chemical and Environmental Considerations.

Pressure		400 psi			335 psi			250 psi			200 psi			160 psi			125 psi			
Rating		DR 6.0			DR 7.0			DR 9.0			DR 11.0			DR 13.5			DR 17			
IPS Pipe Size	Nom OD (in)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	Min Wall (in)	Avg ID (in)	Wgt (lbs/ft)	IPS Pipe Size
1"	1.315	0.219	0.851	0.33	0.180	0.933	0.29													
1 1/4"	1.660	0.277	1.073	0.52	0.227	1.179	0.46	0.184	1.270	0.37	0.151	1.340	0.31	0.123	1.399	0.26				1 1/4"
1 1/2"	1.900	0.317	1.228	0.69	0.260	1.349	0.61	0.211	1.453	0.49	0.173	1.533	0.41	0.141	1.601	0.34				1 1/2"
2"	2.375	0.396	1.535	1.07	0.325	1.686	0.95	0.264	1.815	0.77	0.216	1.917	0.64	0.176	2.002	0.53	0.140	2.078	0.43	2"
3"	3.500	0.583	2.264	2.33	0.479	2.485	2.06	0.389	2.675	1.66	0.318	2.826	1.39	0.259	2.951	1.16	0.206	3.063	0.94	3"
4"	4.500	0.750	2.910	3.85	0.616	3.194	3.40	0.500	3.440	2.75	0.409	3.633	2.31	0.333	3.794	1.92	0.265	3.938	1.55	4"
6"	6.625	1.104	4.285	8.35	0.908	4.700	7.37	0.736	5.065	5.96	0.602	5.349	5.00	0.491	5.584	4.15	0.390	5.798	3.36	6"
8"	8.625	1.438	5.576	14.15	1.182	6.119	12.50	0.958	6.594	10.11	0.784	6.963	8.47	0.639	7.270	7.04	0.507	7.550	5.69	8"
10"	10.750	1.792	6.951	21.98	1.473	7.627	19.42	1.194	8.219	15.70	0.977	8.679	13.16	0.796	9.062	10.93	0.632	9.410	8.83	10"
12"	12.750	2.125	8.245	30.92	1.747	9.046	27.31	1.417	9.746	22.08	1.159	10.293	18.51	0.944	10.749	15.38	0.750	11.160	12.43	12"
14"	14.000				1.918	9.934	32.93	1.556	10.701	26.63	1.273	11.301	22.32	1.037	11.802	18.54	0.824	12.253	14.98	14"
16"	16.000				2.192	11.353	43.01	1.778	12.231	34.78	1.455	12.915	29.15	1.185	13.488	24.22	0.941	14.005	19.57	16"
18"	18.000				2.466	12.772	54.43	2.000	13.760	44.02	1.636	14.532	36.89	1.333	15.174	30.65	1.059	15.755	24.77	18"
20"	20.000				2.740	14.191	67.20	2.222	15.289	54.34	1.818	16.146	45.54	1.481	16.860	37.84	1.176	17.507	30.58	20"
22"	22.000				3.014	15.610	81.32	2.444	16.819	65.75	2.000	17.760	55.10	1.630	18.544	45.79	1.294	19.257	37.00	22"
24"	24.000				3.288	17.029	96.77	2.667	18.346	78.25	2.182	19.374	65.58	1.778	20.231	54.49	1.412	21.007	44.03	24"
26"	26.000							2.889	19.875	91.84	2.364	20.988	76.96	1.926	21.917	63.95	1.529	22.759	51.67	26"
28"	28.000							3.111	21.405	106.51	2.545	22.605	89.26	2.074	23.603	74.17	1.647	24.508	59.93	28"
30"	30.000							3.333	22.934	122.27	2.727	24.219	102.47	2.222	25.289	85.14	1.765	26.258	68.80	30"
32"	32.000										2.909	25.833	116.58	2.370	26.976	96.87	1.882	28.010	78.28	32"
34"	34.000										3.091	27.447	131.61	2.519	28.660	109.36	2.000	29.760	88.37	34"
36"	36.000										3.273	29.061	147.55	2.667	30.346	122.60	2.118	31.510	99.07	36"

Pressure ratings are calculated using 0.63 design factor for HDS at 73ÁF as listed in PPI TR-4 for PE4710 materials. Temperature, chemical and environmental use considerations may require use of additional design factors.

Other Sizes and Dimensions Available

Bulletin: PP 155-4710 (PE 3408)
Page 1 of 1

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April 2009 supersedes all previous publications

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Plano, TX 75026-9006

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Fax: 972-599-7348

Attachment B

Hazen-Williams formula for friction (head) loss in psi:

$$p_f = \frac{0.0009015\,L}{d^{4.8655}}\left(\frac{100\,Q}{C}\right)^{1.85}$$

Where

h_f = friction (head) loss, feet of water
L = pipe length, ft
d = pipe inside diameter, in.
Q = flow, gal./min.
C = Hazen-Williams Friction Factor, dimensionless
p_f = friction (head) loss for water, psi

Table 7 Hazen-Williams Friction Factor, C

Pipe Material	*Values for C*		
	Range High / Low	*Average Value*	*Typical Design Value*
Polyethylene pipe or tubing	160 / 150	150-155^A	150
Cement or mastic lined iron or steel pipe	160 / 130	148	140
Copper, brass, lead, tin or glass pipe or tubing	150 / 120	140	130
Wood stave	145 / 110	120	110
Welded and seamless steel	150 / 80	130	100
Cast and ductile iron	150 / 80	130	100
Concrete	152 / 85	120	100
Corrugated steel	–	60	60
^{A} Determined on butt fused pipe with internal beads in place.			

Water flows through pipes of different materials and diameters may be compared using the following formula. The subscripts 1 and 2 refer to the known pipe and the unknown pipe.

$$\%\,flow = 100\,\frac{d_2}{d_1}\left(\frac{C_2}{C_1}\right)^{0.3806}$$

Manning

For open channel water flow under conditions of constant grade, and uniform channel cross section, the Manning equation may be used. Open channel flow exists in a pipe when it runs partially full. Like the Hazen-Williams formula, the Manning equation is limited to water or liquids with a kinematic viscosity equal to water.

Manning Equation

$$V = \frac{1.486}{n} r^{2/3} S^{1/2}$$

where

V = flow velocity, ft/sec
n = roughness coefficient, dimensionless (Table 8)
r = hydraulic radius, ft

$$r = \frac{A}{P}$$

A = channel cross section area, ft^2
P = perimeter wetted by flow, ft
S = hydraulic slope, ft/ft

$$S = \frac{h_1 - h_2}{L} = \frac{h_f}{L}$$

h_1 =upstream pipe elevation, ft
h_2 = downstream pipe elevation, ft
h_f = friction (head) loss, ft of liquid

It is convenient to combine the Manning equation with

$$Q = AV$$

To obtain

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

Where terms are as defined above, and

Q = flow, cu-ft/sec

When a circular pipe is running full or half-full,

$$r = \frac{D}{4} = \frac{d}{48}$$

Where

D = pipe bore, ft
d = pipe bore, in

Full pipe flow in cu-ft per second may be estimated using:

$$Q = \left(6.136 \times 10^{-4}\right)\frac{d^{8/3} S^{1/2}}{n}$$

Full pipe flow in gallons per minute may be estimated using:

$$Q' = 0.275 \frac{d^{8/3} S^{1/2}}{n}$$

Nearly full circular pipes will carry more liquid than a completely full pipe. When slightly less than full, the hydraulic radius is significantly reduced, but the actual flow area is only slightly lessened. Maximum flow is achieved at about 93% of full pipe flow, and maximum velocity at about 78% of full pipe flow.

Table 8 Values of n for use with Manning Equation

Surface	*n, range*	*n, typical design*
Polyethylene pipe	0.008 – 0.011	0.009
Uncoated cast or ductile iron pipe	0.012 – 0.015	0.013
Corrugated steel pipe	0.021 – 0.030	0.024
Concrete pipe	0.012 – 0.016	0.015
Vitrified clay pipe	0.011 – 0.017	0.013
Brick and cement mortar sewers	0.012 – 0.017	0.015
Wood stave	0.010 – 0.013	0.011
Rubble masonry	0.017 – 0.030	0.021

Comparative Flows for Slipliners

Sliplining rehabilitation of deteriorated gravity flow sewers involves installing a polyethylene liner inside of the original pipe. For conventional sliplining, clearance between the liner outside diameter, and the existing pipe bore is required to install the liner. So after rehabilitation, the flow channel is smaller than the original pipe. However, DriscoPlex® polyethylene pipe has a smooth surface that resists aging and deposition. It may be

B.5 SECONDARY TRAVEL TIME

PURPOSE:

Demonstrate that the critical flow path in the secondary leachate collection system (LCS) meets the 24-hour detection time required by Env-Sw 805.07(b)(1).

ASSUMPTIONS AND DATA:

- The proposed secondary LCS pipe is an 8-in. diameter SDR 17 HDPE pipe, with an inside diameter of 7.55 in. and a Manning's Coefficient of 0.011. Conveying a depth of flow of 0.01 ft.
- The shallowest slope of the pipe is applied over the entire length.
- Typical drainage geocomposite thickness = 0.25 in. [Reference 1]
- Porosity values for a geonet component of the drainage geocomposite typically range from 0.4 to 0.8 [Reference 2]. For this calculation, a value of 0.7 was used.
- The geocomposite is saturated.

METHOD:

- Evaluate critical flow paths located in Phase IV.
- Calculate the travel time in the pipe, if applicable, and subtract from 24 hours to arrive at the allowable travel time in the drainage geocomposite.
- Calculate the allowable transmissivity for the geocomposite for each critical flow path in order to meet the 24-hour leak detection time.
- Apply reduction factors and calculate the required transmissivity for the geocomposite in order to meet the 24-hour leak detection time.

CALCULATION: EXAMPLE CALCULATION FOR PATH 2

1. Use Manning's Equation to solve for the velocity in the 8-inch diameter HDPE SDR 17 pipe:

$$v = \frac{1.49\,(R_h^{\frac{2}{3}} \times S^{\frac{1}{2}})}{n}$$

Where:

v = velocity (ft/sec)
R_h = Hydraulic radius = A/P_w
A = Flow area = $\frac{r^2(\theta - \sin\theta)}{2}$
P_W = Wetted perimeter = $r \times \theta$
r = Radius = $\frac{7.55\text{ in.}}{2}$. = 3.78 in. = 0.315 ft
θ = Central angle (radians) = $2\arccos\frac{r-h}{r}$
h = Depth of flow = 0.01 ft
S = Slope = 0.024 ft/ft (See Attachment A)
n = Manning's Roughness Coefficient = 0.011

$$\theta = 2\arccos\frac{r-h}{r} = 2\arccos\frac{0.315\text{ ft} - 0.010\text{ft}}{0.315\text{ ft}} = 0.505\text{ radians}$$

$$P_w = r \times \theta = 0.315\text{ ft} \times 0.505\text{ radians} = 0.159\text{ ft}$$

$$A = \frac{r^2(\theta - \sin\theta)}{2} = \frac{(0.315\text{ ft})^2(0.505 - \sin(0.505\text{ rad}))}{2} = 0.00105\text{ ft}^2$$

$$R_h = \frac{A}{P_w} = \frac{0.00105\text{ ft}^2}{0.159\text{ ft}} = 0.00660\text{ ft}$$

$$v = \frac{1.49(0.00660\text{ ft}^{\frac{2}{3}} \times 0.024^{\frac{1}{2}})}{0.011} = 0.738\text{ ft/sec}$$

Using a velocity of 0.738 ft/sec, and a pipe drainage length of 1,236 ft (see Attachment A) the travel time in the pipe = $\frac{1{,}236\text{ ft}}{0.738\text{ ft/sec}}$ = 1,675 seconds.

2. Calculate the allowable transmissivity for the drainage geocomposite based on Darcy's Law:

$$q = kiA = (kt)iw = Tiw \qquad \text{[Reference 2, Eq 5.12]}$$

Where:

Q = Flow (ft^3/sec)
k = Hydraulic conductivity (ft/sec)
i = Gradient or base slope
A = Cross sectional area of geocomposite (ft^2)
t = Thickness of geocomposite (ft)
T = Transmissivity (ft^2/sec)
w = Width (ft)
V = Velocity (ft/sec)

Substituting:

$$q = VA = V(tw)$$
$$Vtw = Tiw$$
$$V = Ti/t \qquad \text{[Reference 2, Eq 5.13]}$$

According to the Design Manual of Lateral Drainage Systems for Landfills [Reference 2] the true velocity (also known as the average linear velocity or seepage velocity) through the geonet core of the geocomposite will be greater than the velocity calculated using the equation above due to the reduction in flow area as a result of the pore spaces between the ribs in the geonet. True velocity (V_{true}) is calculated by dividing the apparent velocity by the porosity (n) of the geonet. Therefore,

$$V_{true} = \frac{T \times i}{t \times n} \qquad \text{[Reference 2, Eq 5.14]}$$

t = Thickness of the drainage geocomposite = 0.25 in. (0.021 ft)

i = Gradient of leachate traveling through the geocomposite (ft/ft)

n = porosity = 0.7

$$V_{actual} = \frac{T \times i}{(0.021)(0.7)} = 68.0 \times T \times i$$

The maximum travel time in the geocomposite must be less than or equal to 23.53 hours (84,725 seconds). Calculate the required transmissivity, (T) for a travel time in the geocomposite less than or equal to 84,725 seconds.

$$\text{Travel Time } = \sum \frac{D}{V_{actual}} = \frac{D_1}{68\,Ti_1} + \frac{D_2}{68\,Ti_2} + \ldots$$

$$84{,}725 = \frac{12}{68.0 \times T \times 0.50} + \frac{278}{68.0 \times T \times 0.05} + \frac{35}{68.0 \times T \times 0.056} + \frac{317}{68.0 \times T \times 0.157} + \frac{96}{68.0 \times T \times 0.083} + \frac{20}{68.0 \times T \times 0.33}$$

$$T_{allowed} = 1.64 \times 10^{-3}\frac{ft^2}{sec} = 1.53 \times 10^{-4}\frac{m^2}{sec}$$

3. Calculate the required transmissivity ($T_{required}$) for the drainage geocomposite based on the allowable transmissivity (T_{allow}), and Reduction factors (∑RF).

$$T_{required} = T_{allow} \times \sum RF \qquad \text{[Ref 3, Eq 8.12]}$$

Where:

RF_{IN} = Reduction factor for intrusion of the adjacent geotextiles into the drainage core;
RF_{CR} = Reduction factor for creep deformation of the drainage core;
RF_{CC} = Reduction factor for chemical clogging; and
RF_{BC} = Reduction factor for biological clogging.

$$\sum RF = RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}$$

Reduction factors for chemical and biological clogging were taken as 1.1 due to recommended values stated in GRI-GC8 for a landfill leak detection system [Reference 4].

RF_{in} = 1.5
RF_{cr} = 1.4
RF_{cc} = 1.1
RF_{bc} = 1.1

$$\sum RF = 1.5 \times 1.4 \times 1.1 \times 1.1 = 2.54$$

$$T_{\text{required}} = 1.53 \times 10^{-4}\ \text{m}^2/\text{sec} \times 2.54 = 3.89 \times 10^{-4}\ \text{m}^2/\text{sec}$$

CONCLUSIONS:

The critical path shown in Attachment A results in a required transmissivity of 3.89×10^{-4} m^2/sec to meet the 24-hour detection time required by Env-Sw 805.07(b)(1).

REFERENCES:

[1] Richardson G.N., Zhao A., Giroud G.P. (1999), *Design of Lateral Drainage Systems for Landfills*. Tenax Corp., Baltimore, MD.

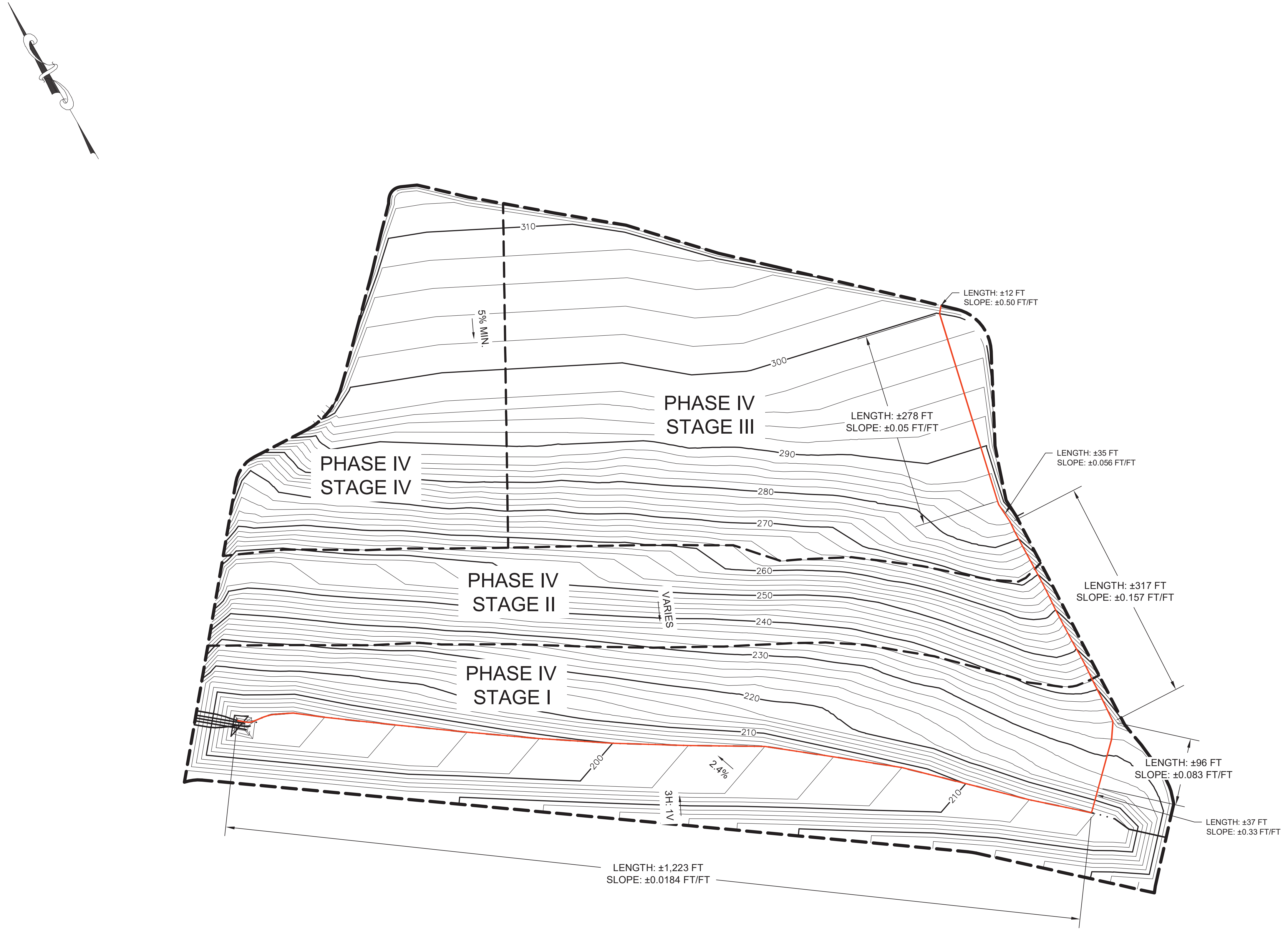
[2] Geosynthetics Magazine (2015), *Drainage Product Data*, Industrial Fabrics Association International, pp 1-6.

[3] Koerner, Robert M. (2012), *Designing with Geosynthetics*, 6th ed. Vol. 2, Xlibris Corporation, pp 872-873.

[4] GRI Standard – GC8 (2001), *Determination of the Allowable Flow Rate of a Drainage Geocomposite,* Rev. 1. Geosynthetics Research Institute, Folsom, PA.

ATTACHMENTS

Attachment A	Secondary Travel Time Worksheet



NOTES:

1. BASE GRADES REPRESENT THE SECONDARY LINER GRADES.

LEGEND:

—210—	PROPOSED 10-FOOT CONTOUR
—	PROPOSED 2-FOOT CONTOUR
▬ ▬ ▬	LIMIT OF WASTE
— · · — · · —	PERFORATED LEACHATE COLLECTION PIPE
—	SOLID LEACHATE RISER PIPE
—	CRITICAL LEACHATE FLOW PATH

- NOT FOR CONSTRUCTION -

FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE

80' 40' 0 80' 160'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: T. PETIT
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: APRIL 2019

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

SECONDARY TRAVEL TIME WORKSHEET

PROJECT NUMBER: 3066.11

FIGURE NUMBER: 1

IMAGES:

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FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\Calculations\Secondary Travel Time.dwg
LAYOUT: 1
USER: jgrace
PLOT DATE: 4-17-19 4:55 PM

C.1 PHASE IV PUMP SIZING (CONTINGENCY)

PURPOSE:

Calculate the pump sizes needed; (i) to remove the volume of leachate, associated with Phase III, generated during a stormwater contingency event and (ii) to operate under normal conditions. The stormwater contingency event is defined as the liquid associated with a 100-year, 24-hour storm event occurring at a time when a lined cell is initially open. [Ref. 1]

DATA:

- Rainfall generated from a 100-year, 24-hour storm event = 7.85 inches [Attachment A]
- Open and tributary areas of Phase IV, see Figure 1 [Attachment B]
- Based on New Hampshire Solid Waste Rule Env-Sw 805.06(f), the liquid associated with the stormwater contingency event is to be removed from an active cell within 7 days.
- Historic leachate flows, see Table 1 [Attachment C].

METHOD:

Contingency Event

Evaluate the each stage to estimate the maximum pumping rate required for Phase IV during a stormwater contingency event, and complete the subsequent steps.

1. Delineate the following areas for each Stage of construction (see Attachment B):

   a) Open area; and
   b) Additional tributary area contributing stormwater runoff.

2. Calculate the stormwater volume associated with the stormwater contingency event assuming 100 percent of the precipitation falling on an active Phase and 50 percent of the precipitation falling on the additional tributary areas.

3. Calculate the pumping rate required to remove the total liquid volume within 7 days.

Normal Operating Conditions

Calculate the expected leachate flow and pumping rate associated with active Phase IV using annual average Phase I and II leachate generation data from 2011-2020 (see Attachment C).

Total Facility Leachate Estimate

Calculated the expected total leachate removal required for Phases I through IV.

CALCULATION:

Contingency Event

1. The open areas for operations scenarios expected to occur throughout development of Phase IV were calculated and are shown on Attachment B entitled "Contributing Areas." The tributary slope areas were estimated based on this grading which is consistent with the grading shown on the interim grading sheets within the design plans. Below is a list of base and tributary slope areas and the corresponding volumes produced by applying the contingency storm event rainfall depth over them (100% in open areas and 50% in tributary areas).

2. Calculate the stormwater volume associated with the stormwater contingency event assuming 100 percent of the precipitation falling on an active cell and 50 percent of the precipitation falling on the additional tributary areas. The total contingency volume for Stage I is calculated below (contingency volumes for the other stages are summarized in the table below):

$$\text{Open Area Contingency Volume} = \frac{7.85\text{ in.}}{12\,\frac{\text{in.}}{\text{ft}}} \times 320{,}500\text{ ft}^2 \times \frac{7.48052\text{ gal}}{\text{ft}^3}$$
$$= 1{,}568{,}400\text{ gallons (gals)}$$

$$\text{Tributary Area Contingency Volume} = 50\% \times \left(\frac{7.85\text{ in.}}{12\,\frac{\text{in.}}{\text{ft}}} \times 0\text{ ft}^2 \times \frac{7.48052\text{ gal}}{\text{ft}^3}\right) = 0\text{ gals}$$

$$\text{Total Contingency Volume} = 1{,}568{,}400\text{ gals} + 0\text{ gals} = 1{,}568{,}400\text{ gals}$$

Phase IV Stage Designation	Rainfall (in)	Open Area (ft²)	Open Area Contingency Volume (gals)	Tributary Area (ft²)	Tributary Area Contingency Volume (gals)	Total Contingency Volume (gals)
Stage I	7.85	320,500	1,568,400	0	0	1,568,400
Stage II		161,900	792,300	69,400	169,800	962,000
Stage III		287,200	1,405,400	25,100	61,400	1,466,800
Stage IV		127,100	622,000	44,500	108,900	730,800

3. Calculate the pumping rate required to remove the total liquid volume within 7 days for Phase IV. The pumping rate for Stage I is calculated below (pumping rates for the other stages are summarized in the table below):

$$1{,}568{,}400\text{ gal} \times \frac{1}{7\text{ days}} \times \frac{1\text{ day}}{24\text{ hr}} \times \frac{1\text{ hr}}{60\text{ min}} = 155\,\frac{\text{gal}}{\text{min}}$$

Phase IV Stage Designation	Total Contingency Volume (gals)	Pumping Rate (gpm)
Stage I	1,817,700	155
Stage II	962,000	95
Stage III	1,466,800	146
Stage IV	730,800	73

Phase IV Normal Operating Conditions

According to Attachment C, the maximum leachate generation for Phases I and II occurred in 2011. Conservatively assume that the expected Phase IV (21.2 acres) leachate generation is 1,946 gpad.

$$1{,}946 \text{ gpad } \times 21.2 \text{ ac} = 41{,}255 \text{ gpd}$$

$$41{,}255 \text{ gpd } \times \frac{1 \text{ days}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 29 \frac{\text{gal}}{\text{min}}$$

Total Facility Leachate Estimate

Because operations recently began in Phase III, the current Phase III leachate flows are not representative of the flows that will be generated within Phase III when Phase IV becomes operational. Conservatively assume that the expected normal operating condition flow for Phase III (5.8 acres) is similar to the maximum leachate generation for Phases I and II (27.7 acres) in 2011.

$$1{,}946 \text{ gpad } \times (27.7 \text{ ac} + 5.8 \text{ ac}) = 65{,}191 \text{ gpd}$$

$$65{,}191 \text{ gpd } \times \frac{1 \text{ days}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 45 \frac{\text{gal}}{\text{min}}$$

During the contingency storm event, the City will be required to pump the contingency storm event volume within Phase IV and the operating flow for Phases I through III:

$$45 \frac{\text{gal}}{\text{min}} + 155 \frac{\text{gal}}{\text{min}} = 200 \frac{\text{gal}}{\text{min}}$$

RESULTS:

For the Phase IV sump, the pumping rate required to remove leachate from the liner system within seven days of the contingency event and normal operating conditions is 155 gpm and 29 gpm, respectively.

Specify a pump capable of pumping 155 gpm for the contingency event (Cleanout Riser).

Specify a pump capable of pumping 29 gpm for normal operating conditions (Primary & Secondary Riser).

The expected maximum pumping rate aligns with the City's discharge limit to the City's sewer system of 200 gpm.

REFERENCES:

[1] State of New Hampshire, Department of Environmental Services, 2008, *Volume 2: Post Construction Best Management Practices: Selection and Design*.

ATTACHMENTS:

Attachment A	Extreme Precipitation Tables
Attachment B	Figure 1 – Contributing Areas
Attachment C	Historic Leachate Flow – Four Hills Landfill, Nashua, New Hampshire

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Attachment A

Extreme Precipitation Tables

Northeast Regional Climate Center

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

Smoothing	Yes
State	New Hampshire
Location	
Longitude	71.522 degrees West
Latitude	42.732 degrees North
Elevation	0 feet
Date/Time	Tue, 10 Apr 2018 08:36:01 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.28	0.42	0.53	0.69	0.86	1.08	**1yr**	0.74	1.02	1.25	1.57	1.98	2.50	2.76	**1yr**	2.21	2.66	3.08	3.79	4.40	**1yr**
2yr	0.33	0.51	0.64	0.84	1.06	1.33	**2yr**	0.92	1.22	1.54	1.92	2.39	2.97	3.31	**2yr**	2.63	3.19	3.69	4.42	5.03	**2yr**
5yr	0.40	0.62	0.77	1.03	1.32	1.68	**5yr**	1.14	1.53	1.94	2.42	3.01	3.72	4.20	**5yr**	3.29	4.04	4.67	5.55	6.26	**5yr**
10yr	0.44	0.70	0.88	1.20	1.56	2.00	**10yr**	1.35	1.80	2.32	2.90	3.59	4.42	5.02	**10yr**	3.91	4.83	5.59	6.60	7.39	**10yr**
25yr	0.53	0.84	1.07	1.47	1.95	2.51	**25yr**	1.68	2.26	2.93	3.66	4.53	5.55	6.38	**25yr**	4.91	6.13	7.09	8.31	9.21	**25yr**
50yr	0.59	0.95	1.22	1.71	2.31	3.01	**50yr**	2.00	2.67	3.51	4.39	5.41	6.60	7.65	**50yr**	5.84	7.35	8.49	9.88	10.88	**50yr**
100yr	0.68	1.10	1.42	2.01	2.74	3.58	**100yr**	2.37	3.17	4.19	5.24	6.45	7.85	9.17	**100yr**	6.95	8.81	10.17	11.76	12.86	**100yr**
200yr	0.78	1.27	1.64	2.35	3.25	4.28	**200yr**	2.81	3.75	5.01	6.27	7.70	9.34	11.00	**200yr**	8.27	10.57	12.19	14.01	15.20	**200yr**
500yr	0.93	1.53	2.00	2.91	4.08	5.40	**500yr**	3.52	4.71	6.34	7.94	9.74	11.77	14.00	**500yr**	10.41	13.46	15.49	17.65	18.98	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.22	0.34	0.41	0.55	0.68	0.79	**1yr**	0.59	0.77	1.04	1.34	1.68	2.33	2.51	**1yr**	2.06	2.41	2.69	3.44	4.04	**1yr**
2yr	0.32	0.49	0.60	0.82	1.01	1.21	**2yr**	0.87	1.18	1.37	1.79	2.29	2.87	3.22	**2yr**	2.54	3.10	3.58	4.27	4.88	**2yr**
5yr	0.36	0.56	0.69	0.95	1.21	1.42	**5yr**	1.04	1.39	1.63	2.12	2.71	3.42	3.97	**5yr**	3.03	3.82	4.33	5.08	5.80	**5yr**
10yr	0.40	0.61	0.76	1.06	1.36	1.59	**10yr**	1.18	1.56	1.80	2.40	3.06	3.90	4.52	**10yr**	3.45	4.35	5.00	5.78	6.61	**10yr**
25yr	0.45	0.69	0.85	1.22	1.60	1.86	**25yr**	1.38	1.82	2.10	2.84	3.58	4.66	5.49	**25yr**	4.12	5.28	6.10	6.88	7.83	**25yr**
50yr	0.49	0.74	0.92	1.33	1.79	2.10	**50yr**	1.54	2.06	2.36	3.23	4.04	5.34	6.38	**50yr**	4.72	6.14	7.10	7.85	8.93	**50yr**
100yr	0.53	0.80	1.00	1.45	1.98	2.37	**100yr**	1.71	2.32	2.65	3.34	4.56	6.13	7.45	**100yr**	5.43	7.16	8.28	8.96	10.21	**100yr**
200yr	0.58	0.87	1.10	1.59	2.22	2.67	**200yr**	1.92	2.61	2.96	3.75	5.18	7.07	8.71	**200yr**	6.26	8.38	9.66	10.21	11.71	**200yr**
500yr	0.65	0.96	1.24	1.80	2.56	3.15	**500yr**	2.21	3.08	3.46	4.35	6.16	8.53	10.75	**500yr**	7.55	10.34	11.91	12.20	13.99	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.31	0.48	0.59	0.79	0.97	1.14	**1yr**	0.84	1.12	1.29	1.68	2.11	2.66	2.99	**1yr**	2.36	2.87	3.37	4.12	4.71	**1yr**
2yr	0.36	0.55	0.68	0.92	1.13	1.32	**2yr**	0.98	1.29	1.50	1.94	2.49	3.10	3.44	**2yr**	2.74	3.31	3.84	4.60	5.23	**2yr**
5yr	0.44	0.67	0.83	1.15	1.46	1.69	**5yr**	1.26	1.65	1.90	2.43	3.05	4.07	4.42	**5yr**	3.60	4.25	5.05	5.98	6.70	**5yr**
10yr	0.52	0.80	0.99	1.39	1.79	2.07	**10yr**	1.55	2.02	2.35	2.91	3.62	5.02	5.63	**10yr**	4.44	5.42	6.23	7.31	8.11	**10yr**
25yr	0.67	1.02	1.26	1.80	2.37	2.70	**25yr**	2.05	2.64	3.05	3.68	4.52	6.64	7.43	**25yr**	5.87	7.15	8.23	9.54	10.43	**25yr**
50yr	0.80	1.22	1.52	2.19	2.95	3.30	**50yr**	2.54	3.22	3.73	4.41	5.35	8.20	9.16	**50yr**	7.26	8.81	10.13	11.66	12.62	**50yr**
100yr	0.97	1.47	1.84	2.66	3.65	4.04	**100yr**	3.15	3.95	4.56	5.70	6.33	10.10	11.29	**100yr**	8.93	10.86	12.47	14.24	15.24	**100yr**
200yr	1.18	1.77	2.24	3.25	4.53	4.94	**200yr**	3.91	4.83	5.56	6.91	7.50	12.43	13.90	**200yr**	11.00	13.36	15.34	17.41	18.43	**200yr**
500yr	1.52	2.27	2.92	4.24	6.03	6.42	**500yr**	5.20	6.28	7.25	8.92	9.38	16.36	18.27	**500yr**	14.48	17.57	20.15	22.71	23.70	**500yr**

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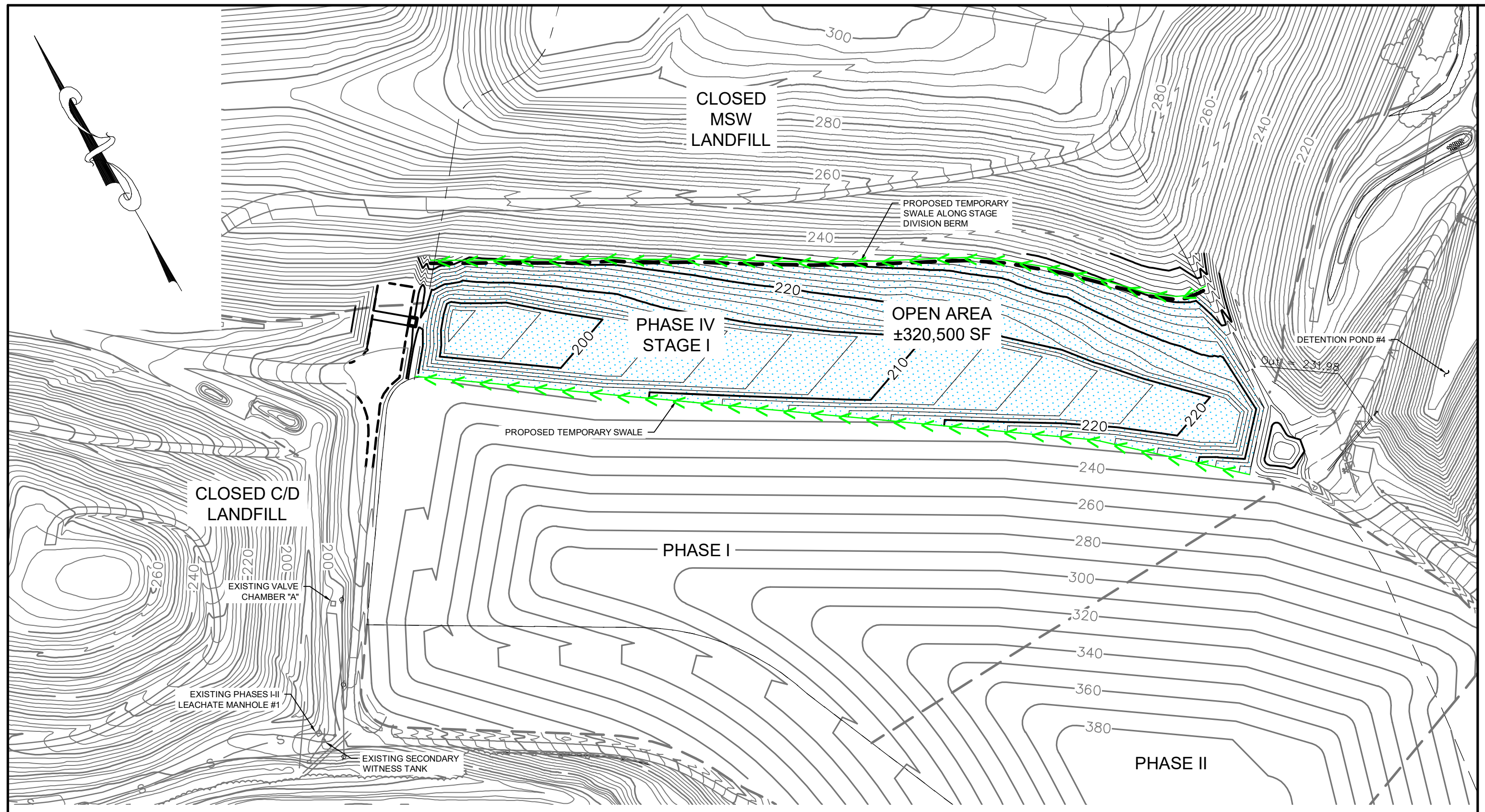
Northeast Regional
Climate Center



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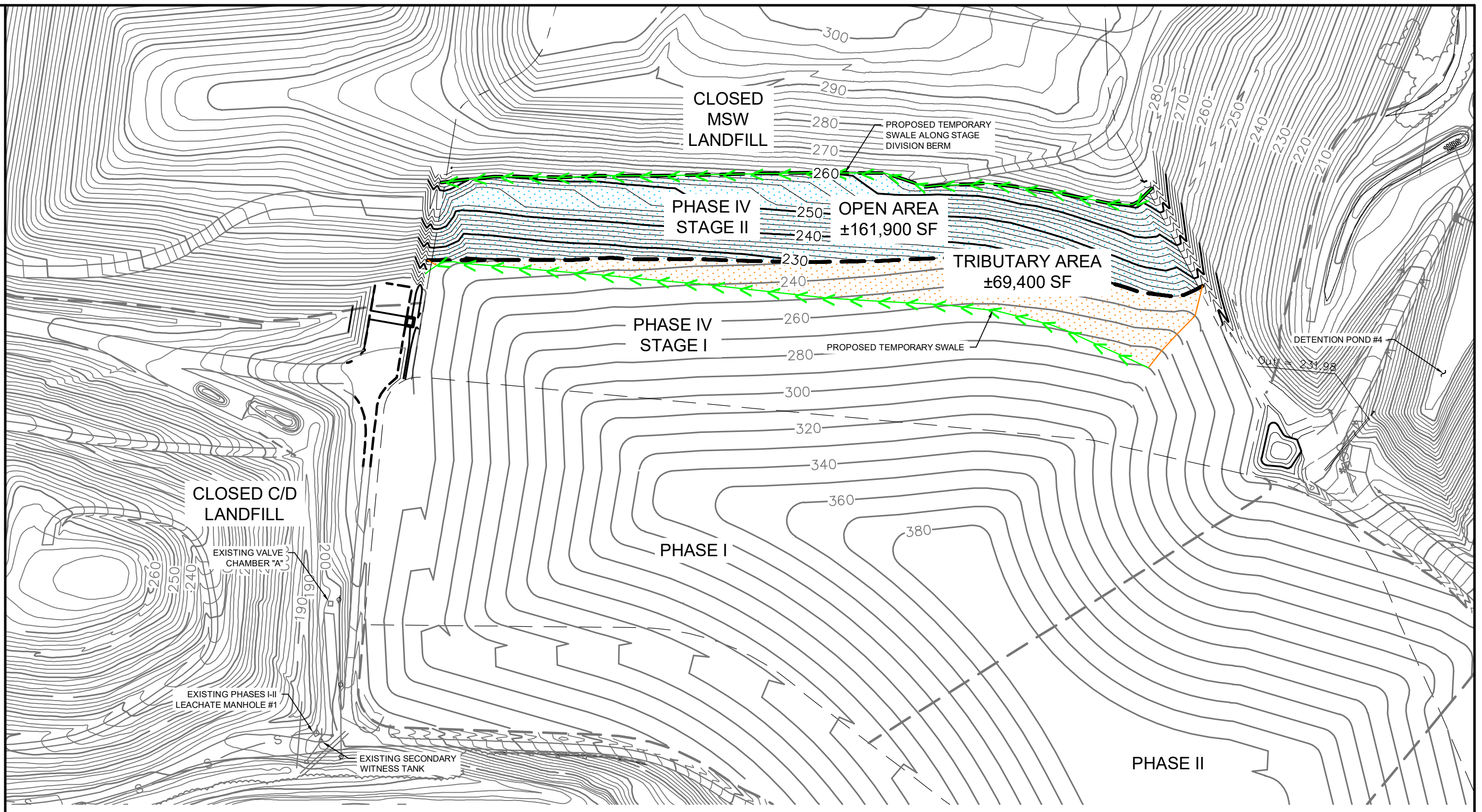

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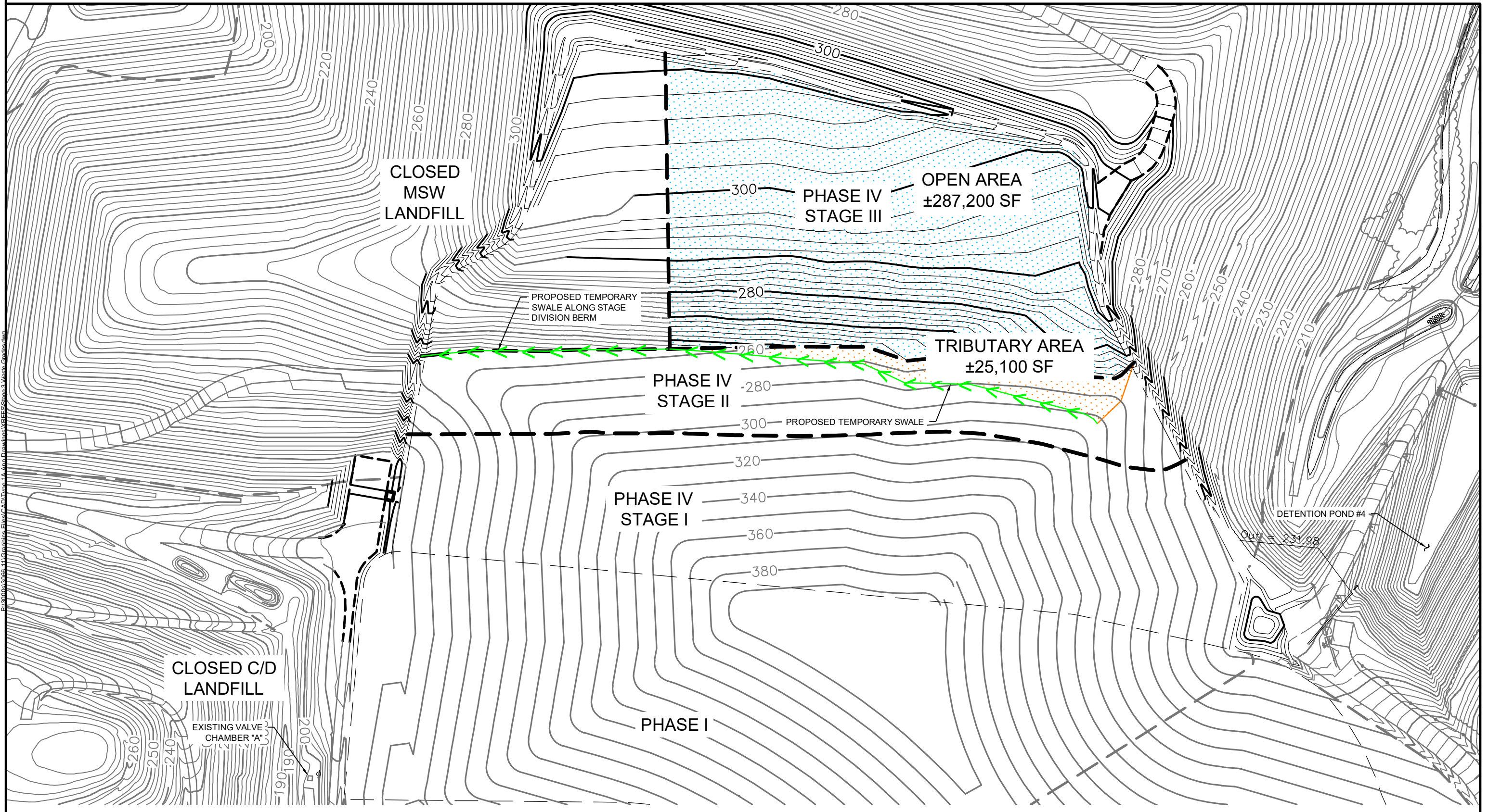

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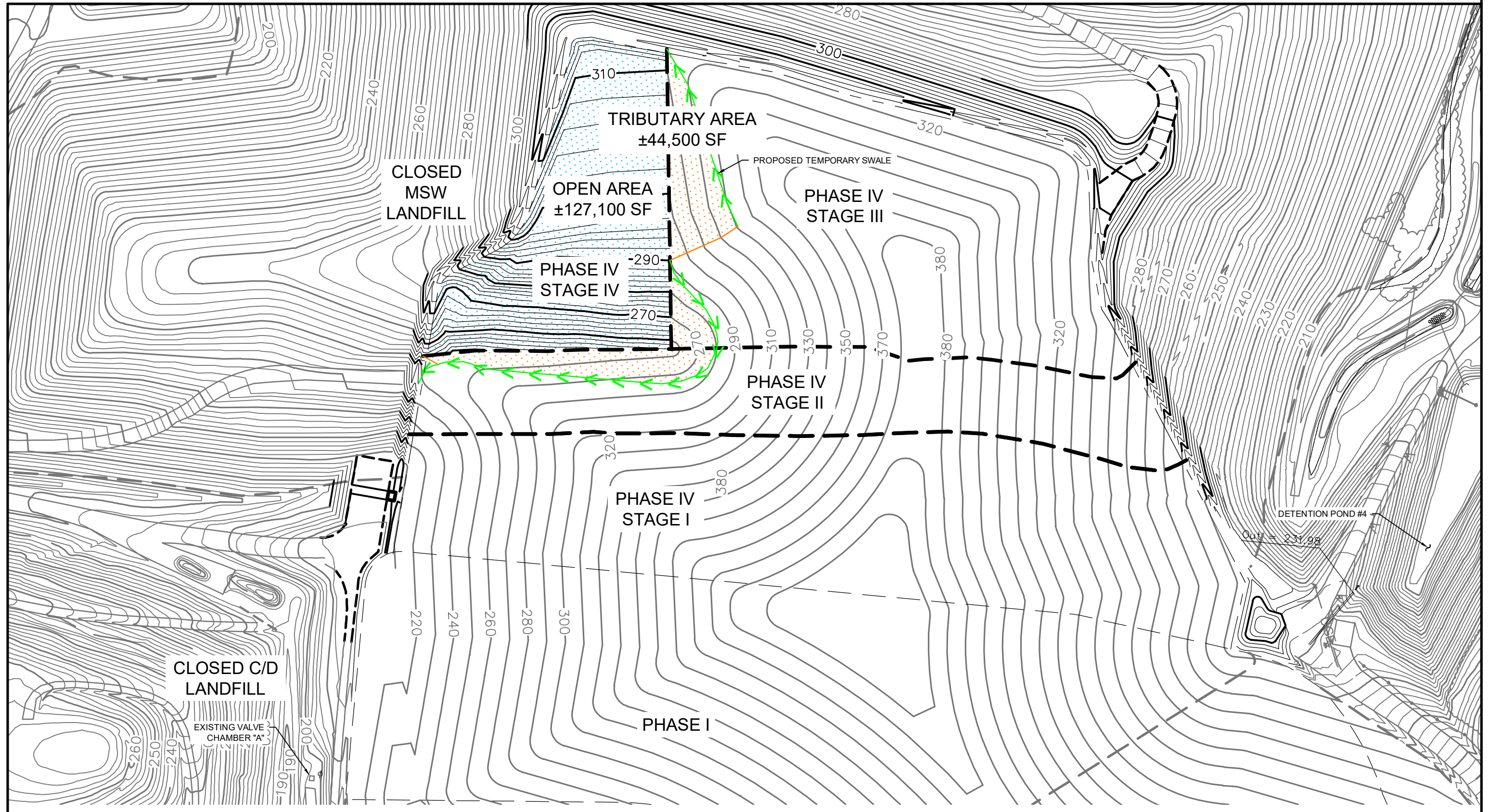

STAGE IV AREAS

SANBORN HEAD

GRAPHICAL SCALE
150' 75' 0 150' 300'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE / E. GALVIN
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

CONTRIBUTING AREAS

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
1

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USER: egalvin
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Attachment C

TABLE 1
Historic Leachate Flow
Phase IV Expansion
Four Hills Landfill
Nashua, New Hampshire

Monthly Average Primary and Secondary Leachate Flow
(Phases I & II)

	2011 (gpd*)	2012 (gpd)	2013 (gpd)	2014 (gpd)	2015 (gpd)	2016 (gpd)	2017 (gpd)	2018 (gpd)	2019 (gpd)	2020 (gpd)
January	28,472	23,045	19,810	30,962	42,072	29,755	61,932	34,271	31,301	38,054
February	37,934	18,414	13,331	10,714	20,166	38,044	58,438	39,481	32,951	37,721
March	52,008	32,223	32,836	50,138	26,850	36,618	45,275	57,762	29,665	52,369
April	30,664	34,700	35,713	45,304	26,049	34,427	83,589	50,903	47,149	83,483
May	47,142	35,532	24,813	14,059	14,207	27,817	66,398	51,256	44,633	
June	48,070	38,719	64,286	32,654	37,562	37,802	62,403	33,605	37,449	
July	30,214	15,355	47,390	30,804	23,070	41,430	55,711	40,988	60,481	
August	67,405	43,623	17,926	27,350	46,368	48,454	53,772	46,290	43,517	
September	92,421	21,003	16,837	22,359	49,581	49,136	43,661	57,621	39,652	
October	74,771	27,666	14,181	61,825	22,796	62,103	52,256	68,729	43,530	
November	57,011	26,785	12,357	59,400	22,449	43,001	44,854	N/A	35,856	
December	46,613	14,665	18,877	90,121	31,878	37,628	17,971	74,654	52,685	
Yearly Average	**51,060**	**27,644**	**26,530**	**39,641**	**30,254**	**40,518**	**53,855**	**50,505**	**41,572**	**52,907**

High Average (2017) (gpd) =	**53,855**
High Average (2017) (gpad) =**	**1,946**

Notes:

1. *gpd = gallons per day

2. **gpad = gallons per acre of landfill per day (assuming the area of Phases I and II at the Four Hills Landfill is 27.67 acres).

3. Monthly leachate flow data provided to Sanborn Head and Associates, Inc. by the City of Nashua.

4. Data captured during November 2018 is considered unusable due to faulty metering/instrumentation equipment as discussed in the City's 2018 Annual Report.

5. Secondary leachate flow data from January 2019 through April 2020 is based on gpad calculated using pump hour meter reading and average pump rate of 28.5 gpm.

SANBORN HEAD

File No. 3066.11 Page 1 of 2
Project Phase IV Expansion Project
Location Four Hills Landfill, Nashua New Hampshire
Subject Leachate Sumps
Calculated By J. Grace Date 4/23/2019
Checked By E. Galvin Date 7/7/2020
File: Leachate Sump Risers.docx

C.2 LEACHATE SUMP RISERS

PURPOSE:

Evaluate the capacity of the proposed sump riser pipes with respect to the pumping rate required to manage the contingency storm event volume. The perforations in the sump riser pipes must not inhibit the flow of leachate to the pumps under this pumping condition.

GIVEN:

- According to the contingency calculations (see Section C.1) the pumping rate required to remove the leachate volume produced by the contingency storm event is 155 gpm.
- The proposed configuration of the sump pipe perforations is 12 rows (30 degrees circumferentially) of 5/8-inch diameter holes spaced 6 inches on center (O.C.).

METHOD:

Calculate the capacity of the perforations to allow leachate into the riser pipe using the orifice flow equation and compare it with the contingency storm event pumping rate of 155 gpm.

CALCULATION:

Riser Pipe Perforations:

For the contingency storm event, the elevation of the leachate surface in the landfill will likely rise above the top of the sump. For this calculation, conservatively assume that the leachate elevation is located near the top of the sump, which is more typical of normal operations.

The 24-inch diameter HDPE cleanout riser pipe is proposed to be perforated with 5/8-inch diameter holes spaced at 30 degrees circumferentially (12 holes around) and 6 inches O.C. axially.

The pipe perforations are proposed to extend the length of the horizontal section of the riser pipe. The bottom of the sump is proposed to be 14 feet long with the end of the riser pipe located 2 feet from the toe of the sump. Due to fittings, assume that 11 feet of the pipe will be perforated.

Use the orifice equation to estimate the flow capacity of the perforations.

$$Q = C_d\ a\ \sqrt{2gh}$$

Where:
Q = flow (cfs)
C = discharge coefficient (use 0.6)
a = submerged area (ft^2)
g = gravitational constant (32.2 ft/sec^2)
h = effective head (ft) = sump depth - riser diameter/2 = 1.5 ft

The area of the perforations is:

$$a = \frac{\pi d^2}{4} \times 24\ \text{holes/ft} \times 11\ \text{ft}$$

Where: d = perforation diameter = 0.625 in = 0.052 ft

$$a = \frac{\pi(0.052)^2}{4} \times 24\ \text{holes/ft} \times 11\ \text{ft}$$

$$a = 0.56\ \text{ft}^2$$

$$Q = 0.6 \times 0.52\ ft^2 \sqrt{2 \times 32.2 \frac{ft}{sec^2} \times 1.5\ \text{ft}}$$

$$Q = 3.07\ \text{ft}^3/\text{sec}$$

$$\frac{3.07\ \text{ft}^3}{\text{sec}} \times \frac{7.48\ \text{gallons}}{\text{ft}^3} \times \frac{60\ \text{sec}}{\text{min}} = 1{,}378\ \text{gpm}$$

RESULTS:

The primary sump riser pipe perforations provide an open area of 0.56 ft^2 per riser, which under an average head of 1.5 feet has a flow capacity of 1,378 gpm. The critical pumping condition will occur following a contingency storm event (155 gpm); therefore, the perforations have about 9 times the capacity required.

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D.1 PUNCTURE RESISTANCE

PURPOSE:

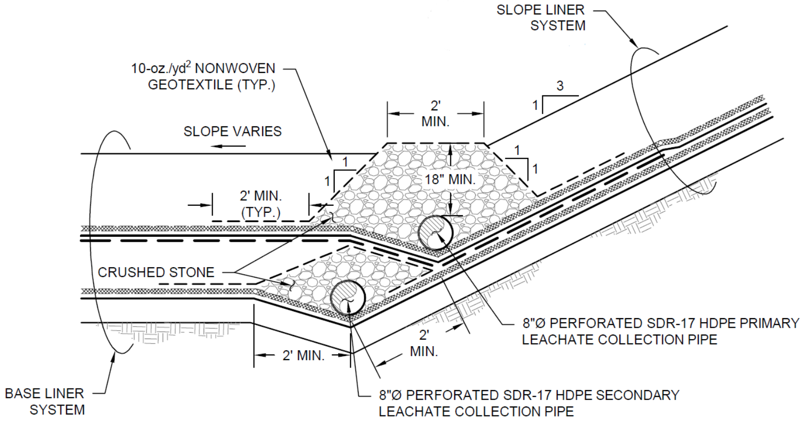
Geomembranes need to be protected from puncture from adjacent aggregate materials. The liner system design includes a drainage geocomposite overlaying the 60-mil thick primary and secondary geomembranes. Crushed Stone overlays the drainage geocomposites in the sump and around leachate collection pipes, and an 18-inch layer of Drainage Sand overlays it everywhere else. Evaluate the puncture resistance of the geomembrane liner system for the following two loading scenarios: (i) the location where the liner system experiences the greatest load; and (ii) the location where the secondary liner system in the leachate collection sump experiences the greatest load.

METHOD:

1. Calculate the allowable force (F_{allow}) to be resisted by the nonwoven geotextile components of the drainage geocomposite and geotextile cushion due to overburden materials for each loading scenario.

2. Use the method described in Ref. 2 to calculate the factor of safety (FS) against puncture of the 60-mil thick geomembranes using properties of the drainage geocomposite and geotextile cushion for each loading scenario.

DATA AND ASSUMPTIONS:



- Maximum diameter of Crushed Stone = 1-1/2 in. (38.1 mm) (Attachment A).
- Average particle diameter of Crushed Stone (mm) = d_{50} = 23.3 mm (Attachment A).
- Thickness and unit weight of material above base liner system from top to bottom:
  - Final capping system thickness: 0.5 feet (ft) topsoil, 0.5 ft moisture retention soil, 1 ft drainage sand, 0.5 ft sand, 1 ft of subgrade soil. Total thickness of 3.5 ft (1.07 m) thick final cover system at 125 pcf (19.6 kN/m^3).
  - 207 ft (63 m) of waste located above liner system at 85 pcf (13.4 kN/m^3) (Attachment B).

  - 33 ft (10.1 m) of waste located above the leachate collection sump at 85 pcf (13.4 kN/m^3) (Attachment B).
  - Primary leachate collection system Crushed Stone – approximately 2 ft (0.61 m) thick at 130 pcf (20.4 kN/m^3).
  - Secondary leachate collection system Crushed Stone – approximately 1 ft (0.305 m) thick at 130 pcf (20.4 kN/m^3)
  - Primary leachate sump Crushed Stone – approximately 2.5 ft (0.762 m) thick at 130 pcf (20.4 kN/m^3).
  - Secondary leachate sump Crushed Stone – approximately 1 ft (0.305 m) thick at 130 pcf (20.4 kN/m^3)
- Geocomposite includes two layers of 10 ounces per square yard (oz/yd^2) nonwoven geotextiles.

- Maximum diameter of 1-1/2 in. Crushed Stone = 1-1/2 in. (38.1 mm) see gradation specification below:

Sieve Size	Percent Passing by Weight
2 in	100
1-1/2 in	95-100
3/4 in	35-70
3/8 in	10-30
No. 4	0-5

CALCULATION:

1. Calculate the allowable force (F_{allow}) to be resisted by the geotextile components of the drainage geocomposite due to overburden materials for the two loading scenarios.

$$FS = \frac{F_{allow}}{F_{reqd}}$$

$$F_{allow} = FS \times F_{required}$$

$$F_{required} = p' d_a^2 S_1 S_2 S_3$$ [Ref 1, Eq 2.30]

Where:

F_{allow} = Allowable force on geotextile (N)
$F_{required}$ = Actual vertical force from overburden materials to be resisted (N)
p' = Pressure exerted on the geotextile from overlying materials (kPa)
FS = Factor of safety = 2 [Ref 3]
d_a = d_{50} = Average diameter of aggregate (mm) = 23.3 mm (Attachment A)
S_1 = Protrusion factor (dimensionless)
S_2 = Scale factor (dimensionless)
S_3 = Shape factor (dimensionless)

Independent factors used to calculate $F_{required}$ [Ref 1, Table 2.9]:

Crushed Stone, assume angular and relatively large:

S_1 = 0.9
S_2 = 0.8
S_3 = 0.9

Calculate the pressure exerted on the geotextile from the overlying materials:

$$p' = H \times \gamma$$

Where:
H = maximum material height over the liner system (m)
γ = density of overlying material (kN/m^3)

For the greatest load applied to the secondary geomembrane liner through the Crushed Stone of the leachate collection system:

$$p' = \underbrace{(1.07\text{ m} \times 19.6\text{ kN/m}^3)}_{}+\underbrace{(63\text{ m} \times 13.4\text{ kN/m}^3)}_{}+\underbrace{[(0.61\text{ m} + 0.305\text{ m}) \times 20.4\text{ kN/m}^3]}_{}$$

(Final cover system) (Waste) (Crushed Stone- Primary and Secondary)

$$p' = \underline{884\text{ kPa}}$$

Calculate the allowable force:

$$F_{allow} = FS \times F_{required} = FS \times p'd_a^2\, S_1 S_2 S_3$$

$$F_{allow} = 2 \times 884\text{ kPa} \times (0.0233\text{ m})^2 \times 0.9 \times 0.8 \times 0.9 = \underline{622\text{ N}}$$

For the greatest load applied to the secondary geomembrane liner through the Crushed Stone of the leachate collection sump:

(Final cover system) (Waste) (Crushed Stone- Primary and Secondary)

$$p' = (1.07\text{ m} \times 19.6\text{ kN/m}^3) + (10.1\text{ m} \times 13.4\text{ kN/m}^3) + [(0.762\text{ m} + 0.305\text{ m}) \times 20.4\text{ kN/m}^3]$$

$$p' = \underline{178\text{ kPa}}$$

Calculate the allowable force:

$$F_{allow} = FS \times F_{required} = FS \times p'd_a^2\, S_1 S_2 S_3$$

$$F_{allow} = 2 \times 178\text{ kPa} \times (0.0233\text{ m})^2 \times 0.9 \times 0.8 \times 0.9 = \underline{125\text{ N}}$$

2. Use the method described in Ref. 2 to calculate the factor of safety (FS) against puncture of the 60-mil thick geomembranes using properties of the drainage geocomposite.

$$\mathrm{FS} = \frac{\mathrm{p}_{allow}}{\mathrm{p}'} \qquad \text{[Ref 2, Eq 5.33]}$$

Where:

FS = factor of safety (against geomembrane puncture) = 2 [Ref 3]
p’ = required pressure due to the landfill contents (or surface impoundment) = 884 kPa
p_{allow}= allowable puncture resistance of a 60-mil thick geomembrane overlain by geotextile

Calculate the allowable puncture resistance of the geomembrane overlain by geotextile:

$$\mathrm{P_{allow}} = \left(50 + 0.00045 \times \frac{\mathrm{M}}{\mathrm{H}^2}\right) \times \left[\frac{1}{\mathrm{MF_S \times MF_{PD} \times MF_A}}\right] \times \left[\frac{1}{\mathrm{RF_{CBD} \times RF_{CR}}}\right] \qquad \text{[Ref 2, Eq 5.34]}$$

Where:

M = Geotextile mass per unit area (g/m^2) = 678 g/m^2 for two 10 oz/yd^2 (339 g/m^2) nonwoven geotextiles [Ref 4]
H = Protrusion height = ½ the maximum particle diameter (m)
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
RF_{CR} = Reduction factor for long term creep

Calculate the protrusion height (H) of the aggregate:

Where:

H= ½ the maximum particle diameter (mm)

$$\mathrm{H} = 38.1\ \mathrm{mm}\ \div 2 = 19.05\ \mathrm{mm} = 0.01905\ \mathrm{m}$$

Select reduction factors – see table below [Table 5.16, Ref 2]:

MF_S		**MF_{PD}**		**MF_A**	
Angular:	1.0	Isolated	1.0	Hydrostatic	1.0
Subrounded:	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded:	0.25	Dense, 25 mm	0.67	Geostatic, mod.	0.50
		Dense, 12mm	0.50	Geostatic, deep	0.25

RF_{CBD}		**RF_{CR}**			
		Mass per unit area (g/m^2)	Protrusion Height (mm)		
			38	**25**	**12**
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3	270	N/R	N/R	N/R
Harsh leachate	1.5	550	N/R	N/R	>1.5
		1100	N/R	1.5	1.3
		>1100	1.3	1.2	1.1

MF_s = 1.0 (assume angular)
MF_{PD} = 0.83 (assume dense)
MF_A = 0.25 (assume geostatic, deep)
RF_{CBD} = 1.3 (assume moderate chemical/ biological degradation)
RF_{CR} = 1.7 for a protrusion height of 25.4 mm and a representative drainage geocomposite with two, 10 oz/yd² (339 g/m²) nonwoven geotextiles

Calculate the allowable puncture resistance:

$$P_{allow} = \left(50 + 0.00045 \times \frac{678\,g/m^2}{(0.01905\ m)^2}\right) \times \left[\frac{1}{1 \times 0.83 \times 0.25}\right] \times \left[\frac{1}{1.3 \times 1.7}\right] = 1{,}942\ kPa$$

Calculate the factor of safety:

For the secondary liner system at leachate collection pipe:

$$FS = \frac{p_{allow}}{p'} = \frac{1{,}942\ kPa}{884\ kPa} = 2.19 \therefore OK$$

For the secondary liner system at the leachate sump:

$$FS = \frac{p_{allow}}{p'} = \frac{1{,}942\ kPa}{178\ kPa} = 10.9 \therefore OK$$

CONCLUSION:

Based on the calculations above, a drainage geocomposite with two, 10 oz/yd^2 nonwoven geotextiles overlying the primary and secondary 60-mil thick HDPE geomembranes provides adequate protection against puncture. The geotextile components of the drainage geocomposite should exhibit a puncture resistance of at least 622 N.

REFERENCES:

[1] Koerner, Robert M. (2012), "Chapter 2." Designing with Geosynthetics, 6th ed. Vol. 1. Xlibris Corporation, pp. 184-186.

[2] Koerner, Robert M. (2012), "Chapter 5." Designing with Geosynthetics. 6th ed. Vol. 2, Xlibris Corporation, pp. 645-648.

[3] Narejo, Dhani, Ph.D., EIT, Richardson, Gregory N., Ph.D., P.E. (2003), "Designing with GRI Standard GC8," www.geosynthetica.net, 4 pages.

[4] Geosynthetics Magazine (2017), *Geotextiles Product Data*, Industrial Fabrics Association International, pp 1-19.

ATTACHMENTS:

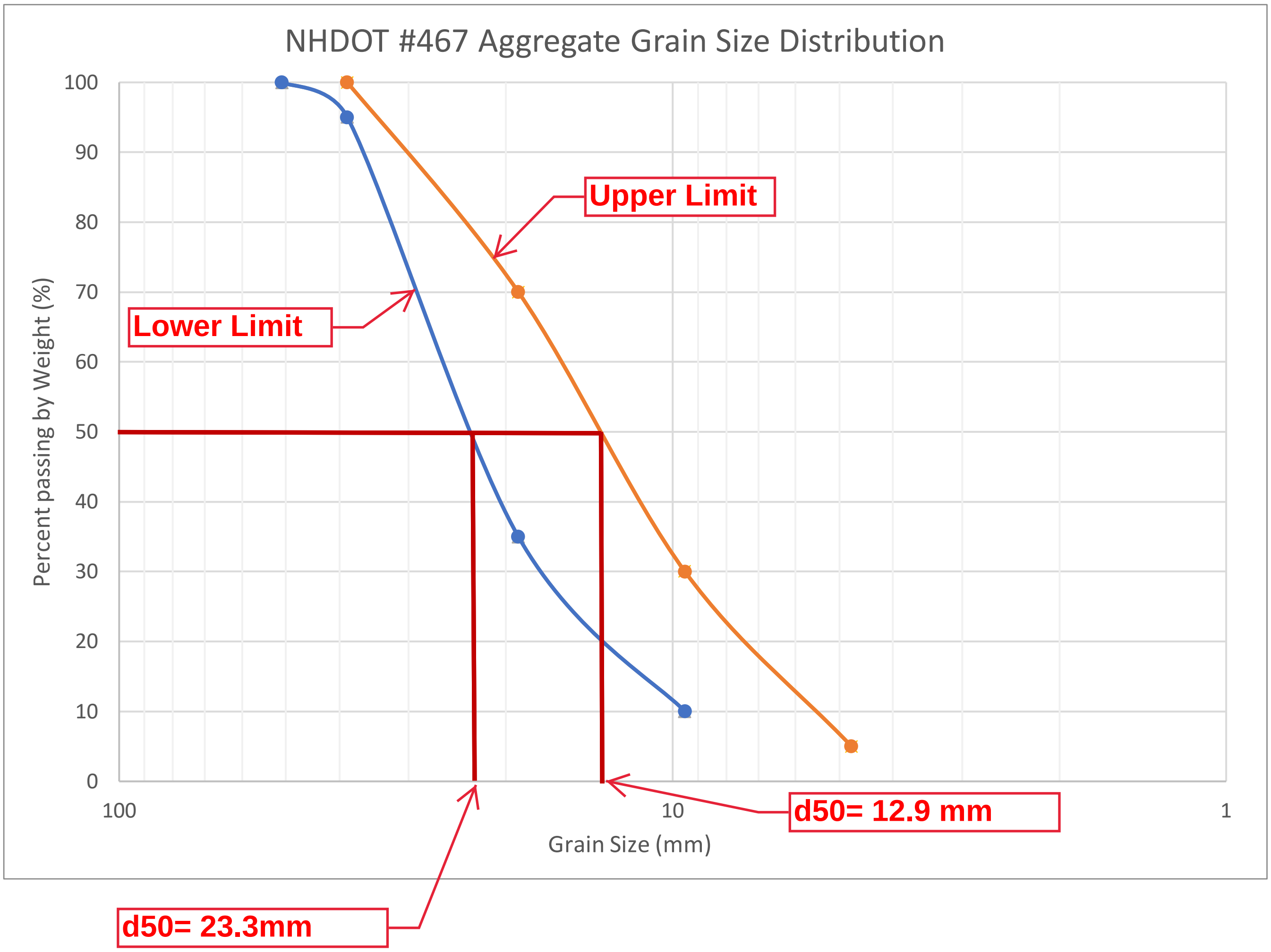
Attachment A	NHDOT #467 Aggregate Grain Size Distribution
Attachment B	Waste Thickness Worksheet
Attachment C	GSE 330 mil Geocomposite Product Data Sheet

Attachment A

NHDOT #467 Aggregate

(See Section 703 of New Hampshire Department of Transportation Standard Specifications)

Sieve Size	Sieve Size	Percent Passing by Weight
2 in	50.8 mm	100
1-1/2 in	38.1 mm	95-100
3/4 in	19 mm	35-70
3/8 in	9.5 mm	10-30
No. 4	4.75 mm	0-5



Use the d50 of the lower limit to be conservative.

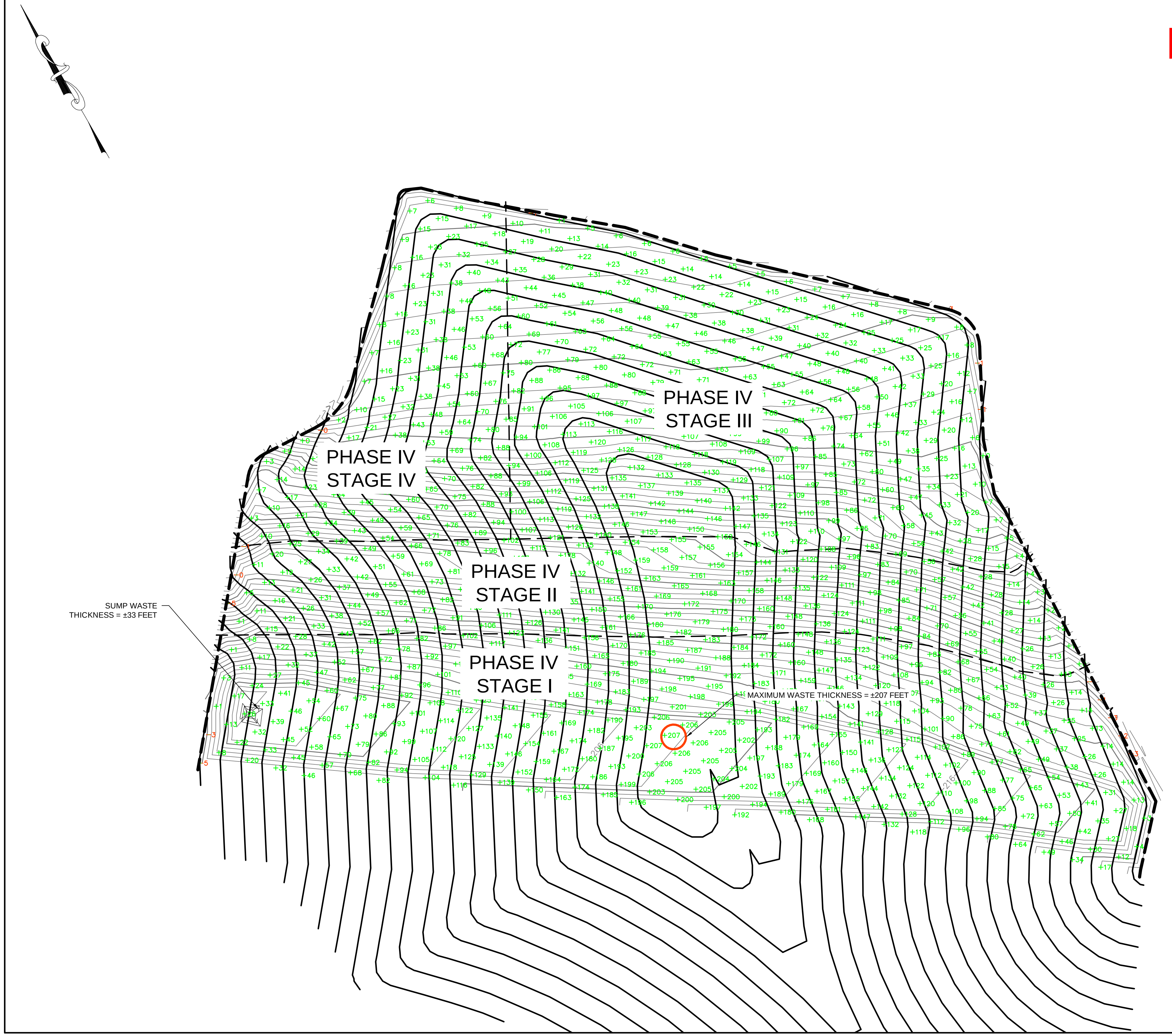
Attachment B

NOTES:

GRADES SHOWN REPRESENT THE SECONDARY LINER GRADES AND FINAL GRADES. SECONDARY LINER GRADES WERE RAISED BY 2.5 FEET AND FINAL GRADES WERE LOWERED BY 3.5 FEET TO CALCULATE WASTE THICKNESS.

LEGEND:

—210—	10-FOOT PHASE IV SECONDARY LINER CONTOUR
——	2-FOOT PHASE IV SECONDARY LINER CONTOUR
—420—	10-FOOT FINAL GRADE CONTOUR
▬ ▬ ▬ ▬	LIMIT OF WASTE
— — — —	STAGE LIMIT
+102	DEPTH OF WASTE (FEET)



- NOT FOR CONSTRUCTION -

FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE

80' 40' 0 80' 160'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

WASTE THICKNESS WORKSHEET

PROJECT NUMBER: 3066.11

FIGURE NUMBER: 1 OF 1

Attachment C

PRODUCT DATA SHEET

GSE PermaNet 330 mil Geocomposite

GSE PermaNet 330 mil geocomposite is manufactured with a GSE PermaNet geonet core heat-bonded on one or both sides with a nonwoven needlepunched geotextile. The round strand, creep resistant structure of this product ensures continuous flow performance and durability under rigorous environmental conditions and is ideal for extremely demanding applications.

AT THE CORE:
The product's structure provides superior performance under demanding conditions.

Product Specifications

Tested Property	Test Method	Frequency	Minimum Average Roll Value		
Geocomposite			6 oz/yd^2	8 oz/yd^2	10 oz/yd^2
Transmissivity(2), gal/min/ft (m^2/sec) Double-Sided Composite Single-Sided Composite	ASTM D 4716	1/540,000 ft^2	9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})	9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})	9.6 (2 x 10^{-3}) 12.5 (2.6 x 10^{-3})
Ply Adhesion, lb/in	ASTM D 7005	1/50,000 ft^2	1.0	1.0	1.0
Geonet Core(1,3) – GSE PermaNet					
Geonet Core Thickness, mil	ASTM D 5199	1/50,000 ft^2	330	330	330
Transmissivity(2), gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	28.8 (6 x 10^{-3})	28.8 (6 x 10^{-3})	28.8 (6 x 10^{-3})
Compressive Strength, lb/ft^2	ASTM D 6364	1/540,000 ft^2	60,000	60,000	60,000
Creep Reduction Factor	ASTM D 7361	per formulation	1.3 @ 25,000 psf	1.3 @ 25,000 psf	1.3 @ 25,000 psf
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94
Tensile Strength (MD), lb/in	ASTM D 7179	1/50,000 ft^2	100	100	100
Carbon Black Content, %	ASTM D 4218	1/50,000 ft^2	2.0	2.0	2.0
Geotextile(1,3)					
Mass per Unit Area, oz/yd^2	ASTM D 5261	1/90,000 ft^2	6	8	10
Grab Tensile, lb	ASTM D 4632	1/90,000 ft^2	160	220	260
Grab Elongation	ASTM D 4632	1/90,000 ft^2	50%	50%	50%
CBR Puncture Strength, lb	ASTM D 6241	1/540,000 ft^2	435	575	725
Trapezoidal Tear Strength	ASTM D 4533	1/90,000 ft^2	65	90	100
AOS, US Sieve, (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)	80 (0.180)	100 (0.150)
Permittivity, sec^{-1}	ASTM D 4491	1/540,000 ft^2	1.5	1.3	1.0
Water Flow Rate, gpm/ft^2	ASTM D 4491	1/540,000 ft^2	110	95	75
UV Resistance, % Retained	ASTM D 4355 (after 500 hours)	per formulation	70	70	70
NOMINAL ROLL DIMENSIONS(4)					
Roll Width, ft			15	15	15
Roll Length, ft	Double-Sided Composite Single-Sided Composite		150 150	140 150	130 140
Roll Area, ft^2	Double-Sided Composite Single-Sided Composite		2,250 2,250	2,100 2,250	1,950 2,100

NOTES:

- (1) All geotextile properties are minimum average roll values except AOS which is maximum average roll value and UV resistance is typical value. Geonet core thickness is nominal value.
- (2) Gradient of 0.1, normal load of 25,000 psf, water at 70° F between steel plates for 15 minutes. Contact GSE for performance transmissivity data for use in design.
- (3) Component properties prior to lamination.
- (4) Roll widths and lengths have a tolerance of ±1%.

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

[DURABILITY RUNS DEEP] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

SANBORN HEAD

File No. 3066.11 Page 1 of 4
Project Phase IV Expansion Project
Location Four Hills Landfill, Nashua, New Hampshire
Subject D.2 Anchor Trench Pullout
Calculated By L. Tracy Date 03/06/2019
Checked By J. Grace Date 04/18/2019
P:\3000s\3066.11\Source Files\Standard App\6-Design\Calculations\D - Liner System\D.2 - Anchor Trench Pullout\Anchor Trench Pullout.docx

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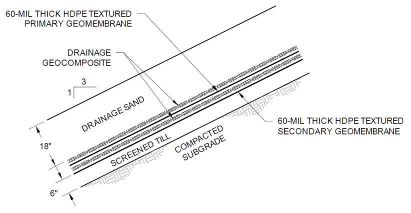
D.2 ANCHOR TRENCH PULLOUT

PURPOSE:

Evaluate the proposed perimeter anchor trench geometry and materials, and verify that the geomembrane will pull out of the anchor trench prior to the geomembrane breaking due to tension.

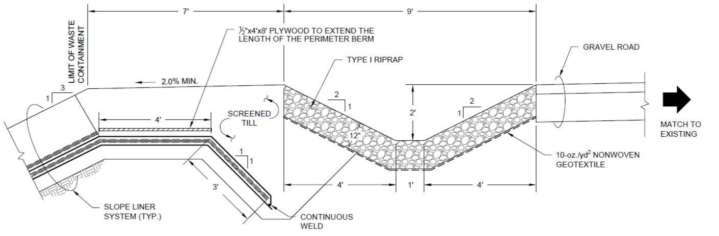
DATA:

- Geomembrane anchor trench dimension (see figure below):
  - Initial bench length = 4 ft (1.22 m)
  - Slope of anchor inclination = 45 degrees
  - Depth of anchor = 3 ft / √2 = 2.12 ft (0.646 m)
- 60-mil (1.5 mm) thick textured HDPE geomembrane [Ref. 1, Attachment A]
  - Ultimate strength at break = 16 N/mm or 16 kN/m
- Depth of soil over geomembrane = 1.50 ft (0.457 m)
- Unit weight of cover soil assume = 125 pcf (19.6 kN/m^3)
- Slope angle of liner system = 18.4 degrees (3H:1V)
- Soil/textured geomembrane interface friction angle = 0 degrees (above geomembrane)
- Textured geomembrane/soil interface friction angle = 26 degrees (below geomembrane). Attachment B states that based on testing data, the residual interface friction angle for textured HDPE and cohesive soil is 22 degrees. Use 26 degrees to be conservative.



SLOPE LINER SYSTEM (TYP.)

NOT TO SCALE



PERIMETER BERM (TYP.)

1 NOT TO SCALE (OUTSIDE OF EXISTING CAP AREA)

METHOD:

1. The anchor trench should be designed such that geomembrane pulls out before it fails due to tension [Ref. 2]. This is directly reflected in the anchorage ratio (AR):

$$AR = \frac{T_{GMallow}}{T_{ATallow}} \qquad (1)$$

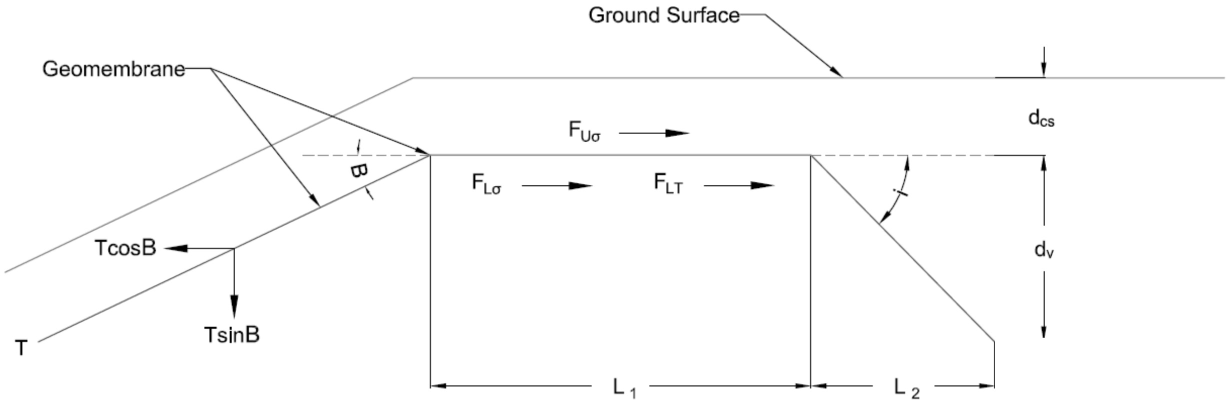
Where:

AR=Anchorage ratio:

$T_{GMallow}$ = Allowable geomembrane tension per unit width (N/m)
$T_{ATallow}$ = Allowable anchor tension per unit width (N/m)

Anchorage Ratio > 1 → Geomembrane pull-out mode controls
Anchorage Ratio = 1 → Balanced Design
Anchorage Ratio < 1 → Geomembrane tension rupture mode controls

2. Calculate the anchor trench run-out length following the method [Ref. 2]:



Using the free-body diagram shown in the figure above, the following equations are derived:

$$T_{ATallow} \cos\beta = F_{U\sigma} + F_{L\sigma} + F_{LT} \quad (2)$$

Where:

$T_{ATallow}$ = Allowable tension per unit width (N/m)
β = Slope angle (degrees)
$F_{U\sigma}$ = Shear force above geomembrane due to cover soil per unit width (note that for thin cover soil layers, tensile cracking will occur, and this value will be negligible) (N/m)
$F_{L\sigma}$ = Shear force below geomembrane due to cover soil per unit width (N/m)
F_{LT} = Shear force below geomembrane due to vertical component of $T_{GMallow}$ per unit width (N/m)

Also,

$$T_{ATallow} = T_{GMult}/FS \quad (3)$$

Where:

$T_{ATallow}$ = Allowable tension per unit width (N/m)
T_{GMult} = Break strength of geomembrane per unit width (N/m)
FS = Factor of Safety (dimensionless) ≥ 1.0

Conservatively assume FS =1, so that $T_{ATallow} = T_{GMult}$

And,

$$T_{ATallow}=\frac{[(\tan\delta_U+\tan\delta_L)]\times\left[(\gamma_{AT}\times d_{cs}\times L_1)+\left(\gamma_{AT}\times\left(d_{cs}+\frac{d_v}{2}\right)\times\frac{L_2}{\cos i}\right)\right]}{\cos\beta\text{-}(\sin\beta\times\tan\delta_L)} \tag{4}$$

Where:

δ_U = Interface friction angle between the geomembrane and the cover soil (degrees)

δ_L = Interface friction angle between the geomembrane and the underlying soil (degrees)

γ_{AT} = Unit weight of cover soil (kN/m^3)

L_1 = Initial bench length (m)

L_2 = Horizontal length of inclined anchor slope (m)

d_{cs} = cover soil thickness (m)

d_v = Depth of inclined slope (m)

i = Angle of inclined slope (degrees)

CALCULATION:

1. Calculate the $T_{ATallow}$ of a 60-mil thick HDPE geomembrane using Equation 3.

   Strength at Break, T_{GMult} = 16 kN/m [Ref. 1]

$$T_{ATallow}=\frac{16\text{ kN/m}}{1.0}=\underline{16\text{ kN/m}}$$

2. Calculate the $T_{ATallow}$ for the proposed anchor trench using Equation 4.

$$T_{ATallow}=\frac{[(\tan 0+\tan 26)]\times\left[(19.6\text{ kN/m}^3\times 0.457\text{ m}\times 1.22\text{ m})+\left(19.6\text{ kN/m}^3\times\left(0.457\text{ m}+\frac{0.646\text{ m}}{2}\right)\times\frac{0.646\text{ m}}{\cos 45}\right)\right]}{\cos 18.4\text{ -}(\sin 18.4\times\tan 26)}$$

$$T_{ATallow}=15.3\ \underline{\text{kN/m}}$$

3. Calculate the AR using Equation 1:

$$\mathrm{AR} = \frac{16\ \mathrm{kN/m}}{15.3\ \mathrm{kN/m}} = 1.05 > 1\ \therefore \mathrm{OK}$$

RESULTS:

Based on the calculations above, the 60-mil thick textured HDPE geomembrane will pull out of the proposed anchor trench before the geomembrane would fail.

REFERENCES:

[1] Geosynthetic Institute, *GRI-GM13 Standard Specification*, Revision 14 dated January 6, 2016.

[2] Koerner, Robert M., (2012), *Designing with Geosynthetics*, 6th Edition, Vol. 2, Xlibris Corporation. pp 596-597.

ATTACHMENTS:

Attachment A	Table 2b of GRI-GM13
Attachment B	Summary of Interface Shear Strengths included in GRI Report #30

Attachment A

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method				60 mil				Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness mils (min. ave.)	D 5994	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	per roll
• lowest individual for 8 out of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
• lowest individual for any of the 10 values		-15%	-15%	-15%	-15%	-15%	-15%	-15%	
Asperity Height mils (min. ave.)	D 7466	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	every 2nd roll *(1)*
Formulated Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) *(2)*	D 6693								9,000 kg
• yield strength	Type IV	11 kN/m	15 kN/m	18 kN/m	22 kN/m	29 kN/m	37 kN/m	44 kN/m	
• break strength		8 kN/m	10 kN/m	13 kN/m	16 kN/m	21 kN/m	26 kN/m	32 kN/m	
• yield elongation		12%	12%	12%	12%	12%	12%	12%	
• break elongation		100%	100%	100%	100%	100%	100%	100%	
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	200N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance *(3)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 *(4)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	9,000 kg
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(6)*									90,000 kg
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
— or —									
(b) High Pressure OIT	D 5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C *(6), (7)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	55%	55%	55%	55%	55%	55%	55%	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance *(8)*	D 7238								
(a) Standard OIT (min. ave.)	D 3895	N.R. *(9)*	N.R. *(9)*	N.R. *(9)*	N.R. *(9)*	N.R. *(9)*	N.R. *(9)*	N.R. *(9)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 5885	50%	50%	50%	50%	50%	50%	50%	

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Attachment B

Appendix Table 1. Summary of interface shear strengths.

Interface 1*	Interface 2*	Peak Strength					Residual Strength				
		Fig. No.	δ (deg)	Ca (kPa)	Points	R^2	Fig. No.	δ (deg)	Ca (kPa)	Points	R^2
HDPE-S	Granular Soil	1a	21	0	162	0.93	1b	17	0	128	0.92
HDPE-S	Cohesive Soil										
	Saturated	1c	11	7	79	0.94	1d	11	0	59	0.95
	Unsaturated	1c	22	0	44	0.93	1d	18	0	32	0.93
HDPE-S	NW-NP GT	1e	11	0	149	0.93	1f	9	0	82	0.96
HDPE-S	Geonet	1g	11	0	196	0.90	1h	9	0	118	0.93
HDPE-S	Geocomposite	1i	15	0	36	0.97	1j	12	0	30	0.93
HDPE-T	Granular Soil	2a	34	0	251	0.98	2b	31	0	239	0.96
HDPE-T	Cohesive Soil										
	Saturated	2c	18	10	167	0.93	2d	16	0	150	0.90
	Unsaturated	2c	19	23	62	0.91	2d	22	0	35	0.93
HDPE-T	NW-NP GT	2e	25	8	254	0.96	2f	17	0	217	0.95
HDPE-T	Geonet	2g	13	0	31	0.99	2h	10	0	27	0.99
HDPE-T	Geocomposite	2i	26	0	168	0.95	2j	15	0	164	0.94
LLDPE-S	Granular Soil	3a	27	0	6	1.00	3b	24	0	9	1.00
LLDPE-S	Cohesive Soil	3c	11	12.4	12	0.94	3d	12	3.7	9	0.93
LLDPE-S	NW-NP GT	3e	10	0	23	0.63	3f	9	0	23	0.49
LLDPE-S	Geonet	3g	11	0	9	0.99	3h	10	0	9	1.00
LLDPE-T	Granular Soil	4a	26	7.7	12	0.95	4b	25	5.2	12	0.95
LLDPE-T	Cohesive Soil	4c	21	5.8	12	1.00	4d	13	7.0	9	0.98
LLDPE-T	NW-NP GT	4e	26	8.1	9	1.00	4f	17	9.5	9	0.96
LLDPE-T	Geonet	4g	15	3.6	6	0.97	4h	11	0	6	0.98
PVC-S	Granular Soil	5a	26	0.4	6	0.99	5b	19	0	6	0.99
PVC-S	Cohesive Soil	5c	22	0.9	11	0.88	5d	15	0	9	0.95
PVC-S	NW-NP GT	5e	20	0	89	0.91	5f	16	0	83	0.74
PVC-S	NW-HB GT	5g	18	0	3	1.00	5h	12	0.1	3	1.00
PVC-S	Woven GT	5i	17	0	6	0.54	5j	7	0	6	0.93
PVC-S	Geonet	5k	18	0.1	3	1.00	5l	16	0.6	3	1.00

Koerner, G., and Narejo, D., 2005, "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces," Geosynthetic Research Institute, GRI Report #30.

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File No. 3066.11 Page 1 of 3
Project Phase IV Design
Location Four Hills Landfill, Nashua, New Hampshire
Subject Final Cover System Veneer Slope Stability Calculations
Calculated By E. Galvin Date 6/30/2020
Checked By E. Steinhauser Date 7/1/2020
P:\3000s\3066.11\Source Files\Type I-A PMA\App A - Design\Att A - Calcs\D - Liner System\D.3 - Liner Veneer Stability\Liner Veneer Stability.docx

D.3 Liner System Veneer Slope Stability

PURPOSE:

Calculate the factor of safety for the veneer stability of the Phase IV sloped portion of the proposed liner system. The minimum factor of safety of the liner system is 1.3 as it is a temporary condition.

METHOD:

1. Identify the condition(s) where veneer stability of the liner system slope is of concern.

2. Calculate the factors of safety for slip surfaces above (FS_A) and below (FS_B) the geomembrane component of the liner system, using the following equations [Ref. 1, equations 58 and 59, respectively, p. 1173].

$$FS_A = \frac{\gamma_t\,(t - t_w) + \gamma_b t_w}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\,\frac{\tan\delta_A}{\tan\beta} + \frac{a_A/\sin\beta}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}$$

$$+ \frac{\gamma_t\,(t - t_w^*) + \gamma_b t_w^*}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\,\frac{t}{h}\,\frac{\sin\phi}{2\sin\beta\,\cos\beta\,\cos(\beta + \phi)}$$

$$+ \frac{c\,t/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\,\frac{\cos\phi}{\sin\beta\,\cos(\beta + \phi)}$$

$$+ \frac{T/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}$$

$$FS_B = \frac{\tan\delta_B}{\tan\beta} + \frac{a_B/\sin\beta}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}$$

$$+ \frac{\gamma_t\,(t - t_w^*) + \gamma_b t_w^*}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\,\frac{t}{h}\,\frac{\sin\phi}{2\sin\beta\,\cos\beta\,\cos(\beta + \phi)}$$

$$+ \frac{c\,t/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\,\frac{\cos\phi}{\sin\beta\,\cos(\beta + \phi)}$$

$$+ \frac{T/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}$$

Where: γ_t = Total weight of soil (N/m^3);
γ_b = Buoyant weight of soil (N/m^3);
γ_{sat} = Saturated weight of soil (N/m^3);
δ_A = interface friction angle along the slip surface located above the geomembrane (degrees);
δ_B = interface friction angle along the slip surface located below the geomembrane (degrees);
t = Thickness of soil layer (m);

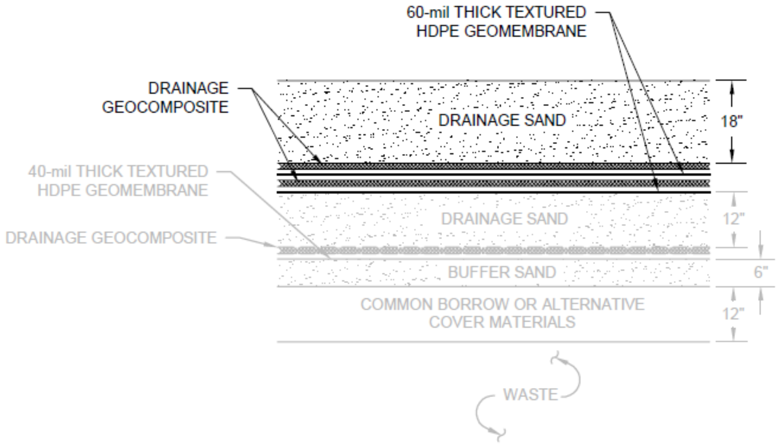
t_w = Water flow thickness (m);
t_w^* = Water flow thickness at toe of slope (m);
a_A = Interface adhesion along the slip surface above the geomembrane (Pa);
a_B = Interface adhesion along the slip surface below the geomembrane (Pa);
ϕ = internal angle of friction of soil above the geomembrane (degrees);
β = slope angle (degrees);
h = height of slope (m);
c = cohesion of soil above the geomembrane (Pa); and
T = geosynthetic tension (N/m).

3. Should the condition exist where dry soil is needed above the geomembrane to maintain a stable slope (FS>1.0), then calculate the factor of safety of the system using the following equation [Ref. 1, equation 51, 1169].

$$FS_A = \frac{\tan\delta}{\tan\beta} + \frac{a_A}{\gamma\, t\, \sin\beta} + \frac{t}{h}\,\frac{\sin\phi}{2\sin\beta\,\cos\beta\,\cos(\beta+\phi)} + \frac{c}{\gamma\, t}\,\frac{\cos\phi}{\sin\beta\,\cos(\beta+\phi)} + \frac{T}{\gamma\, h\, t}$$

FINAL COVER SYSTEM DATA:

- The liner system components from top down include: a 18-inch thick layer of Drainage Sand, a 330-mil thick drainage geocomposite, a 60-mil thick HDPE (primary) geomembrane, a 330-mil thick drainage geocomposite, a 60-mil thick HDPE (secondary) geomembrane, a 12-inch thick layer of existing Drainage Sand, and the remaining existing Unlined Landfill cover materials.



- The critical height of the proposed liner system slope occurs in Stage II and has an inclination of 3H:1V (18.4°) (conservative); and is approximately 40 feet (12.2 meters [m]) high.

- Summary of values for Giroud method FS equations:

γ_t = 19.6 kN/m^3 (assumed total unit weight of 125 pcf)
γ_b = 11.3 N/m^3 (Assumes a soil with a void ratio = 0.43 and a specific gravity of 2.65)

γ_{sat} = 21.1 N/m^3 (Assumes a soil with a void ratio = 0.43 and a specific gravity of 2.65)
δ_A = 26° (See Attachment A)
t = 0.457 m (18 inches of soil above the cap geomembrane)
t_w = 0.00838 m (conservative, assumes drainage geocomposite is full)
t_w^* = 0.051 m (conservative assumption - assumes 2 inches of water at the toe of slope)
a_A = 0 (See Attachment A)
a_B = 0 (conservative assumption)
ϕ = 32°
β = 18.4°
h = 12.2 m
c = 0 (conservative assumption)
T = 0 (conservative assumption)

CALCULATION:

The veneer stability analysis was performed for the upper layers of the liner system (i.e., 18-inch thick layer of Granular Drainage Sand; the 330-mil thick drainage geocomposite; and the primary geomembrane). The calculations assume that leachate flow in the geocomposite is contained within the material and that up to 2 inches of liquid accumulates at the toe of the slope.

The analysis was not performed for the lower layers of the liner system because the leachate head is greater for the primary geomembrane than for the secondary geomembrane.

The attached spreadsheets summarize the calculations.

RESULTS:

The results for the attached veneer slope stability analysis for the Phase IV liner system are as follows:

Factor of Safety for Slip Surface Above Geomembrane, FS_A (wet) = 1.5 ≥ 1.3 **OK**
Factor of Safety for Slip Surface Below Geomembrane, FS_B (wet) = 1.5 ≥ 1.3 **OK**
Factor of Safety for Slip Surface Above Geomembrane, FS_A (dry) = 1.5 ≥ 1.3 **OK**

CONCLUSION:

The liner system over the 3H:1V slope may be constructed to its full height.

REFERENCES:

[1] Giroud, J.P., Bachus, R.C., and Bonaparte, R., 1995, "Influence of Water Flow on the Stability of Geosynthetic-Soil Layers Systems on Slopes," *Geosynthetics International,* Vol. 2, No. 6, pp 1149 - 1180.

Attachment A

Appendix Table 1. Summary of interface shear strengths.

Interface 1*	Interface 2*	Peak Strength					Residual Strength				
		Fig. No.	δ (deg)	Ca (kPa)	Points	R^2	Fig. No.	δ (deg)	Ca (kPa)	Points	R^2
HDPE-S	Granular Soil	1a	21	0	162	0.93	1b	17	0	128	0.92
HDPE-S	Cohesive Soil										
	Saturated	1c	11	7	79	0.94	1d	11	0	59	0.95
	Unsaturated	1c	22	0	44	0.93	1d	18	0	32	0.93
HDPE-S	NW-NP GT	1e	11	0	149	0.93	1f	9	0	82	0.96
HDPE-S	Geonet	1g	11	0	196	0.90	1h	9	0	118	0.93
HDPE-S	Geocomposite	1i	15	0	36	0.97	1j	12	0	30	0.93
HDPE-T	Granular Soil	2a	34	0	251	0.98	2b	31	0	239	0.96
HDPE-T	Cohesive Soil										
	Saturated	2c	18	10	167	0.93	2d	16	0	150	0.90
	Unsaturated	2c	19	23	62	0.91	2d	22	0	35	0.93
HDPE-T	NW-NP GT	2e	25	8	254	0.96	2f	17	0	217	0.95
HDPE-T	Geonet	2g	13	0	31	0.99	2h	10	0	27	0.99
HDPE-T	Geocomposite	2i	26	0	168	0.95	2j	15	0	164	0.94
LLDPE-S	Granular Soil	3a	27	0	6	1.00	3b	24	0	9	1.00
LLDPE-S	Cohesive Soil	3c	11	12.4	12	0.94	3d	12	3.7	9	0.93
LLDPE-S	NW-NP GT	3e	10	0	23	0.63	3f	9	0	23	0.49
LLDPE-S	Geonet	3g	11	0	9	0.99	3h	10	0	9	1.00
LLDPE-T	Granular Soil	4a	26	7.7	12	0.95	4b	25	5.2	12	0.95
LLDPE-T	Cohesive Soil	4c	21	5.8	12	1.00	4d	13	7.0	9	0.98
LLDPE-T	NW-NP GT	4e	26	8.1	9	1.00	4f	17	9.5	9	0.96
LLDPE-T	Geonet	4g	15	3.6	6	0.97	4h	11	0	6	0.98
PVC-S	Granular Soil	5a	26	0.4	6	0.99	5b	19	0	6	0.99
PVC-S	Cohesive Soil	5c	22	0.9	11	0.88	5d	15	0	9	0.95
PVC-S	NW-NP GT	5e	20	0	89	0.91	5f	16	0	83	0.74
PVC-S	NW-HB GT	5g	18	0	3	1.00	5h	12	0.1	3	1.00
PVC-S	Woven GT	5i	17	0	6	0.54	5j	7	0	6	0.93
PVC-S	Geonet	5k	18	0.1	3	1.00	5l	16	0.6	3	1.00

Koerner, G., and Narejo, D., 2005, "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces," Geosynthetic Research Institute, GRI Report #30.

3H:1V Slope - Veneer Slope Stability ABOVE the Geomembrane LINER (Wet)

Notes

Actual scenario with maximum "height of slope"

Description	Symbol	Value	Units		Notes
unit weight of soil	γ_t	19.60	kN/m^3		18 in. Drainage Sand
soil cover thickness	t	0.457	meters		Minimum cover of 18 in
thickness of water in slope, wedge 2	t_w	0.00838	meters		Assume flow is contained in geocomposite (330 mils)
thickness of water in slope, wedge 1	t^*_w	0.0510	meters		Assume 2 inches of water at toe of slope
Saturated unit weight of soil	γ_{sat}	21.1	kN/m^3	γ_{sat}	
buoyant unit weight of soil	γ_b	11.3	kN/m^3	γ_b	
geosynthetic interface adhesion	a	0.0	kPa	a_A	
geosynthetic interface friction angle	δ	26.0	degrees	δ_A	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	β	3H:1V slope
soil friction angle	φ	32.0	degrees	φ	Value is assumed based on Drainage Sand
cohesion of soil	c	0.0	kPa	c	
geosynthetic tension	T	0.0	kN/m	T	
height of slope	h	12.2	meters	h	40 ft

	Numerator	Denominator	Total
Term 1	4.3348	2.9838	1.4528
Term 2	0.0000	8.9698	0.0000
Term 3	2.0667	41.7843	0.0495
Term 4	0.0000	1.8047	0.0000
Term 5	0.0000	8.9698	0.0000
Factor of Safety			1.50

$$FS_A = \frac{\gamma_t (t - t_w) + \gamma_b t_w}{\gamma_t (t - t_w) + \gamma_{sat} t_w} \; \frac{\tan \delta_A}{\tan \beta} + \frac{a_A / \sin \beta}{\gamma_t \, (t - t_w) + \gamma_{sat} t_w} + \frac{\gamma_t \left(t - t_w^*\right) + \gamma_b t_w^*}{\gamma_t (t - t_w) + \gamma_{sat} t_w} \; \frac{t}{h} \; \frac{}{2 \sin \beta}$$

3H:1V Slope - Veneer Slope Stability ABOVE the Geomembrane LINER (Dry)

Notes

Actual scenario with maximum "height of slope"

Description	Symbol	Value	Units		
unit weight of soil	γ_t	19.60	kN/m^3		18 in. Drainage Sand
soil cover thickness	t	0.457	meters		Minimum cover of 18 in
geosynthetic interface adhesion	a	0.0	kPa	a_A	
geosynthetic interface friction angle	δ	26.0	degrees	δ_A	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	β	3H:1V slope
soil friction angle	φ	32.0	degrees	φ	Value is assumed based on Drainage Sand
cohesion of soil	c	0.0	kPa	c	
geosynthetic tension	T	0.0	kN/m	T	
height of slope	h	12.2	meters	h	40 ft

	Numerator	Denominator	Total
Term 1	0.4877	0.3327	1.4662
Term 2	0.0000	3.9266	0.0000
Term 3	0.2422	4.6584	0.0520
Term 4	0.0000	1.8022	0.0000
Term 5	0.0000	109.2778	0.0000
Factor of Safety			1.52

3H:1V Slope - Veneer Slope Stability BELOW the Geomembrane LINER

Notes

Actual scenario with maximum "height of slope"

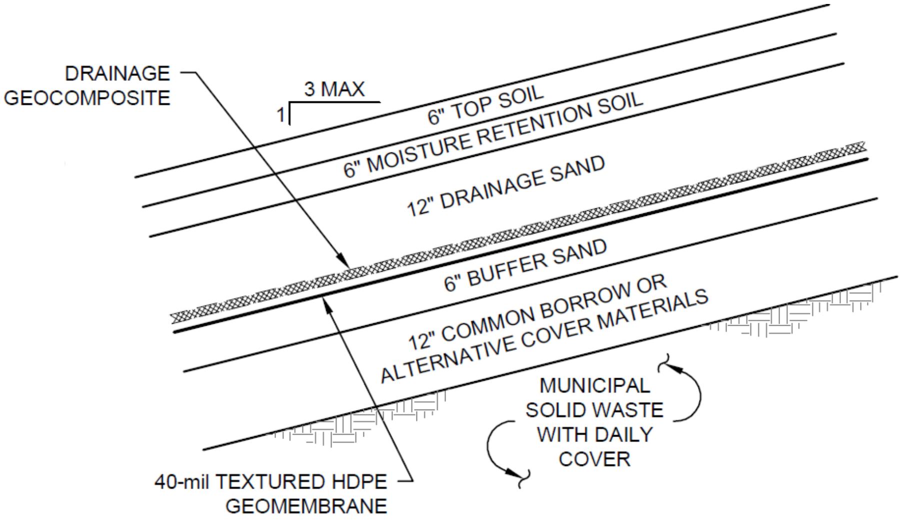
Description	Symbol	Value	Units	
unit weight of soil	γ_t	19.60	kN/m^3	18 in. Drainage Sand
soil cover thickness	t	0.457	meters	Minimum cover of 18 in
thickness of water in slope, wedge 2	t_w	0.00838	meters	Assume flow is contained in geocomposite (330 mils)
thickness of water in slope, wedge 1	t^*_w	0.0510	meters	Assume 2 inches of flow at toe of slope
Saturated unit weight of soil	γ_{sat}	21.1	kN/m^3	
buoyant unit weight of soil	γ_b	11.3	kN/m^3	
geosynthetic interface adhesion	a	0.0	kPa	
geosynthetic interface friction angle	δ	26.0	degrees	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	3H:1V slope
soil friction angle	φ	32.0	degrees	Value is assumed based on Typical Cover Soil
cohesion of soil	c	0.0	kPa	
geosynthetic tension	T	0.0	kN/m	
height of slope	h	12.2	meters	40 ft

	Numerator	Denominator	Total
Term 1	0.4877	0.3327	1.4662
Term 2	0.0000	8.9698	0.0000
Term 3	2.0667	41.7843	0.0495
Term 4	0.0000	1.8047	0.0000
Term 5	0.0000	8.9698	0.0000
Factor of Safety			1.52

E.1 CAP GEOCOMPOSITE (TRANSMISSIVITY)

PURPOSE:

Calculate the required transmissivity for the final cover drainage geocomposite considering the 3H:1V side slope.



DATA AND ASSUMPTIONS:

- Typical swale spacing for 3H:1V side slope at the site = 100 feet (30.5 m).
- Consider the topsoil layer to provide the lowest hydraulic conductivity of the final cover system soils. Therefore, the impingement rate to the drainage geocomposite (q_h) will be equal to the hydraulic conductivity of the topsoil layer. $q_h = k_{topsoil} = 1 \times 10^{-4}$ cm/sec (1×10^{-6} m/sec).
- Assume a factor of safety of 1.5.

METHOD:

- Using the hydraulic conductivity of the topsoil layer, calculate the design transmissivity of the geocomposite in the final cover system (T_{design}).
- Select reduction factors applicable to the final cover system. Calculate the required transmissivity of the drainage geocomposite.

CALCULATIONS:

1. Calculate the design transmissivity (T_{design}) of the drainage geocomposite based on the topsoil hydraulic conductivity:

$$T_{design} = \frac{q_i L}{\sin\beta} \qquad \text{[Ref 1, Eq 4.6]}$$

Where:
q_i = ipingement rate = 1×10^{-6} m/sec
L = maximum horizontal distance between drainage swales = 30.5 m
β =slope angle for a 3H:1V side slope = 18.4°

$$T_{design} = \frac{1 \times 10^{-6}\ \text{m/sec} \times 30.5\ \text{m}}{\sin 18.4°} = \underline{9.66 \times 10^{-5}\ \text{m}^2\text{/sec}}$$

2. Calculate the required transmissivity ($T_{required}$) for the drainage geocomposite based on the design transmissivity (T_{design}), a Factor of Safety (FS) of 1.5, and Reduction factors (∑RF) based on a reduction factor table included as Attachment A.

Reduction factors and solve for the required transmissivity ($T_{required}$):

$$\mathrm{T_{required}} = \mathrm{T_{design}} \times FS \times \sum \mathrm{RF} \qquad \text{[Ref 2, Eq 8.12]}$$

Where:
RF_{IN} = reduction factor for intrusion of the adjacent geotextiles into the drainage core;
RF_{CR} = reduction factor for creep deformation of the drainage core;
RF_{CC} = reduction factor for chemical clogging; and
RF_{BC} = reduction factor for biological clogging.

$$\sum \mathrm{RF} = \mathrm{RF_{in}} \times \mathrm{RF_{cr}} \times \mathrm{RF_{cc}} \times \mathrm{RF_{bc}}$$

Where:

RF_{in} = 1.5
RF_{cr} = 1.4
RF_{cc} = 1.0
RF_{bc} = 1.5

$$\sum RF = 1.5 \times 1.4 \times 1.0 \times 1.5 = 3.15$$

$$\mathrm{T_{required}} = 9.66 \times 10^{-5}\ \mathrm{m^2/sec} \times 1.5 \times 3.15 = \underline{\underline{4.6 \times 10^{-4}\ \mathrm{m^2/sec}}}$$

REFERENCES:

[1] Bachus, B., Narejo D., Theil, R., Soong, T.Y., (2004), *The GSE Drainage Design Manual.* GSE Environmental, Chapters 4 – 6

[2] Koerner, Robert M. (2012), *Designing with Geosynthetics*., 6th ed. Vol. 2, Xlibris Corporation, pp. 872-873.

ATTACHMENTS:

Attachment A – Reduction Factor Table from Page 873 of Reference 2

Attachment A

RF_{CR} = reduction factor for creep deformation of the drainage core itself and/or creep intrusion of the adjacent geotextile into the drainage core space,
RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals onto the geotextile or within the drainage core space, and
RF_{BC} = reduction factor for biological clogging of the geotextile or within the drainage core space.

TABLE 8.5 RECOMMENDED REDUCTION FACTORS FOR EQ. (8.12) TO DETERMINE ALLOWABLE FLOW RATE OF DRAINAGE GEOCOMPOSITES [SHEET DRAINS (most applications), WICK DRAINS AND EDGE DRAINS]

Application Area	RF_{IN}	RF_{CR}*	RF_{CC}	RF_{BC}
Sport fields	1.0 to 1.2	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.3 to 1.5	1.2 to 1.4	1.1 to 1.5	1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill caps	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.2 to 1.5
Secondary leachate collection (landfill)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Primary leachate collection (landfill)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Wick drains (or PVDs)†	1.5 to 2.5	1.0 to 2.5	1.0 to 1.2	1.0 to 1.2
Highway edge drains	1.2 to 1.8	1.5 to 3.0	1.1 to 5.0	1.0 to 1.2

* These values assume that the ultimate value was obtained using an applied normal pressure of approximately 1.5 times the field anticipated maximum value. If not, the values must be increased.

† An additional term for kinking, or crimping, should be included, where RF_{KG} = 1.0 to 4.0.

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File No. 3066.11 Page 1 of 3
Project Phase IV Design
Location Four Hills Landfill, Nashua, New Hampshire
Subject Final Cover System Veneer Slope Stability Calculations
Calculated By E. Galvin Date 6/30/2020
Checked By E. Steinhauser Date 7/1/2020
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E.2 CAP VENEER SLOPE STABILITY

PURPOSE:

Calculate the factor of safety for the veneer stability of the Phase IV sloped portion of the proposed final cover system. The minimum factor of safety of the cover system is 1.5 as it is a final condition.

METHOD:

1. Identify the condition(s) where veneer stability of the final cover slope is of concern.

2. Calculate the factors of safety for slip surfaces above (FS_A) and below (FS_B) the geomembrane component of the cover system, using the following equations [Ref. 1, equations 58 and 59, respectively, p. 1173].

$$
\begin{aligned}
FS_A = {} & \frac{\gamma_t\,(t - t_w) + \gamma_b t_w}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\;\frac{\tan \delta_A}{\tan \beta} + \frac{a_A/\sin \beta}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w} \\
& + \frac{\gamma_t\,(t - t_w^*) + \gamma_b t_w^*}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\;\frac{t}{h}\;\frac{\sin \phi}{2 \sin \beta\ \cos \beta\ \cos(\beta + \phi)} \\
& + \frac{c\,t/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\;\frac{\cos \phi}{\sin \beta\ \cos(\beta + \phi)} \\
& + \frac{T/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}
\end{aligned}
$$

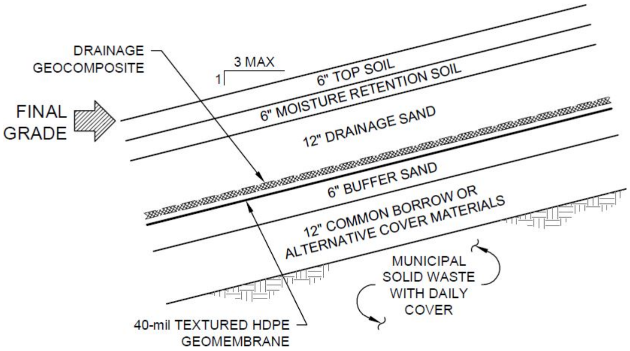
$$
\begin{aligned}
FS_B = {} & \frac{\tan \delta_B}{\tan \beta} + \frac{a_B/\sin \beta}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w} \\
& + \frac{\gamma_t\,(t - t_w^*) + \gamma_b t_w^*}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\;\frac{t}{h}\;\frac{\sin \phi}{2 \sin \beta\ \cos \beta\ \cos(\beta + \phi)} \\
& + \frac{c\,t/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}\;\frac{\cos \phi}{\sin \beta\ \cos(\beta + \phi)} \\
& + \frac{T/h}{\gamma_t\,(t - t_w) + \gamma_{sat} t_w}
\end{aligned}
$$

Where: γ_t = Total weight of soil (N/m^3);
γ_b = Buoyant weight of soil (N/m^3);
γ_{sat} = Saturated weight of soil (N/m^3);
δ_A = interface friction angle along the slip surface located above the geomembrane (degrees);
δ_B = interface friction angle along the slip surface located below the geomembrane (degrees);
t = Thickness of soil layer (m);

t_w = Water flow thickness (m);
t_w^* = Water flow thickness at toe of slope (m);
a_A = Interface adhesion along the slip surface above the geomembrane (Pa);
a_B = Interface adhesion along the slip surface below the geomembrane (Pa);
ϕ = internal angle of friction of soil above the geomembrane (degrees);
β = slope angle (degrees);
h = height of slope (m);
c = cohesion of soil above the geomembrane (Pa); and
T = geosynthetic tension (N/m).

FINAL COVER SYSTEM DATA:

- The cover system components from top down include: a 6-inch thick layer of Topsoil, 6-inch Moisture Retention soil layer, 12-inch Drainage Sand layer, a 250-mil thick drainage geocomposite, a 40-mil thick textured HDPE geomembrane, a 6-inch Buffer Sand layer, and a 12-inch thick layer of common borrow or alternative cover materials.



- The typical height of the 3H:1V (18.4°) cover system slope is approximately 30 feet (9.1 meters [m]) between intermediate swales, with a slope length of approximately 100 feet (30.5 m).

- Summary of values for Giroud method FS equations:

γ_t = 19.6 kN/m^3 (assumed total unit weight of 125 pcf)
γ_b = 11.3 N/m^3 (Assumes a soil with a void ratio = 0.43 and a specific gravity of 2.65)
γ_{sat} = 21.1 N/m^3 (Assumes a soil with a void ratio = 0.43 and a specific gravity of 2.65)
δ_A = 26° (See Attachment A)
t = 0.610 m (24 inches of soil above the cap geomembrane)
t_w = 0.00635 m (conservative, assumes drainage geocomposite is full)
t_w^* = 0.051 m and 0.305 (conservative assumption - assumes 2 in of water at the toe of slope and 12 in of water at the toe of slope for dry and wet conditions, respectively)
a_A = 0 (See Attachment A)
a_B = 0 (conservative assumption)
ϕ = 32°
β = 18.4°

h = 9.1 m
c = 0 (conservative assumption)
T = 0 (conservative assumption)

CALCULATION:

The attached spreadsheets summarize the calculations for above and below the geomembrane cap and with and without a saturated sand layer.

RESULTS:

The results for the attached veneer slope stability analysis for the Phase IV final cover system are as follows:

Factor of Safety for Slip Surface Above Geomembrane, FS_A (dry) = 1.6 ≥ 1.5 **OK**
Factor of Safety for Slip Surface Above Geomembrane, FS_A (wet) = 1.5 ≥ 1.5 **OK**
Factor of Safety for Slip Surface Below Geomembrane, FS_B (dry) = 1.6 ≥ 1.5 **OK**
Factor of Safety for Slip Surface Below Geomembrane, FS_B (wet) = 1.5 ≥ 1.5 **OK**

CONCLUSION:

The cover system over the 3H:1V slopes may be constructed to the proposed Phase IV final grades shown on in the Phase IV Design Drawings.

REFERENCES:

[1] Giroud, J.P., Bachus, R.C., and Bonaparte, R., 1995, "Influence of Water Flow on the Stability of Geosynthetic-Soil Layers Systems on Slopes," *Geosynthetics International,* Vol. 2, No. 6, pp 1149 - 1180.

Attachment A

Appendix Table 1. Summary of interface shear strengths.

Interface 1*	Interface 2*	Peak Strength					Residual Strength				
		Fig. No.	δ (deg)	Ca (kPa)	Points	R^2	Fig. No.	δ (deg)	Ca (kPa)	Points	R^2
HDPE-S	Granular Soil	1a	21	0	162	0.93	1b	17	0	128	0.92
HDPE-S	Cohesive Soil										
	Saturated	1c	11	7	79	0.94	1d	11	0	59	0.95
	Unsaturated	1c	22	0	44	0.93	1d	18	0	32	0.93
HDPE-S	NW-NP GT	1e	11	0	149	0.93	1f	9	0	82	0.96
HDPE-S	Geonet	1g	11	0	196	0.90	1h	9	0	118	0.93
HDPE-S	Geocomposite	1i	15	0	36	0.97	1j	12	0	30	0.93
HDPE-T	Granular Soil	2a	34	0	251	0.98	2b	31	0	239	0.96
HDPE-T	Cohesive Soil										
	Saturated	2c	18	10	167	0.93	2d	16	0	150	0.90
	Unsaturated	2c	19	23	62	0.91	2d	22	0	35	0.93
HDPE-T	NW-NP GT	2e	25	8	254	0.96	2f	17	0	217	0.95
HDPE-T	Geonet	2g	13	0	31	0.99	2h	10	0	27	0.99
HDPE-T	Geocomposite	2i	26	0	168	0.95	2j	15	0	164	0.94
LLDPE-S	Granular Soil	3a	27	0	6	1.00	3b	24	0	9	1.00
LLDPE-S	Cohesive Soil	3c	11	12.4	12	0.94	3d	12	3.7	9	0.93
LLDPE-S	NW-NP GT	3e	10	0	23	0.63	3f	9	0	23	0.49
LLDPE-S	Geonet	3g	11	0	9	0.99	3h	10	0	9	1.00
LLDPE-T	Granular Soil	4a	26	7.7	12	0.95	4b	25	5.2	12	0.95
LLDPE-T	Cohesive Soil	4c	21	5.8	12	1.00	4d	13	7.0	9	0.98
LLDPE-T	NW-NP GT	4e	26	8.1	9	1.00	4f	17	9.5	9	0.96
LLDPE-T	Geonet	4g	15	3.6	6	0.97	4h	11	0	6	0.98
PVC-S	Granular Soil	5a	26	0.4	6	0.99	5b	19	0	6	0.99
PVC-S	Cohesive Soil	5c	22	0.9	11	0.88	5d	15	0	9	0.95
PVC-S	NW-NP GT	5e	20	0	89	0.91	5f	16	0	83	0.74
PVC-S	NW-HB GT	5g	18	0	3	1.00	5h	12	0.1	3	1.00
PVC-S	Woven GT	5i	17	0	6	0.54	5j	7	0	6	0.93
PVC-S	Geonet	5k	18	0.1	3	1.00	5l	16	0.6	3	1.00

Koerner, G., and Narejo, D., 2005, "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces," Geosynthetic Research Institute, GRI Report #30.

3H:1V Slope - Veneer Slope Stability ABOVE the Geomembrane COVER

Description	Symbol	Value	Units		**Notes**
					Actual scenario with maximum "height of slope"
unit weight of soil	γ_t	19.60	kN/m^3		12 in. drainage sand, 6 in. of moisture retention soil, and 6 in. of topsoil
soil cover thickness	t	0.610	meters		Minimum cover of 24 in
thickness of water in slope, wedge 2	t_w	0.00635	meters		Assume flow is contained in geocomposite
thickness of water in slope, wedge 1	t^*_w	0.3050	meters		Assume 12 inches of water at toe of slope (binded geocomposite and sar
Saturated unit weight of soil	γ_{sat}	21.1	kN/m^3	γ_{sat}	
buoyant unit weight of soil	γ_b	11.3	kN/m^3	γ_b	
geosynthetic interface adhesion	a	0.0	kPa	a_A	
geosynthetic interface friction angle	δ	26.0	degrees	δ_A	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	β	3H:1V slope
soil friction angle	φ	32.0	degrees	φ	Value is assumed based on Typical Cover Soil
cohesion of soil	c	0.0	kPa	c	
geosynthetic tension	T	0.0	kN/m	T	
height of slope	h	9.1	meters	h	30 ft

	Numerator	Denominator	Total
Term 1	5.8018	3.9778	1.4585
Term 2	0.0000	11.9577	0.0000
Term 3	3.0419	41.5490	0.0732
Term 4	0.0000	2.4059	0.0000
Term 5	0.0000	11.9577	0.0000
Factor of Safety			1.53

3H:1V Slope - Veneer Slope Stability ABOVE the Geomembrane COVER

Notes

Actual scenario with maximum "height of slope"

Description	Symbol	Value	Units		Notes
unit weight of soil	γ_t	19.60	kN/m^3		12 in. drainage sand, 6 in. of moisture retention soil, and 6 in. of topsoil
soil cover thickness	t	0.610	meters		Minimum cover of 24 in
thickness of water in slope, wedge 2	t_w	0.00635	meters		Assume flow is contained in geocomposite
thickness of water in slope, wedge 1	t^*_w	0.0510	meters		Assume 2 inches of water at toe of slope
Saturated unit weight of soil	γ_{sat}	21.1	kN/m^3	γ_{sat}	
buoyant unit weight of soil	γ_b	11.3	kN/m^3	γ_b	
geosynthetic interface adhesion	a	0.0	kPa	a_A	
geosynthetic interface friction angle	δ	26.0	degrees	δ_A	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	β	3H:1V slope
soil friction angle	φ	32.0	degrees	φ	Value is assumed based on Typical Cover Soil
cohesion of soil	c	0.0	kPa	c	
geosynthetic tension	T	0.0	kN/m	T	
height of slope	h	9.1	meters	h	30 ft

	Numerator	Denominator	Total
Term 1	5.8018	3.9778	1.4585
Term 2	0.0000	11.9577	0.0000
Term 3	3.7230	41.5490	0.0896
Term 4	0.0000	2.4059	0.0000
Term 5	0.0000	11.9577	0.0000
Factor of Safety			1.55

$$FS_A = \frac{\gamma_t (t - t_w) + \gamma_b t_w}{\gamma_t (t - t_w) + \gamma_{sat} t_w} \frac{\tan \delta_A}{\tan \beta} + \frac{a_A / \sin \beta}{\gamma_t (t - t_w) + \gamma_{sat} t_w} + \frac{\gamma_t (t - t^*_w) + \gamma_b t^*_w}{\gamma_t (t - t_w) + \gamma_{sat} t_w} \frac{t}{h} \frac{}{2 \sin \beta}$$

3H:1V Slope - Veneer Slope Stability BELOW the Geomembrane COVER

Description	Symbol	Value	Units	**Notes** Actual scenario with maximum "height of slope"
unit weight of soil	γ_t	19.60	kN/m^3	12 inches of cover materials and 6 inches of buffer sand (125 pcf)
soil cover thickness	t	0.610	meters	Minimum cover of 18 in
thickness of water in slope, wedge 2	t_w	0.00635	meters	Assume flow is contained in the geocomposite
thickness of water in slope, wedge 1	t^*_w	0.0510	meters	Assume 2 inches of flow at toe of slope
Saturated unit weight of soil	γ_{sat}	21.1	kN/m^3	
buoyant unit weight of soil	γ_b	11.3	kN/m^3	
geosynthetic interface adhesion	a	0.0	kPa	
geosynthetic interface friction angle	δ	26.0	degrees	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	3H:1V slope
soil friction angle	φ	32.0	degrees	Value is assumed based on Typical Cover Soil
cohesion of soil	c	0.0	kPa	
geosynthetic tension	T	0.0	kN/m	
height of slope	h	9.1	meters	30 ft

	Numerator	Denominator	Total
Term 1	0.4877	0.3327	1.4662
Term 2	0.0000	11.9655	0.0000
Term 3	3.7280	41.5763	0.0897
Term 4	0.0000	2.4075	0.0000
Term 5	0.0000	11.9655	0.0000
Factor of Safety			1.56

3H:1V Slope - Veneer Slope Stability BELOW the Geomembrane COVER

Description	Symbol	Value	Units	Notes
				Actual scenario with maximum "height of slope"
unit weight of soil	γ_t	19.60	kN/m^3	12 inches of cover materials and 6 inches of buffer sand (125 pcf)
soil cover thickness	t	0.610	meters	Minimum cover of 18 in
thickness of water in slope, wedge 2	t_w	0.00635	meters	Assume flow is contained in the geocomposite
thickness of water in slope, wedge 1	t^*_w	0.3050	meters	Assume 12 inches of water at toe of slope (binded geocomposite and sa
Saturated unit weight of soil	γ_{sat}	21.1	kN/m^3	
buoyant unit weight of soil	γ_b	11.3	kN/m^3	
geosynthetic interface adhesion	a	0.0	kPa	
geosynthetic interface friction angle	δ	26.0	degrees	Interface Shear Strength Figure 2i (GRI Report #30 page 57)
angle of slope	β	18.4	degrees	3H:1V slope
soil friction angle	φ	32.0	degrees	Value is assumed based on Typical Cover Soil
cohesion of soil	c	0.0	kPa	
geosynthetic tension	T	0.0	kN/m	
height of slope	h	9.1	meters	30 ft

	Numerator	Denominator	Total
Term 1	0.4877	0.3327	1.4662
Term 2	0.0000	11.9655	0.0000
Term 3	3.0465	41.5763	0.0733
Term 4	0.0000	2.4075	0.0000
Term 5	0.0000	11.9655	0.0000
Factor of Safety			1.54

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File No. 3066.11 Page 1 of 8
Project Phase IV Expansion
Location Four Hills Landfill, Nashua, New Hampshire
Subject Stormwater Calculation Summary
Calculated By R. Clay / O. Hernandez Date 6/17/2020
Checked By E. Steinhauser Date 7/8/2020
P:\3000s\3066.11\Source Files\Calculations\Stormwater\20200617 Stormwater Sizing Calc.docx

F.1 STORMWATER MANAGEMENT CALCULATIONS

PURPOSE:

- Demonstrate that the stormwater management infrastructure proposed for the Phase IV expansion at the City of Nashua's Four Hills Landfill is adequately sized to convey stormwater runoff generated during the 25-year, 24-hour storm event (Env-Sw 805.10(h)) as defined by the Northeast Regional Climate Center (NRCC).
- Demonstrate that the existing stormwater detention basins located on site have capacity to manage runoff from the 50-year, 24-hour storm event without overtopping (Env-Wq 1508.03).
- Demonstrate that post-development discharge rates are below pre-development discharge rates for the 10-year and 50-year, 24-hour storm events (Env-Wq 1507.06).
- Demonstrate that the design meets the channel protection requirements of Env-Wq 1507.05.

GIVEN:

Rainfall intensities were obtained from the Northeast Regional Climate Center (NRCC) Extreme Precipitation Estimates on May 5, 2020 (refer to Attachment A).

- Rainfall for a 2-year, 24-hour storm event = 2.97 inches.
- Rainfall for a 10-year, 24-hour storm event = 4.42 inches.
- Rainfall for a 25-year, 24-hour storm event = 5.55 inches.
- Rainfall for a 50-year, 24-hour storm event = 6.60 inches.

Proposed site conditions are depicted on the attached drainage plan (refer to Attachment B). The grades shown on the drawing were developed prior to performing stormwater analysis.

ASSUMPTIONS:

The following parameters were used for this calculation:

- Curve Number for Landfill Final Cover System = 74
- Curve Number for Gravel Roads = 89
- Curve Number for Unconnected Pavement = 98
- Manning's "n" coefficient for riprap-lined swale = 0.04
- Manning's "n" coefficient for grass-lined swale = 0.03

METHOD:

1. Use HydroCAD to predict the rate of runoff for the 10-year, 25-year, and 50-year, 24-hour storm events.
2. Size stormwater management infrastructure based on the predicted flow rates.
3. Evaluate and summarize available freeboard in the existing stormwater detention basins.

4. Compare post-development runoff rates to pre-development runoff rates.

CALCULATION:

1. Calculations for the peak runoff associated with the 2-year, 10-year, 25-year, and 50-year, 24-hour storm events were performed using HydroCAD™ version 10.0, developed by HydroCAD Software Solutions, LLC of Chocorua, New Hampshire (HydroCAD). HydroCAD uses synthetic rainfall distributions developed by the National Resource Conservation Service (NRCS) to calculate the peak rate of runoff for a given watershed based on the average land slope, weighted average curve number, and time of concentration. Selections of curve numbers (CN) used in the modeling are based on proposed ground cover types. Rainfall depths are based on rainfall data obtained from the Northeast Regional Climate Center Extreme Precipitation Estimates, and a Type-III rainfall distribution. Attachment C contains the summary output model reports for the 2-year, 10-year, and 50-year, 24-hour storm events and the full output model reports for the 10-year and 25-year, 24-hour storms.

2. HydroCAD uses the Manning's equation to evaluate open channel flow, allowing input of slope and dimensions for rectangular, vee, trapezoidal, parabolic, and/or circular (pipe) open channels. Based on the input geometry, HydroCAD establishes the relationship between flow rate, cross-sectional area of flow, and flow depth in the channel. Based on the results of initial calculations, designers can iterate to select channel dimensions, and/or channel linings, that provide acceptable performance with regards to channel freeboard and velocity. The Manning's equation can be expressed in several forms. For example, using the equation, V = Q/A as a definition for flow velocity, the Manning equation can be expressed in terms of velocity:

$$V = \frac{1.49R^{\frac{2}{3}}\sqrt{S}}{n}$$

Where:
V = Velocity (ft/sec)
n = Roughness coefficient
R = Hydraulic radius (ft) = Area of Flow (ft^2)/Wetted Perimeter (ft)
S = Slope of channel (ft/ft)

Using HydroCAD to iterate based on the results of the Manning's equation, the following open channel sizes and linings were ultimately selected and their performance is demonstrated as follows:

Swale 16R: 2-ft deep trapezoidal swale with 1-ft wide base and 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.09 ft/ft (or 9%)
n = 0.04 (gabion lined)

Roadside Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	30.6	7.8	0.6

Swale 17R: 2-ft deep trapezoidal swale with 1-ft wide base and 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.11 ft/ft (or 11%)
n = 0.04 (gabion lined)

Perimeter Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	5.1	5.49	1.5

Swale 18R: 2-ft deep trapezoidal swale with 1-ft wide base and 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.02 ft/ft (or 2%)
n = 0.03 (grass lined)

Perimeter Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	6.1	3.44	1.3

Swale 19R: 2-ft deep trapezoidal swale with 1-ft wide base and 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.15 ft/ft (or 15%)
n = 0.04 (gabion lined)

Perimeter Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	11.9	7.7	1.3

Swale 20R: 2-ft deep trapezoidal swale with 1-ft wide base and 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.01 ft/ft (or 1%)
n = 0.04 (gabion lined)

Perimeter Swale No. 1			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	11.8	2.79	0.8

Swale 22R: 2-ft deep trapezoidal swale with 1-ft wide base and 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.02 ft/ft (or 2%)
n = 0.04 (gabion lined)

Perimeter Swale No. 1			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	40.2	5.1	1.5

Existing Swale 15R: Existing 2-ft deep triangular swale with 2H:1V side slope on the downhill side and 2H:1V side slope on the uphill side

Slope of channel at design location = 0.09 ft/ft (or 9%)
n = 0.04 (gabion lined)

Existing Perimeter Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	18.9	7.1	0.9

Existing Swale 3R: Existing 2-ft deep trapezoidal swale with 6-ft wide base and 3H:1V side slope on the downhill side and 3H:1V side slope on the uphill side

Slope of channel at design location = 0.03 ft/ft (or 3%)
n = 0.04 (riprap lined)

Existing Perimeter Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	74.7	5.8	0.7

Existing Swale 4R: 2-ft deep triangular swale with 3H:1V side slope on the downhill side and 3H:1V side slope on the uphill side

Slope of channel at design location = 0.004 ft/ft (or 0.4%)
n = 0.03 (grass lined)

Perimeter Swale No. 1			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	33.1	3.49	0.4

Culvert 6R: Pipe size = 36-inch diameter
n = 0.012 (smooth-wall pipe)

Culvert			
Design Storm	**Inflow to Pipe (ft^3/s)**	**Discharge Velocity (ft/s)**	**Freeboard (ft)**
25-yr storm	28.8	5.1	0.6

Culverts 21R: Pipe size = 42-inch diameter x 2 (dual culverts)
n = 0.012 (smooth-wall pipe)

Dual Culverts			
Design Storm	**Inflow to Pipe (ft^3/s)**	**Discharge Velocity (ft/s)**	**Freeboard (ft)**
25-yr storm	68.9	5.2	1.2

Culverts 23R: Pipe size = 36-inch diameter x 2 (dual culverts)
n = 0.012 (smooth-wall pipe)

Dual Culverts			
Design Storm	**Inflow to Pipe (ft^3/s)**	**Discharge Velocity (ft/s)**	**Freeboard (ft)**
25-yr storm	73.5	7.3	1.3

Catch Basin CB3: Existing Catch Basin; Pipe size = 24-inch diameter
n = 0.012 (smooth-wall pipe)

Existing Catch Basin			
Design Storm	**Inflow to Pipe (ft^3/s)**	**Discharge Velocity (ft/s)**	**Freeboard (ft)**
25-yr storm	18.4	5.9	0.02

Sideslope Swale: The intermediate (side slope) swale with the largest contributing drainage area was modeled as the design case scenario for the intermediate swales (refer to Attachment F). The intermediate swales are 2-ft deep grass-lined triangular swale with 2H:1V side slope on the downhill side and 3H:1V side slope on the uphill side.

Slope of channel = 0.02 ft/ft (or 2%)
n = 0.03 (grass lined)

Intermediate Side Slope Swale			
Design Storm	**Inflow to Channel (ft^3/s)**	**Max. Velocity in Channel (ft/s)**	**Freeboard (ft)**
25-yr storm	10.2	4.0	1.1

3. HydroCAD allows users to input pond storage capacities and define pond outlet conditions. Based on this information, HydroCAD develops a stage-discharge relationship for each pond (basin) that is used to predict pond outflow and peak water elevation in the basin.

   For the 50-year, 24-hour storm event, the predicted performance and available freeboard for each stormwater detention basin directly receiving stormwater from the Phase IV expansion is demonstrated as follows:

Pond No. 2 – (Existing Detention Basin)			
Design Storm	**Inflow (ft^3/s)**	**Outflow (ft/s)**	**Freeboard (ft)**
50-yr storm	179.8	12.9	0.4

Pond No. 4 – (Existing Detention Basin)			
Design Storm	**Inflow (ft^3/s)**	**Outflow (ft/s)**	**Freeboard (ft)**
50-yr storm	105.3	7.9	3.3

4. Comparing post-development discharge rates to pre-development discharge rates for the 10-year and 50-year, 24-hour storm events (Env-Wq 1507.06), the predicted pre- and post-development peak flows are summarized below for each discharge location.

Discharge Location	**10-yr Pre-Dev Peak Flow (ft^3/s)**	**10-yr Post-Dev Peak Flow (ft^3/s)**	**50-yr Pre-Dev Peak Flow (ft^3/s)**	**50-yr Post-Dev Peak Flow (ft^3/s)**
Pond 2	8.7	8.0	13.0	12.9
Pond 4	6.1	4.9	8.6	7.9

5. Demonstrate that the 2-year, 24-hour post-development peak flow rate and volume is less than the 2-year, 24-hour pre-development peak flow rate and volume.

Discharge Location	**2-yr Pre-Dev Peak Flow (ft^3/s)**	**2-yr Post-Dev Peak Flow (ft^3/s)**	**2-yr Pre-Dev Discharge Volume (af)**	**2-yr Post-Dev Discharge Volume (af)**
Pond 2	3.8	2.9	2.7	2.4
Pond 4	3.7	1.8	2.0	1.6

CONCLUSIONS:

- As demonstrated, the proposed stormwater conveyance features (i.e., swales and culverts) are adequately sized to convey peak runoff generated during the 25-year, 24-hour design storm event.
- The existing stormwater detention basins are adequately sized to manage the 50-year, 24-hour storm event without overtopping.
- The proposed post-development discharge rates are predicted to be less than the pre-development discharge rates.

ATTACHMENTS:

A Rainfall Data
B Drainage Plans (Pre- & Post-Development)
C HydroCAD Model Output (2-year, 10-year, 25-year, and 50-year, 24-hour storms)
D BMP Worksheets
E Riprap Sizing Calculations
F Sideslope Swale Sizing Check

ATTACHMENT A
RAINFALL DATA

Extreme Precipitation Tables

Northeast Regional Climate Center

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

Smoothing	Yes
State	New Hampshire
Location	
Longitude	71.522 degrees West
Latitude	42.732 degrees North
Elevation	0 feet
Date/Time	Tue, 05 May 2020 11:07:54 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.28	0.42	0.53	0.69	0.86	1.08	**1yr**	0.74	1.02	1.25	1.57	1.98	2.50	2.76	**1yr**	2.21	2.66	3.08	3.79	4.40	**1yr**
2yr	0.33	0.51	0.64	0.84	1.06	1.33	**2yr**	0.92	1.22	1.54	1.92	2.39	2.97	3.31	**2yr**	2.63	3.19	3.69	4.42	5.03	**2yr**
5yr	0.40	0.62	0.77	1.03	1.32	1.68	**5yr**	1.14	1.53	1.94	2.42	3.01	3.72	4.20	**5yr**	3.29	4.04	4.67	5.55	6.26	**5yr**
10yr	0.44	0.70	0.88	1.20	1.56	2.00	**10yr**	1.35	1.80	2.32	2.90	3.59	4.42	5.02	**10yr**	3.91	4.83	5.59	6.60	7.39	**10yr**
25yr	0.53	0.84	1.07	1.47	1.95	2.51	**25yr**	1.68	2.26	2.93	3.66	4.53	5.55	6.38	**25yr**	4.91	6.13	7.09	8.31	9.21	**25yr**
50yr	0.59	0.95	1.22	1.71	2.31	3.01	**50yr**	2.00	2.67	3.51	4.39	5.41	6.60	7.65	**50yr**	5.84	7.35	8.49	9.88	10.88	**50yr**
100yr	0.68	1.10	1.42	2.01	2.74	3.58	**100yr**	2.37	3.17	4.19	5.24	6.45	7.85	9.17	**100yr**	6.95	8.81	10.17	11.76	12.86	**100yr**
200yr	0.78	1.27	1.64	2.35	3.25	4.28	**200yr**	2.81	3.75	5.01	6.27	7.70	9.34	11.00	**200yr**	8.27	10.57	12.19	14.01	15.20	**200yr**
500yr	0.93	1.53	2.00	2.91	4.08	5.40	**500yr**	3.52	4.71	6.34	7.94	9.74	11.77	14.00	**500yr**	10.41	13.46	15.49	17.65	18.98	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.22	0.34	0.41	0.55	0.68	0.79	**1yr**	0.59	0.77	1.04	1.34	1.68	2.33	2.51	**1yr**	2.06	2.41	2.69	3.44	4.04	**1yr**
2yr	0.32	0.49	0.60	0.82	1.01	1.21	**2yr**	0.87	1.18	1.37	1.79	2.29	2.87	3.22	**2yr**	2.54	3.10	3.58	4.27	4.88	**2yr**
5yr	0.36	0.56	0.69	0.95	1.21	1.42	**5yr**	1.04	1.39	1.63	2.12	2.71	3.42	3.97	**5yr**	3.03	3.82	4.33	5.08	5.80	**5yr**
10yr	0.40	0.61	0.76	1.06	1.36	1.59	**10yr**	1.18	1.56	1.80	2.40	3.06	3.90	4.52	**10yr**	3.45	4.35	5.00	5.78	6.61	**10yr**
25yr	0.45	0.69	0.85	1.22	1.60	1.86	**25yr**	1.38	1.82	2.10	2.84	3.58	4.66	5.49	**25yr**	4.12	5.28	6.10	6.88	7.83	**25yr**
50yr	0.49	0.74	0.92	1.33	1.79	2.10	**50yr**	1.54	2.06	2.36	3.23	4.04	5.34	6.38	**50yr**	4.72	6.14	7.10	7.85	8.93	**50yr**
100yr	0.53	0.80	1.00	1.45	1.98	2.37	**100yr**	1.71	2.32	2.65	3.34	4.56	6.13	7.45	**100yr**	5.43	7.16	8.28	8.96	10.21	**100yr**
200yr	0.58	0.87	1.10	1.59	2.22	2.67	**200yr**	1.92	2.61	2.96	3.75	5.18	7.07	8.71	**200yr**	6.26	8.38	9.66	10.21	11.71	**200yr**
500yr	0.65	0.96	1.24	1.80	2.56	3.15	**500yr**	2.21	3.08	3.46	4.35	6.16	8.53	10.75	**500yr**	7.55	10.34	11.91	12.20	13.99	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.31	0.48	0.59	0.79	0.97	1.14	**1yr**	0.84	1.12	1.29	1.68	2.11	2.66	2.99	**1yr**	2.36	2.87	3.37	4.12	4.71	**1yr**
2yr	0.36	0.55	0.68	0.92	1.13	1.32	**2yr**	0.98	1.29	1.50	1.94	2.49	3.10	3.44	**2yr**	2.74	3.31	3.84	4.60	5.23	**2yr**
5yr	0.44	0.67	0.83	1.15	1.46	1.69	**5yr**	1.26	1.65	1.90	2.43	3.05	4.07	4.42	**5yr**	3.60	4.25	5.05	5.98	6.70	**5yr**
10yr	0.52	0.80	0.99	1.39	1.79	2.07	**10yr**	1.55	2.02	2.35	2.91	3.62	5.02	5.63	**10yr**	4.44	5.42	6.23	7.31	8.11	**10yr**
25yr	0.67	1.02	1.26	1.80	2.37	2.70	**25yr**	2.05	2.64	3.05	3.68	4.52	6.64	7.43	**25yr**	5.87	7.15	8.23	9.54	10.43	**25yr**
50yr	0.80	1.22	1.52	2.19	2.95	3.30	**50yr**	2.54	3.22	3.73	4.41	5.35	8.20	9.16	**50yr**	7.26	8.81	10.13	11.66	12.62	**50yr**
100yr	0.97	1.47	1.84	2.66	3.65	4.04	**100yr**	3.15	3.95	4.56	5.70	6.33	10.10	11.29	**100yr**	8.93	10.86	12.47	14.24	15.24	**100yr**
200yr	1.18	1.77	2.24	3.25	4.53	4.94	**200yr**	3.91	4.83	5.56	6.91	7.50	12.43	13.90	**200yr**	11.00	13.36	15.34	17.41	18.43	**200yr**
500yr	1.52	2.27	2.92	4.24	6.03	6.42	**500yr**	5.20	6.28	7.25	8.92	9.38	16.36	18.27	**500yr**	14.48	17.57	20.15	22.71	23.70	**500yr**

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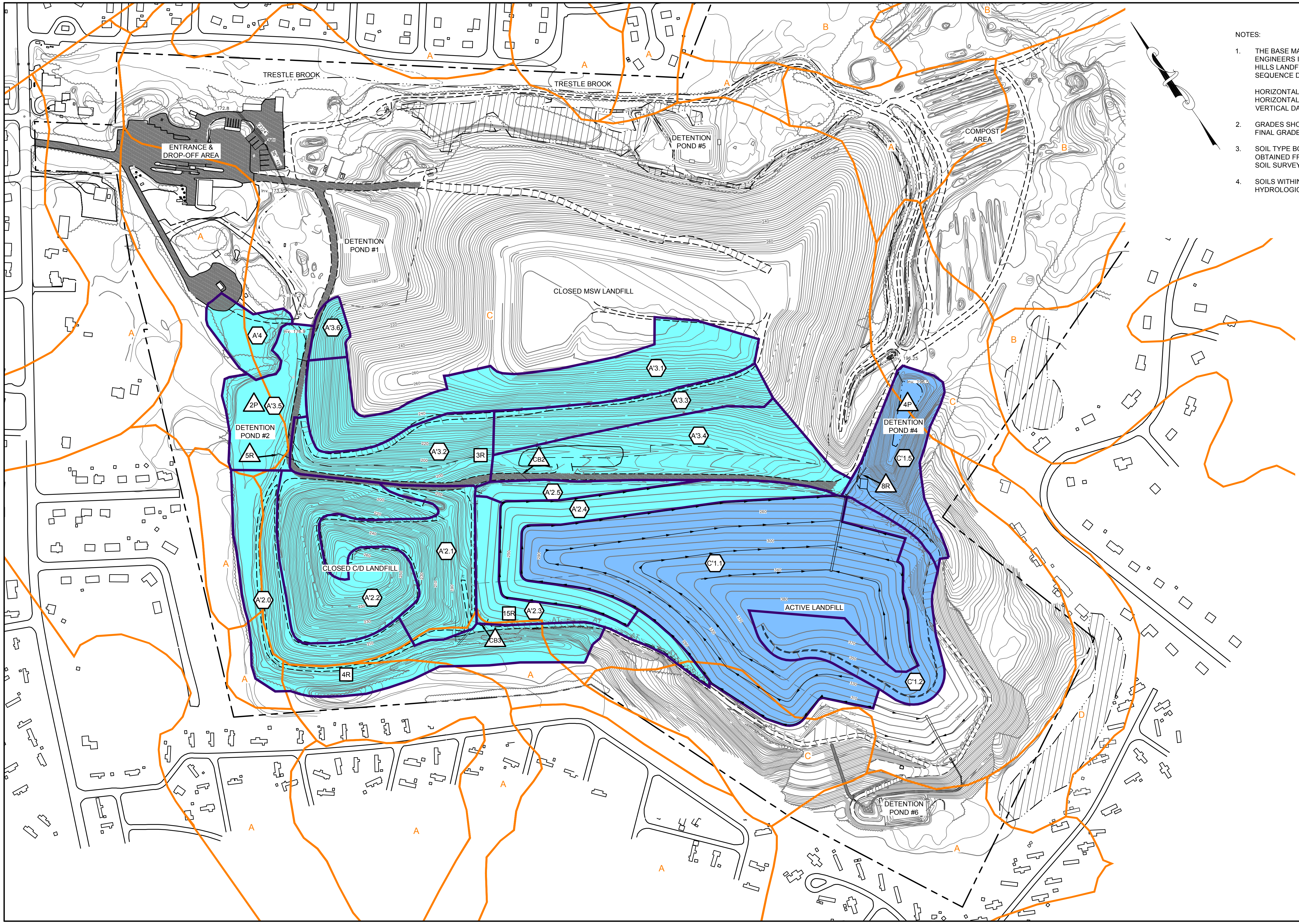
Climate Center

ATTACHMENT B
DRAINAGE PLANS
(PRE- & POST-DEVELOPMENT)



NOTES:

1. THE BASE MAP SHOWN WAS OBTAINED FROM A DRAWING PREPARED BY CMA ENGINEERS INC. OF PORTSMOUTH, NH (CMA), TITLED, "CITY OF NASHUA , NH, FOUR HILLS LANDFILL, PHASE II SECURE SOLID WASTE, PHASE II OPERATING PLAN, FILLING SEQUENCE DRAWINGS, PHASE II, STAGE 1- INITIAL LIFT,", DATED JUNE 2010.

HORIZONTAL DATUM:	NAD83 (2001)
HORIZONTAL PROJECTION:	NH STATE PLANE
VERTICAL DATUM:	NGVD 1929

2. GRADES SHOWN WITHIN THE ACTIVE LANDFILL FOOTPRINT REPRESENT PERMITTED FINAL GRADES.

3. SOIL TYPE BOUNDARIES AND HYDROLOGIC SOIL GROUP (HSG) DESIGNATIONS WERE OBTAINED FROM USDA NATURAL RESOURCES CONSERVATION SERVICES (NRCS) WEB SOIL SURVEY (WSS).

4. SOILS WITHIN LANDFILL LIMITS OF WASTE CONTAINMENT WERE ASSUMED TO BE HYDROLOGIC SOIL GROUP C.

DRAINAGE LEGEND:

1S	WATERSHED (SUBCATCHMENT)
1R	REACH
1P	POND (OR REACH WITH LIMITED STORAGE)
DP1	DISCHARGE POINT
━	WATERSHED BOUNDARY
━	TIME OF CONCENTRATION FLOW PATH
- - -	LIMIT OF WASTE CONTAINMENT
— - —	PROPERTY LINE
←	INTERMEDIATE SWALE
▨	GABION-LINED SWALE
☐	BUILDING
▨	PAVEMENT (IMPERVIOUS)
C	SOILS DELINEATION AND HYDROLOGIC SOILS GROUP DESIGNATION
🟦	AREA DRAINING TO POND NO. 2
🟦	AREA DRAINING TO POND NO. 4

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USER: ohernandezpaz
PLOT DATE: 7-10-20 9:49 AM

SANBORN HEAD

GRAPHICAL SCALE
200' 100' 0' 200' 400'

NO.	DATE	DESCRIPTION	BY

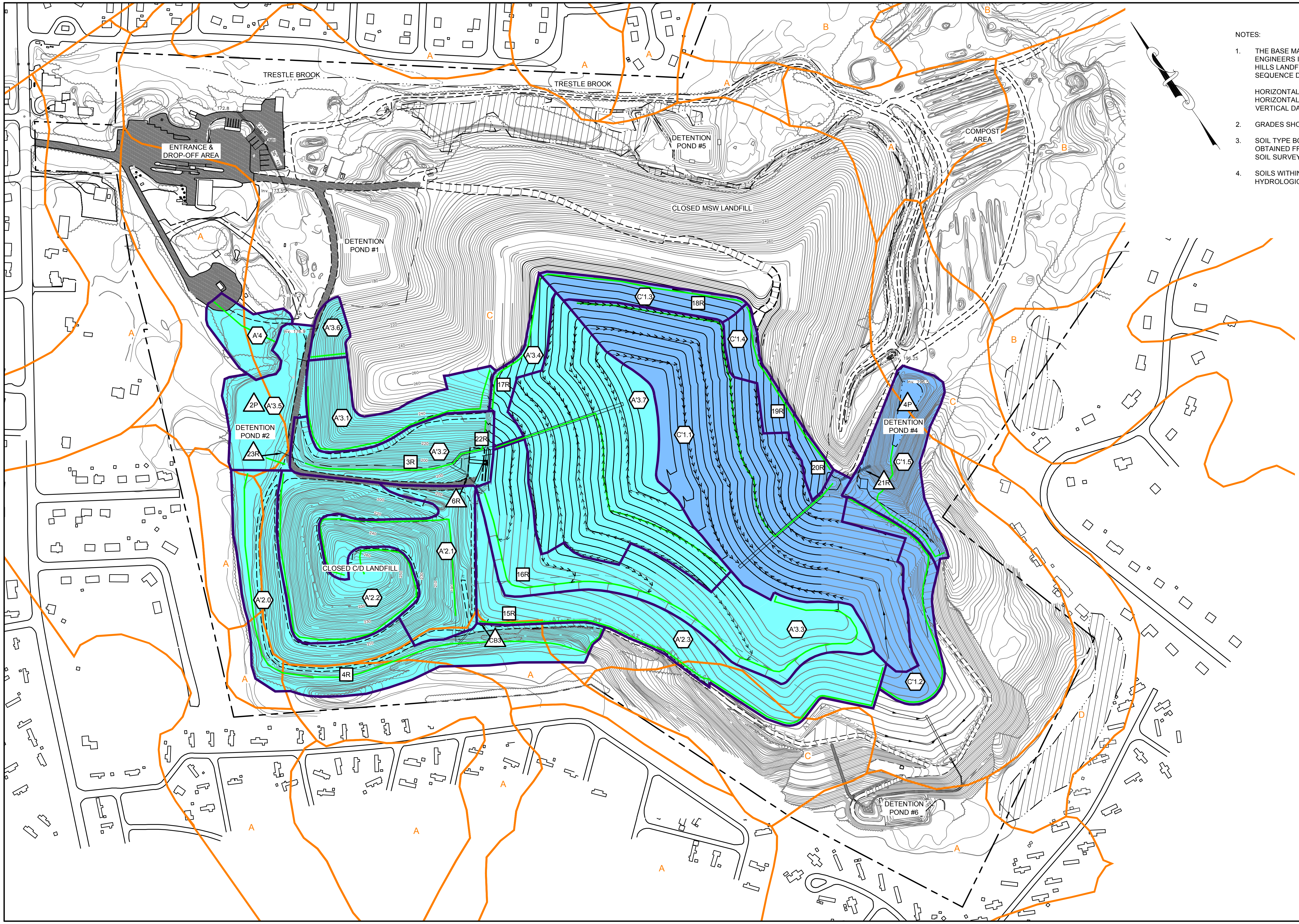
DRAWN BY: O. HERNANDEZ
DESIGNED BY: O. HERNANDEZ / R. CLAY
REVIEWED BY: R. CLAY
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV EXPANSION
FOUR HILLS LANDFILL
CITY OF NASHUA, NEW HAMPSHIRE
NASHUA, NEW HAMPSHIRE

PRE-DEVELOPMENT DRAINAGE PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
1 OF 1



NOTES:

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   HORIZONTAL DATUM: NAD83 (2001)
   HORIZONTAL PROJECTION: NH STATE PLANE
   VERTICAL DATUM: NGVD 1929

2. GRADES SHOWN FOR PHASES I, II, III, AND IV ARE PROPOSED FINAL GRADES.

3. SOIL TYPE BOUNDARIES AND HYDROLOGIC SOIL GROUP (HSG) DESIGNATIONS WERE OBTAINED FROM USDA NATURAL RESOURCES CONSERVATION SERVICES (NRCS) WEB SOIL SURVEY (WSS).

4. SOILS WITHIN LANDFILL LIMITS OF WASTE CONTAINMENT WERE ASSUMED TO BE HYDROLOGIC SOIL GROUP C.

DRAINAGE LEGEND:

1S	WATERSHED (SUBCATCHMENT)
1R	REACH
1P	POND (OR REACH WITH LIMITED STORAGE)
DP1	DISCHARGE POINT
▬	WATERSHED BOUNDARY
▬	TIME OF CONCENTRATION FLOW PATH
- - - -	LIMIT OF WASTE CONTAINMENT
— —	PROPERTY LINE
←	INTERMEDIATE SWALE
▨	GABION-LINED SWALE
☐	BUILDING
▨	PAVEMENT (IMPERVIOUS)
C	SOILS DELINEATION AND HYDROLOGIC SOILS GROUP DESIGNATION
🟦	AREA DRAINING TO POND NO. 2
🟦	AREA DRAINING TO POND NO. 4

GRAPHICAL SCALE
200' 100' 0' 200' 400'

SANBORN HEAD

NO.	DATE	DESCRIPTION	BY

DRAWN BY: O. HERNANDEZ
DESIGNED BY: O. HERNANDEZ / R. CLAY
REVIEWED BY: R. CLAY
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

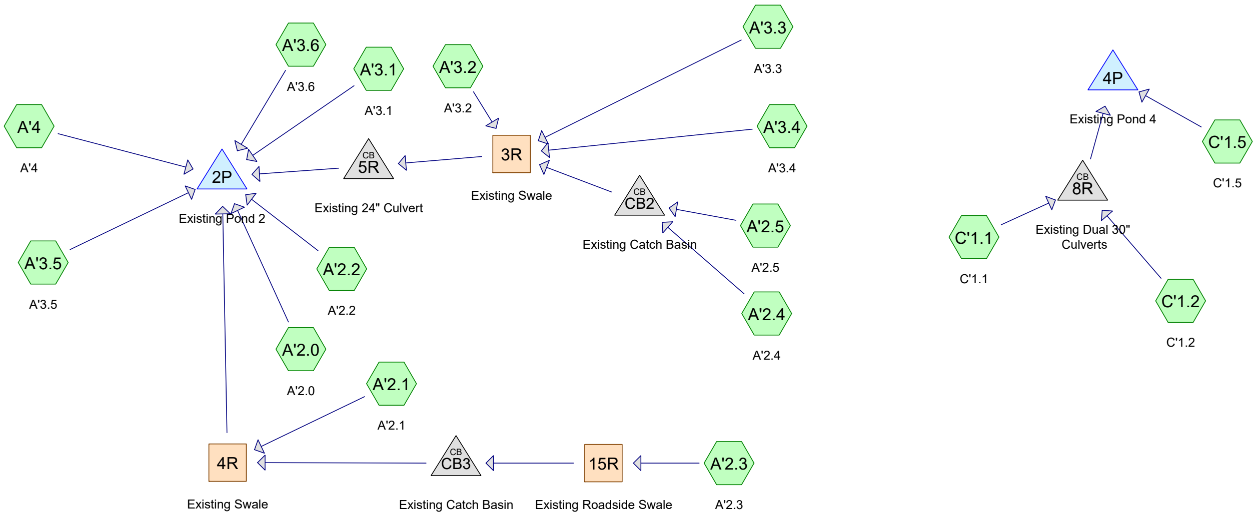
PHASE IV EXPANSION
FOUR HILLS LANDFILL
CITY OF NASHUA, NEW HAMPSHIRE
NASHUA, NEW HAMPSHIRE

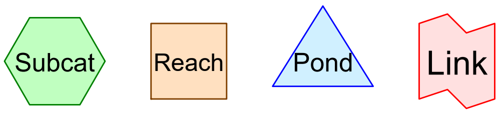
POST-DEVELOPMENT DRAINAGE PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
1 OF 1

ATTACHMENT C
HYDROCAD MODEL OUTPUT





Routing Diagram for Design Pre-Development Model - Phase IV
Prepared by Sanborn, Head & Associates, Inc., Printed 6/12/2020
HydroCAD® 10.00-24 s/n 08733 © 2018 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
5.801	39	>75% Grass cover, Good HSG A (A'2.0, A'2.1, A'2.3, A'3.5, A'4)
69.313	74	>75% Grass cover, Good HSG C (A'2.0, A'2.1, A'2.2, A'2.3, A'2.4, A'2.5, A'3.1, A'3.2, A'3.3, A'3.4, A'3.5, A'3.6, A'4, C'1.1, C'1.2, C'1.5)
0.738	76	Gravel roads HSG A (A'2.0, A'2.1, A'2.3, A'4)
4.129	89	Gravel roads HSG C (A'2.0, A'2.1, A'2.2, A'2.3, A'3.1, A'3.2, A'3.3, A'3.4, A'3.5, A'4, C'1.2, C'1.5)
0.028	98	Roofs HSG C (C'1.5)
0.120	98	Unconnected pavement HSG A (A'3.5, A'4)
1.789	98	Unconnected pavement HSG C (A'2.1, A'2.2, A'2.4, A'2.5, A'3.2, A'3.4, A'3.5, A'3.6)
0.335	98	Water Surface HSG C (C'1.5)
0.047	73	Woods, Fair HSG C (A'4)
1.916	30	Woods, Good HSG A (A'2.0, A'3.5, A'4)
0.993	70	Woods, Good HSG C (A'2.0, A'4, C'1.5)
85.209	**72**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
8.575	HSG A	A'2.0, A'2.1, A'2.3, A'3.5, A'4
0.000	HSG B	
76.635	HSG C	A'2.0, A'2.1, A'2.2, A'2.3, A'2.4, A'2.5, A'3.1, A'3.2, A'3.3, A'3.4, A'3.5, A'3.6, A'4, C'1.1, C'1.2, C'1.5
0.000	HSG D	
0.000	Other	
85.209		**TOTAL AREA**

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>0.14"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=0.22 cfs 0.103 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.41% Impervious Runoff Depth>0.99"
Flow Length=1,198' Slope=0.2331 '/' Tc=8.6 min CN=76 Runoff=5.18 cfs 0.422 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>0.94"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=5.75 cfs 0.517 af

Subcatchment A'2.3: A'2.3 Runoff Area=120,544 sf 0.00% Impervious Runoff Depth>0.84"
Flow Length=927' Slope=0.2959 '/' Tc=6.8 min CN=73 Runoff=2.43 cfs 0.193 af

Subcatchment A'2.4: A'2.4 Runoff Area=186,212 sf 0.90% Impervious Runoff Depth>0.89"
Slope=0.3064 '/' Tc=0.0 min CN=74 Runoff=5.07 cfs 0.317 af

Subcatchment A'2.5: A'2.5 Runoff Area=50,395 sf 0.87% Impervious Runoff Depth>0.89"
Slope=0.2813 '/' Tc=0.0 min CN=74 Runoff=1.37 cfs 0.086 af

Subcatchment A'3.1: A'3.1 Runoff Area=352,418 sf 0.00% Impervious Runoff Depth>0.89"
Slope=0.1959 '/' Tc=0.0 min CN=74 Runoff=9.60 cfs 0.600 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 9.62% Impervious Runoff Depth>1.05"
Slope=0.2049 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=5.83 cfs 0.352 af

Subcatchment A'3.3: A'3.3 Runoff Area=148,484 sf 0.00% Impervious Runoff Depth>0.94"
Slope=0.2342 '/' Tc=0.0 min CN=75 Runoff=4.34 cfs 0.267 af

Subcatchment A'3.4: A'3.4 Runoff Area=318,663 sf 11.01% Impervious Runoff Depth>1.05"
Slope=0.1085 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=10.62 cfs 0.640 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>0.16"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=0.16 cfs 0.044 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>0.94"
Slope=0.2653 '/' Tc=0.0 min UI Adjusted CN=75 Runoff=0.91 cfs 0.056 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>0.29"
Slope=0.0564 '/' Tc=0.0 min UI Adjusted CN=59 Runoff=0.28 cfs 0.040 af

Subcatchment C'1.1: C'1.1 Runoff Area=848,950 sf 0.00% Impervious Runoff Depth>0.89"
Slope=0.2974 '/' Tc=0.0 min CN=74 Runoff=23.12 cfs 1.444 af

Subcatchment C'1.2: C'1.2 Runoff Area=205,026 sf 0.00% Impervious Runoff Depth>0.94"
Slope=0.3604 '/' Tc=0.0 min CN=75 Runoff=5.99 cfs 0.369 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>1.11"
Slope=0.2676 '/' Tc=0.0 min CN=78 Runoff=5.91 cfs 0.353 af

Reach 3R: Existing Swale Avg. Flow Depth=1.11' Max Vel=6.46 fps Inflow=27.23 cfs 1.662 af
n=0.022 L=970.0' S=0.0216 '/' Capacity=115.15 cfs Outflow=23.69 cfs 1.659 af

Reach 4R: Existing Swale Avg. Flow Depth=0.86' Max Vel=2.28 fps Inflow=7.29 cfs 0.615 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=5.06 cfs 0.609 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.51' Max Vel=4.14 fps Inflow=2.43 cfs 0.193 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=2.16 cfs 0.193 af

Pond 2P: Existing Pond 2 Peak Elev=177.90' Storage=198,245 cf Inflow=37.56 cfs 3.628 af
18.0" Round Culvert n=0.012 L=137.0' S=0.0051 '/' Outflow=3.76 cfs 2.691 af

Pond 4P: Existing Pond 4 Peak Elev=198.54' Storage=36,959 cf Inflow=35.02 cfs 2.167 af
12.0" Round Culvert n=0.012 L=85.0' S=0.0029 '/' Outflow=3.68 cfs 1.993 af

Pond 5R: Existing 24" Culvert Peak Elev=184.81' Inflow=23.69 cfs 1.659 af
24.0" Round Culvert n=0.012 L=100.0' S=0.0056 '/' Outflow=23.69 cfs 1.659 af

Pond 8R: Existing Dual 30" Culverts Peak Elev=237.69' Inflow=29.11 cfs 1.813 af
30.0" Round Culvert x 2.00 n=0.011 L=143.0' S=0.0286 '/' Outflow=29.11 cfs 1.813 af

Pond CB2: Existing Catch Basin Peak Elev=206.12' Inflow=6.44 cfs 0.403 af
24.0" Round Culvert n=0.012 L=90.0' S=0.0111 '/' Outflow=6.44 cfs 0.403 af

Pond CB3: Existing Catch Basin Peak Elev=199.61' Inflow=2.16 cfs 0.193 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=2.16 cfs 0.193 af

Total Runoff Area = 85.209 ac Runoff Volume = 5.804 af Average Runoff Depth = 0.82"
97.33% Pervious = 82.937 ac 2.67% Impervious = 2.272 ac

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>0.60"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=2.43 cfs 0.443 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.41% Impervious Runoff Depth>2.06"
Flow Length=1,198' Slope=0.2331 '/' Tc=8.6 min CN=76 Runoff=11.24 cfs 0.877 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>1.98"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=12.85 cfs 1.093 af

Subcatchment A'2.3: A'2.3 Runoff Area=120,544 sf 0.00% Impervious Runoff Depth>1.83"
Flow Length=927' Slope=0.2959 '/' Tc=6.8 min CN=73 Runoff=5.70 cfs 0.423 af

Subcatchment A'2.4: A'2.4 Runoff Area=186,212 sf 0.90% Impervious Runoff Depth>1.91"
Slope=0.3064 '/' Tc=0.0 min CN=74 Runoff=11.60 cfs 0.681 af

Subcatchment A'2.5: A'2.5 Runoff Area=50,395 sf 0.87% Impervious Runoff Depth>1.91"
Slope=0.2813 '/' Tc=0.0 min CN=74 Runoff=3.14 cfs 0.184 af

Subcatchment A'3.1: A'3.1 Runoff Area=352,418 sf 0.00% Impervious Runoff Depth>1.91"
Slope=0.1959 '/' Tc=0.0 min CN=74 Runoff=21.95 cfs 1.288 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 9.62% Impervious Runoff Depth>2.15"
Slope=0.2049 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=12.34 cfs 0.718 af

Subcatchment A'3.3: A'3.3 Runoff Area=148,484 sf 0.00% Impervious Runoff Depth>1.99"
Slope=0.2342 '/' Tc=0.0 min CN=75 Runoff=9.65 cfs 0.565 af

Subcatchment A'3.4: A'3.4 Runoff Area=318,663 sf 11.01% Impervious Runoff Depth>2.15"
Slope=0.1085 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=22.48 cfs 1.308 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>0.66"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=1.82 cfs 0.177 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>1.99"
Slope=0.2653 '/' Tc=0.0 min UI Adjusted CN=75 Runoff=2.02 cfs 0.118 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>0.92"
Slope=0.0564 '/' Tc=0.0 min UI Adjusted CN=59 Runoff=1.75 cfs 0.126 af

Subcatchment C'1.1: C'1.1 Runoff Area=848,950 sf 0.00% Impervious Runoff Depth>1.91"
Slope=0.2974 '/' Tc=0.0 min CN=74 Runoff=52.87 cfs 3.104 af

Subcatchment C'1.2: C'1.2 Runoff Area=205,026 sf 0.00% Impervious Runoff Depth>1.99"
Slope=0.3604 '/' Tc=0.0 min CN=75 Runoff=13.33 cfs 0.780 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>2.23"
Slope=0.2676 '/' Tc=0.0 min CN=78 Runoff=12.22 cfs 0.710 af

Reach 3R: Existing Swale Avg. Flow Depth=1.49' Max Vel=7.90 fps Inflow=59.20 cfs 3.456 af
n=0.022 L=970.0' S=0.0216 '/' Capacity=115.15 cfs Outflow=52.98 cfs 3.451 af

Reach 4R: Existing Swale Avg. Flow Depth=1.20' Max Vel=2.85 fps Inflow=16.46 cfs 1.299 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=12.38 cfs 1.291 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.71' Max Vel=5.17 fps Inflow=5.70 cfs 0.423 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=5.26 cfs 0.422 af

Pond 2P: Existing Pond 2 Peak Elev=178.78' Storage=294,486 cf Inflow=88.80 cfs 7.988 af
18.0" Round Culvert n=0.012 L=137.0' S=0.0051 '/' Outflow=8.71 cfs 6.446 af

Pond 4P: Existing Pond 4 Peak Elev=200.81' Storage=91,975 cf Inflow=78.42 cfs 4.594 af
12.0" Round Culvert n=0.012 L=85.0' S=0.0029 '/' Outflow=6.12 cfs 4.297 af

Pond 5R: Existing 24" Culvert Peak Elev=200.55' Inflow=52.98 cfs 3.451 af
24.0" Round Culvert n=0.012 L=100.0' S=0.0056 '/' Outflow=52.98 cfs 3.451 af

Pond 8R: Existing Dual 30" Culverts Peak Elev=239.28' Inflow=66.20 cfs 3.883 af
30.0" Round Culvert x 2.00 n=0.011 L=143.0' S=0.0286 '/' Outflow=66.20 cfs 3.883 af

Pond CB2: Existing Catch Basin Peak Elev=206.93' Inflow=14.73 cfs 0.865 af
24.0" Round Culvert n=0.012 L=90.0' S=0.0111 '/' Outflow=14.73 cfs 0.865 af

Pond CB3: Existing Catch Basin Peak Elev=199.99' Inflow=5.26 cfs 0.422 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=5.26 cfs 0.422 af

Total Runoff Area = 85.209 ac Runoff Volume = 12.596 af Average Runoff Depth = 1.77"
97.33% Pervious = 82.937 ac 2.67% Impervious = 2.272 ac

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>1.69"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=8.98 cfs 1.242 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.41% Impervious Runoff Depth>3.90"
Flow Length=1,198' Slope=0.2331 '/' Tc=8.6 min CN=76 Runoff=21.35 cfs 1.658 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>3.79"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=24.82 cfs 2.090 af

Subcatchment A'2.3: A'2.3 Runoff Area=120,544 sf 0.00% Impervious Runoff Depth>3.59"
Flow Length=927' Slope=0.2959 '/' Tc=6.8 min CN=73 Runoff=11.34 cfs 0.827 af

Subcatchment A'2.4: A'2.4 Runoff Area=186,212 sf 0.90% Impervious Runoff Depth>3.70"
Slope=0.3064 '/' Tc=0.0 min CN=74 Runoff=22.69 cfs 1.316 af

Subcatchment A'2.5: A'2.5 Runoff Area=50,395 sf 0.87% Impervious Runoff Depth>3.70"
Slope=0.2813 '/' Tc=0.0 min CN=74 Runoff=6.14 cfs 0.356 af

Subcatchment A'3.1: A'3.1 Runoff Area=352,418 sf 0.00% Impervious Runoff Depth>3.70"
Slope=0.1959 '/' Tc=0.0 min CN=74 Runoff=42.94 cfs 2.492 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 9.62% Impervious Runoff Depth>4.01"
Slope=0.2049 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=23.07 cfs 1.342 af

Subcatchment A'3.3: A'3.3 Runoff Area=148,484 sf 0.00% Impervious Runoff Depth>3.80"
Slope=0.2342 '/' Tc=0.0 min CN=75 Runoff=18.59 cfs 1.079 af

Subcatchment A'3.4: A'3.4 Runoff Area=318,663 sf 11.01% Impervious Runoff Depth>4.01"
Slope=0.1085 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=42.01 cfs 2.443 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>1.79"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=6.72 cfs 0.482 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>3.80"
Slope=0.2653 '/' Tc=0.0 min UI Adjusted CN=75 Runoff=3.89 cfs 0.226 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>2.23"
Slope=0.0564 '/' Tc=0.0 min UI Adjusted CN=59 Runoff=5.02 cfs 0.305 af

Subcatchment C'1.1: C'1.1 Runoff Area=848,950 sf 0.00% Impervious Runoff Depth>3.70"
Slope=0.2974 '/' Tc=0.0 min CN=74 Runoff=103.44 cfs 6.002 af

Subcatchment C'1.2: C'1.2 Runoff Area=205,026 sf 0.00% Impervious Runoff Depth>3.80"
Slope=0.3604 '/' Tc=0.0 min CN=75 Runoff=25.67 cfs 1.490 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>4.11"
Slope=0.2676 '/' Tc=0.0 min CN=78 Runoff=22.52 cfs 1.312 af

Reach 3R: Existing Swale Avg. Flow Depth=1.92' Max Vel=9.33 fps Inflow=112.50 cfs 6.537 af
n=0.022 L=970.0' S=0.0216 '/' Capacity=115.15 cfs Outflow=102.80 cfs 6.530 af

Reach 4R: Existing Swale Avg. Flow Depth=1.58' Max Vel=3.42 fps Inflow=32.01 cfs 2.484 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=25.44 cfs 2.472 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.93' Max Vel=6.17 fps Inflow=11.34 cfs 0.827 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=10.69 cfs 0.826 af

Pond 2P: Existing Pond 2 Peak Elev=180.50' Storage=508,270 cf Inflow=180.78 cfs 15.838 af
18.0" Round Culvert n=0.012 L=137.0' S=0.0051 '/' Outflow=12.99 cfs 11.581 af

Pond 4P: Existing Pond 4 Peak Elev=204.35' Storage=198,762 cf Inflow=151.63 cfs 8.804 af
12.0" Round Culvert n=0.012 L=85.0' S=0.0029 '/' Outflow=8.64 cfs 7.569 af

Pond 5R: Existing 24" Culvert Peak Elev=254.97' Inflow=102.80 cfs 6.530 af
24.0" Round Culvert n=0.012 L=100.0' S=0.0056 '/' Outflow=102.80 cfs 6.530 af

Pond 8R: Existing Dual 30" Culverts Peak Elev=244.78' Inflow=129.11 cfs 7.492 af
30.0" Round Culvert x 2.00 n=0.011 L=143.0' S=0.0286 '/' Outflow=129.11 cfs 7.492 af

Pond CB2: Existing Catch Basin Peak Elev=209.63' Inflow=28.83 cfs 1.673 af
24.0" Round Culvert n=0.012 L=90.0' S=0.0111 '/' Outflow=28.83 cfs 1.673 af

Pond CB3: Existing Catch Basin Peak Elev=200.51' Inflow=10.69 cfs 0.826 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=10.69 cfs 0.826 af

Total Runoff Area = 85.209 ac Runoff Volume = 24.663 af Average Runoff Depth = 3.47"
97.33% Pervious = 82.937 ac 2.67% Impervious = 2.272 ac

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>0.60"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=2.43 cfs 0.443 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.41% Impervious Runoff Depth>2.06"
Flow Length=1,198' Slope=0.2331 '/' Tc=8.6 min CN=76 Runoff=11.24 cfs 0.877 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>1.98"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=12.85 cfs 1.093 af

Subcatchment A'2.3: A'2.3 Runoff Area=120,544 sf 0.00% Impervious Runoff Depth>1.83"
Flow Length=927' Slope=0.2959 '/' Tc=6.8 min CN=73 Runoff=5.70 cfs 0.423 af

Subcatchment A'2.4: A'2.4 Runoff Area=186,212 sf 0.90% Impervious Runoff Depth>1.91"
Slope=0.3064 '/' Tc=0.0 min CN=74 Runoff=11.60 cfs 0.681 af

Subcatchment A'2.5: A'2.5 Runoff Area=50,395 sf 0.87% Impervious Runoff Depth>1.91"
Slope=0.2813 '/' Tc=0.0 min CN=74 Runoff=3.14 cfs 0.184 af

Subcatchment A'3.1: A'3.1 Runoff Area=352,418 sf 0.00% Impervious Runoff Depth>1.91"
Slope=0.1959 '/' Tc=0.0 min CN=74 Runoff=21.95 cfs 1.288 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 9.62% Impervious Runoff Depth>2.15"
Slope=0.2049 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=12.34 cfs 0.718 af

Subcatchment A'3.3: A'3.3 Runoff Area=148,484 sf 0.00% Impervious Runoff Depth>1.99"
Slope=0.2342 '/' Tc=0.0 min CN=75 Runoff=9.65 cfs 0.565 af

Subcatchment A'3.4: A'3.4 Runoff Area=318,663 sf 11.01% Impervious Runoff Depth>2.15"
Slope=0.1085 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=22.48 cfs 1.308 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>0.66"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=1.82 cfs 0.177 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>1.99"
Slope=0.2653 '/' Tc=0.0 min UI Adjusted CN=75 Runoff=2.02 cfs 0.118 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>0.92"
Slope=0.0564 '/' Tc=0.0 min UI Adjusted CN=59 Runoff=1.75 cfs 0.126 af

Subcatchment C'1.1: C'1.1 Runoff Area=848,950 sf 0.00% Impervious Runoff Depth>1.91"
Slope=0.2974 '/' Tc=0.0 min CN=74 Runoff=52.87 cfs 3.104 af

Subcatchment C'1.2: C'1.2 Runoff Area=205,026 sf 0.00% Impervious Runoff Depth>1.99"
Slope=0.3604 '/' Tc=0.0 min CN=75 Runoff=13.33 cfs 0.780 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>2.23"
Slope=0.2676 '/' Tc=0.0 min CN=78 Runoff=12.22 cfs 0.710 af

Reach 3R: Existing Swale Avg. Flow Depth=1.49' Max Vel=7.90 fps Inflow=59.20 cfs 3.456 af
n=0.022 L=970.0' S=0.0216 '/' Capacity=115.15 cfs Outflow=52.98 cfs 3.451 af

Reach 4R: Existing Swale Avg. Flow Depth=1.20' Max Vel=2.85 fps Inflow=16.46 cfs 1.299 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=12.38 cfs 1.291 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.71' Max Vel=5.17 fps Inflow=5.70 cfs 0.423 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=5.26 cfs 0.422 af

Pond 2P: Existing Pond 2 Peak Elev=178.78' Storage=294,486 cf Inflow=88.80 cfs 7.988 af
18.0" Round Culvert n=0.012 L=137.0' S=0.0051 '/' Outflow=8.71 cfs 6.446 af

Pond 4P: Existing Pond 4 Peak Elev=200.81' Storage=91,975 cf Inflow=78.42 cfs 4.594 af
12.0" Round Culvert n=0.012 L=85.0' S=0.0029 '/' Outflow=6.12 cfs 4.297 af

Pond 5R: Existing 24" Culvert Peak Elev=200.55' Inflow=52.98 cfs 3.451 af
24.0" Round Culvert n=0.012 L=100.0' S=0.0056 '/' Outflow=52.98 cfs 3.451 af

Pond 8R: Existing Dual 30" Culverts Peak Elev=239.28' Inflow=66.20 cfs 3.883 af
30.0" Round Culvert x 2.00 n=0.011 L=143.0' S=0.0286 '/' Outflow=66.20 cfs 3.883 af

Pond CB2: Existing Catch Basin Peak Elev=206.93' Inflow=14.73 cfs 0.865 af
24.0" Round Culvert n=0.012 L=90.0' S=0.0111 '/' Outflow=14.73 cfs 0.865 af

Pond CB3: Existing Catch Basin Peak Elev=199.99' Inflow=5.26 cfs 0.422 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=5.26 cfs 0.422 af

Total Runoff Area = 85.209 ac Runoff Volume = 12.596 af Average Runoff Depth = 1.77"
97.33% Pervious = 82.937 ac 2.67% Impervious = 2.272 ac

Summary for Subcatchment A'2.0: A'2.0

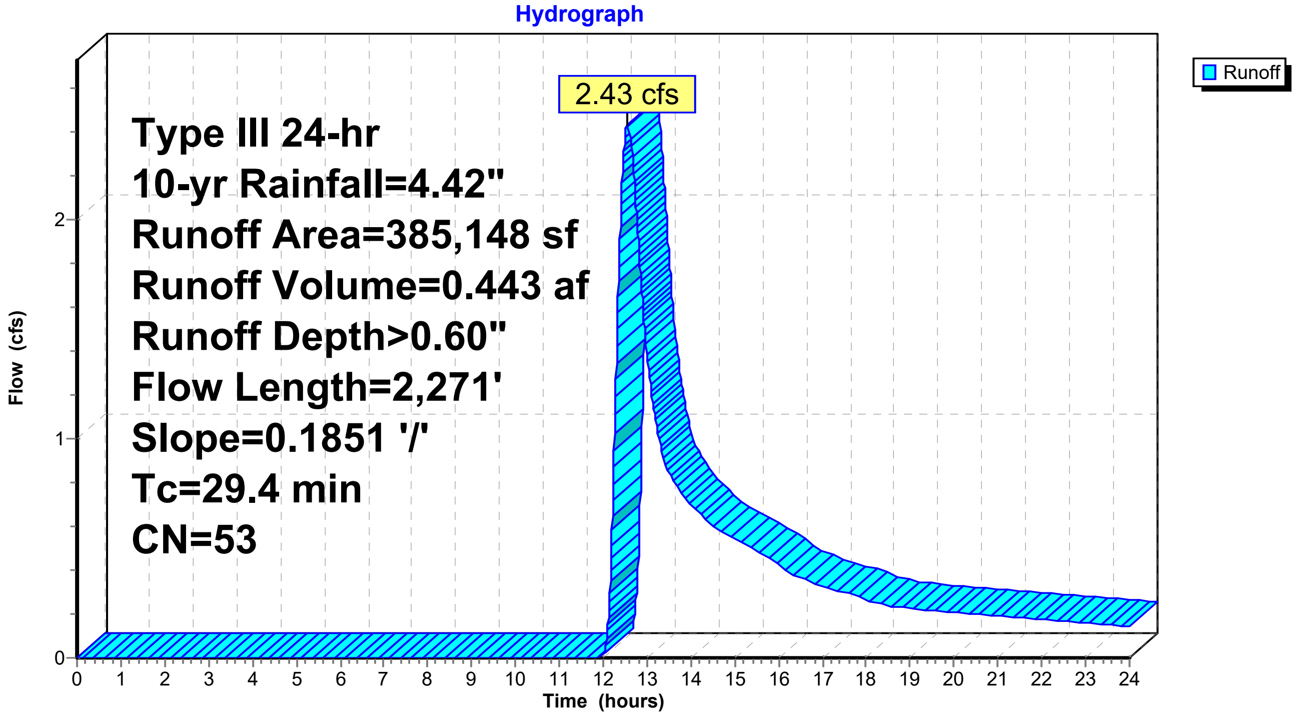
Runoff = 2.43 cfs @ 12.55 hrs, Volume= 0.443 af, Depth> 0.60"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
26,373	70	Woods, Good HSG C
18,788	89	Gravel roads HSG C
22,982	76	Gravel roads HSG A
72,099	30	Woods, Good HSG A
145,807	39	>75% Grass cover, Good HSG A
99,100	74	>75% Grass cover, Good HSG C
385,148	53	Weighted Average
385,148		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4	2,271	0.1851	1.29		**Lag/CN Method,**

Subcatchment A'2.0: A'2.0



Summary for Subcatchment A'2.1: A'2.1

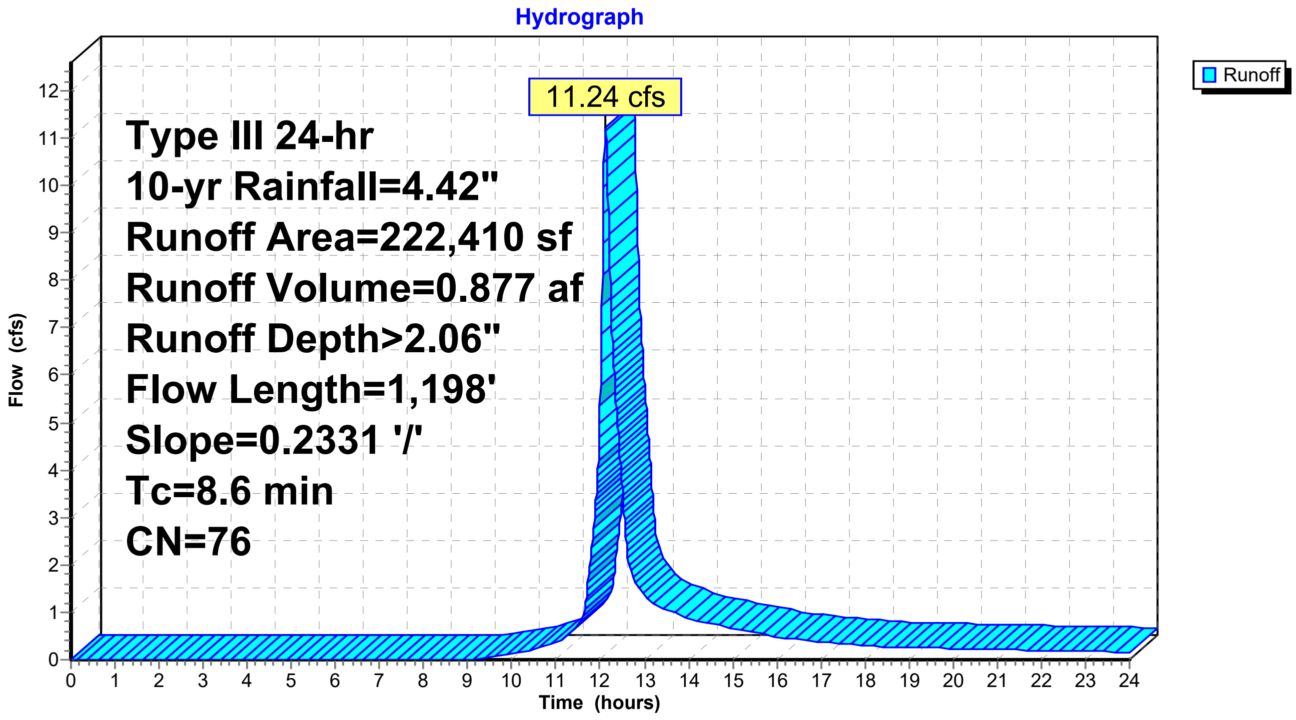
Runoff = 11.24 cfs @ 12.13 hrs, Volume= 0.877 af, Depth> 2.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
7,074	76	Gravel roads HSG A
24,709	89	Gravel roads HSG C
5,356	98	Unconnected pavement HSG C
2,607	39	>75% Grass cover, Good HSG A
182,663	74	>75% Grass cover, Good HSG C
222,410	76	Weighted Average
217,054		97.59% Pervious Area
5,356		2.41% Impervious Area
5,356		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	1,198	0.2331	2.33		**Lag/CN Method,**

Subcatchment A'2.1: A'2.1



Summary for Subcatchment A'2.2: A'2.2

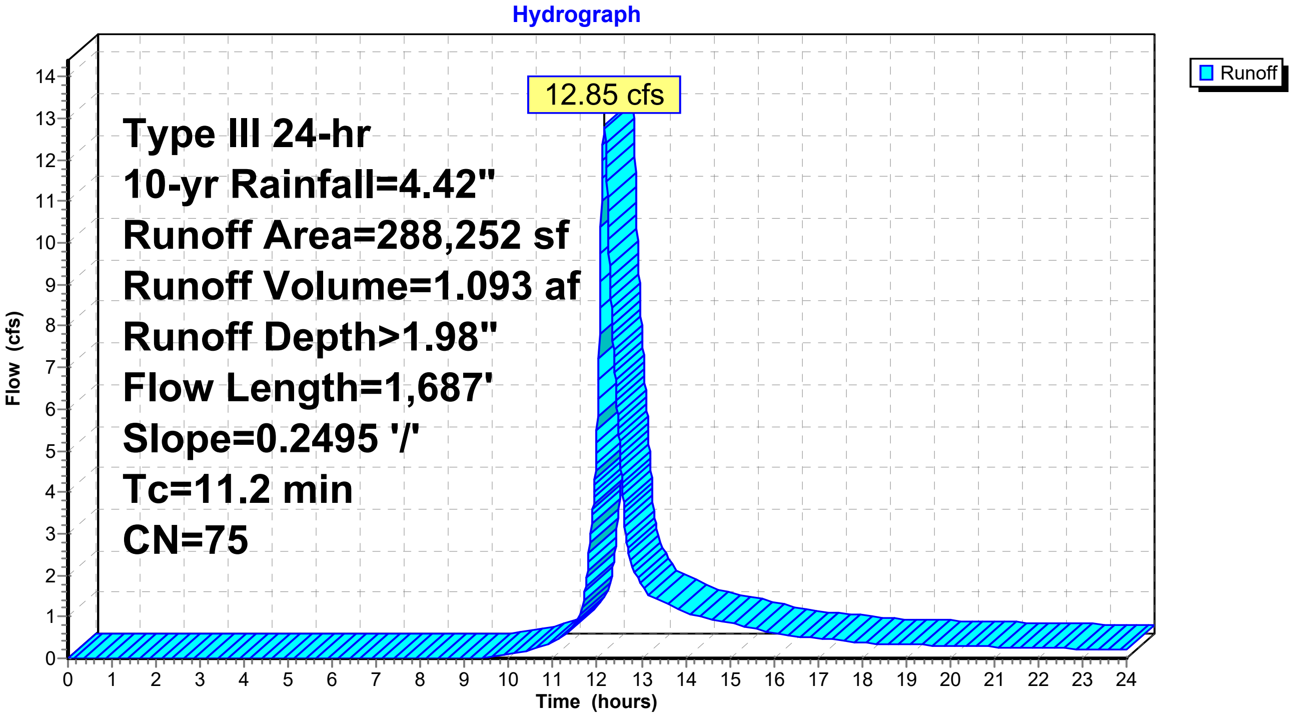
Runoff = 12.85 cfs @ 12.16 hrs, Volume= 1.093 af, Depth> 1.98"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
15,419	89	Gravel roads HSG C
4,954	98	Unconnected pavement HSG C
267,880	74	>75% Grass cover, Good HSG C
288,252	75	Weighted Average
283,298		98.28% Pervious Area
4,954		1.72% Impervious Area
4,954		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	1,687	0.2495	2.50		**Lag/CN Method,**

Subcatchment A'2.2: A'2.2



Summary for Subcatchment A'2.3: A'2.3

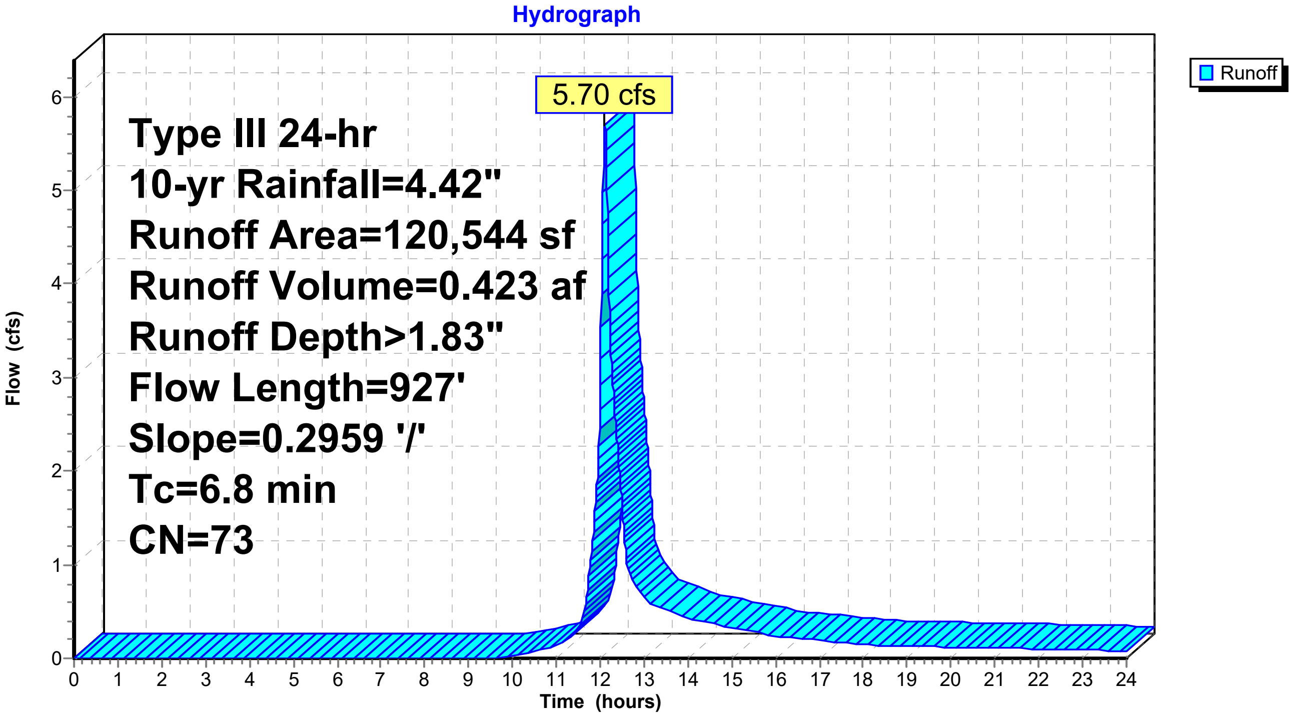
Runoff = 5.70 cfs @ 12.10 hrs, Volume= 0.423 af, Depth> 1.83"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
2,548	89	Gravel roads HSG C
164	76	Gravel roads HSG A
99,045	74	>75% Grass cover, Good HSG C
3,648	39	>75% Grass cover, Good HSG A
15,139	74	>75% Grass cover, Good HSG C
120,544	73	Weighted Average
120,544		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.8	927	0.2959	2.29		**Lag/CN Method,**

Subcatchment A'2.3: A'2.3



Summary for Subcatchment A'2.4: A'2.4

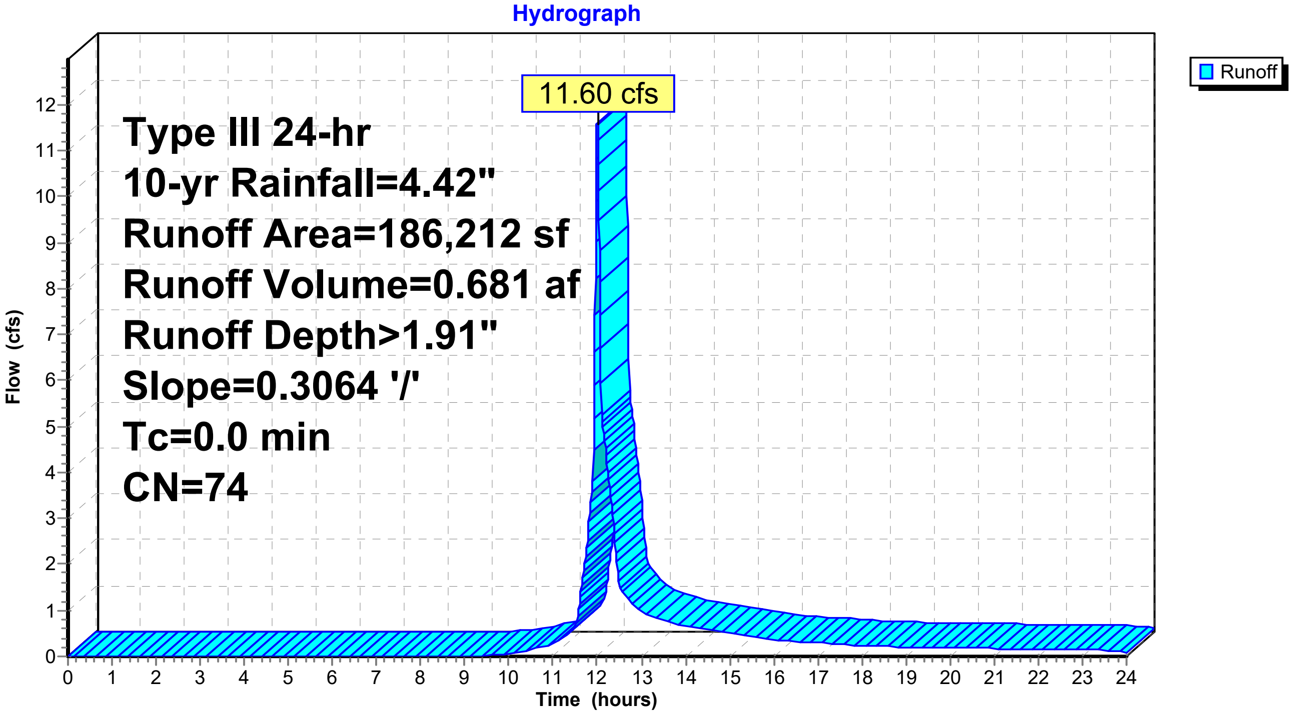
Runoff = 11.60 cfs @ 12.00 hrs, Volume= 0.681 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
1,675	98	Unconnected pavement HSG C
173,025	74	>75% Grass cover, Good HSG C
11,512	74	>75% Grass cover, Good HSG C
186,212	74	Weighted Average
184,537		99.10% Pervious Area
1,675		0.90% Impervious Area
1,675		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.3064			**Lag/CN Method,**

Subcatchment A'2.4: A'2.4



Summary for Subcatchment A'2.5: A'2.5

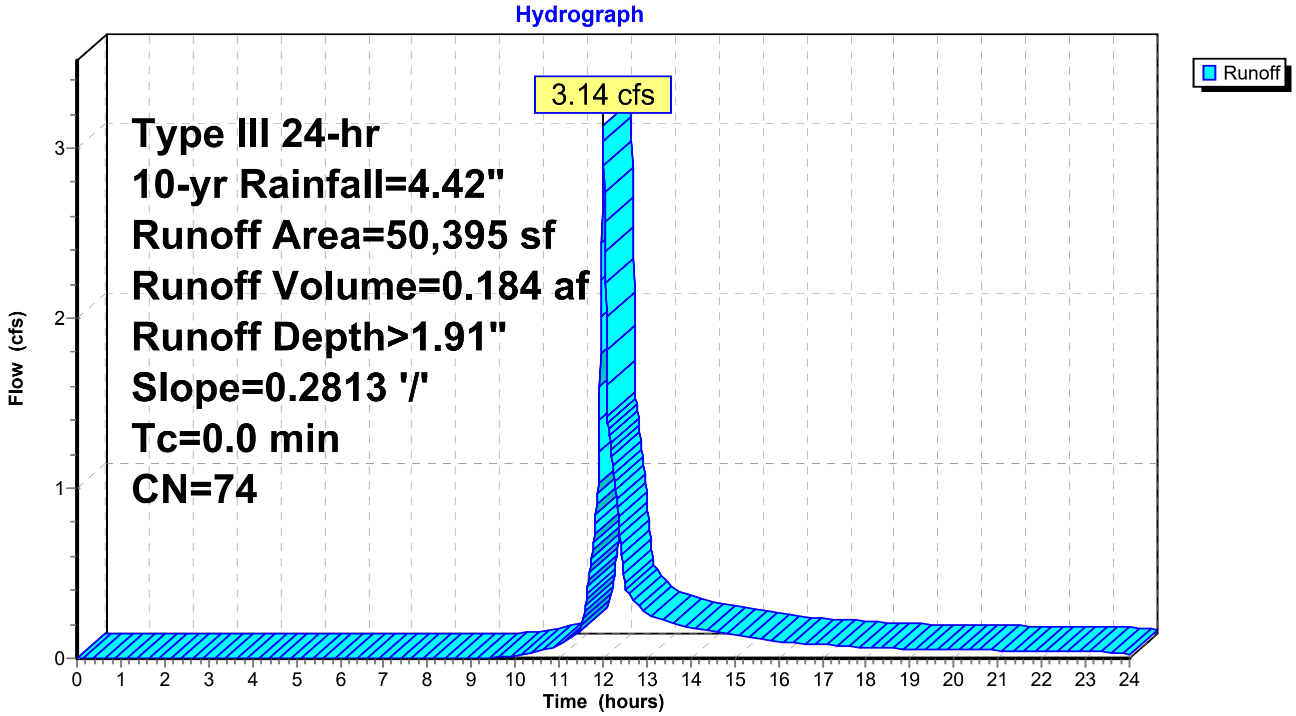
Runoff = 3.14 cfs @ 12.00 hrs, Volume= 0.184 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
438	98	Unconnected pavement HSG C
36,436	74	>75% Grass cover, Good HSG C
13,520	74	>75% Grass cover, Good HSG C
50,395	74	Weighted Average
49,957		99.13% Pervious Area
438		0.87% Impervious Area
438		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2813			**Lag/CN Method,**

Subcatchment A'2.5: A'2.5



Summary for Subcatchment A'3.1: A'3.1

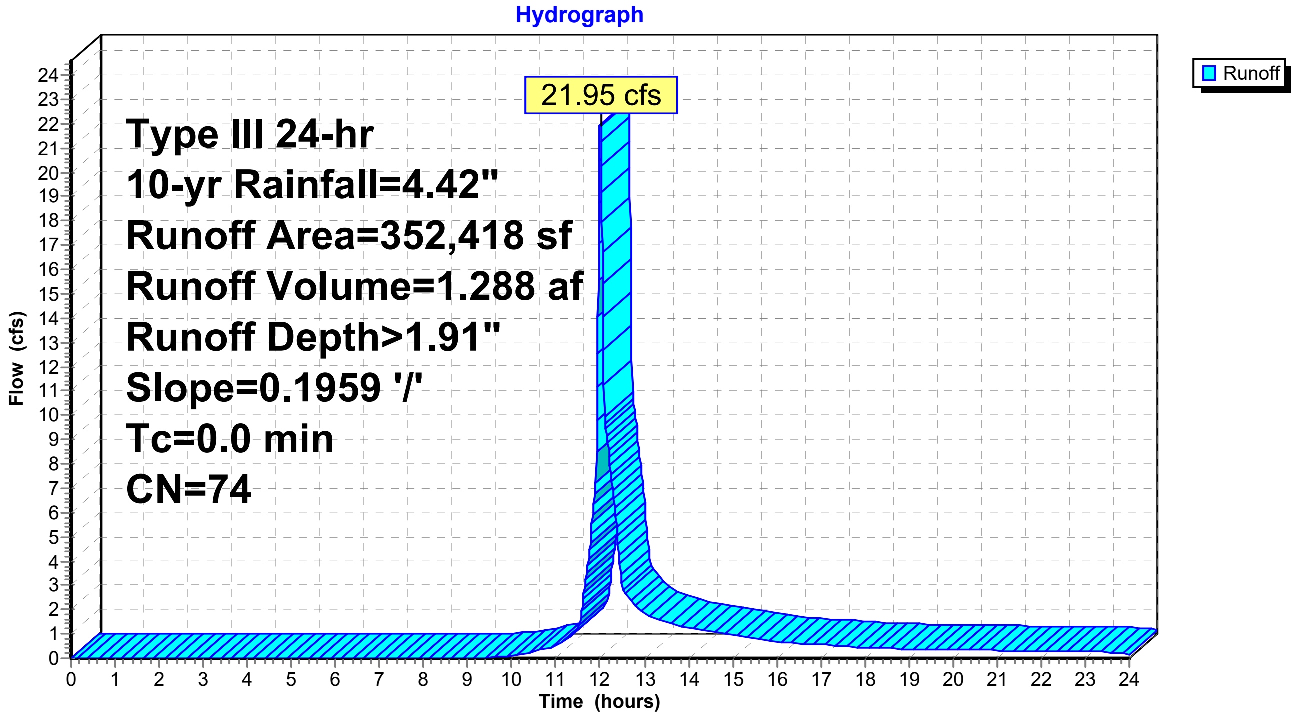
Runoff = 21.95 cfs @ 12.00 hrs, Volume= 1.288 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
348,612	74	>75% Grass cover, Good HSG C
3,806	89	Gravel roads HSG C
352,418	74	Weighted Average
352,418		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.1959			**Lag/CN Method,**

Subcatchment A'3.1: A'3.1



Summary for Subcatchment A'3.2: A'3.2

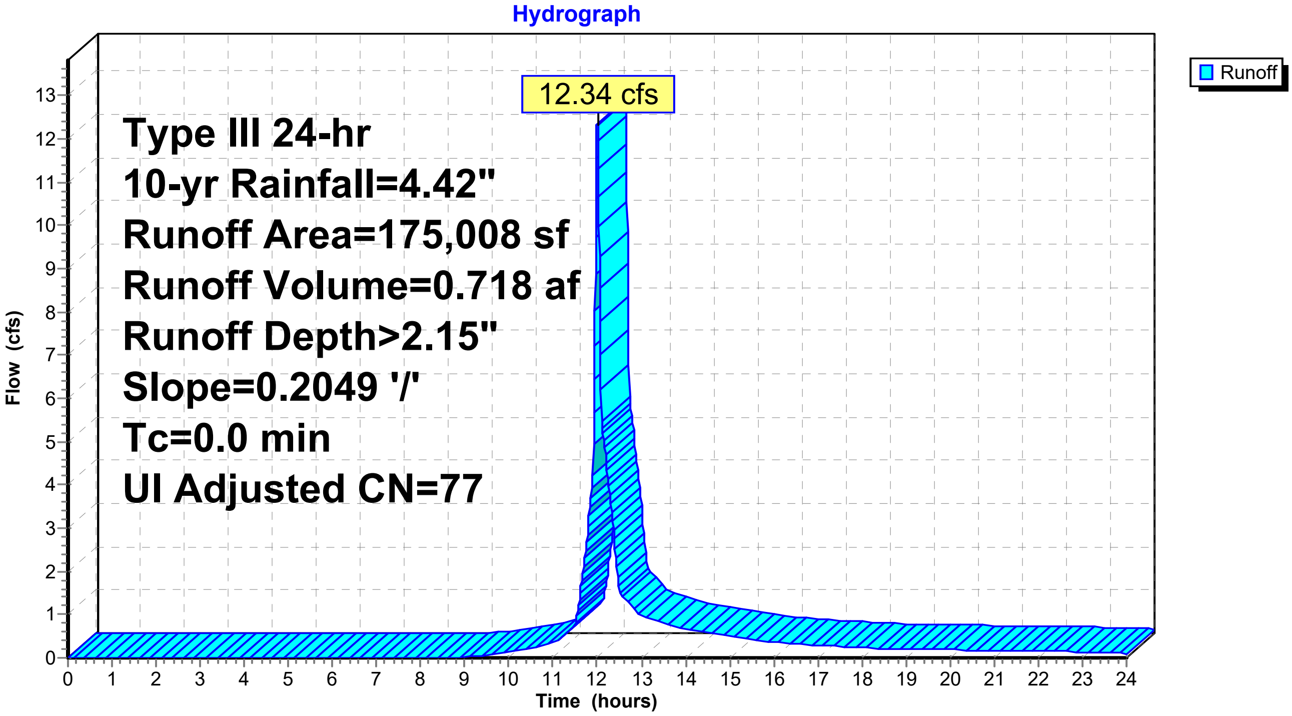
Runoff = 12.34 cfs @ 12.00 hrs, Volume= 0.718 af, Depth> 2.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
88,310	74		>75% Grass cover, Good HSG C
19,670	89		Gravel roads HSG C
16,829	98		Unconnected pavement HSG C
50,199	74		>75% Grass cover, Good HSG C
175,008	78	77	Weighted Average, UI Adjusted
158,179			90.38% Pervious Area
16,829			9.62% Impervious Area
16,829			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2049			**Lag/CN Method,**

Subcatchment A'3.2: A'3.2



Summary for Subcatchment A'3.3: A'3.3

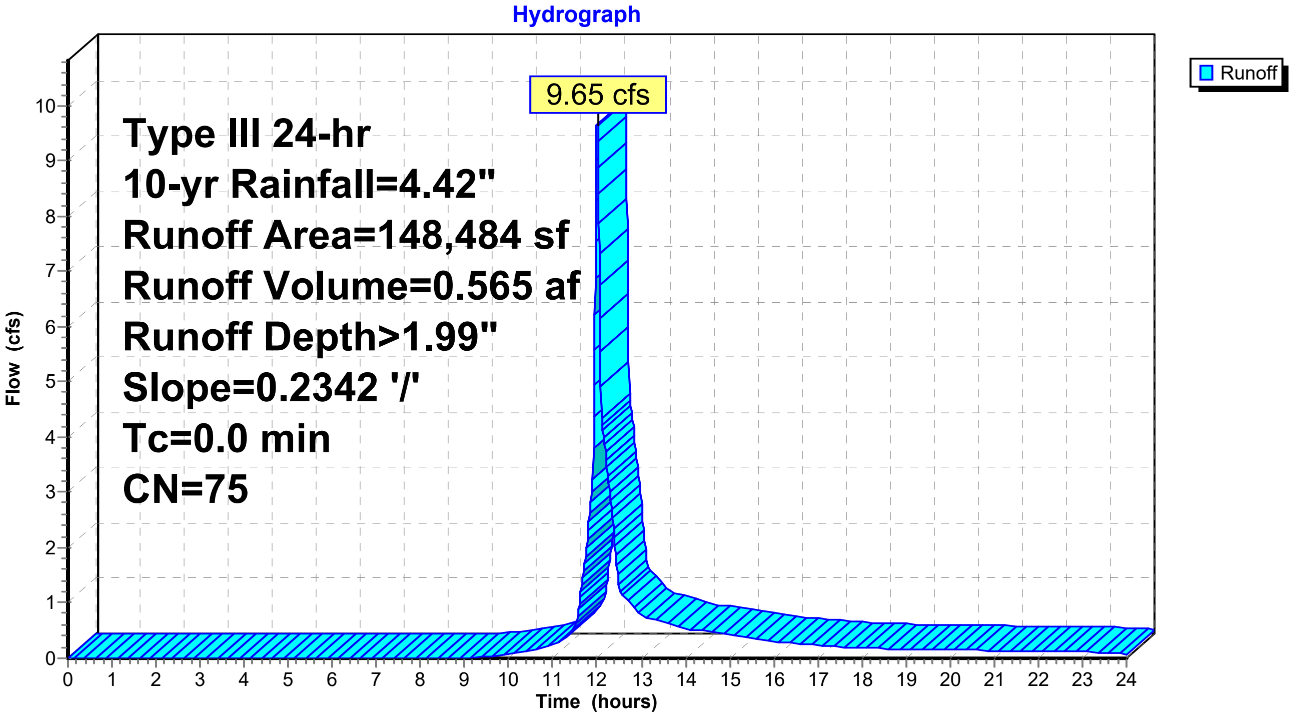
Runoff = 9.65 cfs @ 12.00 hrs, Volume= 0.565 af, Depth> 1.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
133,973	74	>75% Grass cover, Good HSG C
14,172	89	Gravel roads HSG C
339	74	>75% Grass cover, Good HSG C
148,484	75	Weighted Average
148,484		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2342			**Lag/CN Method,**

Subcatchment A'3.3: A'3.3



Summary for Subcatchment A'3.4: A'3.4

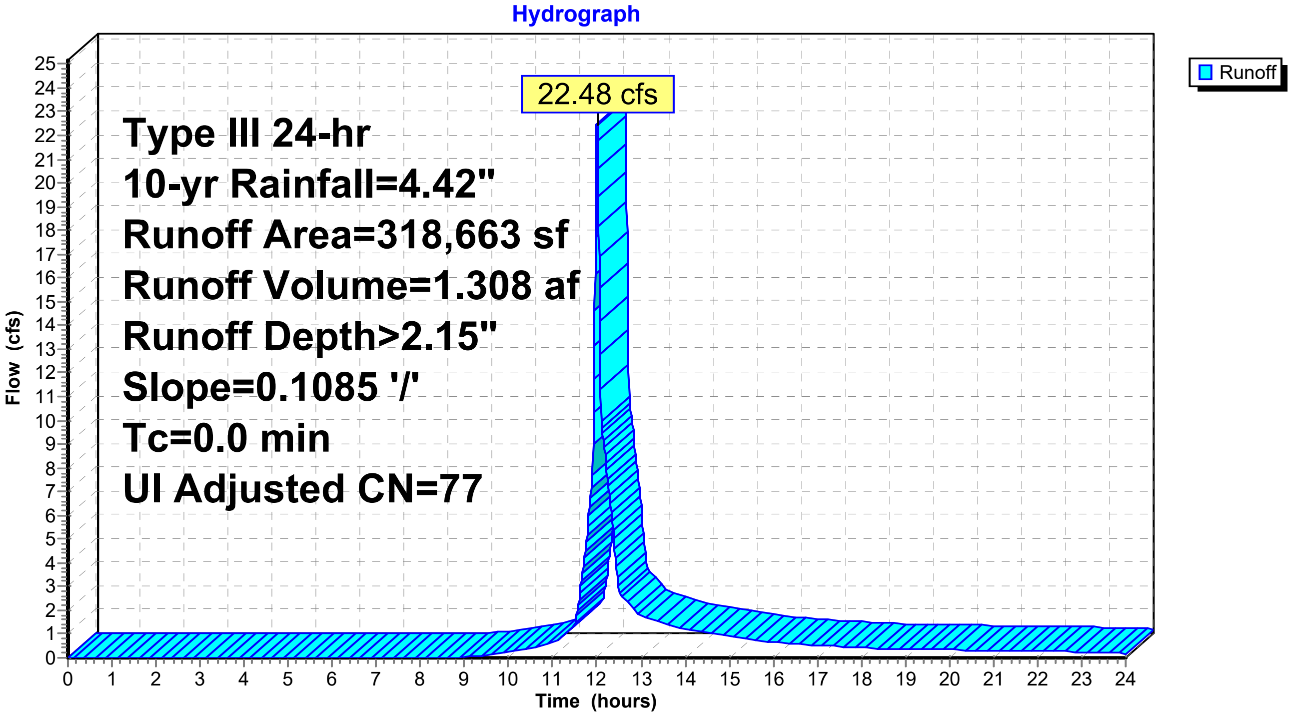
Runoff = 22.48 cfs @ 12.00 hrs, Volume= 1.308 af, Depth> 2.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
137,966	74		>75% Grass cover, Good HSG C
38,050	89		Gravel roads HSG C
35,076	98		Unconnected pavement HSG C
107,571	74		>75% Grass cover, Good HSG C
318,663	78	77	Weighted Average, UI Adjusted
283,588			88.99% Pervious Area
35,076			11.01% Impervious Area
35,076			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.1085			**Lag/CN Method,**

Subcatchment A'3.4: A'3.4



Summary for Subcatchment A'3.5: A'3.5

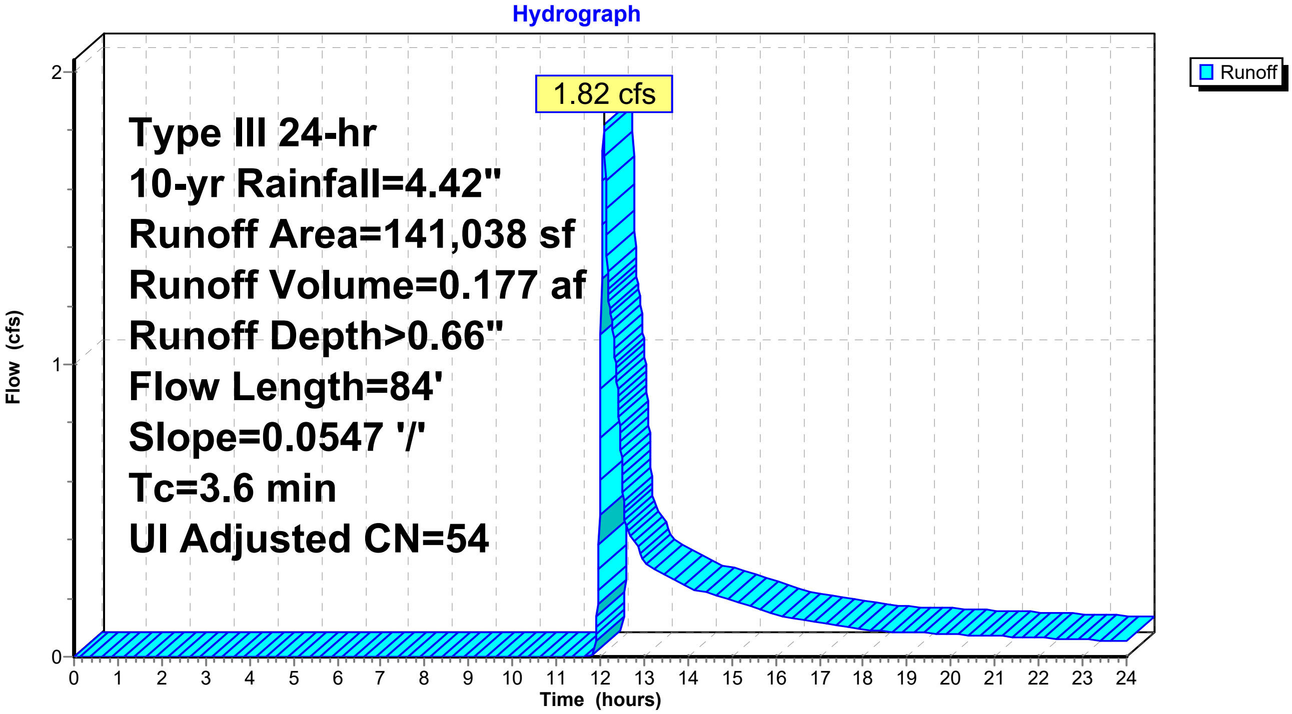
Runoff = 1.82 cfs @ 12.08 hrs, Volume= 0.177 af, Depth> 0.66"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
11,556	98		Unconnected pavement HSG C
1,043	74		>75% Grass cover, Good HSG C
5,785	89		Gravel roads HSG C
166	98		Unconnected pavement HSG A
2,800	30		Woods, Good HSG A
78,447	39		>75% Grass cover, Good HSG A
41,241	74		>75% Grass cover, Good HSG C
141,038	56	54	Weighted Average, UI Adjusted
129,316			91.69% Pervious Area
11,722			8.31% Impervious Area
11,722			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	84	0.0547	0.39		**Lag/CN Method,**

Subcatchment A'3.5: A'3.5



Summary for Subcatchment A'3.6: A'3.6

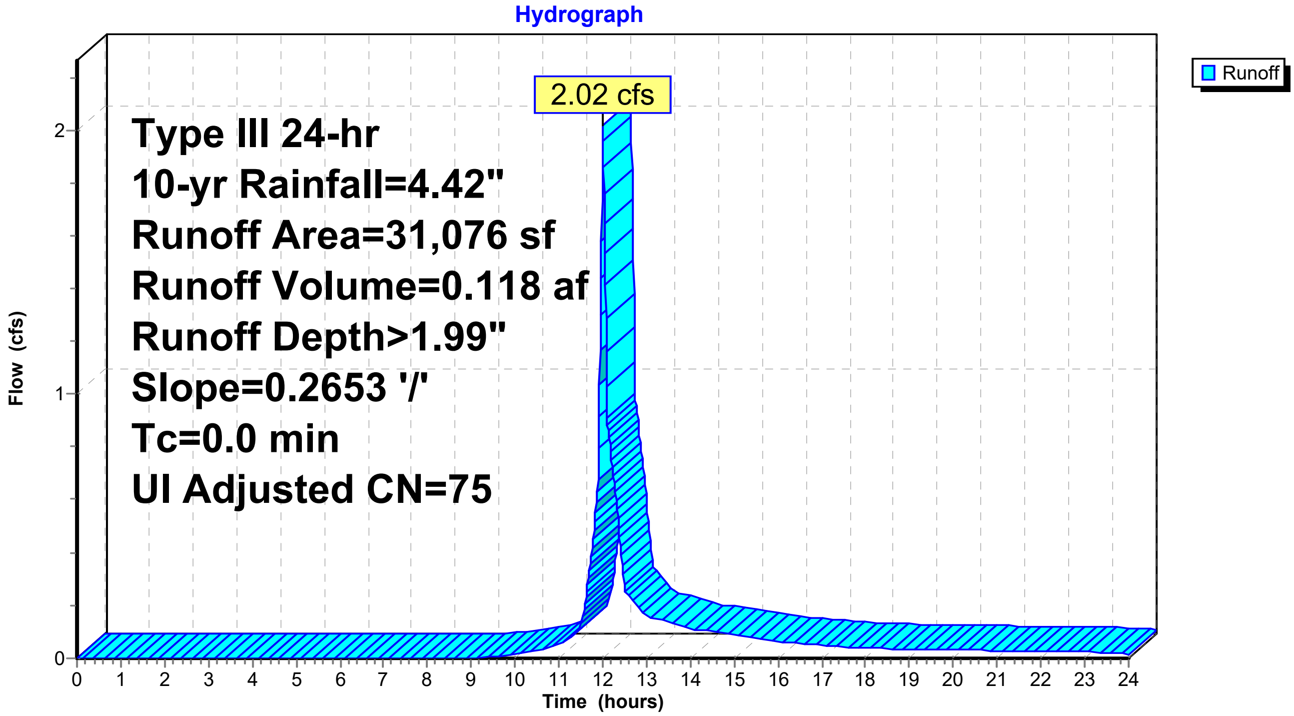
Runoff = 2.02 cfs @ 12.00 hrs, Volume= 0.118 af, Depth> 1.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
23,729	74		>75% Grass cover, Good HSG C
2,061	98		Unconnected pavement HSG C
5,286	74		>75% Grass cover, Good HSG C
31,076	76	75	Weighted Average, UI Adjusted
29,015			93.37% Pervious Area
2,061			6.63% Impervious Area
2,061			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2653			**Lag/CN Method,**

Subcatchment A'3.6: A'3.6



Summary for Subcatchment A'4: A'4

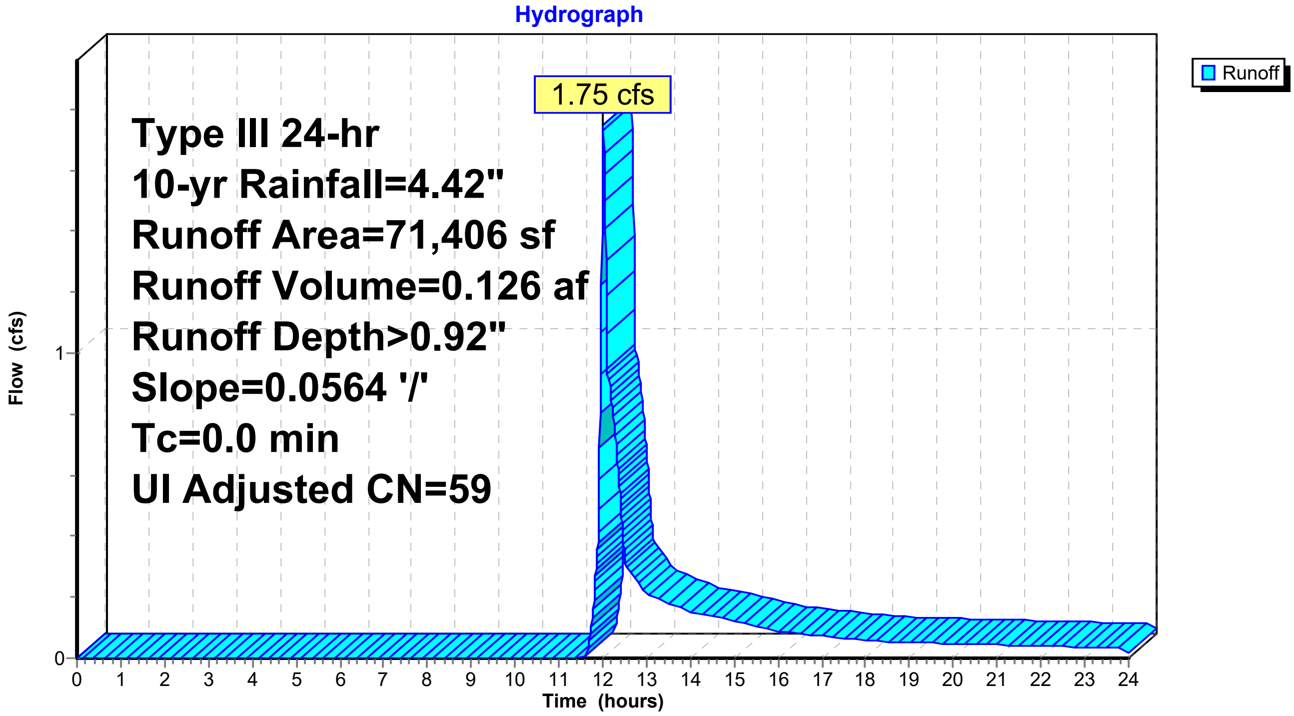
Runoff = 1.75 cfs @ 12.01 hrs, Volume= 0.126 af, Depth> 0.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
2,773	70		Woods, Good HSG C
4,240	89		Gravel roads HSG C
1,927	76		Gravel roads HSG A
5,080	98		Unconnected pavement HSG A
8,540	30		Woods, Good HSG A
2,046	73		Woods, Fair HSG C
22,175	39		>75% Grass cover, Good HSG A
24,627	74		>75% Grass cover, Good HSG C
71,406	60	59	Weighted Average, UI Adjusted
66,327			92.89% Pervious Area
5,080			7.11% Impervious Area
5,080			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.0564			**Lag/CN Method,**

Subcatchment A'4: A'4



Summary for Subcatchment C'1.1: C'1.1

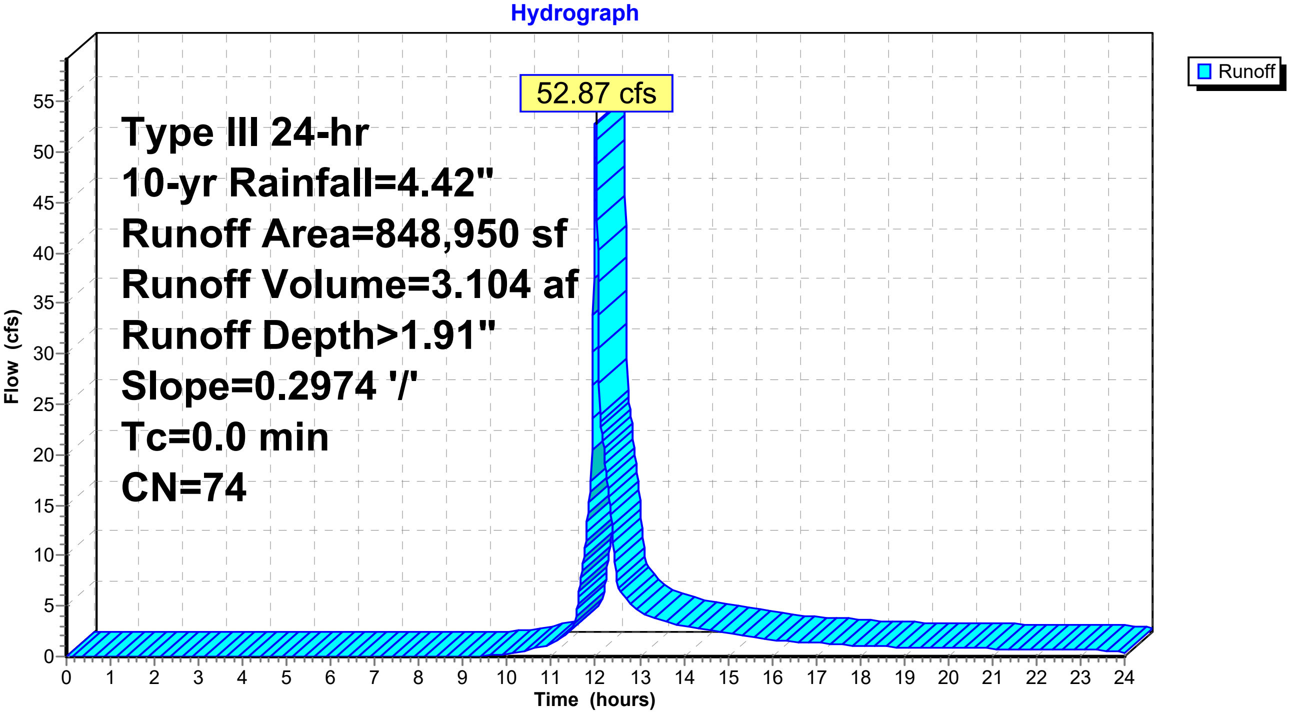
Runoff = 52.87 cfs @ 12.00 hrs, Volume= 3.104 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
848,336	74	>75% Grass cover, Good HSG C
613	74	>75% Grass cover, Good HSG C
848,950	74	Weighted Average
848,950		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2974			**Lag/CN Method,**

Subcatchment C'1.1: C'1.1



Summary for Subcatchment C'1.2: C'1.2

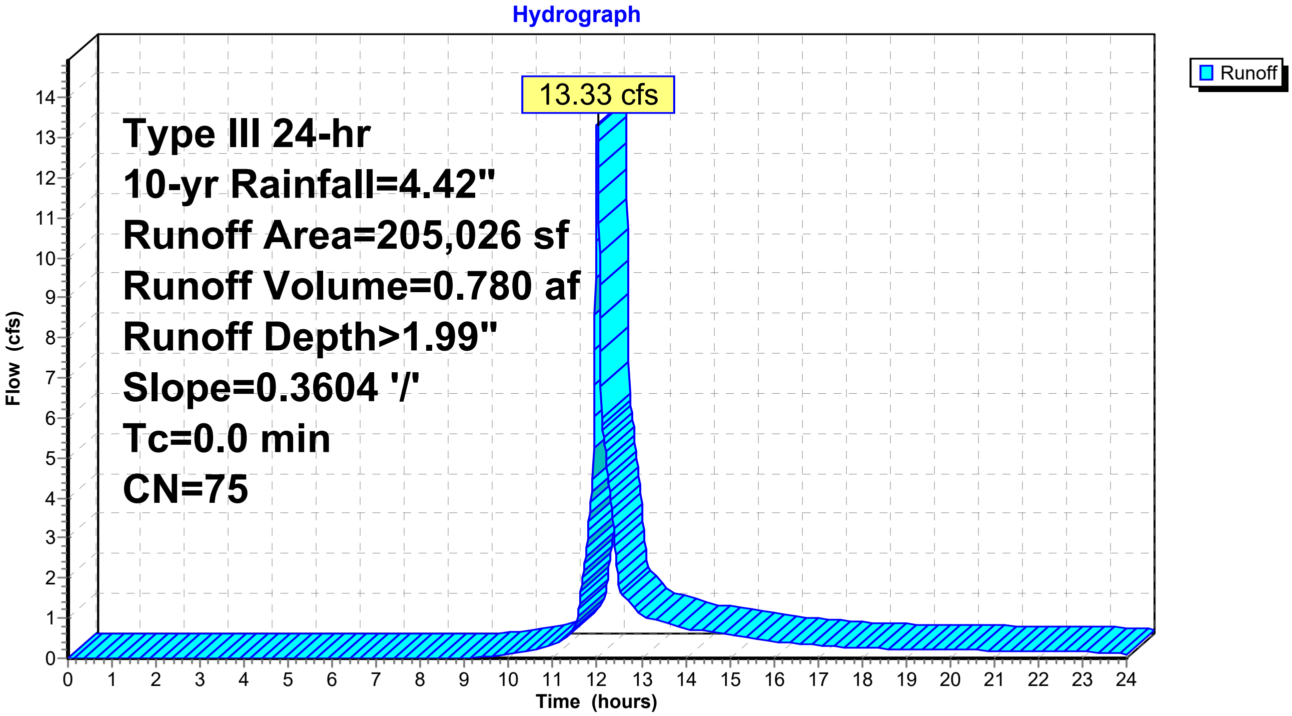
Runoff = 13.33 cfs @ 12.00 hrs, Volume= 0.780 af, Depth> 1.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
8,955	89	Gravel roads HSG C
175,959	74	>75% Grass cover, Good HSG C
20,113	74	>75% Grass cover, Good HSG C
205,026	75	Weighted Average
205,026		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.3604			**Lag/CN Method,**

Subcatchment C'1.2: C'1.2



Summary for Subcatchment C'1.5: C'1.5

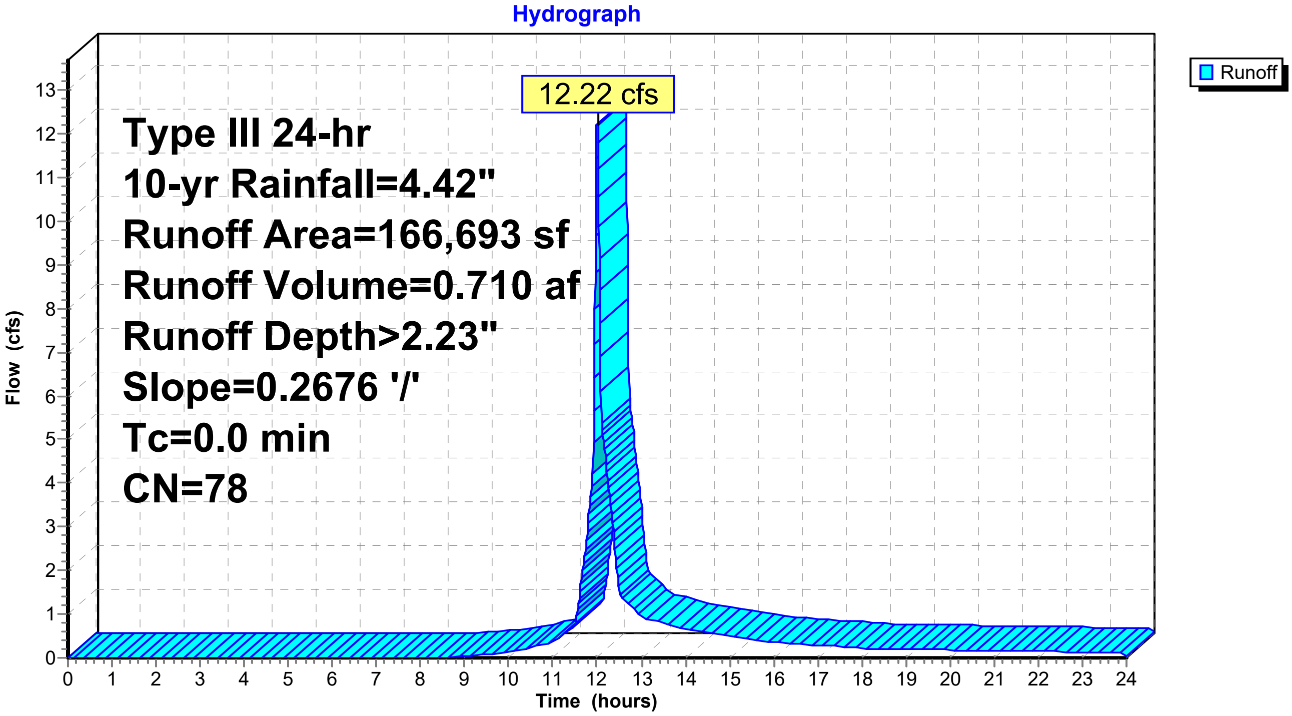
Runoff = 12.22 cfs @ 12.00 hrs, Volume= 0.710 af, Depth> 2.23"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
23,733	89	Gravel roads HSG C
14,125	70	Woods, Good HSG C
14,584	98	Water Surface HSG C
1,200	98	Roofs HSG C
113,050	74	>75% Grass cover, Good HSG C
166,693	78	Weighted Average
150,909		90.53% Pervious Area
15,784		9.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2676			**Lag/CN Method,**

Subcatchment C'1.5: C'1.5



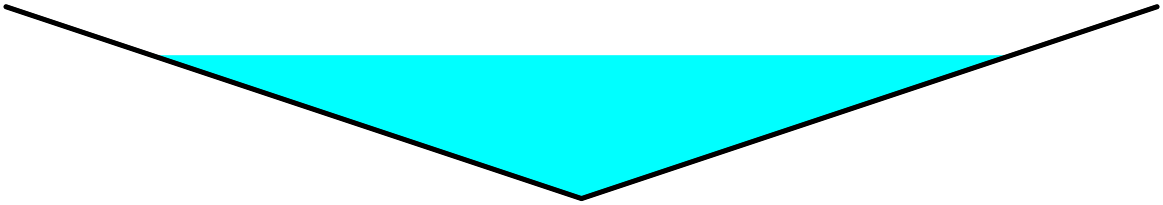
Summary for Reach 3R: Existing Swale

Inflow Area = 20.174 ac, 6.15% Impervious, Inflow Depth > 2.06" for 10-yr event
Inflow = 59.20 cfs @ 12.00 hrs, Volume= 3.456 af
Outflow = 52.98 cfs @ 12.03 hrs, Volume= 3.451 af, Atten= 11%, Lag= 1.4 min

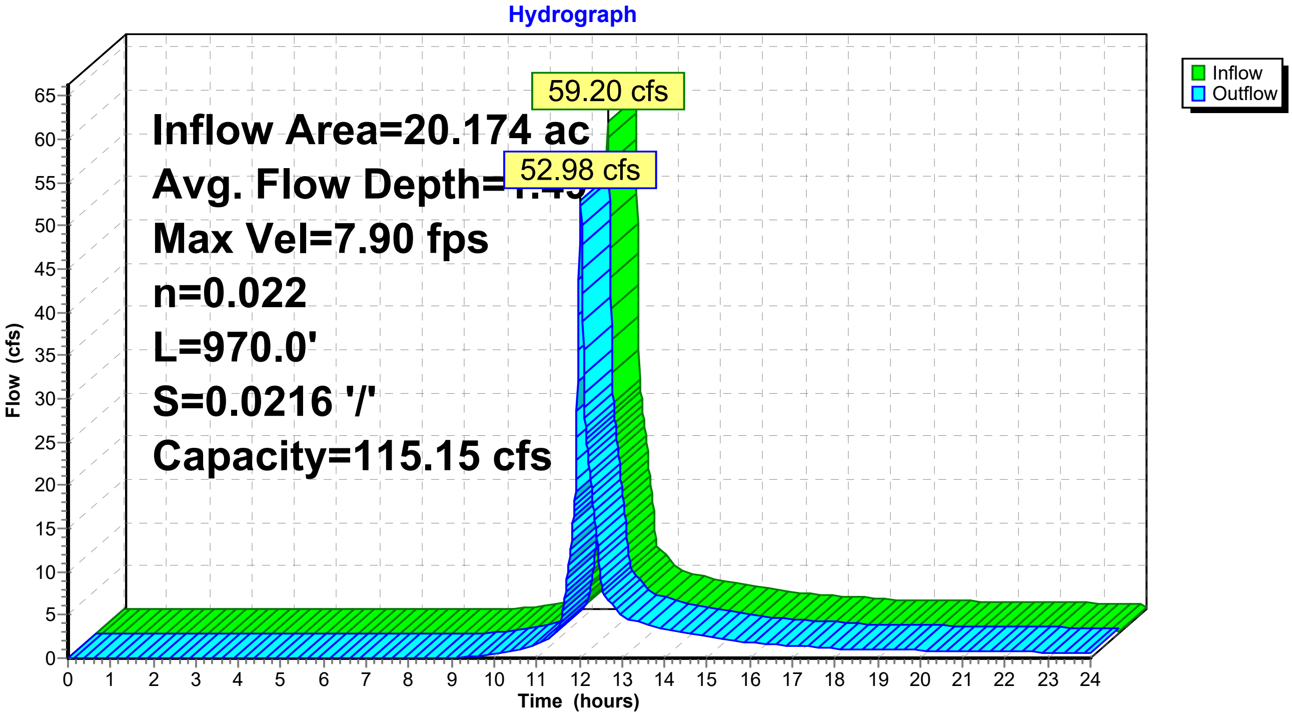
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.90 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 3.25 fps, Avg. Travel Time= 5.0 min

Peak Storage= 6,503 cf @ 12.03 hrs
Average Depth at Peak Storage= 1.49'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 115.15 cfs

0.00' x 2.00' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 970.0' Slope= 0.0216 '/'
Inlet Invert= 204.00', Outlet Invert= 183.00'



Reach 3R: Existing Swale



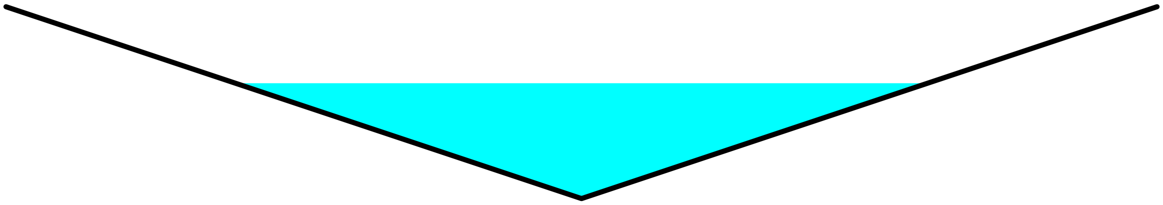
Summary for Reach 4R: Existing Swale

```
Inflow Area =         7.873 ac,   1.56% Impervious,  Inflow Depth >   1.98"   for  10-yr event
Inflow      =        16.46 cfs @   12.13 hrs,  Volume=             1.299 af
Outflow     =        12.38 cfs @   12.22 hrs,  Volume=             1.291 af,  Atten= 25%,  Lag= 5.5 min
```

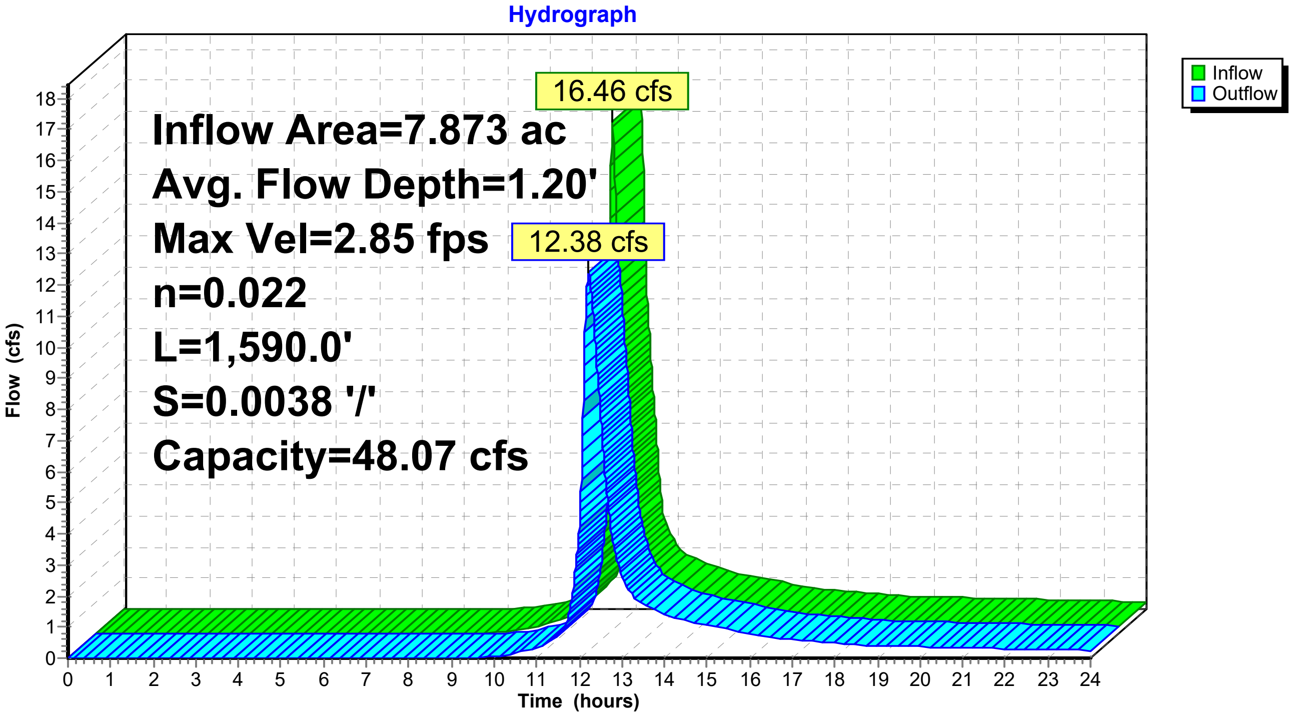
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.85 fps, Min. Travel Time= 9.3 min
Avg. Velocity = 1.33 fps, Avg. Travel Time= 20.0 min

Peak Storage= 6,899 cf @ 12.22 hrs
Average Depth at Peak Storage= 1.20'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 48.07 cfs

0.00' x 2.00' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 1,590.0' Slope= 0.0038 '/'
Inlet Invert= 184.00', Outlet Invert= 178.00'



Reach 4R: Existing Swale



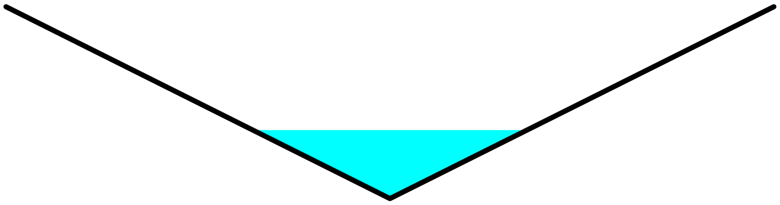
Summary for Reach 15R: Existing Roadside Swale

Inflow Area = 2.767 ac, 0.00% Impervious, Inflow Depth > 1.83" for 10-yr event
Inflow = 5.70 cfs @ 12.10 hrs, Volume= 0.423 af
Outflow = 5.26 cfs @ 12.14 hrs, Volume= 0.422 af, Atten= 8%, Lag= 2.2 min

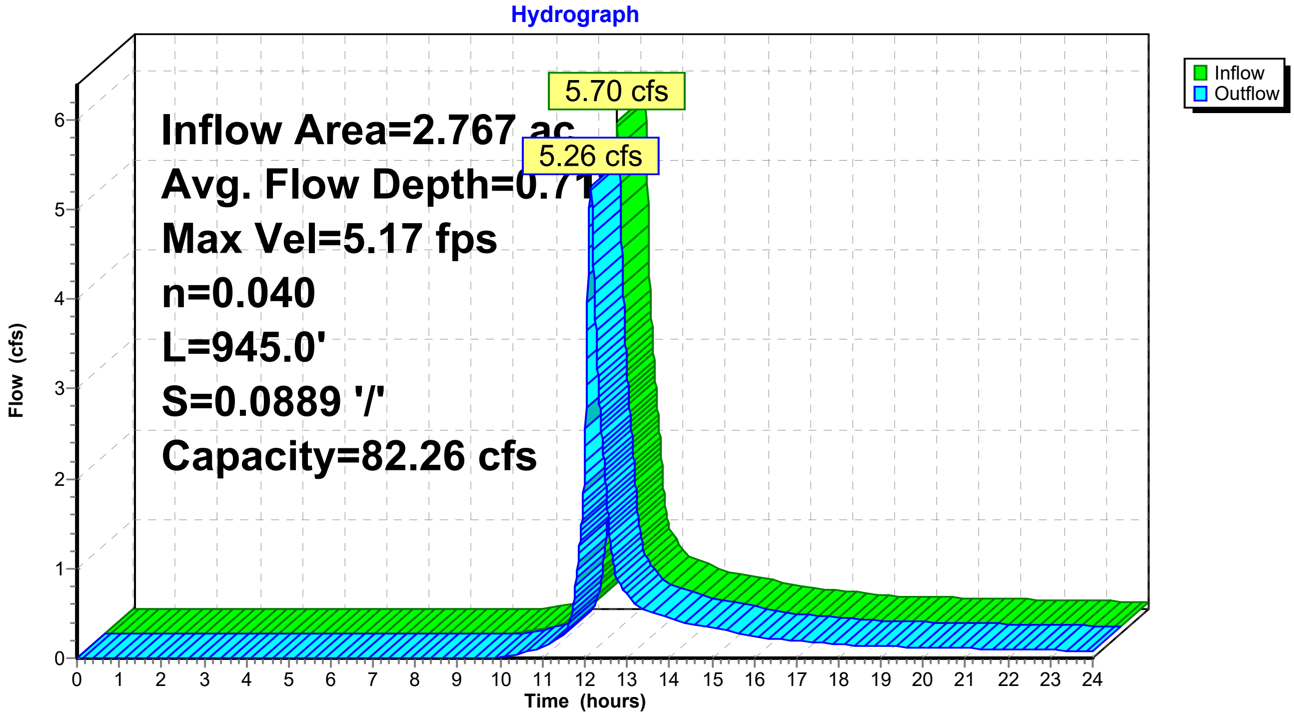
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.17 fps, Min. Travel Time= 3.0 min
Avg. Velocity = 2.31 fps, Avg. Travel Time= 6.8 min

Peak Storage= 961 cf @ 12.14 hrs
Average Depth at Peak Storage= 0.71'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 82.26 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 945.0' Slope= 0.0889 '/'
Inlet Invert= 288.00', Outlet Invert= 204.00'



Reach 15R: Existing Roadside Swale



Summary for Pond 2P: Existing Pond 2

Inflow Area = 57.187 ac, 3.34% Impervious, Inflow Depth > 1.68" for 10-yr event
Inflow = 88.80 cfs @ 12.02 hrs, Volume= 7.988 af
Outflow = 8.71 cfs @ 13.87 hrs, Volume= 6.446 af, Atten= 90%, Lag= 111.1 min
Primary = 8.71 cfs @ 13.87 hrs, Volume= 6.446 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Starting Elev= 176.90' Surf.Area= 0 sf Storage= 123,527 cf
Peak Elev= 178.78' @ 13.87 hrs Surf.Area= 0 sf Storage= 294,486 cf (170,959 cf above start)
Flood Elev= 181.50' Surf.Area= 0 sf Storage= 654,228 cf (530,701 cf above start)

Plug-Flow detention time= 447.8 min calculated for 3.609 af (45% of inflow)
Center-of-Mass det. time= 177.6 min (1,025.4 - 847.8)

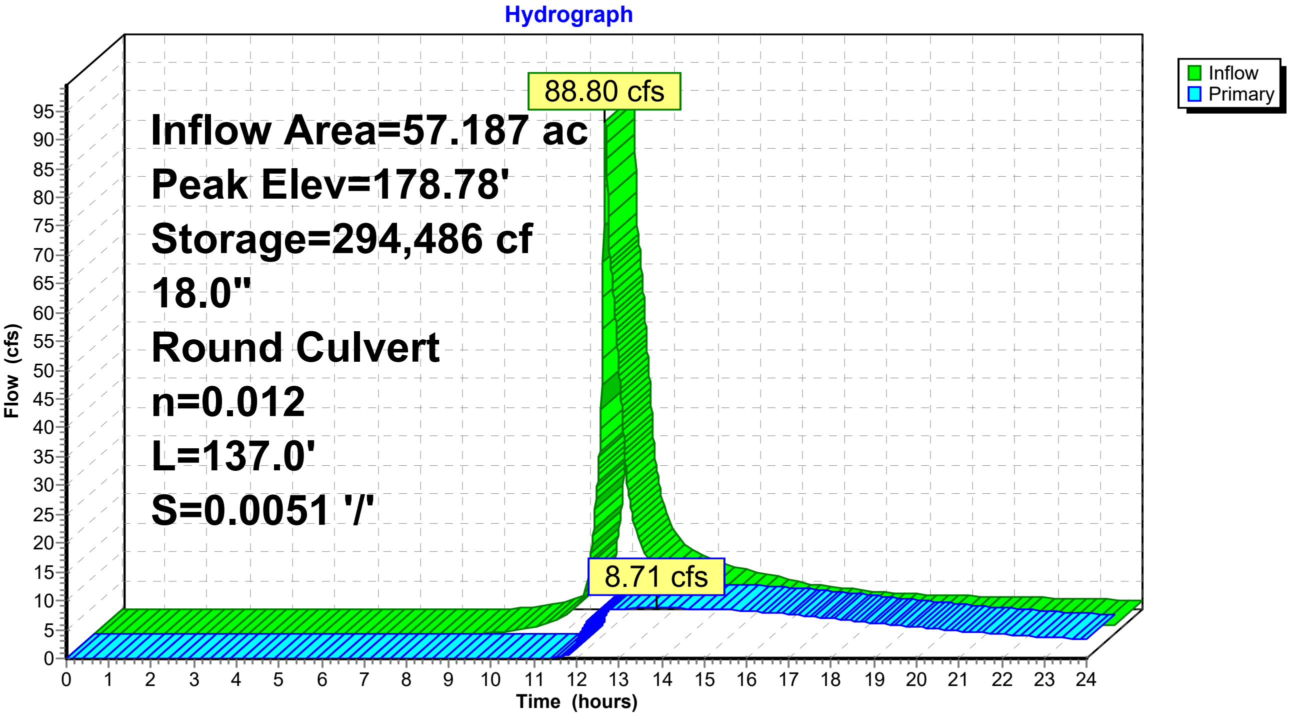
Volume	Invert	Avail.Storage	Storage Description
#1	174.00'	654,228 cf	**Custom Stage Data** Listed below

Elevation (feet)	Cum.Store (cubic-feet)
174.00	0
176.75	113,517
177.25	146,884
177.75	183,300
178.25	234,440
179.00	319,208
179.50	379,233
180.00	438,083
181.00	579,522
181.50	654,228

Device	Routing	Invert	Outlet Devices
#1	Primary	176.90'	**18.0" Round Culvert** L= 137.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 176.90' / 176.20' S= 0.0051 '/' Cc= 0.900 n= 0.012, Flow Area= 1.77 sf

Primary OutFlow Max=8.71 cfs @ 13.87 hrs HW=178.78' (Free Discharge)
└**1=Culvert** (Barrel Controls 8.71 cfs @ 5.05 fps)

Pond 2P: Existing Pond 2



Summary for Pond 4P: Existing Pond 4

```
Inflow Area =      28.023 ac,   1.29% Impervious,  Inflow Depth >   1.97"    for  10-yr event
Inflow      =     78.42 cfs @   12.00 hrs,  Volume=          4.594 af
Outflow     =      6.12 cfs @   13.07 hrs,  Volume=          4.297 af,  Atten= 92%,  Lag= 63.9 min
Primary     =      6.12 cfs @   13.07 hrs,  Volume=          4.297 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 200.81' @ 13.07 hrs   Surf.Area= 26,737 sf   Storage= 91,975 cf
Flood Elev= 208.00'   Surf.Area= 41,741 sf   Storage= 336,443 cf

Plug-Flow detention time= 197.2 min calculated for 4.297 af (94% of inflow)
Center-of-Mass det. time= 163.3 min ( 999.3 - 836.0 )

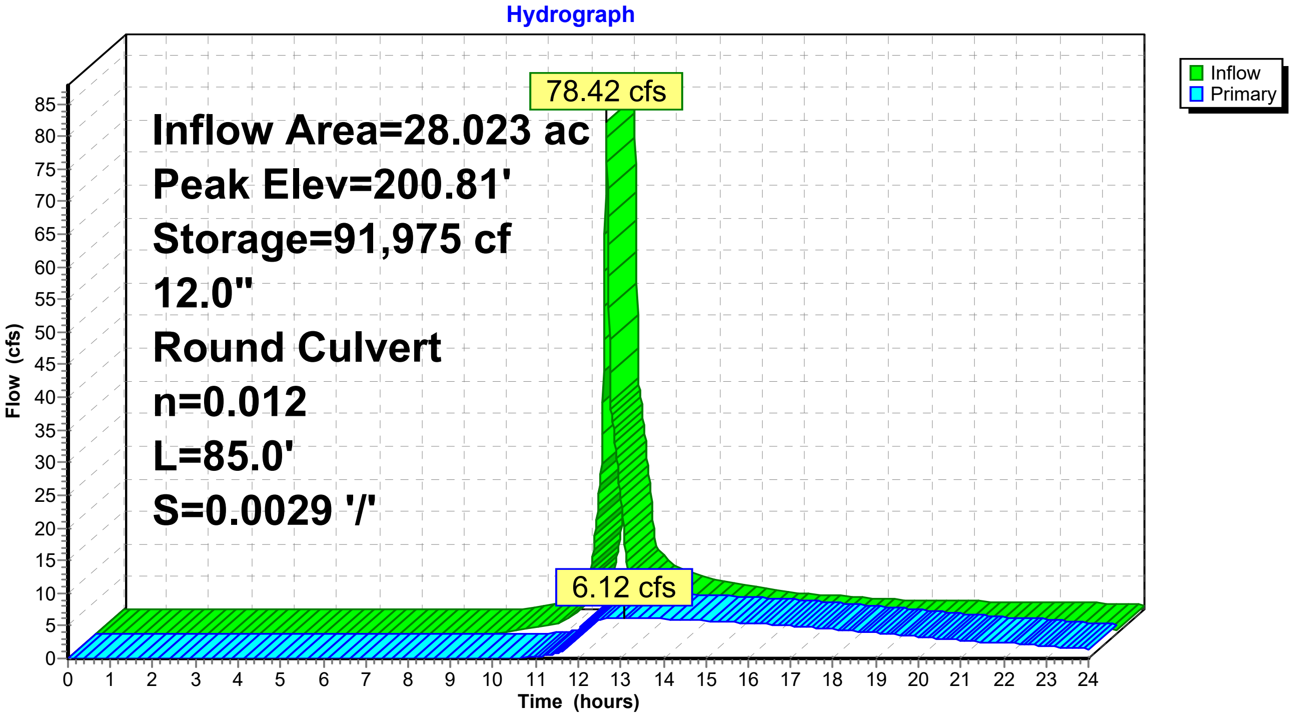
Volume      Invert     Avail.Storage   Storage Description
  #1       196.50'        336,443 cf   Custom Stage Data (Irregular) Listed below (Recalc)

 Elevation       Surf.Area     Perim.        Inc.Store        Cum.Store        Wet.Area
    (feet)         (sq-ft)     (feet)     (cubic-feet)     (cubic-feet)         (sq-ft)
    196.50          14,584      631.3                0                0          14,584
    198.00          20,032      794.2           25,854           25,854          33,094
    200.00          25,197      855.2           45,130           70,985          41,269
    202.00          29,091      888.5           54,241          125,226          46,207
    204.00          32,908      922.4           61,960          187,186          51,417
    206.00          37,348      956.0           70,209          257,395          56,780
    208.00          41,741    1,006.2           79,048          336,443          64,860

Device   Routing          Invert   Outlet Devices
  #1     Primary         196.50'   12.0"  Round Culvert  L= 85.0'  RCP, square edge headwall,  Ke= 0.500
                                   Inlet / Outlet Invert= 196.50' / 196.25'   S= 0.0029 '/'   Cc= 0.900
                                   n= 0.012  Concrete pipe, finished,  Flow Area= 0.79 sf

Primary OutFlow  Max=6.12 cfs @ 13.07 hrs  HW=200.81'   (Free Discharge)
└─1=Culvert  (Barrel Controls 6.12 cfs @ 7.79 fps)
```

Pond 4P: Existing Pond 4



Summary for Pond 5R: Existing 24" Culvert

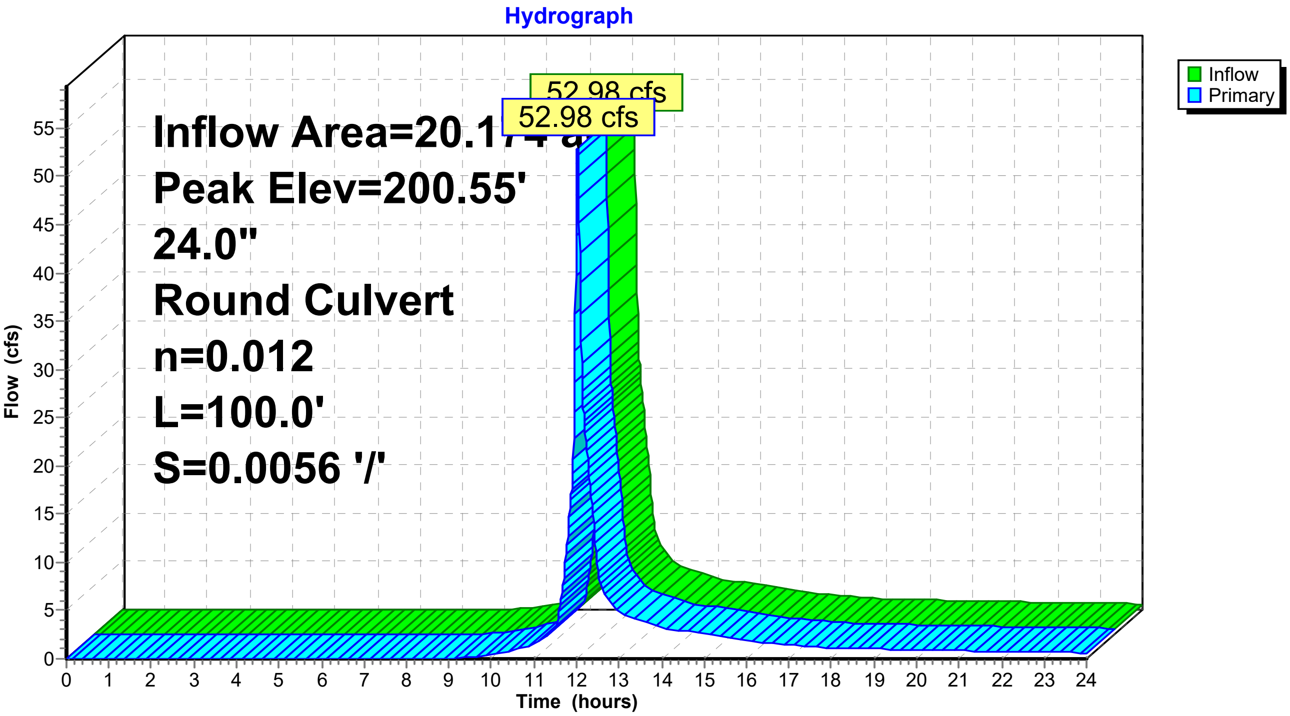
```
Inflow Area =       20.174 ac,   6.15% Impervious, Inflow Depth >   2.05"   for 10-yr event
Inflow      =      52.98 cfs @  12.03 hrs, Volume=          3.451 af
Outflow     =      52.98 cfs @  12.03 hrs, Volume=          3.451 af, Atten= 0%, Lag= 0.0 min
Primary     =      52.98 cfs @  12.03 hrs, Volume=          3.451 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 200.55' @ 12.03 hrs
Flood Elev= 184.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	179.87'	**24.0" Round Culvert** L= 100.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 179.87' / 179.31' S= 0.0056 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=52.85 cfs @ 12.03 hrs HW=200.46' TW=177.79' (Dynamic Tailwater)
└─**1=Culvert** (Inlet Controls 52.85 cfs @ 16.82 fps)

Pond 5R: Existing 24" Culvert



Summary for Pond 8R: Existing Dual 30" Culverts

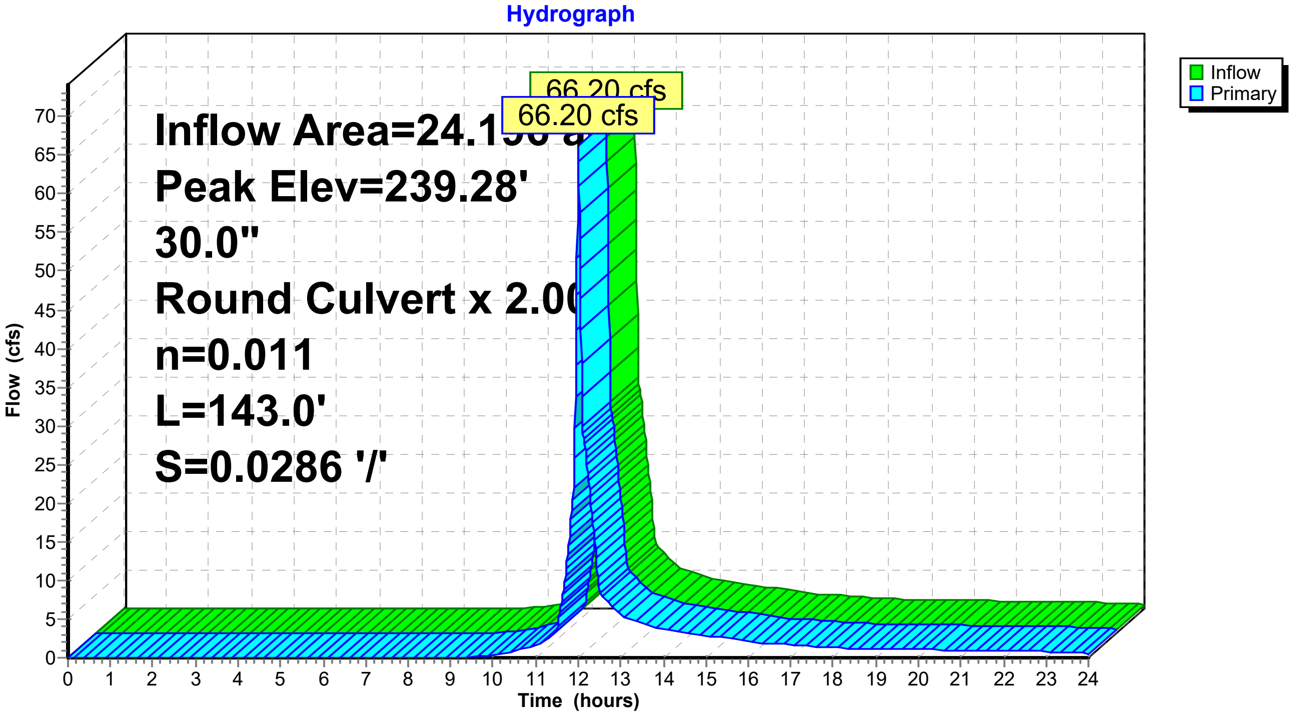
Inflow Area =	24.196 ac,	0.00% Impervious,	Inflow Depth >	1.93"	for 10-yr event
Inflow =	66.20 cfs @	12.00 hrs,	Volume=	3.883 af	
Outflow =	66.20 cfs @	12.00 hrs,	Volume=	3.883 af,	Atten= 0%, Lag= 0.0 min
Primary =	66.20 cfs @	12.00 hrs,	Volume=	3.883 af	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 239.28' @ 12.00 hrs
Flood Elev= 240.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	236.07'	**30.0" Round Culvert X 2.00** L= 143.0' Ke= 0.500 Inlet / Outlet Invert= 236.07' / 231.98' S= 0.0286 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 4.91 sf

Primary OutFlow Max=65.71 cfs @ 12.00 hrs HW=239.25' TW=198.88' (Dynamic Tailwater)
└─**1=Culvert** (Inlet Controls 65.71 cfs @ 6.69 fps)

Pond 8R: Existing Dual 30" Culverts



Summary for Pond CB2: Existing Catch Basin

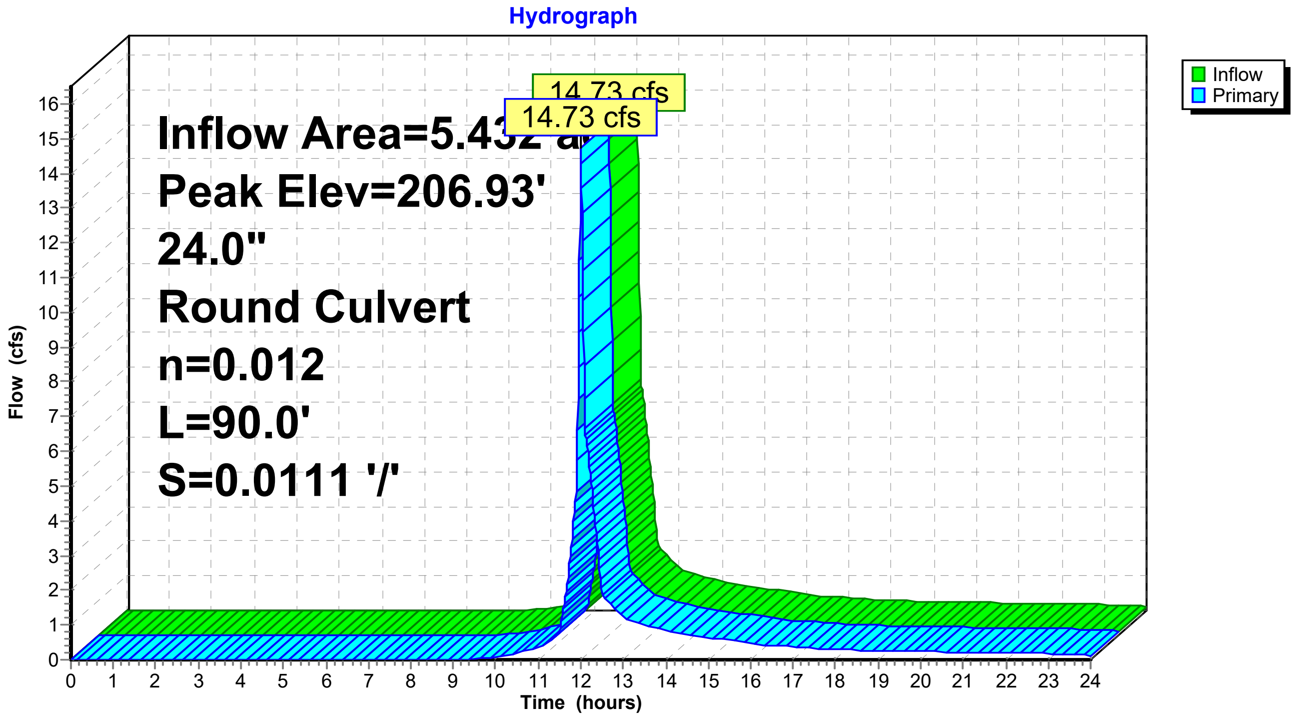
Inflow Area =	5.432 ac,	0.89% Impervious, Inflow Depth >	1.91"	for 10-yr event	
Inflow =	14.73 cfs @	12.00 hrs, Volume=	0.865 af		
Outflow =	14.73 cfs @	12.00 hrs, Volume=	0.865 af,	Atten= 0%,	Lag= 0.0 min
Primary =	14.73 cfs @	12.00 hrs, Volume=	0.865 af		

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 206.93' @ 12.00 hrs
Flood Elev= 208.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	205.00'	**24.0" Round Culvert** L= 90.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 205.00' / 204.00' S= 0.0111 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=14.63 cfs @ 12.00 hrs HW=206.92' TW=205.45' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 14.63 cfs @ 4.72 fps)

Pond CB2: Existing Catch Basin



Summary for Pond CB3: Existing Catch Basin

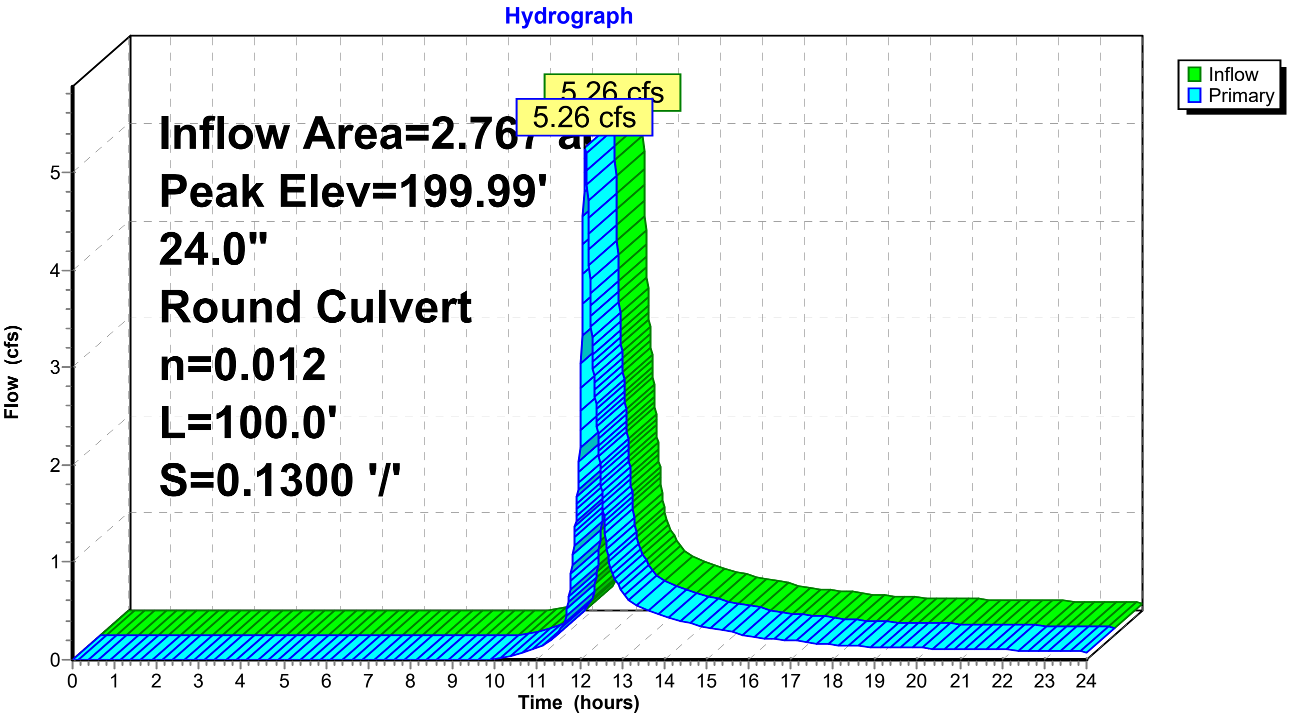
Inflow Area = 2.767 ac, 0.00% Impervious, Inflow Depth > 1.83" for 10-yr event
Inflow = 5.26 cfs @ 12.14 hrs, Volume= 0.422 af
Outflow = 5.26 cfs @ 12.14 hrs, Volume= 0.422 af, Atten= 0%, Lag= 0.0 min
Primary = 5.26 cfs @ 12.14 hrs, Volume= 0.422 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 199.99' @ 12.14 hrs
Flood Elev= 201.50'

Device	Routing	Invert	Outlet Devices
#1	Primary	199.00'	**24.0" Round Culvert** L= 100.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 199.00' / 186.00' S= 0.1300 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=5.26 cfs @ 12.14 hrs HW=199.99' TW=185.13' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 5.26 cfs @ 3.39 fps)

Pond CB3: Existing Catch Basin



Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>1.12"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=5.48 cfs 0.823 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.41% Impervious Runoff Depth>2.99"
Flow Length=1,198' Slope=0.2331 '/' Tc=8.6 min CN=76 Runoff=16.39 cfs 1.272 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>2.90"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=18.94 cfs 1.597 af

Subcatchment A'2.3: A'2.3 Runoff Area=120,544 sf 0.00% Impervious Runoff Depth>2.72"
Flow Length=927' Slope=0.2959 '/' Tc=6.8 min CN=73 Runoff=8.56 cfs 0.626 af

Subcatchment A'2.4: A'2.4 Runoff Area=186,212 sf 0.90% Impervious Runoff Depth>2.81"
Slope=0.3064 '/' Tc=0.0 min CN=74 Runoff=17.23 cfs 1.001 af

Subcatchment A'2.5: A'2.5 Runoff Area=50,395 sf 0.87% Impervious Runoff Depth>2.81"
Slope=0.2813 '/' Tc=0.0 min CN=74 Runoff=4.66 cfs 0.271 af

Subcatchment A'3.1: A'3.1 Runoff Area=352,418 sf 0.00% Impervious Runoff Depth>2.81"
Slope=0.1959 '/' Tc=0.0 min CN=74 Runoff=32.61 cfs 1.895 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 9.62% Impervious Runoff Depth>3.09"
Slope=0.2049 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=17.83 cfs 1.034 af

Subcatchment A'3.3: A'3.3 Runoff Area=148,484 sf 0.00% Impervious Runoff Depth>2.90"
Slope=0.2342 '/' Tc=0.0 min CN=75 Runoff=14.20 cfs 0.824 af

Subcatchment A'3.4: A'3.4 Runoff Area=318,663 sf 11.01% Impervious Runoff Depth>3.09"
Slope=0.1085 '/' Tc=0.0 min UI Adjusted CN=77 Runoff=32.46 cfs 1.883 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>1.20"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=4.15 cfs 0.322 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>2.90"
Slope=0.2653 '/' Tc=0.0 min UI Adjusted CN=75 Runoff=2.97 cfs 0.173 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>1.56"
Slope=0.0564 '/' Tc=0.0 min UI Adjusted CN=59 Runoff=3.35 cfs 0.213 af

Subcatchment C'1.1: C'1.1 Runoff Area=848,950 sf 0.00% Impervious Runoff Depth>2.81"
Slope=0.2974 '/' Tc=0.0 min CN=74 Runoff=78.56 cfs 4.564 af

Subcatchment C'1.2: C'1.2 Runoff Area=205,026 sf 0.00% Impervious Runoff Depth>2.90"
Slope=0.3604 '/' Tc=0.0 min CN=75 Runoff=19.61 cfs 1.138 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>3.18"
Slope=0.2676 '/' Tc=0.0 min CN=78 Runoff=17.50 cfs 1.016 af

Reach 3R: Existing Swale Avg. Flow Depth=1.73' Max Vel=8.71 fps Inflow=86.39 cfs 5.014 af
n=0.022 L=970.0' S=0.0216 '/' Capacity=115.15 cfs Outflow=78.33 cfs 5.008 af

Reach 4R: Existing Swale Avg. Flow Depth=1.41' Max Vel=3.17 fps Inflow=24.36 cfs 1.897 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=18.95 cfs 1.887 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.83' Max Vel=5.74 fps Inflow=8.56 cfs 0.626 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=8.00 cfs 0.625 af

Pond 2P: Existing Pond 2 Peak Elev=179.68' Storage=399,989 cf Inflow=134.95 cfs 11.917 af
18.0" Round Culvert n=0.012 L=137.0' S=0.0051 '/' Outflow=10.92 cfs 9.333 af

Pond 4P: Existing Pond 4 Peak Elev=202.65' Storage=144,479 cf Inflow=115.67 cfs 6.718 af
12.0" Round Culvert n=0.012 L=85.0' S=0.0029 '/' Outflow=7.54 cfs 6.081 af

Pond 5R: Existing 24" Culvert Peak Elev=223.89' Inflow=78.33 cfs 5.008 af
24.0" Round Culvert n=0.012 L=100.0' S=0.0056 '/' Outflow=78.33 cfs 5.008 af

Pond 8R: Existing Dual 30" Culverts Peak Elev=241.63' Inflow=98.17 cfs 5.703 af
30.0" Round Culvert x 2.00 n=0.011 L=143.0' S=0.0286 '/' Outflow=98.17 cfs 5.703 af

Pond CB2: Existing Catch Basin Peak Elev=208.09' Inflow=21.90 cfs 1.272 af
24.0" Round Culvert n=0.012 L=90.0' S=0.0111 '/' Outflow=21.90 cfs 1.272 af

Pond CB3: Existing Catch Basin Peak Elev=200.26' Inflow=8.00 cfs 0.625 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=8.00 cfs 0.625 af

Total Runoff Area = 85.209 ac Runoff Volume = 18.653 af Average Runoff Depth = 2.63"
97.33% Pervious = 82.937 ac 2.67% Impervious = 2.272 ac

Summary for Subcatchment A'2.0: A'2.0

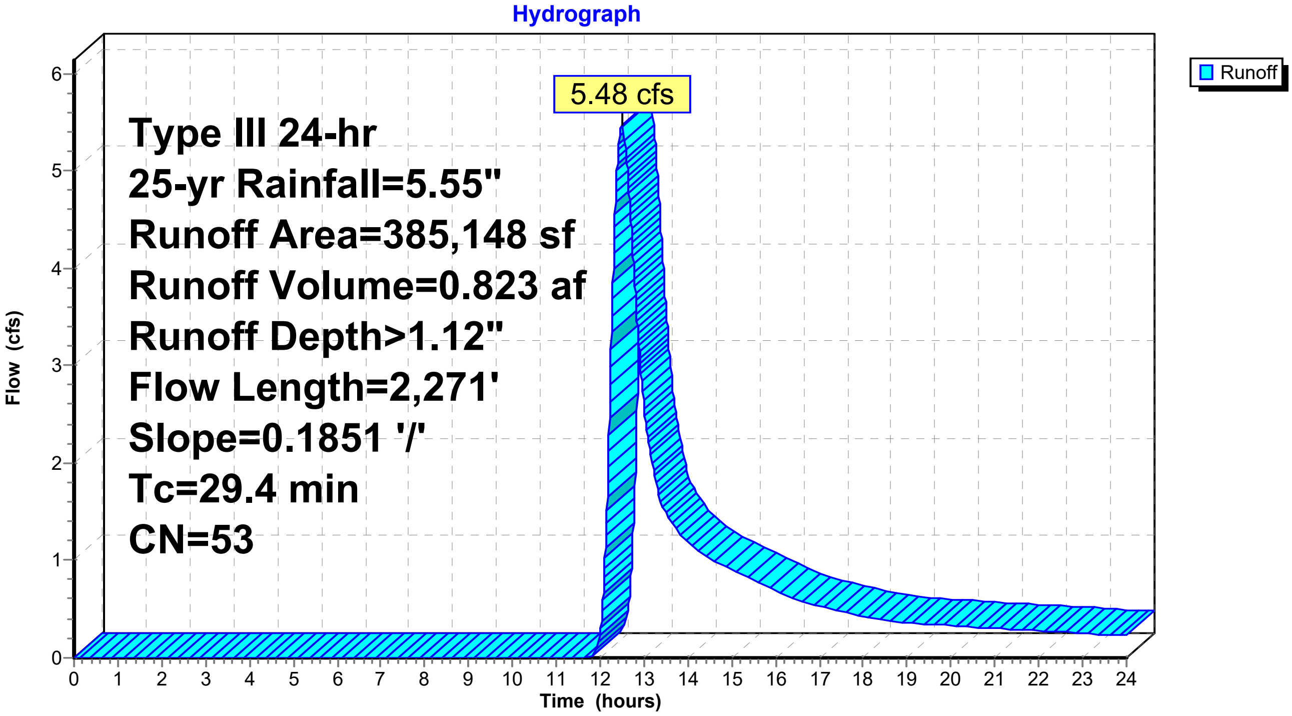
Runoff = 5.48 cfs @ 12.50 hrs, Volume= 0.823 af, Depth> 1.12"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
26,373	70	Woods, Good HSG C
18,788	89	Gravel roads HSG C
22,982	76	Gravel roads HSG A
72,099	30	Woods, Good HSG A
145,807	39	>75% Grass cover, Good HSG A
99,100	74	>75% Grass cover, Good HSG C
385,148	53	Weighted Average
385,148		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4	2,271	0.1851	1.29		**Lag/CN Method,**

Subcatchment A'2.0: A'2.0



Summary for Subcatchment A'2.1: A'2.1

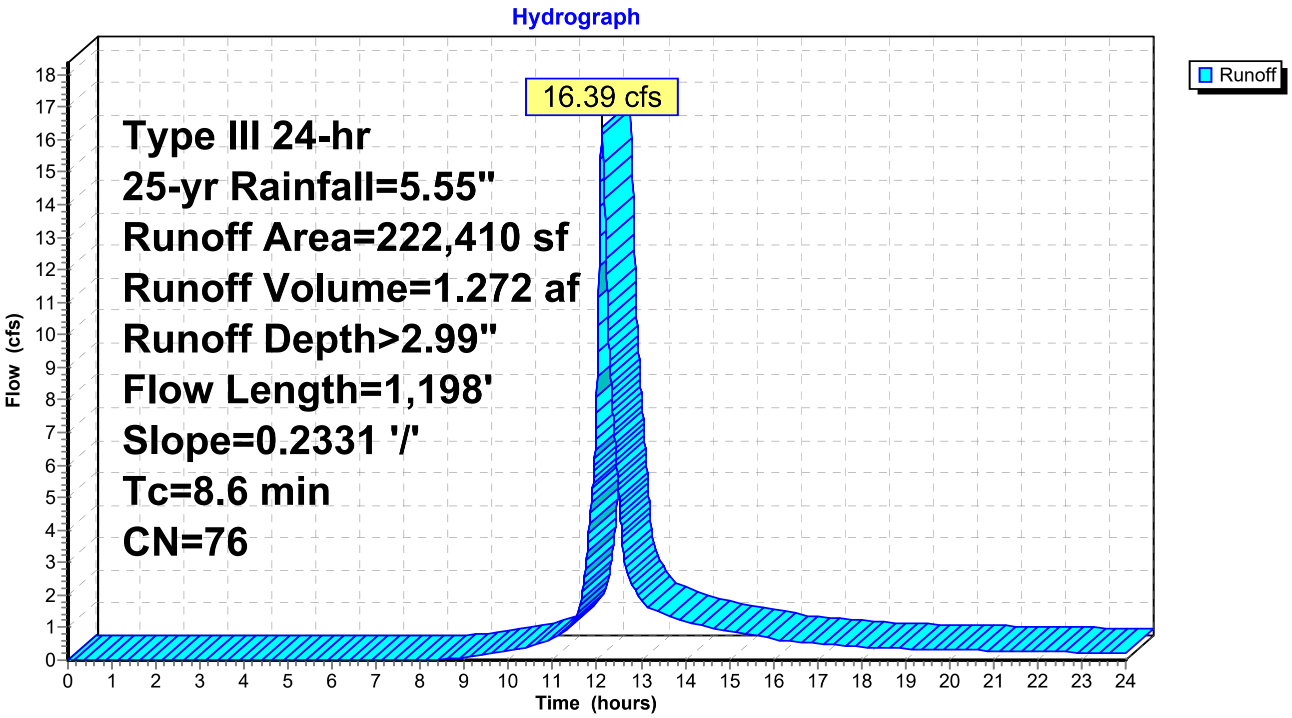
Runoff = 16.39 cfs @ 12.12 hrs, Volume= 1.272 af, Depth> 2.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
7,074	76	Gravel roads HSG A
24,709	89	Gravel roads HSG C
5,356	98	Unconnected pavement HSG C
2,607	39	>75% Grass cover, Good HSG A
182,663	74	>75% Grass cover, Good HSG C
222,410	76	Weighted Average
217,054		97.59% Pervious Area
5,356		2.41% Impervious Area
5,356		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	1,198	0.2331	2.33		**Lag/CN Method,**

Subcatchment A'2.1: A'2.1



Summary for Subcatchment A'2.2: A'2.2

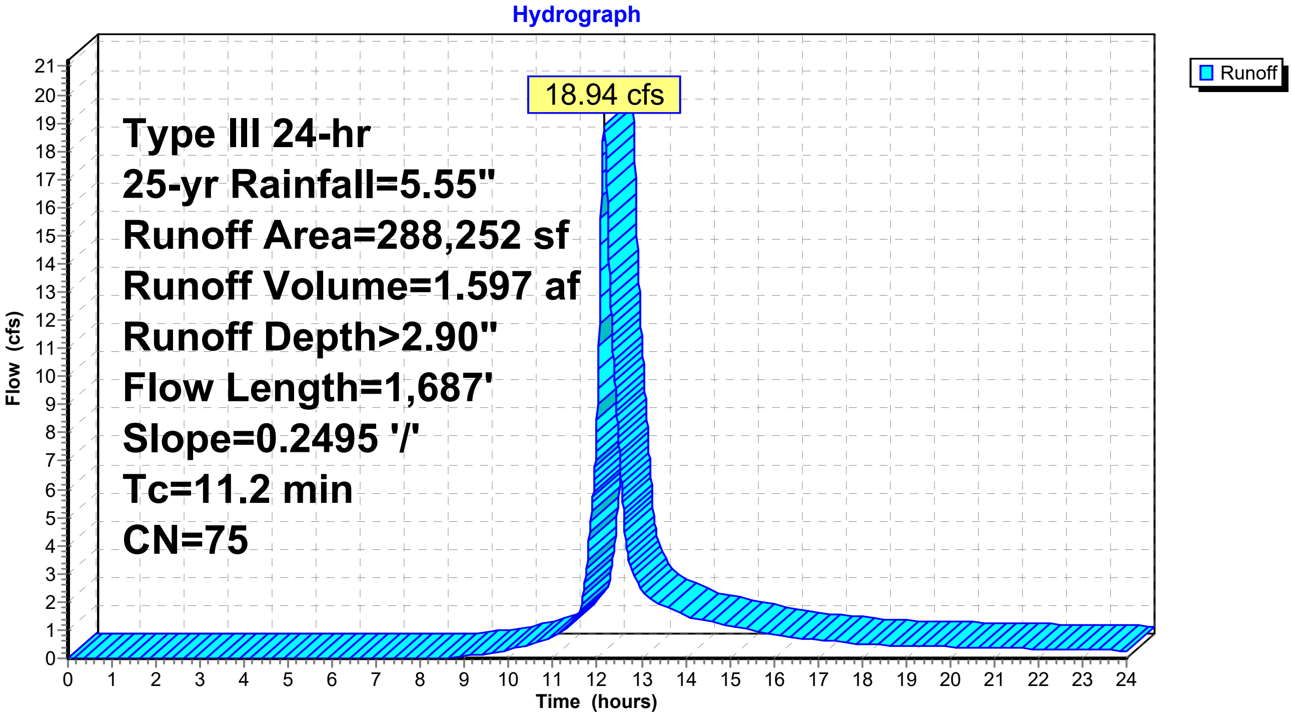
Runoff = 18.94 cfs @ 12.16 hrs, Volume= 1.597 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
15,419	89	Gravel roads HSG C
4,954	98	Unconnected pavement HSG C
267,880	74	>75% Grass cover, Good HSG C
288,252	75	Weighted Average
283,298		98.28% Pervious Area
4,954		1.72% Impervious Area
4,954		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	1,687	0.2495	2.50		**Lag/CN Method,**

Subcatchment A'2.2: A'2.2



Summary for Subcatchment A'2.3: A'2.3

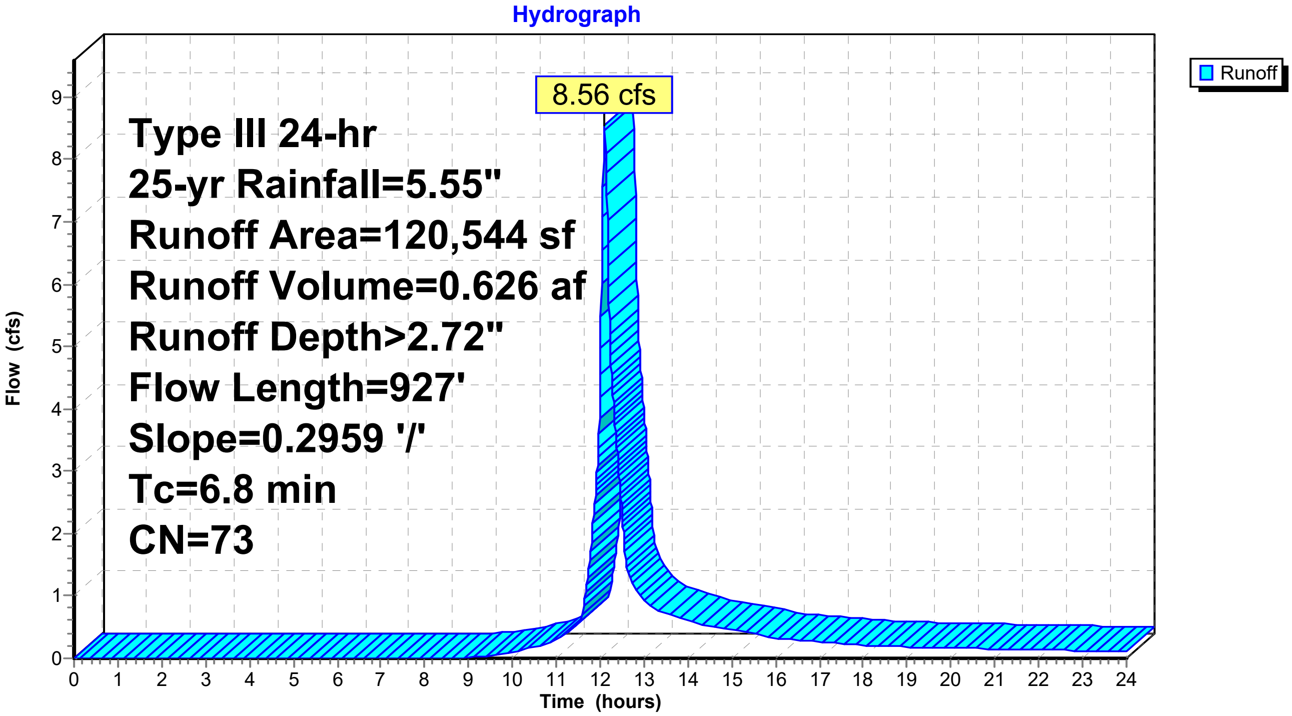
Runoff = 8.56 cfs @ 12.10 hrs, Volume= 0.626 af, Depth> 2.72"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
2,548	89	Gravel roads HSG C
164	76	Gravel roads HSG A
99,045	74	>75% Grass cover, Good HSG C
3,648	39	>75% Grass cover, Good HSG A
15,139	74	>75% Grass cover, Good HSG C
120,544	73	Weighted Average
120,544		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.8	927	0.2959	2.29		**Lag/CN Method,**

Subcatchment A'2.3: A'2.3



Summary for Subcatchment A'2.4: A'2.4

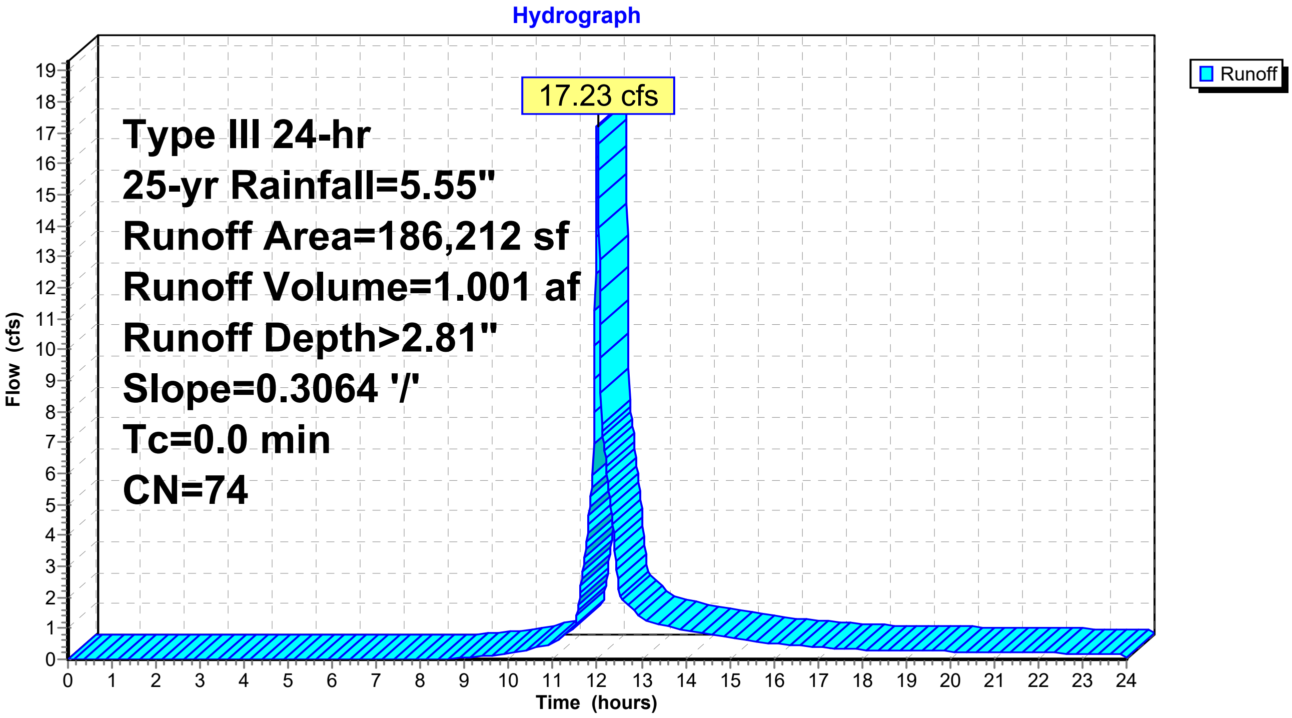
Runoff = 17.23 cfs @ 12.00 hrs, Volume= 1.001 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
1,675	98	Unconnected pavement HSG C
173,025	74	>75% Grass cover, Good HSG C
11,512	74	>75% Grass cover, Good HSG C
186,212	74	Weighted Average
184,537		99.10% Pervious Area
1,675		0.90% Impervious Area
1,675		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.3064			**Lag/CN Method,**

Subcatchment A'2.4: A'2.4



Summary for Subcatchment A'2.5: A'2.5

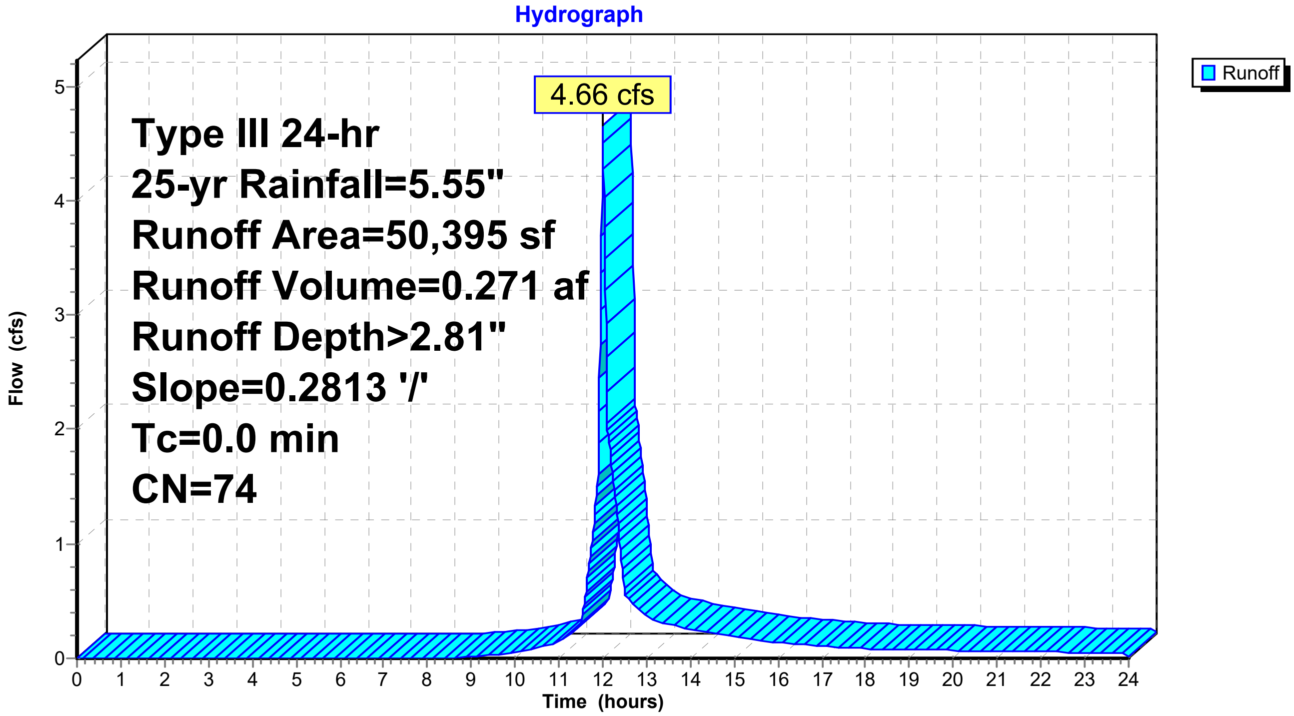
Runoff = 4.66 cfs @ 12.00 hrs, Volume= 0.271 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
438	98	Unconnected pavement HSG C
36,436	74	>75% Grass cover, Good HSG C
13,520	74	>75% Grass cover, Good HSG C
50,395	74	Weighted Average
49,957		99.13% Pervious Area
438		0.87% Impervious Area
438		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2813			**Lag/CN Method,**

Subcatchment A'2.5: A'2.5



Summary for Subcatchment A'3.1: A'3.1

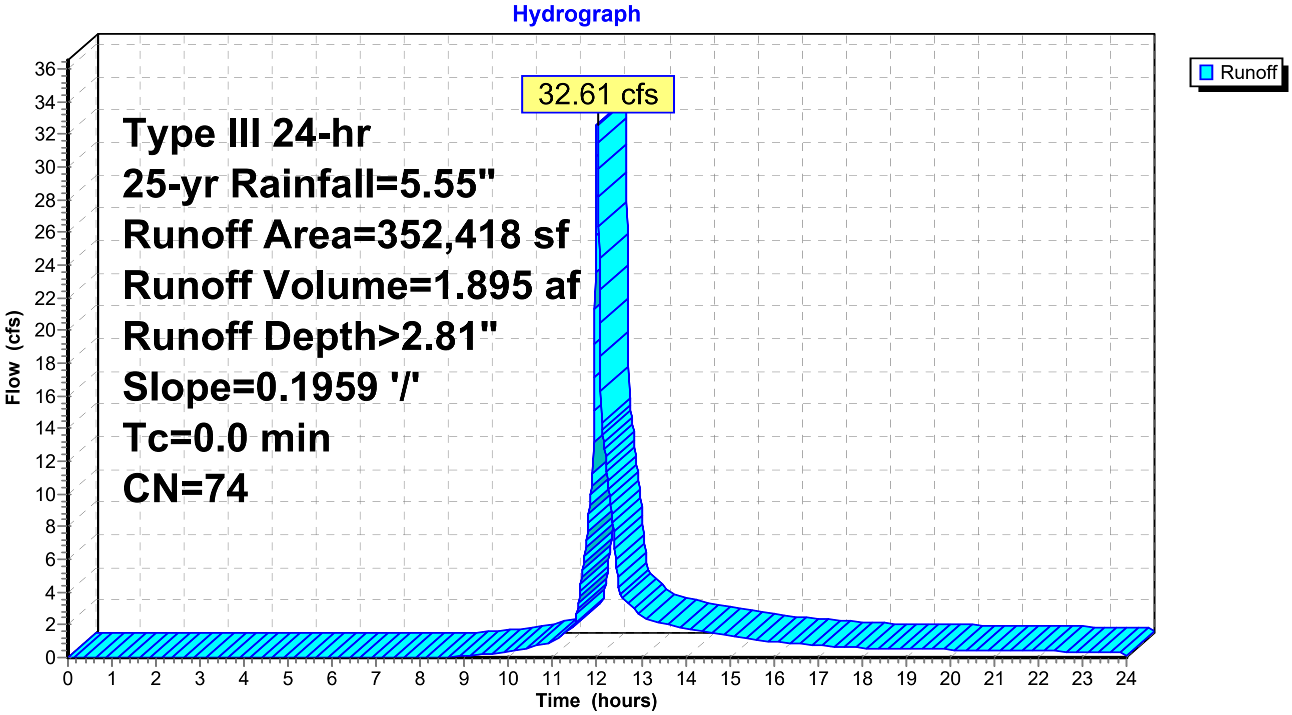
Runoff = 32.61 cfs @ 12.00 hrs, Volume= 1.895 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
348,612	74	>75% Grass cover, Good HSG C
3,806	89	Gravel roads HSG C
352,418	74	Weighted Average
352,418		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.1959			**Lag/CN Method,**

Subcatchment A'3.1: A'3.1



Summary for Subcatchment A'3.2: A'3.2

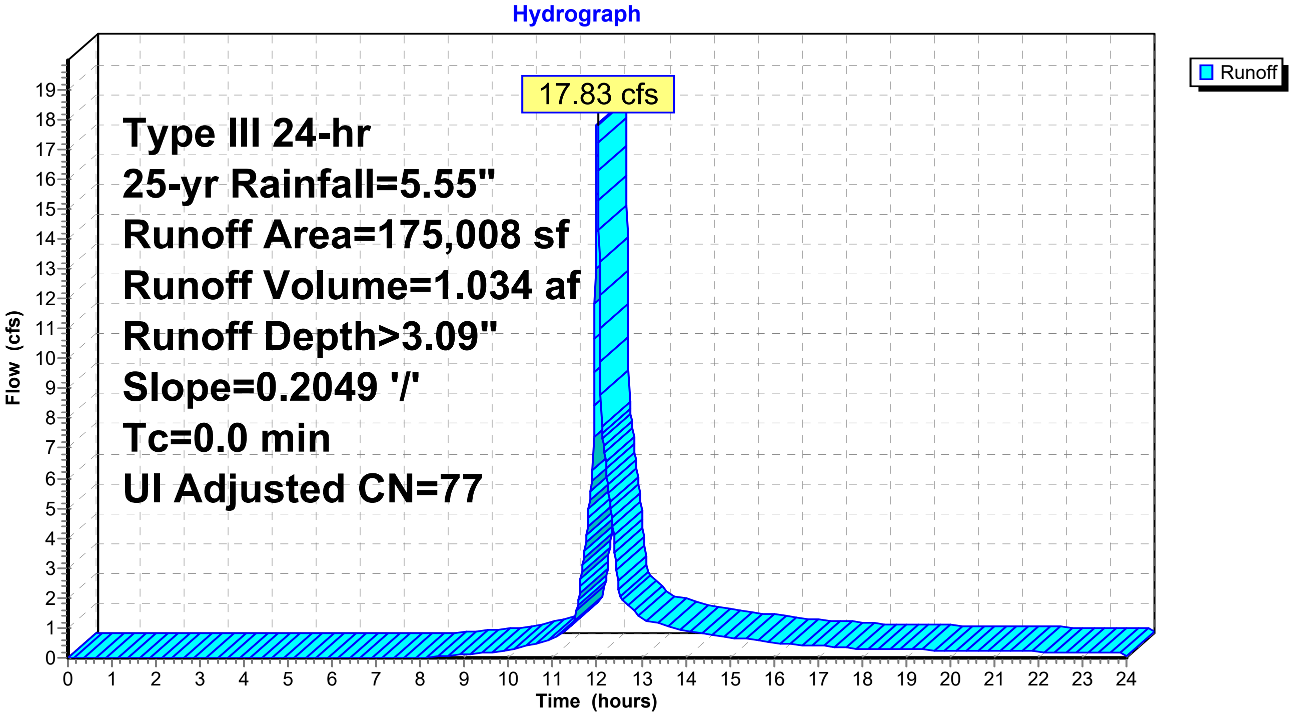
Runoff = 17.83 cfs @ 12.00 hrs, Volume= 1.034 af, Depth> 3.09"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
88,310	74		>75% Grass cover, Good HSG C
19,670	89		Gravel roads HSG C
16,829	98		Unconnected pavement HSG C
50,199	74		>75% Grass cover, Good HSG C
175,008	78	77	Weighted Average, UI Adjusted
158,179			90.38% Pervious Area
16,829			9.62% Impervious Area
16,829			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2049			**Lag/CN Method,**

Subcatchment A'3.2: A'3.2



Summary for Subcatchment A'3.3: A'3.3

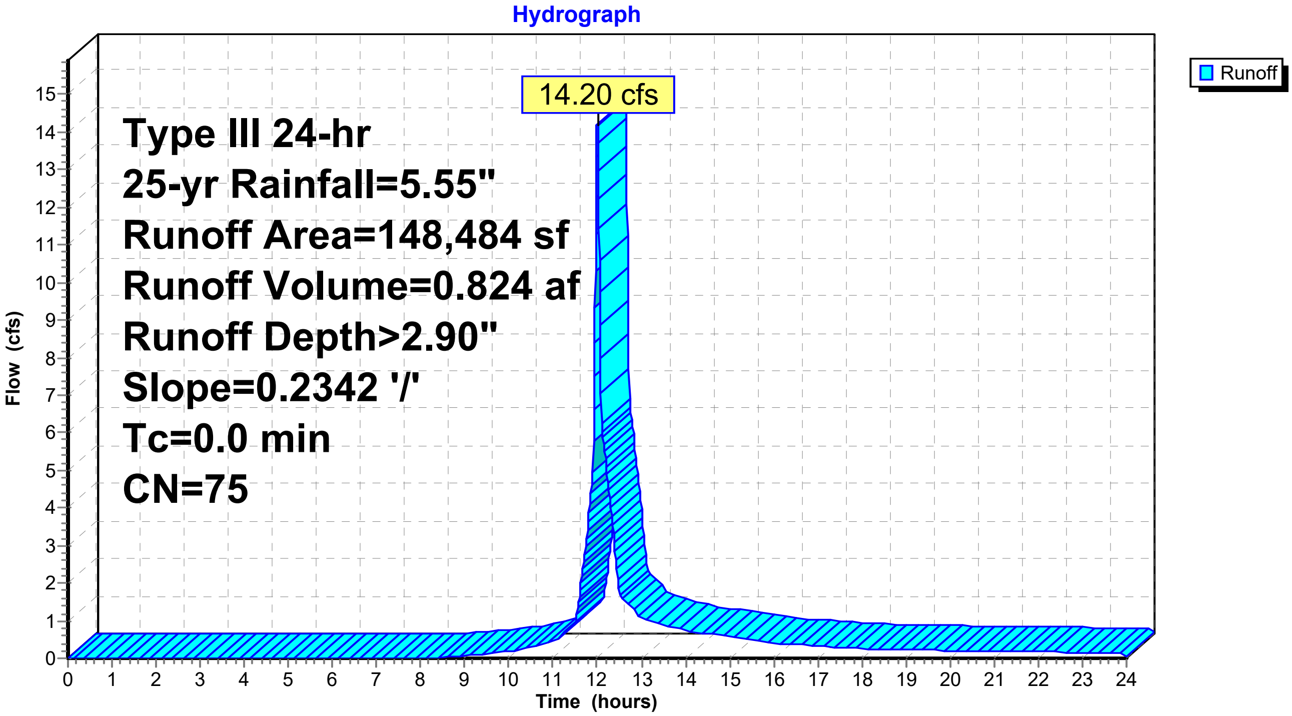
Runoff = 14.20 cfs @ 12.00 hrs, Volume= 0.824 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
133,973	74	>75% Grass cover, Good HSG C
14,172	89	Gravel roads HSG C
339	74	>75% Grass cover, Good HSG C
148,484	75	Weighted Average
148,484		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2342			**Lag/CN Method,**

Subcatchment A'3.3: A'3.3



Summary for Subcatchment A'3.4: A'3.4

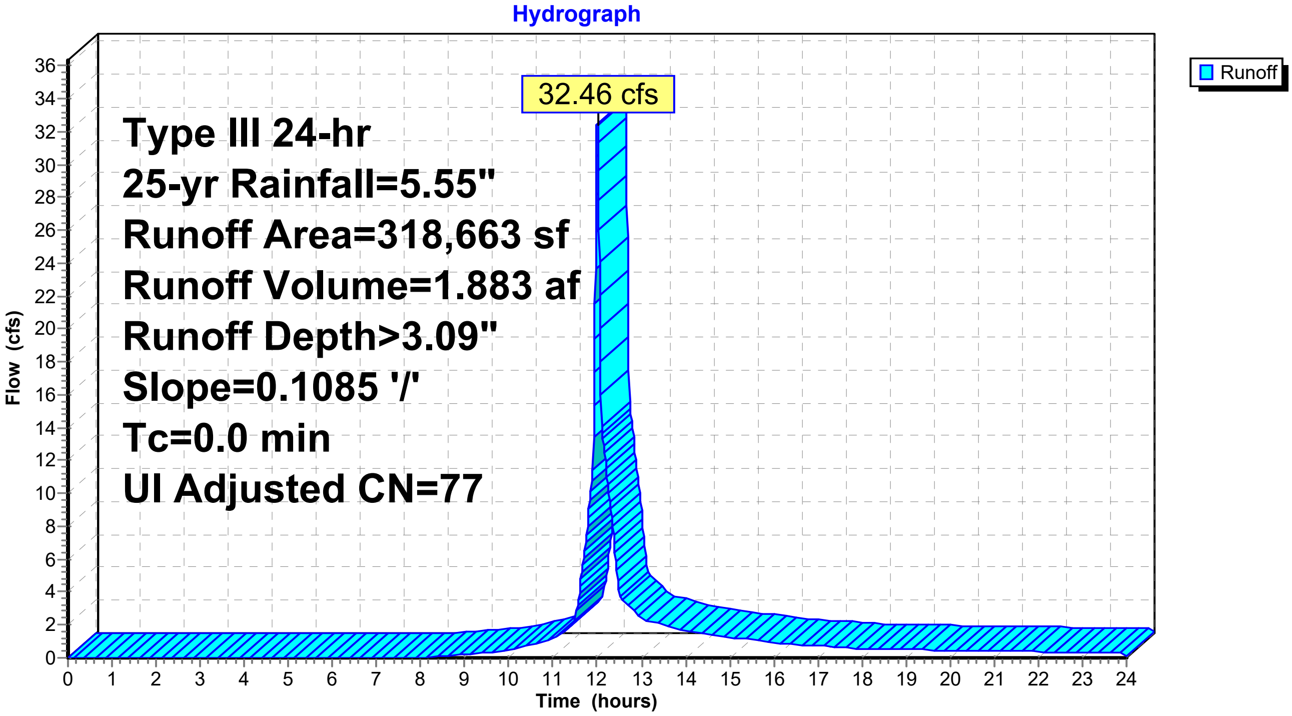
Runoff = 32.46 cfs @ 12.00 hrs, Volume= 1.883 af, Depth> 3.09"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
137,966	74		>75% Grass cover, Good HSG C
38,050	89		Gravel roads HSG C
35,076	98		Unconnected pavement HSG C
107,571	74		>75% Grass cover, Good HSG C
318,663	78	77	Weighted Average, UI Adjusted
283,588			88.99% Pervious Area
35,076			11.01% Impervious Area
35,076			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.1085			**Lag/CN Method,**

Subcatchment A'3.4: A'3.4



Summary for Subcatchment A'3.5: A'3.5

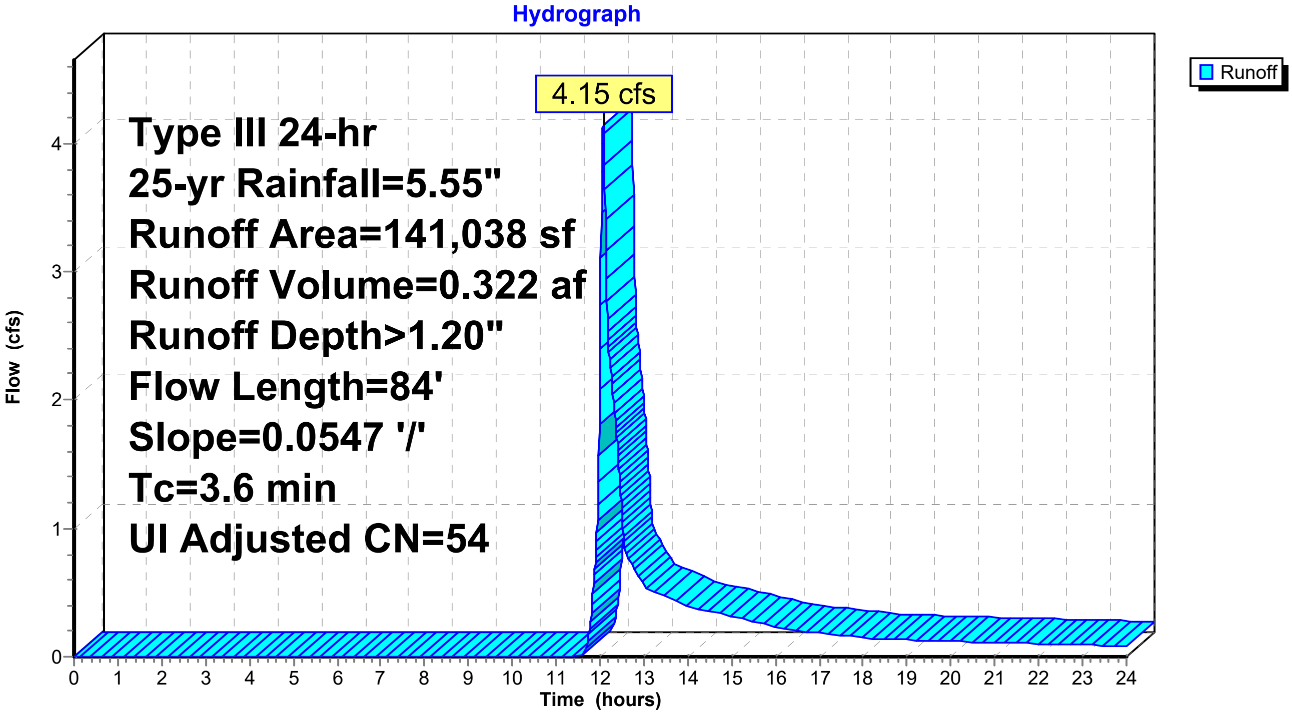
Runoff = 4.15 cfs @ 12.07 hrs, Volume= 0.322 af, Depth> 1.20"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
11,556	98		Unconnected pavement HSG C
1,043	74		>75% Grass cover, Good HSG C
5,785	89		Gravel roads HSG C
166	98		Unconnected pavement HSG A
2,800	30		Woods, Good HSG A
78,447	39		>75% Grass cover, Good HSG A
41,241	74		>75% Grass cover, Good HSG C
141,038	56	54	Weighted Average, UI Adjusted
129,316			91.69% Pervious Area
11,722			8.31% Impervious Area
11,722			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	84	0.0547	0.39		**Lag/CN Method,**

Subcatchment A'3.5: A'3.5



Summary for Subcatchment A'3.6: A'3.6

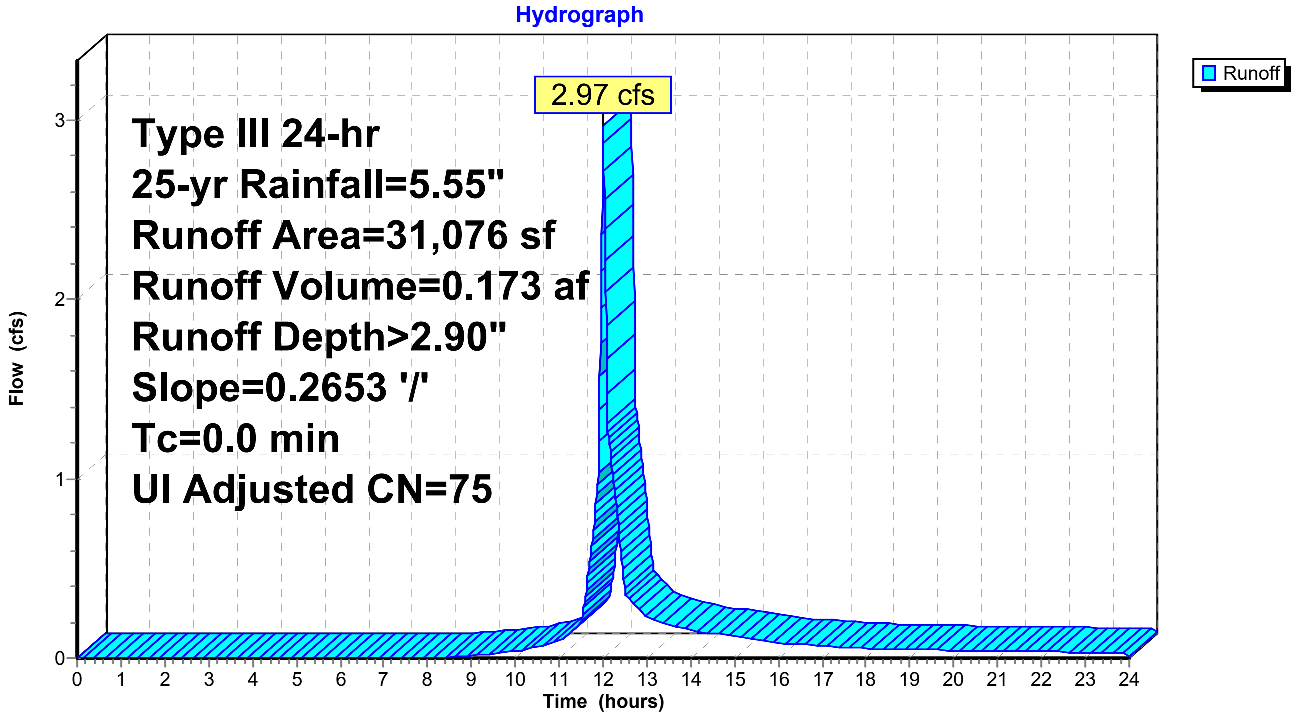
Runoff = 2.97 cfs @ 12.00 hrs, Volume= 0.173 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
23,729	74		>75% Grass cover, Good HSG C
2,061	98		Unconnected pavement HSG C
5,286	74		>75% Grass cover, Good HSG C
31,076	76	75	Weighted Average, UI Adjusted
29,015			93.37% Pervious Area
2,061			6.63% Impervious Area
2,061			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2653			**Lag/CN Method,**

Subcatchment A'3.6: A'3.6



Summary for Subcatchment A'4: A'4

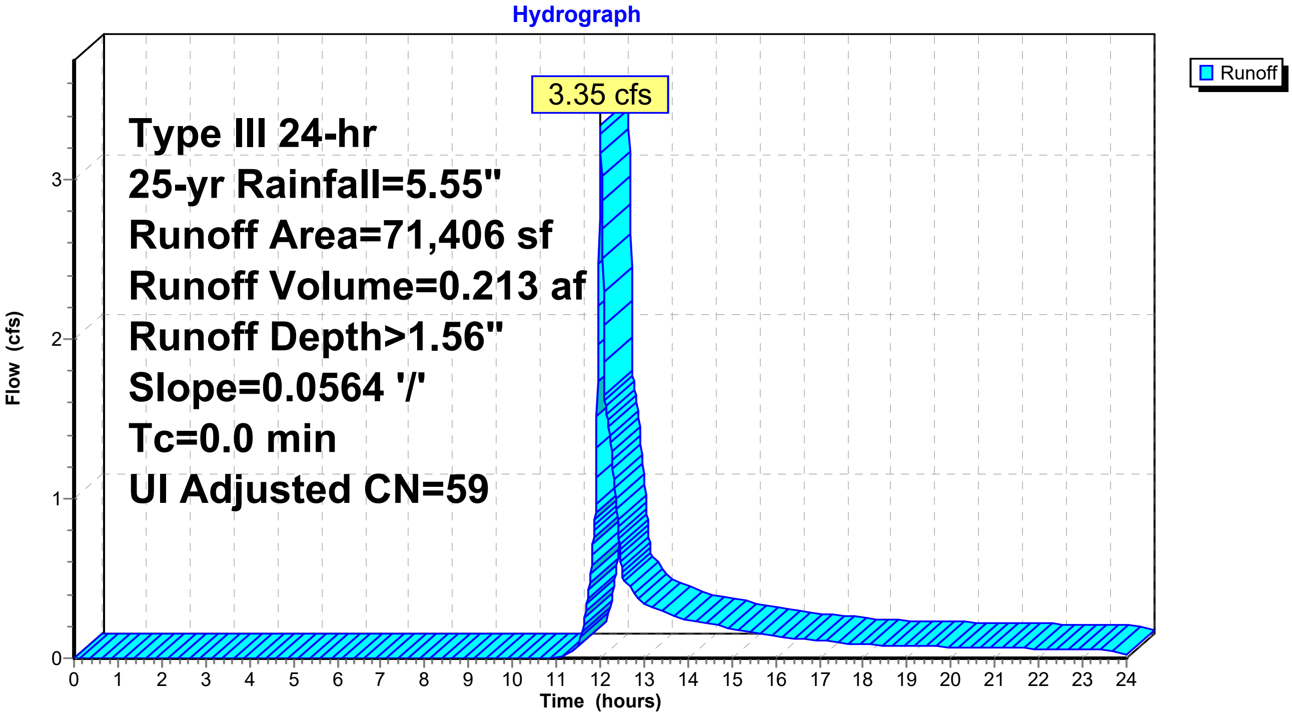
Runoff = 3.35 cfs @ 12.00 hrs, Volume= 0.213 af, Depth> 1.56"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
2,773	70		Woods, Good HSG C
4,240	89		Gravel roads HSG C
1,927	76		Gravel roads HSG A
5,080	98		Unconnected pavement HSG A
8,540	30		Woods, Good HSG A
2,046	73		Woods, Fair HSG C
22,175	39		>75% Grass cover, Good HSG A
24,627	74		>75% Grass cover, Good HSG C
71,406	60	59	Weighted Average, UI Adjusted
66,327			92.89% Pervious Area
5,080			7.11% Impervious Area
5,080			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.0564			**Lag/CN Method,**

Subcatchment A'4: A'4



Summary for Subcatchment C'1.1: C'1.1

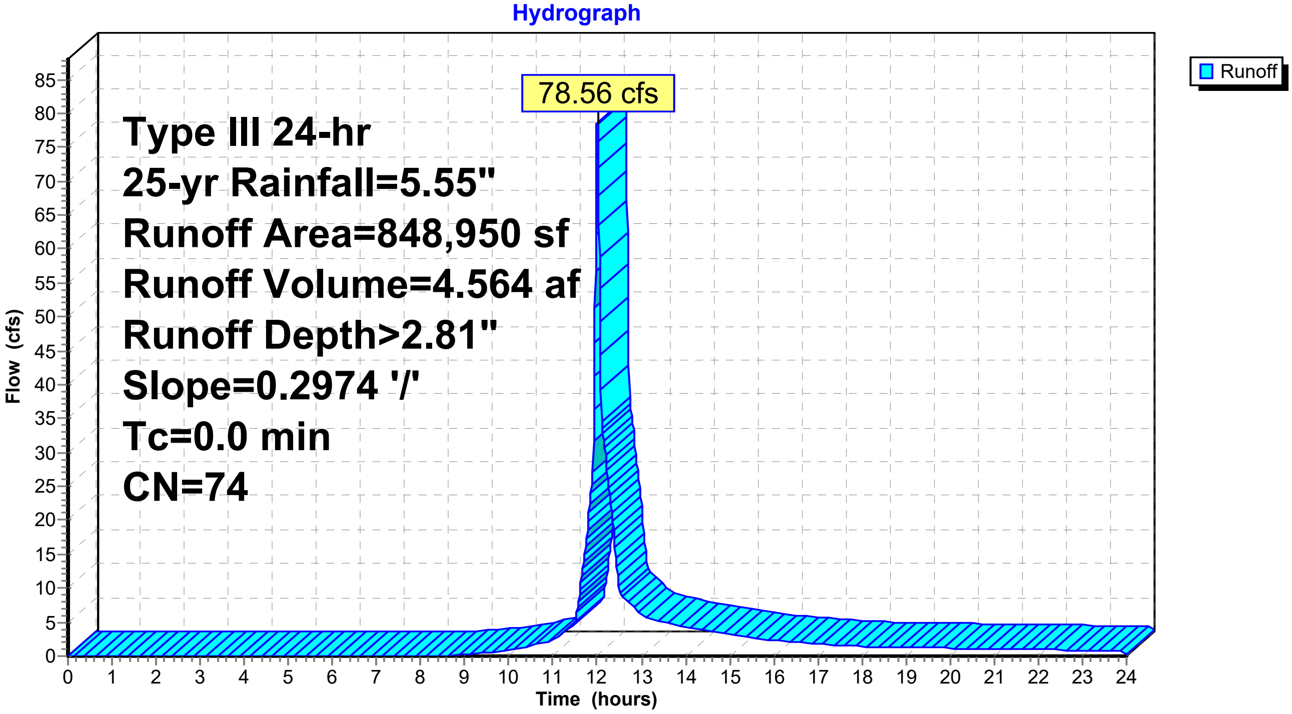
Runoff = 78.56 cfs @ 12.00 hrs, Volume= 4.564 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
848,336	74	>75% Grass cover, Good HSG C
613	74	>75% Grass cover, Good HSG C
848,950	74	Weighted Average
848,950		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2974			**Lag/CN Method,**

Subcatchment C'1.1: C'1.1



Summary for Subcatchment C'1.2: C'1.2

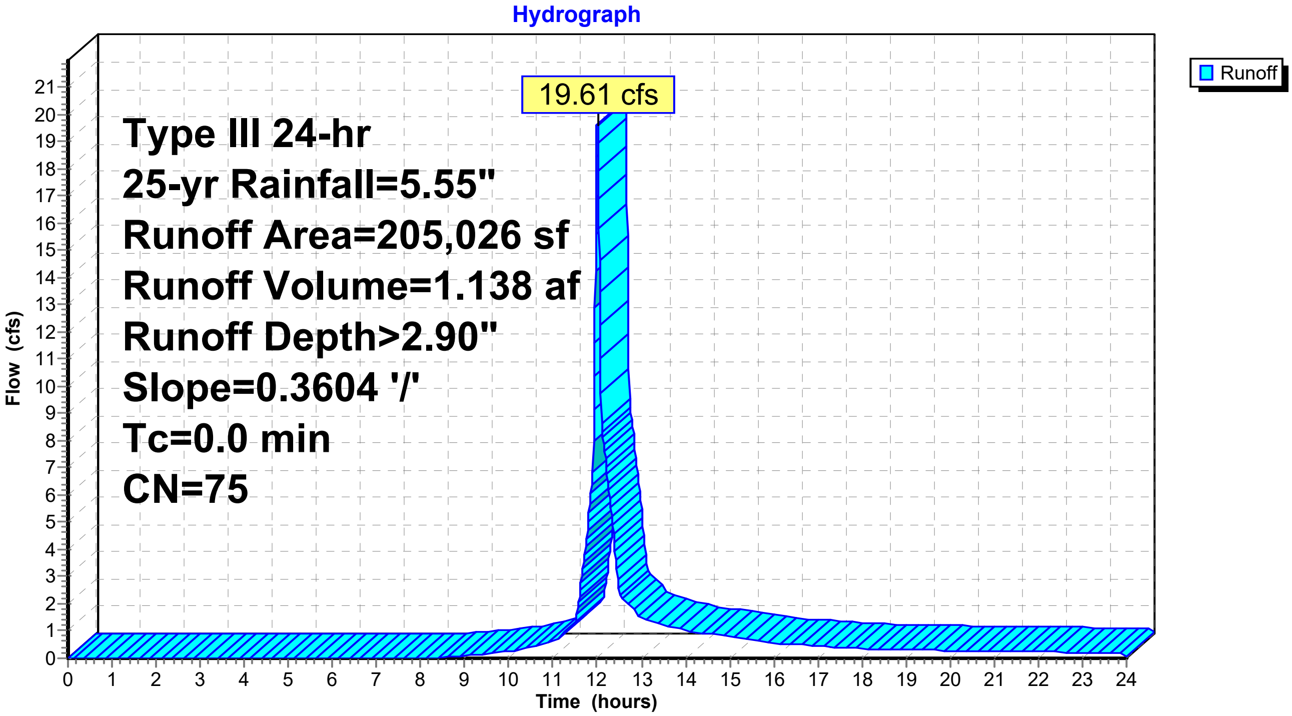
Runoff = 19.61 cfs @ 12.00 hrs, Volume= 1.138 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
8,955	89	Gravel roads HSG C
175,959	74	>75% Grass cover, Good HSG C
20,113	74	>75% Grass cover, Good HSG C
205,026	75	Weighted Average
205,026		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.3604			**Lag/CN Method,**

Subcatchment C'1.2: C'1.2



Summary for Subcatchment C'1.5: C'1.5

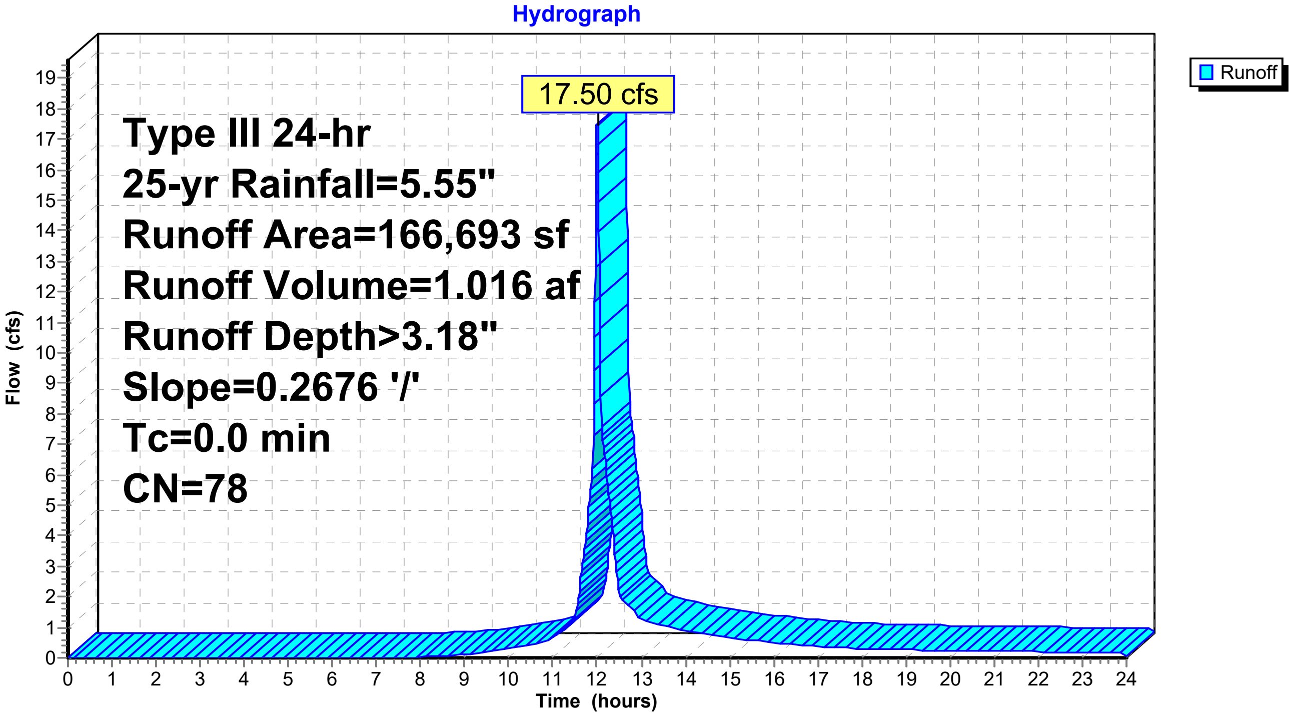
Runoff = 17.50 cfs @ 12.00 hrs, Volume= 1.016 af, Depth> 3.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
23,733	89	Gravel roads HSG C
14,125	70	Woods, Good HSG C
14,584	98	Water Surface HSG C
1,200	98	Roofs HSG C
113,050	74	>75% Grass cover, Good HSG C
166,693	78	Weighted Average
150,909		90.53% Pervious Area
15,784		9.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0		0.2676			**Lag/CN Method,**

Subcatchment C'1.5: C'1.5



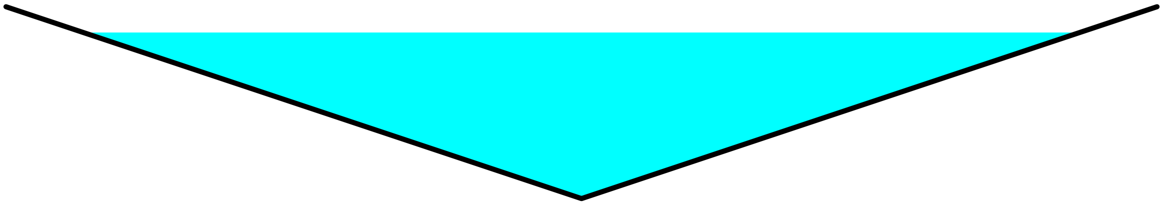
Summary for Reach 3R: Existing Swale

```
Inflow Area =       20.174 ac,   6.15% Impervious,  Inflow Depth >   2.98"    for  25-yr event
Inflow      =      86.39 cfs @   12.00 hrs,  Volume=              5.014 af
Outflow     =      78.33 cfs @   12.02 hrs,  Volume=              5.008 af,  Atten= 9%,  Lag= 1.2 min
```

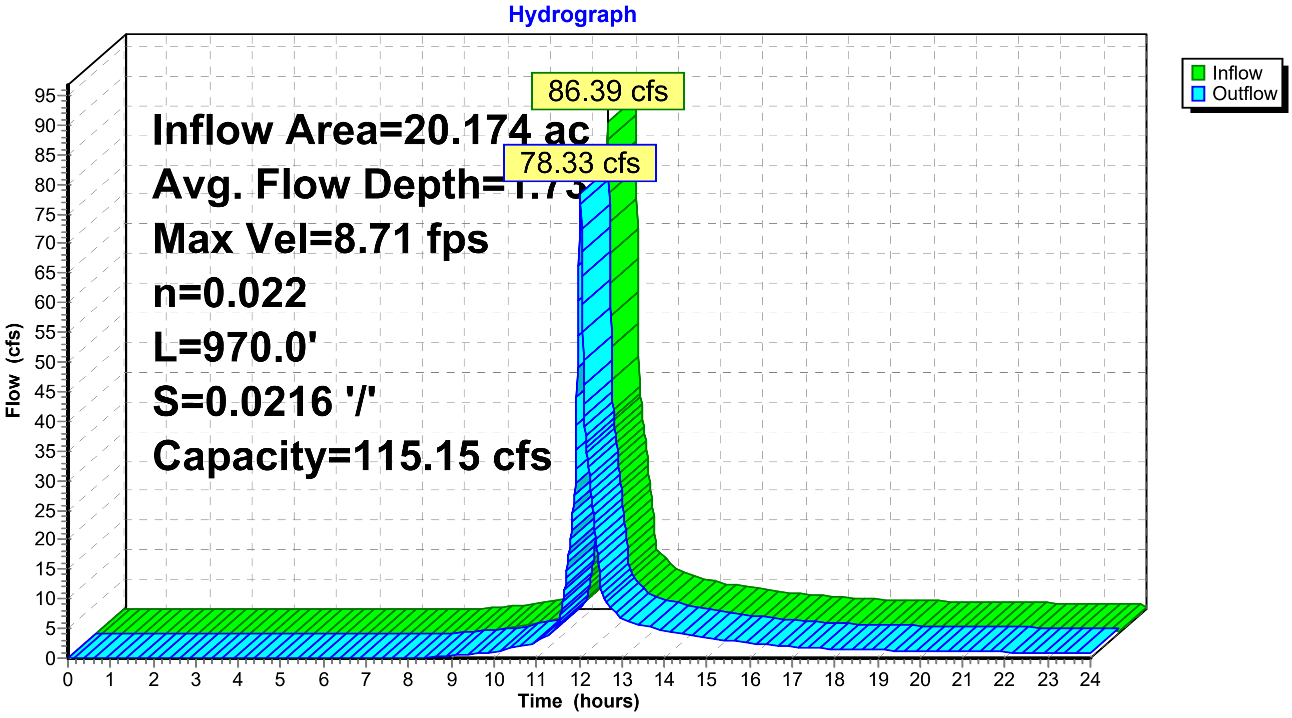
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 8.71 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 3.48 fps, Avg. Travel Time= 4.6 min

Peak Storage= 8,719 cf @ 12.02 hrs
Average Depth at Peak Storage= 1.73'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 115.15 cfs

0.00' x 2.00' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 970.0' Slope= 0.0216 '/'
Inlet Invert= 204.00', Outlet Invert= 183.00'



Reach 3R: Existing Swale



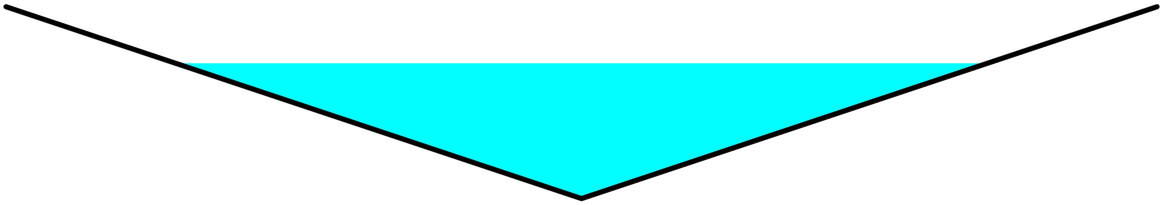
Summary for Reach 4R: Existing Swale

Inflow Area = 7.873 ac, 1.56% Impervious, Inflow Depth > 2.89" for 25-yr event
Inflow = 24.36 cfs @ 12.13 hrs, Volume= 1.897 af
Outflow = 18.95 cfs @ 12.21 hrs, Volume= 1.887 af, Atten= 22%, Lag= 4.9 min

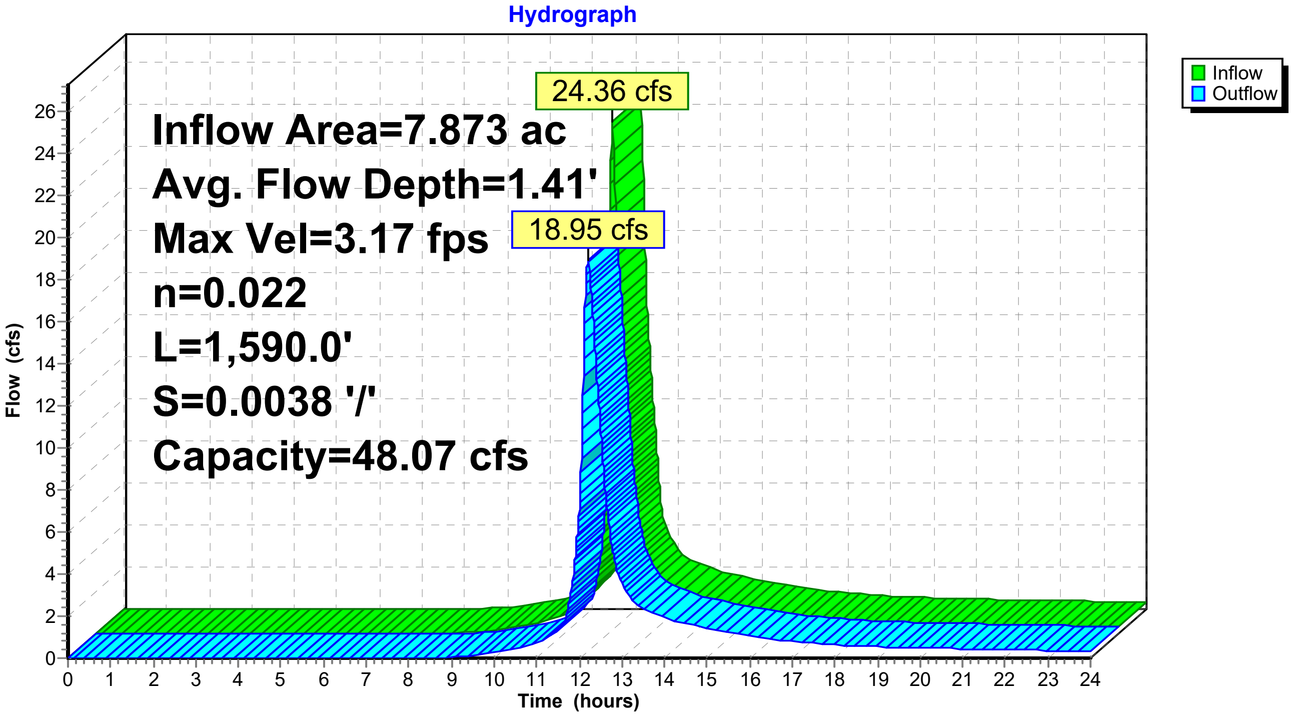
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.17 fps, Min. Travel Time= 8.3 min
Avg. Velocity = 1.42 fps, Avg. Travel Time= 18.6 min

Peak Storage= 9,493 cf @ 12.21 hrs
Average Depth at Peak Storage= 1.41'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 48.07 cfs

0.00' x 2.00' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 1,590.0' Slope= 0.0038 '/'
Inlet Invert= 184.00', Outlet Invert= 178.00'



Reach 4R: Existing Swale



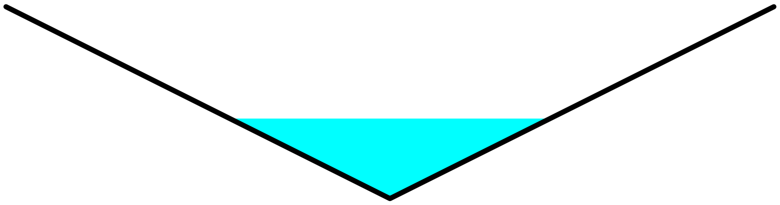
Summary for Reach 15R: Existing Roadside Swale

Inflow Area = 2.767 ac, 0.00% Impervious, Inflow Depth > 2.72" for 25-yr event
Inflow = 8.56 cfs @ 12.10 hrs, Volume= 0.626 af
Outflow = 8.00 cfs @ 12.13 hrs, Volume= 0.625 af, Atten= 7%, Lag= 1.9 min

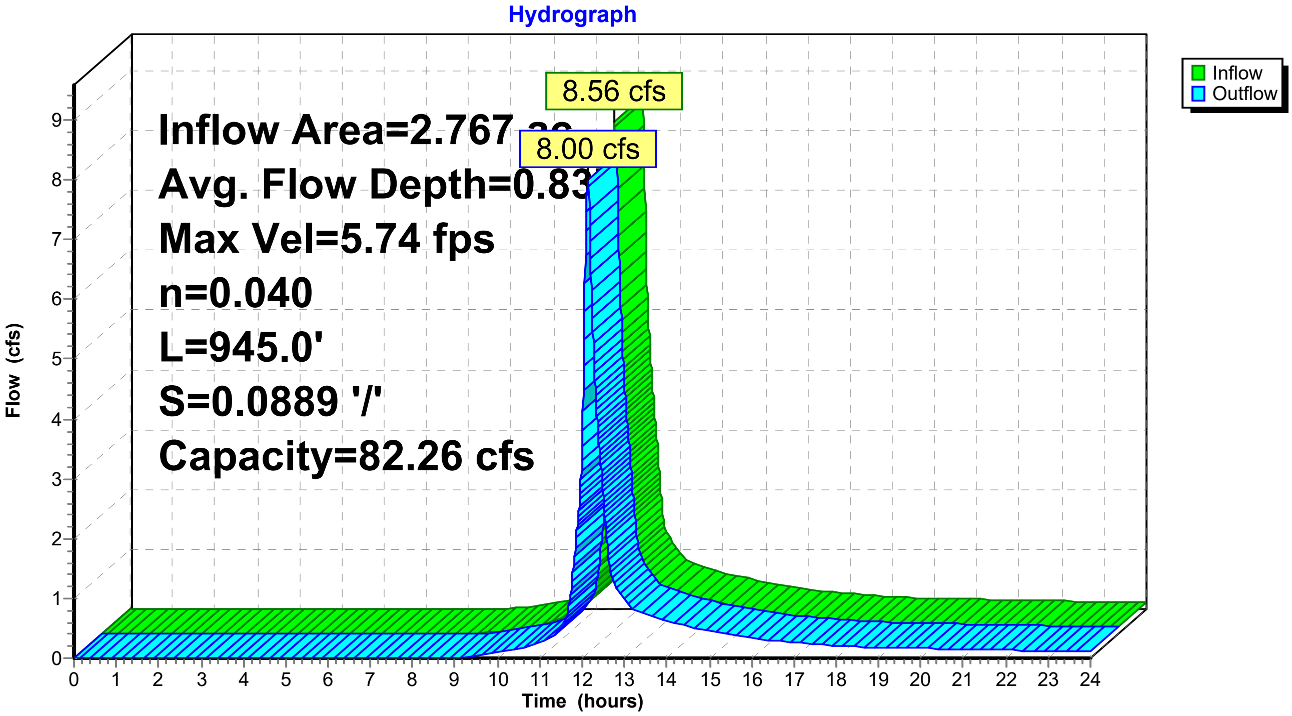
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.74 fps, Min. Travel Time= 2.7 min
Avg. Velocity = 2.48 fps, Avg. Travel Time= 6.3 min

Peak Storage= 1,317 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.83'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 82.26 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 945.0' Slope= 0.0889 '/'
Inlet Invert= 288.00', Outlet Invert= 204.00'



Reach 15R: Existing Roadside Swale



Summary for Pond 2P: Existing Pond 2

Inflow Area = 57.187 ac, 3.34% Impervious, Inflow Depth > 2.50" for 25-yr event
Inflow = 134.95 cfs @ 12.02 hrs, Volume= 11.917 af
Outflow = 10.92 cfs @ 14.22 hrs, Volume= 9.333 af, Atten= 92%, Lag= 131.9 min
Primary = 10.92 cfs @ 14.22 hrs, Volume= 9.333 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Starting Elev= 176.90' Surf.Area= 0 sf Storage= 123,527 cf
Peak Elev= 179.68' @ 14.22 hrs Surf.Area= 0 sf Storage= 399,989 cf (276,462 cf above start)
Flood Elev= 181.50' Surf.Area= 0 sf Storage= 654,228 cf (530,701 cf above start)

Plug-Flow detention time= 433.9 min calculated for 6.497 af (55% of inflow)
Center-of-Mass det. time= 212.8 min (1,049.8 - 837.0)

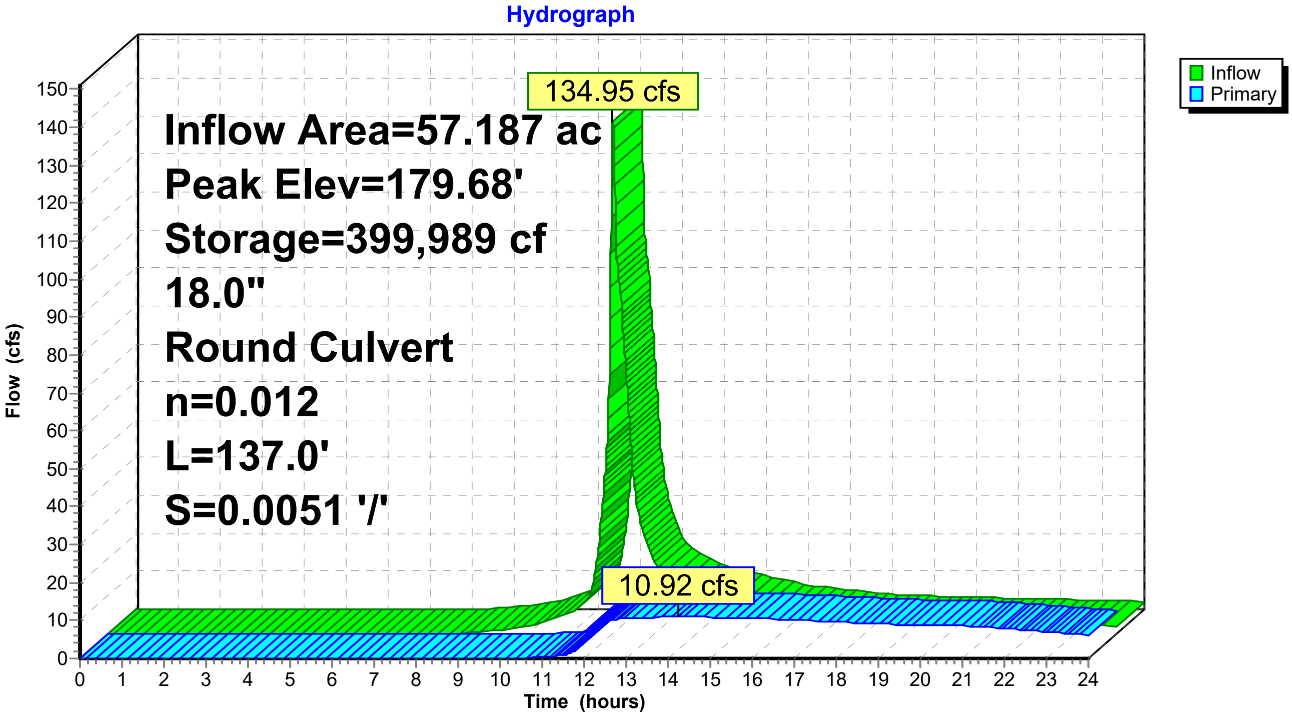
Volume	Invert	Avail.Storage	Storage Description
#1	174.00'	654,228 cf	**Custom Stage Data** Listed below

Elevation (feet)	Cum.Store (cubic-feet)
174.00	0
176.75	113,517
177.25	146,884
177.75	183,300
178.25	234,440
179.00	319,208
179.50	379,233
180.00	438,083
181.00	579,522
181.50	654,228

Device	Routing	Invert	Outlet Devices
#1	Primary	176.90'	**18.0" Round Culvert** L= 137.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 176.90' / 176.20' S= 0.0051 '/' Cc= 0.900 n= 0.012, Flow Area= 1.77 sf

Primary OutFlow Max=10.92 cfs @ 14.22 hrs HW=179.68' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 10.92 cfs @ 6.18 fps)

Pond 2P: Existing Pond 2



Summary for Pond 4P: Existing Pond 4

```
Inflow Area =      28.023 ac,   1.29% Impervious,  Inflow Depth >   2.88"    for  25-yr event
Inflow      =     115.67 cfs @   12.00 hrs,  Volume=          6.718 af
Outflow     =       7.54 cfs @   13.43 hrs,  Volume=          6.081 af,  Atten= 93%,  Lag= 86.0 min
Primary     =       7.54 cfs @   13.43 hrs,  Volume=          6.081 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 202.65' @ 13.43 hrs Surf.Area= 30,303 sf Storage= 144,479 cf
Flood Elev= 208.00' Surf.Area= 41,741 sf Storage= 336,443 cf

Plug-Flow detention time= 239.9 min calculated for 6.081 af (91% of inflow)
Center-of-Mass det. time= 193.2 min (1,018.1 - 824.9)

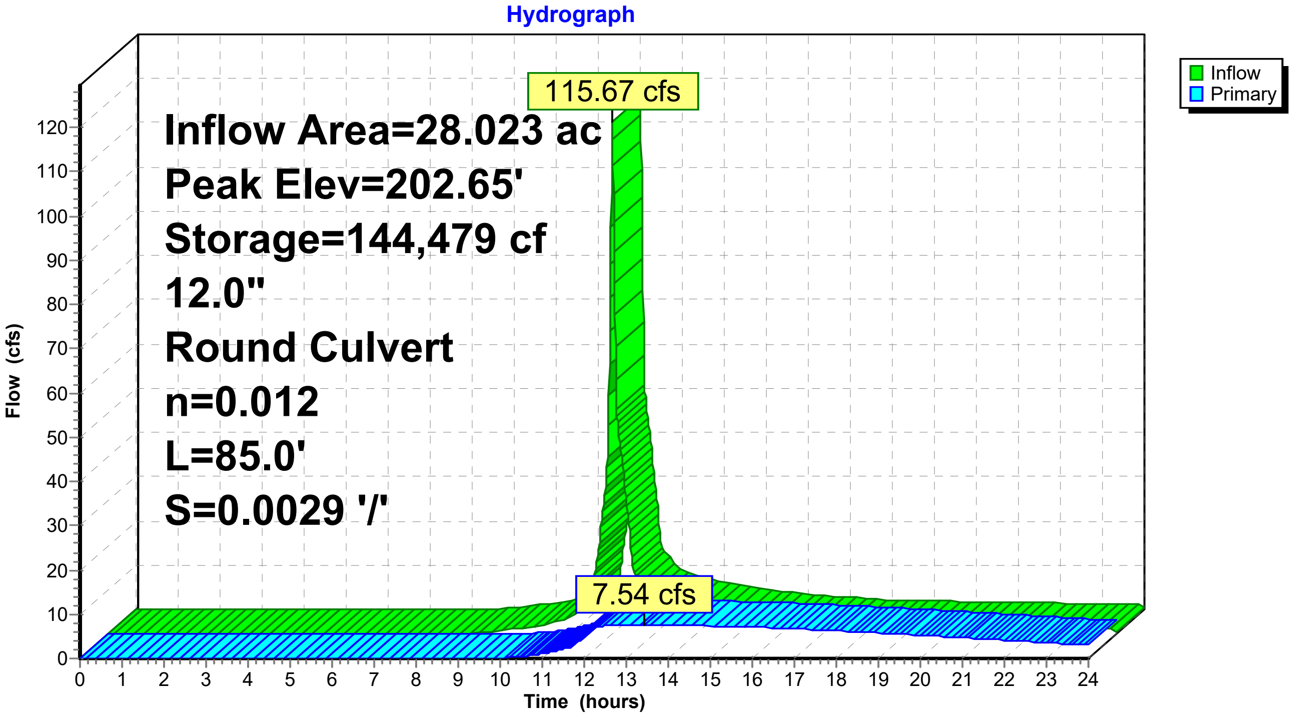
Volume	Invert	Avail.Storage	Storage Description
#1	196.50'	336,443 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
196.50	14,584	631.3	0	0	14,584
198.00	20,032	794.2	25,854	25,854	33,094
200.00	25,197	855.2	45,130	70,985	41,269
202.00	29,091	888.5	54,241	125,226	46,207
204.00	32,908	922.4	61,960	187,186	51,417
206.00	37,348	956.0	70,209	257,395	56,780
208.00	41,741	1,006.2	79,048	336,443	64,860

Device	Routing	Invert	Outlet Devices
#1	Primary	196.50'	**12.0" Round Culvert** L= 85.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 196.50' / 196.25' S= 0.0029 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 0.79 sf

Primary OutFlow Max=7.54 cfs @ 13.43 hrs HW=202.65' (Free Discharge)
└─**1=Culvert** (Barrel Controls 7.54 cfs @ 9.60 fps)

Pond 4P: Existing Pond 4



Summary for Pond 5R: Existing 24" Culvert

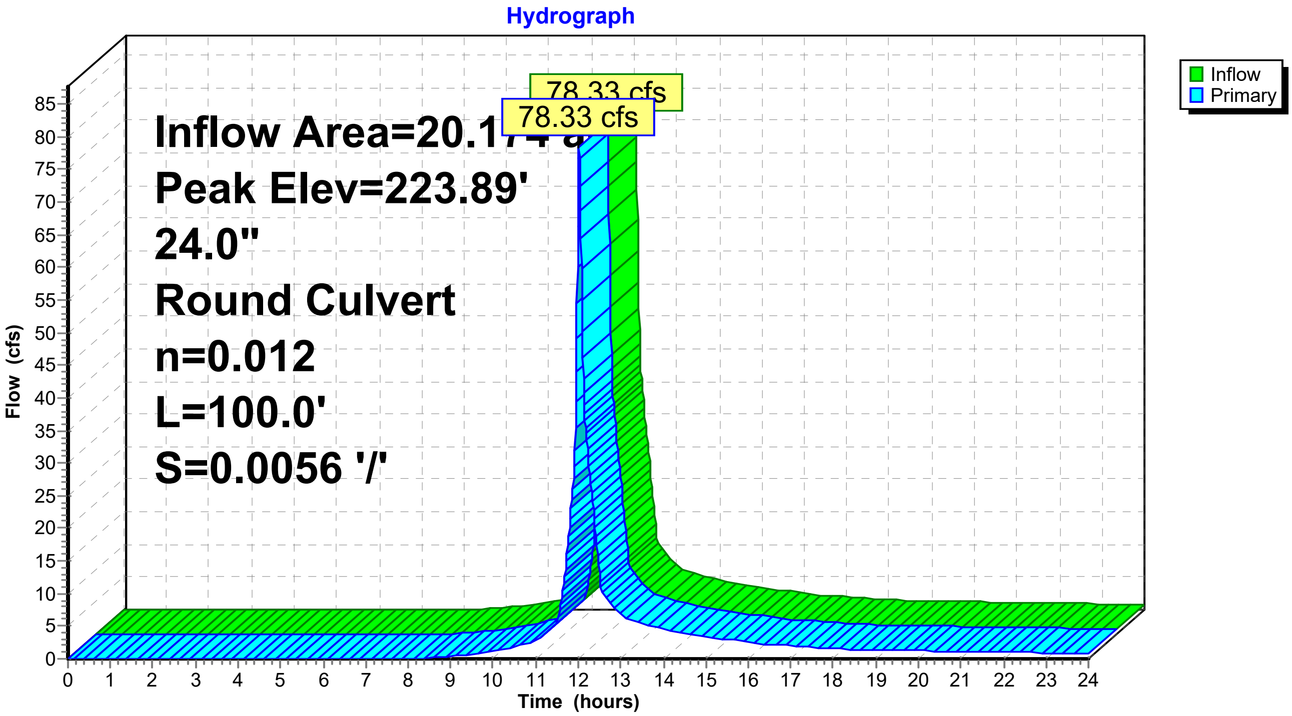
```
Inflow Area =       20.174 ac,   6.15% Impervious,  Inflow Depth >   2.98"   for  25-yr event
Inflow      =      78.33 cfs @  12.02 hrs,  Volume=          5.008 af
Outflow     =      78.33 cfs @  12.02 hrs,  Volume=          5.008 af,  Atten= 0%,  Lag= 0.0 min
Primary     =      78.33 cfs @  12.02 hrs,  Volume=          5.008 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 223.89' @ 12.02 hrs
Flood Elev= 184.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	179.87'	**24.0" Round Culvert** L= 100.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 179.87' / 179.31' S= 0.0056 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=78.14 cfs @ 12.02 hrs HW=223.69' TW=178.21' (Dynamic Tailwater)
↑**1=Culvert** (Inlet Controls 78.14 cfs @ 24.87 fps)

Pond 5R: Existing 24" Culvert



Summary for Pond 8R: Existing Dual 30" Culverts

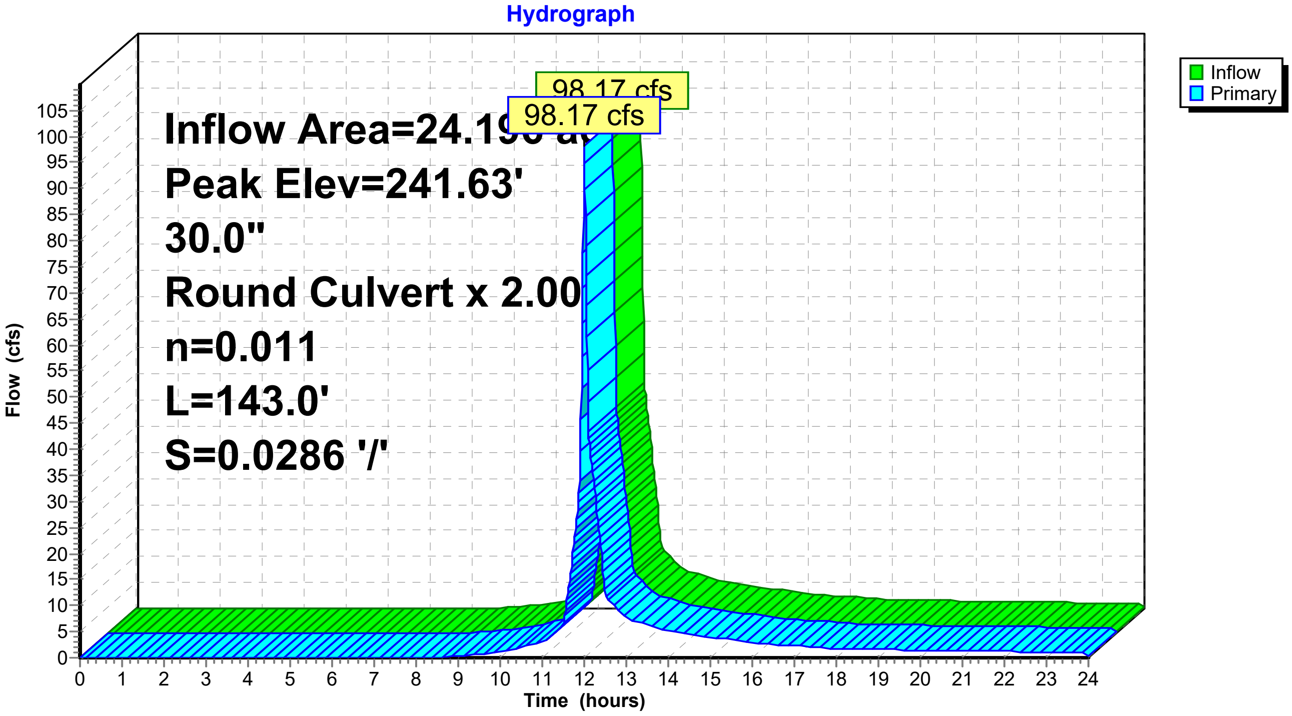
Inflow Area = 24.196 ac, 0.00% Impervious, Inflow Depth > 2.83" for 25-yr event
Inflow = 98.17 cfs @ 12.00 hrs, Volume= 5.703 af
Outflow = 98.17 cfs @ 12.00 hrs, Volume= 5.703 af, Atten= 0%, Lag= 0.0 min
Primary = 98.17 cfs @ 12.00 hrs, Volume= 5.703 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 241.63' @ 12.00 hrs
Flood Elev= 240.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	236.07'	**30.0" Round Culvert X 2.00** L= 143.0' Ke= 0.500 Inlet / Outlet Invert= 236.07' / 231.98' S= 0.0286 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 4.91 sf

Primary OutFlow Max=97.59 cfs @ 12.00 hrs HW=241.58' TW=200.03' (Dynamic Tailwater)
↑**1=Culvert** (Inlet Controls 97.59 cfs @ 9.94 fps)

Pond 8R: Existing Dual 30" Culverts



Summary for Pond CB2: Existing Catch Basin

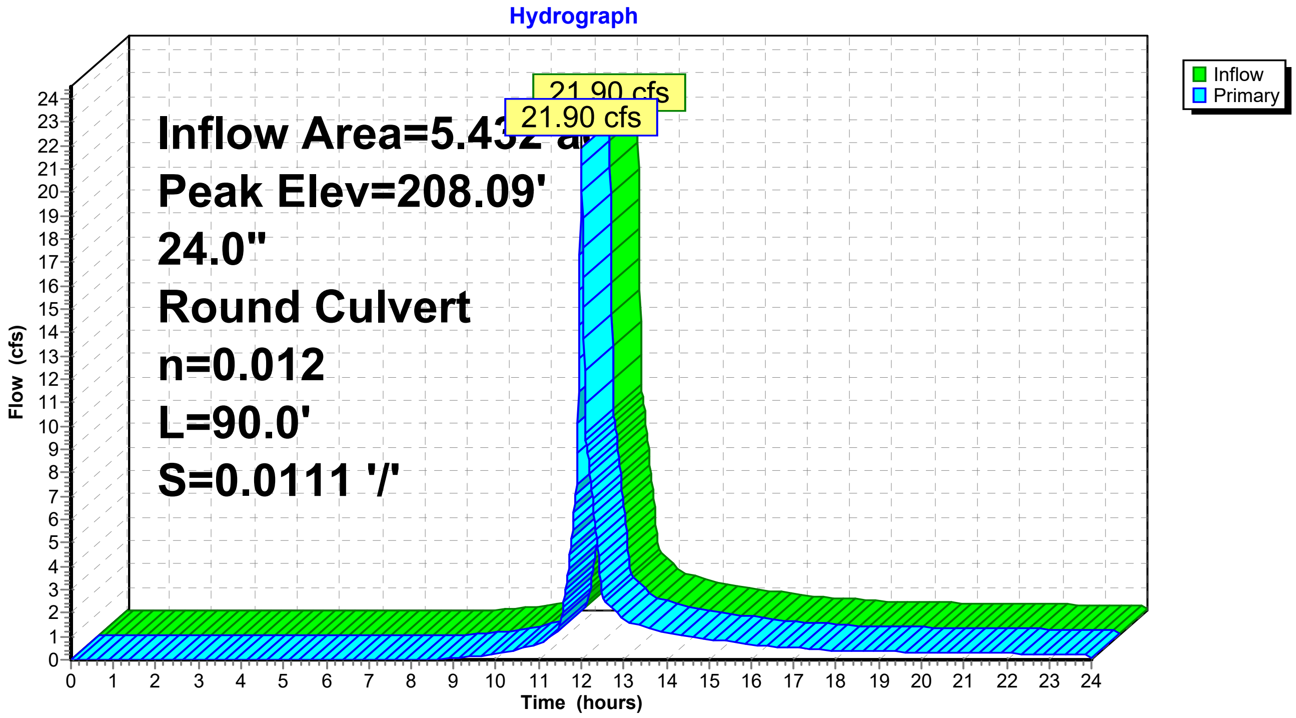
Inflow Area = 5.432 ac, 0.89% Impervious, Inflow Depth > 2.81" for 25-yr event
Inflow = 21.90 cfs @ 12.00 hrs, Volume= 1.272 af
Outflow = 21.90 cfs @ 12.00 hrs, Volume= 1.272 af, Atten= 0%, Lag= 0.0 min
Primary = 21.90 cfs @ 12.00 hrs, Volume= 1.272 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 208.09' @ 12.00 hrs
Flood Elev= 208.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	205.00'	**24.0" Round Culvert** L= 90.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 205.00' / 204.00' S= 0.0111 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=21.76 cfs @ 12.00 hrs HW=208.07' TW=205.69' (Dynamic Tailwater)
└─**1=Culvert** (Inlet Controls 21.76 cfs @ 6.93 fps)

Pond CB2: Existing Catch Basin



Summary for Pond CB3: Existing Catch Basin

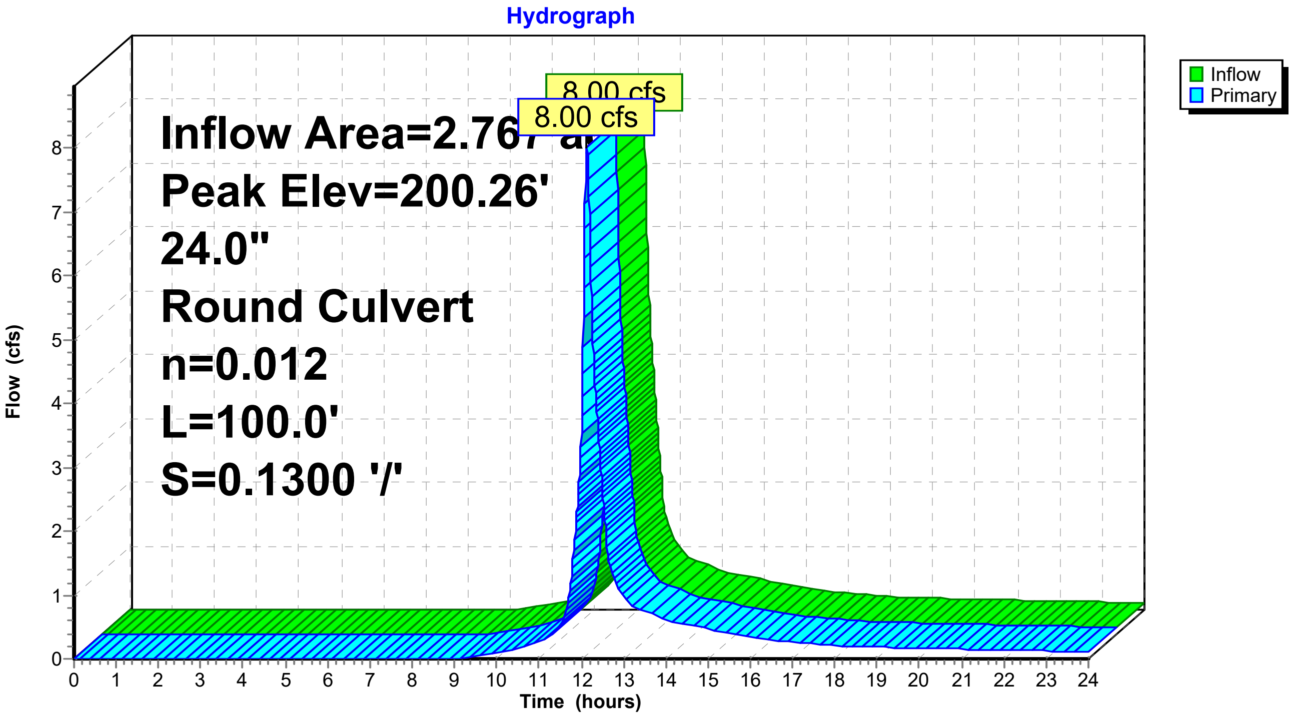
```
Inflow Area =        2.767 ac,   0.00% Impervious,  Inflow Depth >   2.71"    for  25-yr event
Inflow      =       8.00 cfs @   12.13 hrs,  Volume=            0.625 af
Outflow     =       8.00 cfs @   12.13 hrs,  Volume=            0.625 af,  Atten= 0%,  Lag= 0.0 min
Primary     =       8.00 cfs @   12.13 hrs,  Volume=            0.625 af
```

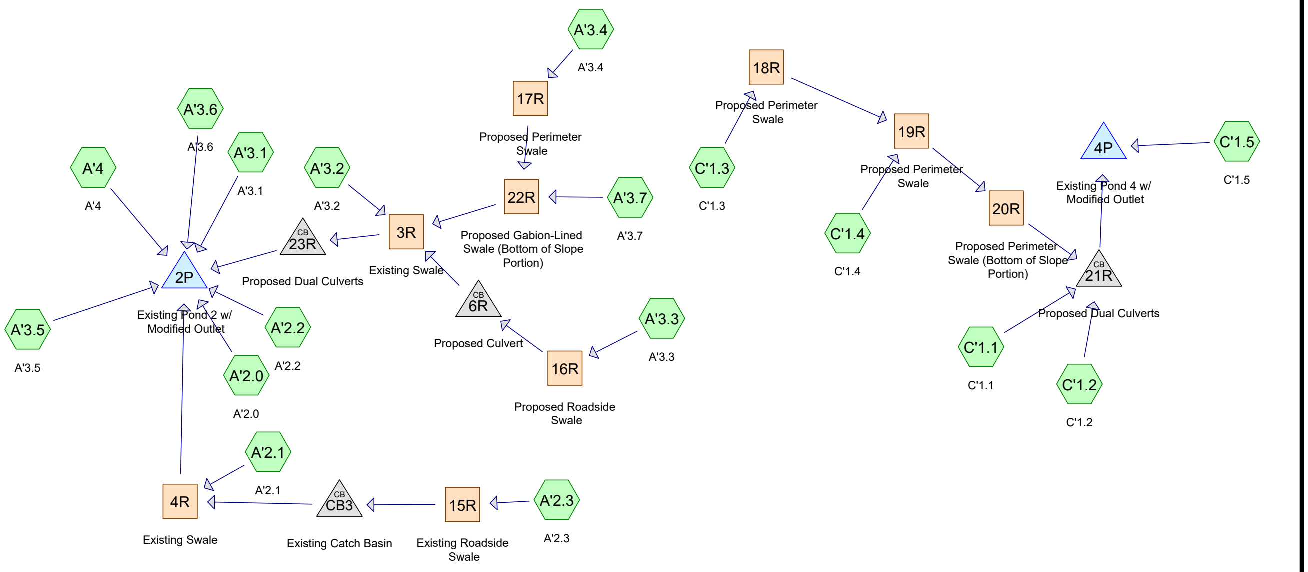
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 200.26' @ 12.13 hrs
Flood Elev= 201.50'

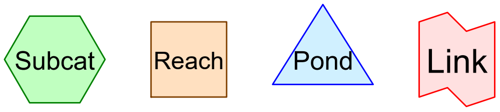
Device	Routing	Invert	Outlet Devices
#1	Primary	199.00'	**24.0" Round Culvert** L= 100.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 199.00' / 186.00' S= 0.1300 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=7.99 cfs @ 12.13 hrs HW=200.26' TW=185.33' (Dynamic Tailwater)
↑**1=Culvert** (Inlet Controls 7.99 cfs @ 3.83 fps)

Pond CB3: Existing Catch Basin







Routing Diagram for Design Post-Development Model - Phase IV
Prepared by Sanborn, Head & Associates, Inc., Printed 6/12/2020
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Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
5.801	39	>75% Grass cover, Good HSG A (A'2.0, A'2.1, A'2.3, A'3.5, A'4)
75.944	74	>75% Grass cover, Good HSG C (A'2.0, A'2.1, A'2.2, A'2.3, A'3.1, A'3.2, A'3.3, A'3.4, A'3.5, A'3.6, A'3.7, A'4, C'1.1, C'1.2, C'1.3, C'1.4, C'1.5)
0.738	76	Gravel roads HSG A (A'2.0, A'2.1, A'2.3, A'4)
5.449	89	Gravel roads HSG C (A'2.0, A'2.1, A'2.2, A'2.3, A'3.1, A'3.2, A'3.3, A'3.5, A'4, C'1.1, C'1.2, C'1.5)
0.028	98	Roofs HSG C (C'1.5)
0.120	98	Unconnected pavement HSG A (A'3.5, A'4)
0.843	98	Unconnected pavement HSG C (A'2.1, A'2.2, A'3.2, A'3.5, A'3.6)
0.335	98	Water Surface HSG C (C'1.5)
0.047	73	Woods, Fair HSG C (A'4)
1.916	30	Woods, Good HSG A (A'2.0, A'3.5, A'4)
0.993	70	Woods, Good HSG C (A'2.0, A'4, C'1.5)
92.214	**72**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
8.575	HSG A	A'2.0, A'2.1, A'2.3, A'3.5, A'4
0.000	HSG B	
83.639	HSG C	A'2.0, A'2.1, A'2.2, A'2.3, A'3.1, A'3.2, A'3.3, A'3.4, A'3.5, A'3.6, A'3.7, A'4, C'1.1, C'1.2, C'1.3, C'1.4, C'1.5
0.000	HSG D	
0.000	Other	
92.214		**TOTAL AREA**

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>0.14"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=0.22 cfs 0.103 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.27% Impervious Runoff Depth>0.99"
Flow Length=1,198' Slope=0.2381 '/' Tc=8.5 min CN=76 Runoff=5.19 cfs 0.422 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>0.94"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=5.75 cfs 0.517 af

Subcatchment A'2.3: A'2.3 Runoff Area=301,709 sf 0.00% Impervious Runoff Depth>0.89"
Flow Length=1,944' Slope=0.3126 '/' Tc=11.6 min CN=74 Runoff=5.55 cfs 0.512 af

Subcatchment A'3.1: A'3.1 Runoff Area=144,221 sf 0.00% Impervious Runoff Depth>0.89"
Flow Length=1,122' Slope=0.2295 '/' Tc=8.7 min CN=74 Runoff=2.92 cfs 0.245 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 7.49% Impervious Runoff Depth>1.05"
Flow Length=877' Slope=0.2144 '/' Tc=6.6 min UI Adjusted CN=77 Runoff=4.66 cfs 0.351 af

Subcatchment A'3.3: A'3.3 Runoff Area=470,611 sf 0.00% Impervious Runoff Depth>1.05"
Flow Length=2,403' Slope=0.2579 '/' Tc=13.8 min CN=77 Runoff=9.93 cfs 0.942 af

Subcatchment A'3.4: A'3.4 Runoff Area=64,004 sf 0.00% Impervious Runoff Depth>0.89"
Flow Length=606' Slope=0.3371 '/' Tc=4.4 min CN=74 Runoff=1.51 cfs 0.109 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>0.16"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=0.16 cfs 0.044 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>0.94"
Flow Length=144' Slope=0.2653 '/' Tc=1.5 min UI Adjusted CN=75 Runoff=0.87 cfs 0.056 af

Subcatchment A'3.7: A'3.7 Runoff Area=522,498 sf 0.00% Impervious Runoff Depth>0.89"
Flow Length=1,385' Slope=0.3041 '/' Tc=8.9 min CN=74 Runoff=10.49 cfs 0.887 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>0.29"
Flow Length=304' Slope=0.0564 '/' Tc=8.9 min UI Adjusted CN=59 Runoff=0.23 cfs 0.040 af

Subcatchment C'1.1: C'1.1 Runoff Area=750,525 sf 0.00% Impervious Runoff Depth>0.94"
Flow Length=1,795' Slope=0.3046 '/' Tc=10.7 min CN=75 Runoff=15.23 cfs 1.348 af

Subcatchment C'1.2: C'1.2 Runoff Area=113,203 sf 0.00% Impervious Runoff Depth>0.94"
Flow Length=1,245' Slope=0.4885 '/' Tc=6.3 min CN=75 Runoff=2.68 cfs 0.204 af

Subcatchment C'1.3: C'1.3 Runoff Area=79,411 sf 0.00% Impervious Runoff Depth>0.89"
Flow Length=829' Slope=0.3376 '/' Tc=5.6 min CN=74 Runoff=1.80 cfs 0.135 af

Subcatchment C'1.4: C'1.4 Runoff Area=89,617 sf 0.00% Impervious Runoff Depth>0.89"
Flow Length=770' Slope=0.3325 '/' Tc=5.3 min CN=74 Runoff=2.05 cfs 0.152 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>1.11"
Flow Length=629' Slope=0.2680 '/' Tc=4.5 min CN=78 Runoff=5.10 cfs 0.353 af

Reach 3R: Existing Swale Avg. Flow Depth=0.67' Max Vel=4.02 fps Inflow=22.23 cfs 2.284 af
n=0.040 L=650.0' S=0.0277 '/' Capacity=175.54 cfs Outflow=21.63 cfs 2.277 af

Reach 4R: Existing Swale Avg. Flow Depth=1.00' Max Vel=2.52 fps Inflow=9.72 cfs 0.933 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=7.59 cfs 0.925 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.71' Max Vel=5.17 fps Inflow=5.55 cfs 0.512 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=5.27 cfs 0.510 af

Reach 16R: Proposed Roadside Swale Avg. Flow Depth=0.88' Max Vel=5.84 fps Inflow=9.93 cfs 0.942 af
n=0.040 L=1,800.0' S=0.0856 '/' Capacity=80.70 cfs Outflow=9.05 cfs 0.939 af

Reach 17R: Proposed Perimeter Swale Avg. Flow Depth=0.24' Max Vel=3.88 fps Inflow=1.51 cfs 0.109 af
n=0.040 L=600.0' S=0.1133 '/' Capacity=125.53 cfs Outflow=1.41 cfs 0.108 af

Reach 18R: Proposed Perimeter Swale Avg. Flow Depth=0.35' Max Vel=2.44 fps Inflow=1.80 cfs 0.135 af
n=0.030 L=829.0' S=0.0169 '/' Capacity=64.61 cfs Outflow=1.46 cfs 0.134 af

Reach 19R: Proposed Perimeter Swale Avg. Flow Depth=0.35' Max Vel=5.51 fps Inflow=3.32 cfs 0.286 af
n=0.040 L=313.0' S=0.1534 '/' Capacity=146.02 cfs Outflow=3.30 cfs 0.286 af

Reach 20R: Proposed Perimeter Swale (Bottom of Avg. Flow Depth=0.69' Max Vel=2.02 fps Inflow=3.30 cfs 0.286 af
n=0.040 L=100.0' S=0.0100 '/' Capacity=37.29 cfs Outflow=3.28 cfs 0.286 af

Reach 22R: Proposed Gabion-Lined Swale Avg. Flow Depth=0.79' Max Vel=3.59 fps Inflow=11.82 cfs 0.995 af
n=0.040 L=100.0' S=0.0200 '/' Capacity=163.62 cfs Outflow=11.80 cfs 0.995 af

Pond 2P: Existing Pond 2 w/ Modified Outlet Peak Elev=178.18' Storage=227,350 cf Inflow=36.80 cfs 4.208 af
Outflow=2.93 cfs 2.422 af

Pond 4P: Existing Pond 4 w/ Modified Outlet Peak Elev=199.08' Storage=70,616 cf Inflow=24.46 cfs 2.190 af
Outflow=1.84 cfs 1.632 af

Pond 6R: Proposed Culvert Peak Elev=213.15' Inflow=9.05 cfs 0.939 af
36.0" Round Culvert n=0.012 L=115.0' S=0.0522 '/' Outflow=9.05 cfs 0.939 af

Pond 21R: Proposed Dual Culverts Peak Elev=231.17' Inflow=20.69 cfs 1.837 af
Primary=20.69 cfs 1.837 af Secondary=0.00 cfs 0.000 af Outflow=20.69 cfs 1.837 af

Pond 23R: Proposed Dual Culverts Peak Elev=181.26' Inflow=21.63 cfs 2.277 af
36.0" Round Culvert x 2.00 n=0.012 L=100.0' S=0.0100 '/' Outflow=21.63 cfs 2.277 af

Pond CB3: Existing Catch Basin Peak Elev=199.99' Inflow=5.27 cfs 0.510 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=5.27 cfs 0.510 af

Total Runoff Area = 92.214 ac Runoff Volume = 6.419 af Average Runoff Depth = 0.84"
98.56% Pervious = 90.888 ac 1.44% Impervious = 1.326 ac

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>0.60"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=2.43 cfs 0.443 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.27% Impervious Runoff Depth>2.06"
Flow Length=1,198' Slope=0.2381 '/' Tc=8.5 min CN=76 Runoff=11.28 cfs 0.877 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>1.98"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=12.85 cfs 1.093 af

Subcatchment A'2.3: A'2.3 Runoff Area=301,709 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=1,944' Slope=0.3126 '/' Tc=11.6 min CN=74 Runoff=12.71 cfs 1.100 af

Subcatchment A'3.1: A'3.1 Runoff Area=144,221 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=1,122' Slope=0.2295 '/' Tc=8.7 min CN=74 Runoff=6.67 cfs 0.526 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 7.49% Impervious Runoff Depth>2.14"
Flow Length=877' Slope=0.2144 '/' Tc=6.6 min UI Adjusted CN=77 Runoff=9.86 cfs 0.717 af

Subcatchment A'3.3: A'3.3 Runoff Area=470,611 sf 0.00% Impervious Runoff Depth>2.14"
Flow Length=2,403' Slope=0.2579 '/' Tc=13.8 min CN=77 Runoff=21.14 cfs 1.926 af

Subcatchment A'3.4: A'3.4 Runoff Area=64,004 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=606' Slope=0.3371 '/' Tc=4.4 min CN=74 Runoff=3.45 cfs 0.234 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>0.66"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=1.82 cfs 0.177 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>1.99"
Flow Length=144' Slope=0.2653 '/' Tc=1.5 min UI Adjusted CN=75 Runoff=1.94 cfs 0.118 af

Subcatchment A'3.7: A'3.7 Runoff Area=522,498 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=1,385' Slope=0.3041 '/' Tc=8.9 min CN=74 Runoff=24.01 cfs 1.906 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>0.92"
Flow Length=304' Slope=0.0564 '/' Tc=8.9 min UI Adjusted CN=59 Runoff=1.31 cfs 0.125 af

Subcatchment C'1.1: C'1.1 Runoff Area=750,525 sf 0.00% Impervious Runoff Depth>1.98"
Flow Length=1,795' Slope=0.3046 '/' Tc=10.7 min CN=75 Runoff=33.94 cfs 2.847 af

Subcatchment C'1.2: C'1.2 Runoff Area=113,203 sf 0.00% Impervious Runoff Depth>1.99"
Flow Length=1,245' Slope=0.4885 '/' Tc=6.3 min CN=75 Runoff=5.95 cfs 0.430 af

Subcatchment C'1.3: C'1.3 Runoff Area=79,411 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=829' Slope=0.3376 '/' Tc=5.6 min CN=74 Runoff=4.10 cfs 0.290 af

Subcatchment C'1.4: C'1.4 Runoff Area=89,617 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=770' Slope=0.3325 '/' Tc=5.3 min CN=74 Runoff=4.67 cfs 0.327 af

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Subcatchment C'1.5: C'1.5                          Runoff Area=166,693 sf   9.47% Impervious   Runoff Depth>2.22"
                                        Flow Length=629'   Slope=0.2680 '/'   Tc=4.5 min   CN=78   Runoff=10.53 cfs  0.710 af

Reach 3R: Existing Swale                               Avg. Flow Depth=1.05'   Max Vel=5.15 fps   Inflow=50.39 cfs  4.777 af
                                          n=0.040   L=650.0'   S=0.0277 '/'   Capacity=175.54 cfs   Outflow=49.39 cfs  4.767 af

Reach 4R: Existing Swale                               Avg. Flow Depth=1.39'   Max Vel=3.14 fps   Inflow=22.22 cfs  1.976 af
                                         n=0.022   L=1,590.0'   S=0.0038 '/'   Capacity=48.07 cfs   Outflow=18.25 cfs  1.964 af

Reach 15R: Existing Roadside Swale                     Avg. Flow Depth=0.98'   Max Vel=6.39 fps   Inflow=12.71 cfs  1.100 af
                                           n=0.040   L=945.0'   S=0.0889 '/'   Capacity=82.26 cfs   Outflow=12.28 cfs  1.098 af

Reach 16R: Proposed Roadside Swale                     Avg. Flow Depth=1.18'   Max Vel=7.09 fps   Inflow=21.14 cfs  1.926 af
                                         n=0.040   L=1,800.0'   S=0.0856 '/'   Capacity=80.70 cfs   Outflow=19.72 cfs  1.921 af

Reach 17R: Proposed Perimeter Swale                     Avg. Flow Depth=0.38'   Max Vel=4.92 fps   Inflow=3.45 cfs  0.234 af
                                           n=0.040   L=600.0'   S=0.1133 '/'   Capacity=125.53 cfs   Outflow=3.28 cfs  0.233 af

Reach 18R: Proposed Perimeter Swale                     Avg. Flow Depth=0.55'   Max Vel=3.09 fps   Inflow=4.10 cfs  0.290 af
                                             n=0.030   L=829.0'   S=0.0169 '/'   Capacity=64.61 cfs   Outflow=3.53 cfs  0.289 af

Reach 19R: Proposed Perimeter Swale                     Avg. Flow Depth=0.54'   Max Vel=6.94 fps   Inflow=7.88 cfs  0.616 af
                                           n=0.040   L=313.0'   S=0.1534 '/'   Capacity=146.02 cfs   Outflow=7.84 cfs  0.616 af

Reach 20R: Proposed Perimeter Swale (Bottom of Avg. Flow Depth=1.02'   Max Vel=2.52 fps   Inflow=7.84 cfs  0.616 af
                                             n=0.040   L=100.0'   S=0.0100 '/'   Capacity=37.29 cfs   Outflow=7.80 cfs  0.615 af

Reach 22R: Proposed Gabion-Lined Swale                 Avg. Flow Depth=1.23'   Max Vel=4.53 fps   Inflow=27.04 cfs  2.140 af
                                          n=0.040   L=100.0'   S=0.0200 '/'   Capacity=163.62 cfs   Outflow=27.01 cfs  2.139 af

Pond 2P: Existing Pond 2 w/ Modified Outlet             Peak Elev=179.17'  Storage=339,747 cf   Inflow=87.94 cfs  9.214 af
                                                                                                 Outflow=8.03 cfs  6.429 af

Pond 4P: Existing Pond 4 w/ Modified Outlet             Peak Elev=201.18'  Storage=123,767 cf   Inflow=54.55 cfs  4.602 af
                                                                                                 Outflow=4.93 cfs  3.433 af

Pond 6R: Proposed Culvert                                                 Peak Elev=213.77'   Inflow=19.72 cfs  1.921 af
                                           36.0"  Round Culvert  n=0.012  L=115.0'  S=0.0522 '/'   Outflow=19.72 cfs  1.921 af

Pond 21R: Proposed Dual Culverts                                          Peak Elev=231.82'   Inflow=46.58 cfs  3.893 af
                                  Primary=46.58 cfs  3.893 af   Secondary=0.00 cfs  0.000 af   Outflow=46.58 cfs  3.893 af

Pond 23R: Proposed Dual Culverts                                          Peak Elev=182.04'   Inflow=49.39 cfs  4.767 af
                                   36.0"  Round Culvert x 2.00  n=0.012  L=100.0'  S=0.0100 '/'   Outflow=49.39 cfs  4.767 af

Pond CB3: Existing Catch Basin                                            Peak Elev=200.67'   Inflow=12.28 cfs  1.098 af
                                           24.0"  Round Culvert  n=0.012  L=100.0'  S=0.1300 '/'   Outflow=12.28 cfs  1.098 af

                   Total Runoff Area = 92.214 ac   Runoff Volume = 13.848 af   Average Runoff Depth = 1.80"
                                                     98.56% Pervious = 90.888 ac    1.44% Impervious = 1.326 ac
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Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>1.69"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=8.98 cfs 1.242 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.27% Impervious Runoff Depth>3.90"
Flow Length=1,198' Slope=0.2381 '/' Tc=8.5 min CN=76 Runoff=21.43 cfs 1.658 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>3.79"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=24.82 cfs 2.090 af

Subcatchment A'2.3: A'2.3 Runoff Area=301,709 sf 0.00% Impervious Runoff Depth>3.69"
Flow Length=1,944' Slope=0.3126 '/' Tc=11.6 min CN=74 Runoff=24.96 cfs 2.128 af

Subcatchment A'3.1: A'3.1 Runoff Area=144,221 sf 0.00% Impervious Runoff Depth>3.69"
Flow Length=1,122' Slope=0.2295 '/' Tc=8.7 min CN=74 Runoff=13.07 cfs 1.018 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 7.49% Impervious Runoff Depth>4.00"
Flow Length=877' Slope=0.2144 '/' Tc=6.6 min UI Adjusted CN=77 Runoff=18.45 cfs 1.340 af

Subcatchment A'3.3: A'3.3 Runoff Area=470,611 sf 0.00% Impervious Runoff Depth>4.00"
Flow Length=2,403' Slope=0.2579 '/' Tc=13.8 min CN=77 Runoff=39.67 cfs 3.599 af

Subcatchment A'3.4: A'3.4 Runoff Area=64,004 sf 0.00% Impervious Runoff Depth>3.69"
Flow Length=606' Slope=0.3371 '/' Tc=4.4 min CN=74 Runoff=6.75 cfs 0.452 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>1.79"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=6.72 cfs 0.482 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>3.80"
Flow Length=144' Slope=0.2653 '/' Tc=1.5 min UI Adjusted CN=75 Runoff=3.74 cfs 0.226 af

Subcatchment A'3.7: A'3.7 Runoff Area=522,498 sf 0.00% Impervious Runoff Depth>3.69"
Flow Length=1,385' Slope=0.3041 '/' Tc=8.9 min CN=74 Runoff=47.06 cfs 3.688 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>2.23"
Flow Length=304' Slope=0.0564 '/' Tc=8.9 min UI Adjusted CN=59 Runoff=3.70 cfs 0.304 af

Subcatchment C'1.1: C'1.1 Runoff Area=750,525 sf 0.00% Impervious Runoff Depth>3.79"
Flow Length=1,795' Slope=0.3046 '/' Tc=10.7 min CN=75 Runoff=65.55 cfs 5.443 af

Subcatchment C'1.2: C'1.2 Runoff Area=113,203 sf 0.00% Impervious Runoff Depth>3.79"
Flow Length=1,245' Slope=0.4885 '/' Tc=6.3 min CN=75 Runoff=11.46 cfs 0.822 af

Subcatchment C'1.3: C'1.3 Runoff Area=79,411 sf 0.00% Impervious Runoff Depth>3.69"
Flow Length=829' Slope=0.3376 '/' Tc=5.6 min CN=74 Runoff=8.02 cfs 0.561 af

Subcatchment C'1.4: C'1.4 Runoff Area=89,617 sf 0.00% Impervious Runoff Depth>3.69"
Flow Length=770' Slope=0.3325 '/' Tc=5.3 min CN=74 Runoff=9.15 cfs 0.633 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>4.11"
Flow Length=629' Slope=0.2680 '/' Tc=4.5 min CN=78 Runoff=19.41 cfs 1.311 af

Reach 3R: Existing Swale Avg. Flow Depth=1.49' Max Vel=6.22 fps Inflow=98.33 cfs 9.069 af
n=0.040 L=650.0' S=0.0277 '/' Capacity=175.54 cfs Outflow=96.86 cfs 9.056 af

Reach 4R: Existing Swale Avg. Flow Depth=1.82' Max Vel=3.76 fps Inflow=43.55 cfs 3.783 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=37.14 cfs 3.766 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=1.27' Max Vel=7.58 fps Inflow=24.96 cfs 2.128 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=24.34 cfs 2.125 af

Reach 16R: Proposed Roadside Swale Avg. Flow Depth=1.50' Max Vel=8.33 fps Inflow=39.67 cfs 3.599 af
n=0.040 L=1,800.0' S=0.0856 '/' Capacity=80.70 cfs Outflow=37.62 cfs 3.591 af

Reach 17R: Proposed Perimeter Swale Avg. Flow Depth=0.53' Max Vel=5.91 fps Inflow=6.75 cfs 0.452 af
n=0.040 L=600.0' S=0.1133 '/' Capacity=125.53 cfs Outflow=6.49 cfs 0.451 af

Reach 18R: Proposed Perimeter Swale Avg. Flow Depth=0.76' Max Vel=3.71 fps Inflow=8.02 cfs 0.561 af
n=0.030 L=829.0' S=0.0169 '/' Capacity=64.61 cfs Outflow=7.15 cfs 0.559 af

Reach 19R: Proposed Perimeter Swale Avg. Flow Depth=0.75' Max Vel=8.32 fps Inflow=15.77 cfs 1.192 af
n=0.040 L=313.0' S=0.1534 '/' Capacity=146.02 cfs Outflow=15.71 cfs 1.191 af

Reach 20R: Proposed Perimeter Swale (Bottom Avg. Flow Depth=1.38' Max Vel=3.00 fps Inflow=15.71 cfs 1.191 af
n=0.040 L=100.0' S=0.0100 '/' Capacity=37.29 cfs Outflow=15.66 cfs 1.191 af

Reach 22R: Proposed Gabion-Lined Swale Avg. Flow Depth=1.74' Max Vel=5.43 fps Inflow=52.96 cfs 4.139 af
n=0.040 L=100.0' S=0.0200 '/' Capacity=163.62 cfs Outflow=52.94 cfs 4.138 af

Pond 2P: Existing Pond 2 w/ Modified Outlet Peak Elev=181.08' Storage=591,135 cf Inflow=179.79 cfs 18.184 af
Outflow=12.86 cfs 11.735 af

Pond 4P: Existing Pond 4 w/ Modified Outlet Peak Elev=204.71' Storage=232,565 cf Inflow=105.33 cfs 8.767 af
Outflow=7.86 cfs 6.740 af

Pond 6R: Proposed Culvert Peak Elev=214.71' Inflow=37.62 cfs 3.591 af
36.0" Round Culvert n=0.012 L=115.0' S=0.0522 '/' Outflow=37.62 cfs 3.591 af

Pond 21R: Proposed Dual Culverts Peak Elev=232.73' Inflow=90.37 cfs 7.456 af
Primary=90.37 cfs 7.456 af Secondary=0.00 cfs 0.000 af Outflow=90.37 cfs 7.456 af

Pond 23R: Proposed Dual Culverts Peak Elev=183.52' Inflow=96.86 cfs 9.056 af
36.0" Round Culvert x 2.00 n=0.012 L=100.0' S=0.0100 '/' Outflow=96.86 cfs 9.056 af

Pond CB3: Existing Catch Basin Peak Elev=202.59' Inflow=24.34 cfs 2.125 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=24.34 cfs 2.125 af

Total Runoff Area = 92.214 ac Runoff Volume = 26.997 af Average Runoff Depth = 3.51"
98.56% Pervious = 90.888 ac 1.44% Impervious = 1.326 ac

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>0.60"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=2.43 cfs 0.443 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.27% Impervious Runoff Depth>2.06"
Flow Length=1,198' Slope=0.2381 '/' Tc=8.5 min CN=76 Runoff=11.28 cfs 0.877 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>1.98"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=12.85 cfs 1.093 af

Subcatchment A'2.3: A'2.3 Runoff Area=301,709 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=1,944' Slope=0.3126 '/' Tc=11.6 min CN=74 Runoff=12.71 cfs 1.100 af

Subcatchment A'3.1: A'3.1 Runoff Area=144,221 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=1,122' Slope=0.2295 '/' Tc=8.7 min CN=74 Runoff=6.67 cfs 0.526 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 7.49% Impervious Runoff Depth>2.14"
Flow Length=877' Slope=0.2144 '/' Tc=6.6 min UI Adjusted CN=77 Runoff=9.86 cfs 0.717 af

Subcatchment A'3.3: A'3.3 Runoff Area=470,611 sf 0.00% Impervious Runoff Depth>2.14"
Flow Length=2,403' Slope=0.2579 '/' Tc=13.8 min CN=77 Runoff=21.14 cfs 1.926 af

Subcatchment A'3.4: A'3.4 Runoff Area=64,004 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=606' Slope=0.3371 '/' Tc=4.4 min CN=74 Runoff=3.45 cfs 0.234 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>0.66"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=1.82 cfs 0.177 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>1.99"
Flow Length=144' Slope=0.2653 '/' Tc=1.5 min UI Adjusted CN=75 Runoff=1.94 cfs 0.118 af

Subcatchment A'3.7: A'3.7 Runoff Area=522,498 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=1,385' Slope=0.3041 '/' Tc=8.9 min CN=74 Runoff=24.01 cfs 1.906 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>0.92"
Flow Length=304' Slope=0.0564 '/' Tc=8.9 min UI Adjusted CN=59 Runoff=1.31 cfs 0.125 af

Subcatchment C'1.1: C'1.1 Runoff Area=750,525 sf 0.00% Impervious Runoff Depth>1.98"
Flow Length=1,795' Slope=0.3046 '/' Tc=10.7 min CN=75 Runoff=33.94 cfs 2.847 af

Subcatchment C'1.2: C'1.2 Runoff Area=113,203 sf 0.00% Impervious Runoff Depth>1.99"
Flow Length=1,245' Slope=0.4885 '/' Tc=6.3 min CN=75 Runoff=5.95 cfs 0.430 af

Subcatchment C'1.3: C'1.3 Runoff Area=79,411 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=829' Slope=0.3376 '/' Tc=5.6 min CN=74 Runoff=4.10 cfs 0.290 af

Subcatchment C'1.4: C'1.4 Runoff Area=89,617 sf 0.00% Impervious Runoff Depth>1.91"
Flow Length=770' Slope=0.3325 '/' Tc=5.3 min CN=74 Runoff=4.67 cfs 0.327 af

Subcatchment C'1.5: C'1.5 Runoff Area=166,693 sf 9.47% Impervious Runoff Depth>2.22"
Flow Length=629' Slope=0.2680 '/' Tc=4.5 min CN=78 Runoff=10.53 cfs 0.710 af

Reach 3R: Existing Swale Avg. Flow Depth=1.05' Max Vel=5.15 fps Inflow=50.39 cfs 4.777 af
n=0.040 L=650.0' S=0.0277 '/' Capacity=175.54 cfs Outflow=49.39 cfs 4.767 af

Reach 4R: Existing Swale Avg. Flow Depth=1.39' Max Vel=3.14 fps Inflow=22.22 cfs 1.976 af
n=0.022 L=1,590.0' S=0.0038 '/' Capacity=48.07 cfs Outflow=18.25 cfs 1.964 af

Reach 15R: Existing Roadside Swale Avg. Flow Depth=0.98' Max Vel=6.39 fps Inflow=12.71 cfs 1.100 af
n=0.040 L=945.0' S=0.0889 '/' Capacity=82.26 cfs Outflow=12.28 cfs 1.098 af

Reach 16R: Proposed Roadside Swale Avg. Flow Depth=1.18' Max Vel=7.09 fps Inflow=21.14 cfs 1.926 af
n=0.040 L=1,800.0' S=0.0856 '/' Capacity=80.70 cfs Outflow=19.72 cfs 1.921 af

Reach 17R: Proposed Perimeter Swale Avg. Flow Depth=0.38' Max Vel=4.92 fps Inflow=3.45 cfs 0.234 af
n=0.040 L=600.0' S=0.1133 '/' Capacity=125.53 cfs Outflow=3.28 cfs 0.233 af

Reach 18R: Proposed Perimeter Swale Avg. Flow Depth=0.55' Max Vel=3.09 fps Inflow=4.10 cfs 0.290 af
n=0.030 L=829.0' S=0.0169 '/' Capacity=64.61 cfs Outflow=3.53 cfs 0.289 af

Reach 19R: Proposed Perimeter Swale Avg. Flow Depth=0.54' Max Vel=6.94 fps Inflow=7.88 cfs 0.616 af
n=0.040 L=313.0' S=0.1534 '/' Capacity=146.02 cfs Outflow=7.84 cfs 0.616 af

Reach 20R: Proposed Perimeter Swale (Bottom of Avg. Flow Depth=1.02' Max Vel=2.52 fps Inflow=7.84 cfs 0.616 af
n=0.040 L=100.0' S=0.0100 '/' Capacity=37.29 cfs Outflow=7.80 cfs 0.615 af

Reach 22R: Proposed Gabion-Lined Swale Avg. Flow Depth=1.23' Max Vel=4.53 fps Inflow=27.04 cfs 2.140 af
n=0.040 L=100.0' S=0.0200 '/' Capacity=163.62 cfs Outflow=27.01 cfs 2.139 af

Pond 2P: Existing Pond 2 w/ Modified Outlet Peak Elev=179.17' Storage=339,747 cf Inflow=87.94 cfs 9.214 af
Outflow=8.03 cfs 6.429 af

Pond 4P: Existing Pond 4 w/ Modified Outlet Peak Elev=201.18' Storage=123,767 cf Inflow=54.55 cfs 4.602 af
Outflow=4.93 cfs 3.433 af

Pond 6R: Proposed Culvert Peak Elev=213.77' Inflow=19.72 cfs 1.921 af
36.0" Round Culvert n=0.012 L=115.0' S=0.0522 '/' Outflow=19.72 cfs 1.921 af

Pond 21R: Proposed Dual Culverts Peak Elev=231.82' Inflow=46.58 cfs 3.893 af
Primary=46.58 cfs 3.893 af Secondary=0.00 cfs 0.000 af Outflow=46.58 cfs 3.893 af

Pond 23R: Proposed Dual Culverts Peak Elev=182.04' Inflow=49.39 cfs 4.767 af
36.0" Round Culvert x 2.00 n=0.012 L=100.0' S=0.0100 '/' Outflow=49.39 cfs 4.767 af

Pond CB3: Existing Catch Basin Peak Elev=200.67' Inflow=12.28 cfs 1.098 af
24.0" Round Culvert n=0.012 L=100.0' S=0.1300 '/' Outflow=12.28 cfs 1.098 af

Total Runoff Area = 92.214 ac Runoff Volume = 13.848 af Average Runoff Depth = 1.80"
98.56% Pervious = 90.888 ac 1.44% Impervious = 1.326 ac

Summary for Subcatchment A'2.0: A'2.0

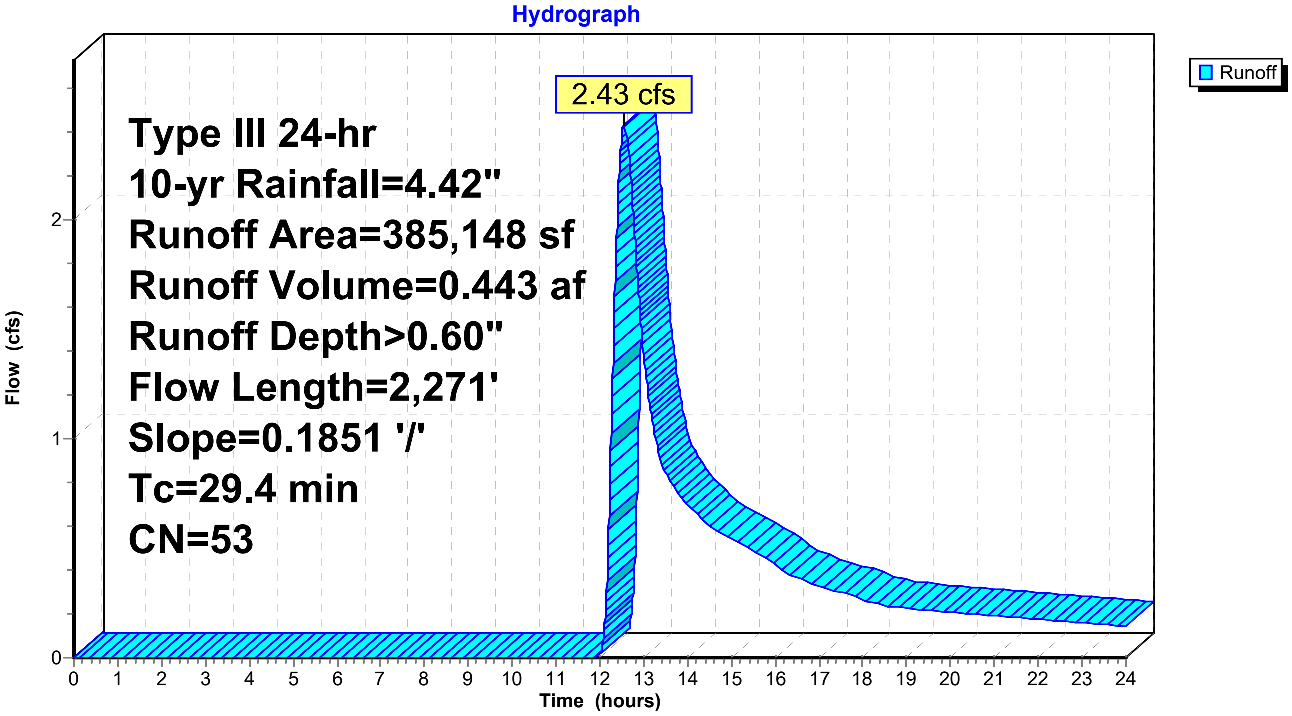
Runoff = 2.43 cfs @ 12.55 hrs, Volume= 0.443 af, Depth> 0.60"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
26,373	70	Woods, Good HSG C
18,788	89	Gravel roads HSG C
22,982	76	Gravel roads HSG A
72,099	30	Woods, Good HSG A
145,807	39	>75% Grass cover, Good HSG A
99,100	74	>75% Grass cover, Good HSG C
385,148	53	Weighted Average
385,148		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4	2,271	0.1851	1.29		**Lag/CN Method,**

Subcatchment A'2.0: A'2.0



Summary for Subcatchment A'2.1: A'2.1

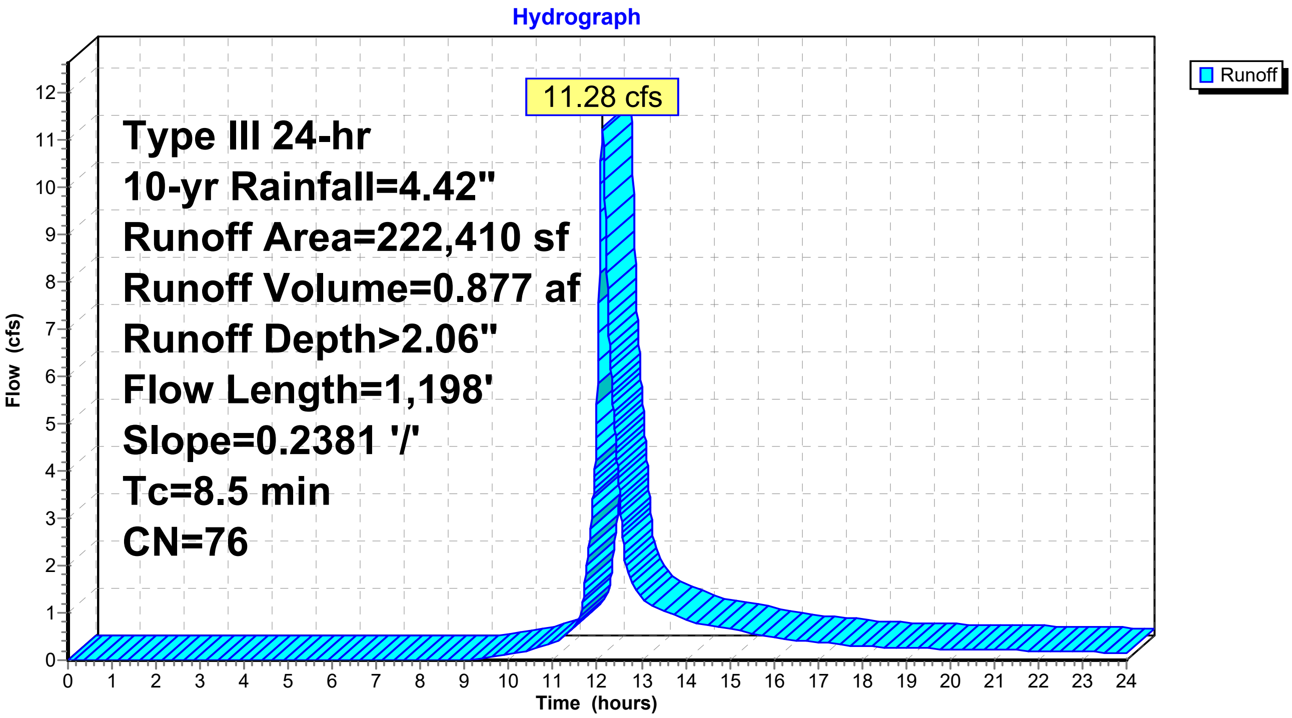
Runoff = 11.28 cfs @ 12.12 hrs, Volume= 0.877 af, Depth> 2.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
7,074	76	Gravel roads HSG A
24,840	89	Gravel roads HSG C
5,052	98	Unconnected pavement HSG C
2,607	39	>75% Grass cover, Good HSG A
182,835	74	>75% Grass cover, Good HSG C
222,410	76	Weighted Average
217,357		97.73% Pervious Area
5,052		2.27% Impervious Area
5,052		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.5	1,198	0.2381	2.35		**Lag/CN Method,**

Subcatchment A'2.1: A'2.1



Summary for Subcatchment A'2.2: A'2.2

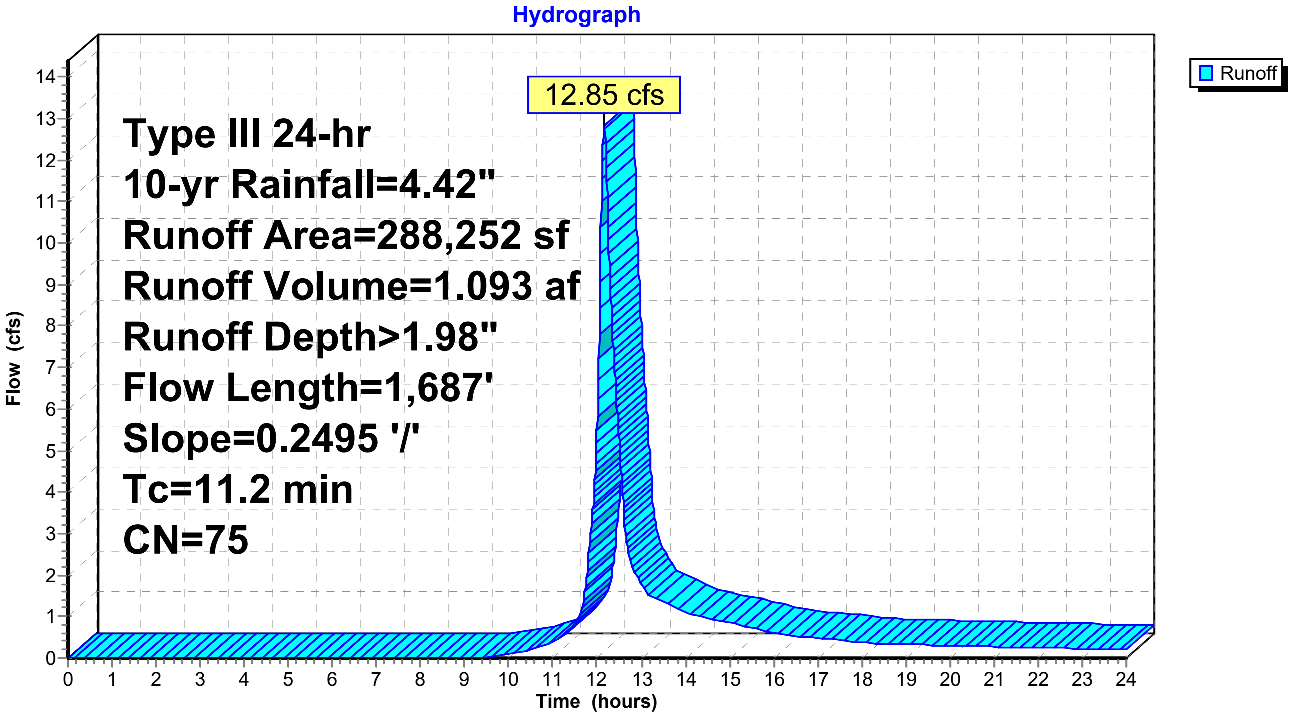
Runoff = 12.85 cfs @ 12.16 hrs, Volume= 1.093 af, Depth> 1.98"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
15,419	89	Gravel roads HSG C
4,954	98	Unconnected pavement HSG C
267,880	74	>75% Grass cover, Good HSG C
288,252	75	Weighted Average
283,298		98.28% Pervious Area
4,954		1.72% Impervious Area
4,954		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	1,687	0.2495	2.50		**Lag/CN Method,**

Subcatchment A'2.2: A'2.2



Summary for Subcatchment A'2.3: A'2.3

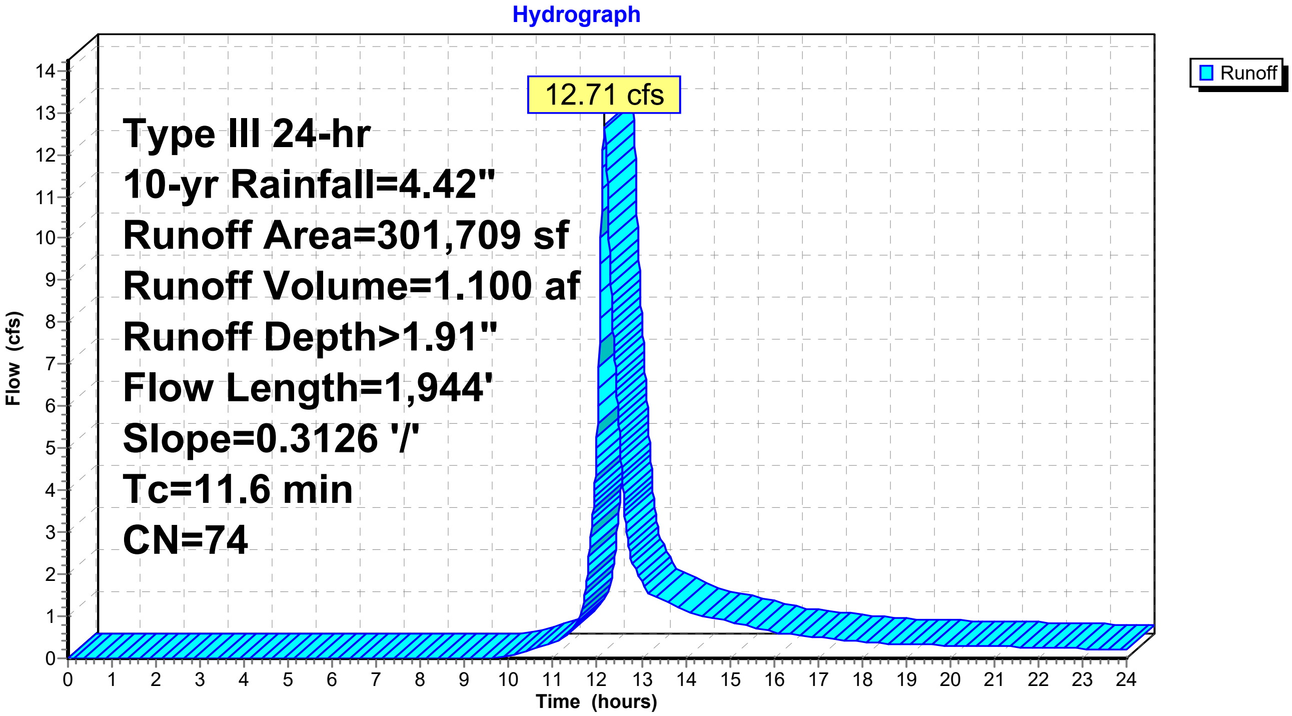
Runoff = 12.71 cfs @ 12.16 hrs, Volume= 1.100 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
164	76	Gravel roads HSG A
4,164	89	Gravel roads HSG C
279,787	74	>75% Grass cover, Good HSG C
3,648	39	>75% Grass cover, Good HSG A
13,945	74	>75% Grass cover, Good HSG C
301,709	74	Weighted Average
301,709		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	1,944	0.3126	2.80		**Lag/CN Method,**

Subcatchment A'2.3: A'2.3



Summary for Subcatchment A'3.1: A'3.1

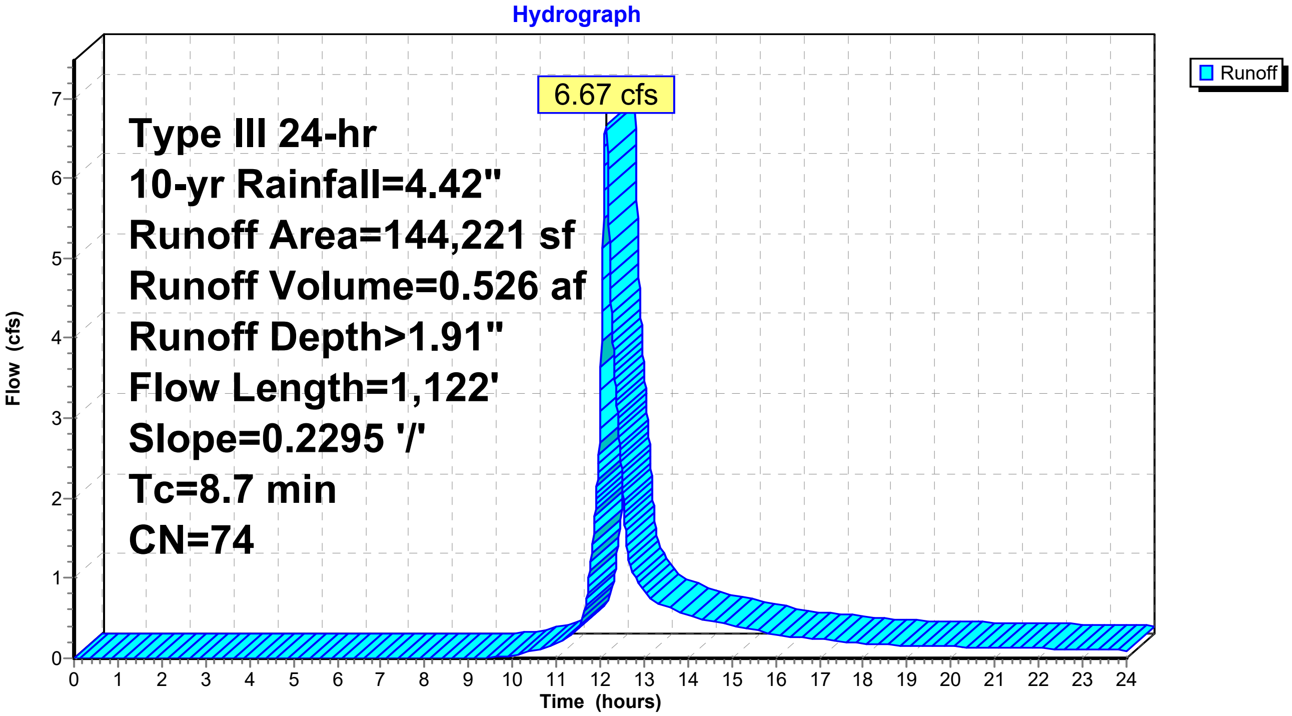
Runoff = 6.67 cfs @ 12.13 hrs, Volume= 0.526 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
139,893	74	>75% Grass cover, Good HSG C
2,604	89	Gravel roads HSG C
1,724	74	>75% Grass cover, Good HSG C
144,221	74	Weighted Average
144,221		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.7	1,122	0.2295	2.15		**Lag/CN Method,**

Subcatchment A'3.1: A'3.1



Summary for Subcatchment A'3.2: A'3.2

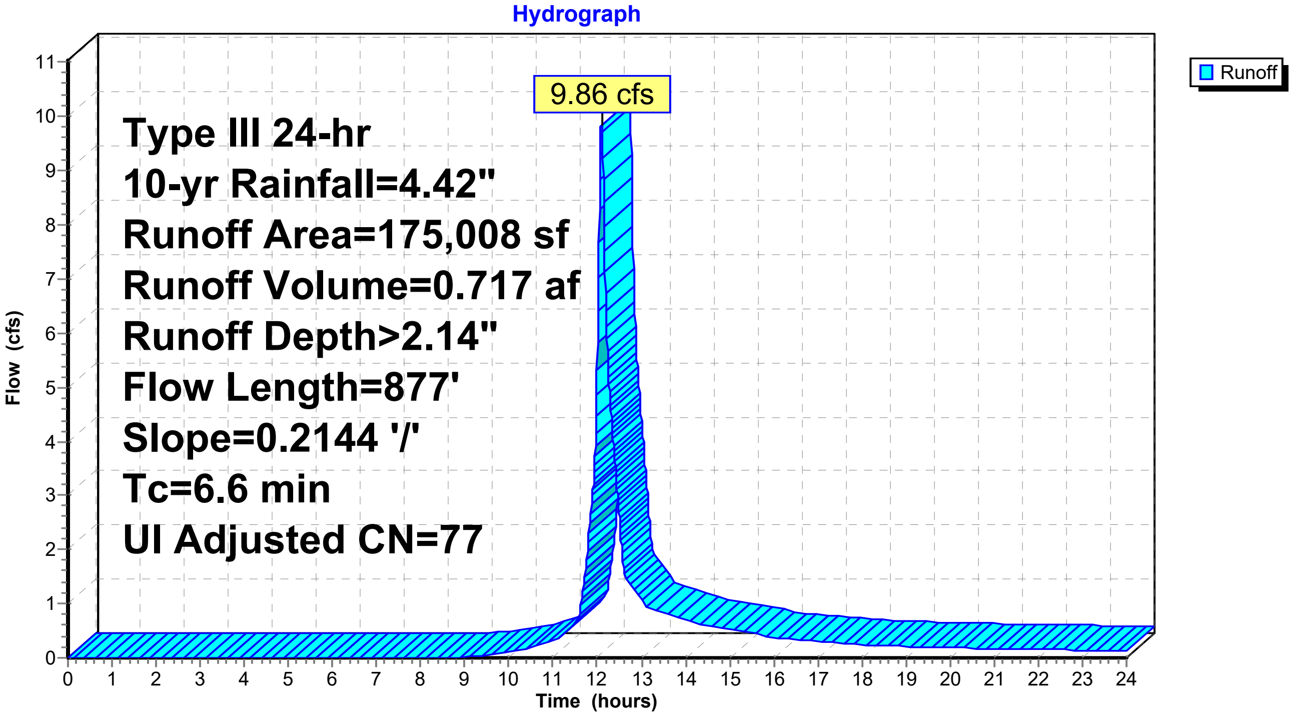
Runoff = 9.86 cfs @ 12.10 hrs, Volume= 0.717 af, Depth> 2.14"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
75,729	74		>75% Grass cover, Good HSG C
22,687	89		Gravel roads HSG C
13,108	98		Unconnected pavement HSG C
63,483	74		>75% Grass cover, Good HSG C
175,008	78	77	Weighted Average, UI Adjusted
161,899			92.51% Pervious Area
13,108			7.49% Impervious Area
13,108			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.6	877	0.2144	2.22		**Lag/CN Method,**

Subcatchment A'3.2: A'3.2



Summary for Subcatchment A'3.3: A'3.3

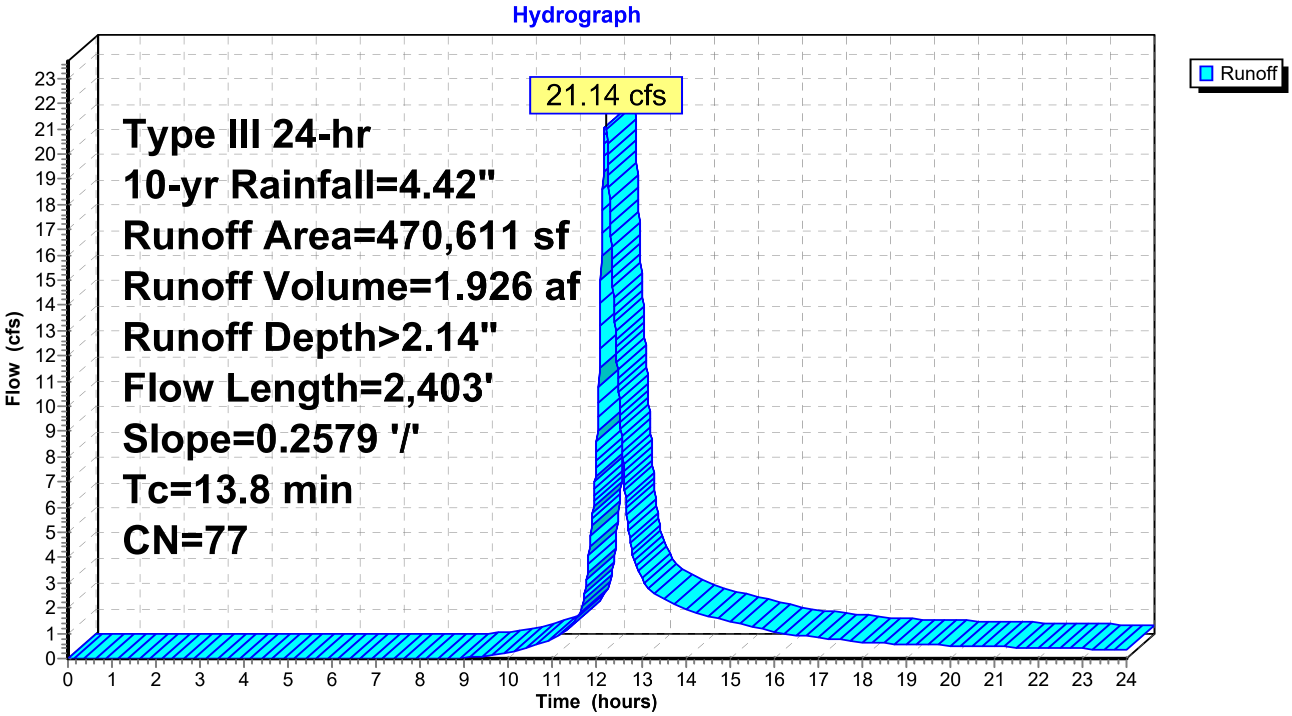
Runoff = 21.14 cfs @ 12.19 hrs, Volume= 1.926 af, Depth> 2.14"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
79,979	89	Gravel roads HSG C
390,633	74	>75% Grass cover, Good HSG C
470,611	77	Weighted Average
470,611		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.8	2,403	0.2579	2.90		**Lag/CN Method,**

Subcatchment A'3.3: A'3.3



Summary for Subcatchment A'3.4: A'3.4

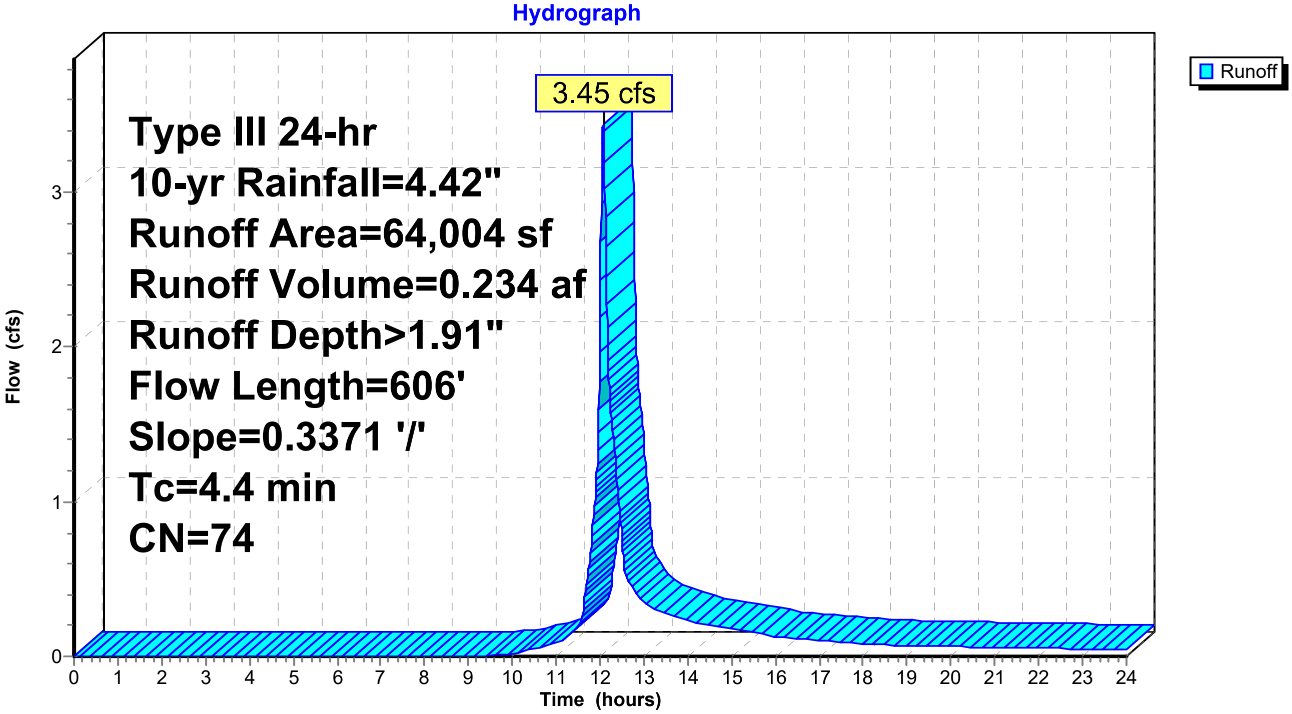
Runoff = 3.45 cfs @ 12.07 hrs, Volume= 0.234 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
64,004	74	>75% Grass cover, Good HSG C
64,004		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.4	606	0.3371	2.31		**Lag/CN Method,**

Subcatchment A'3.4: A'3.4



Summary for Subcatchment A'3.5: A'3.5

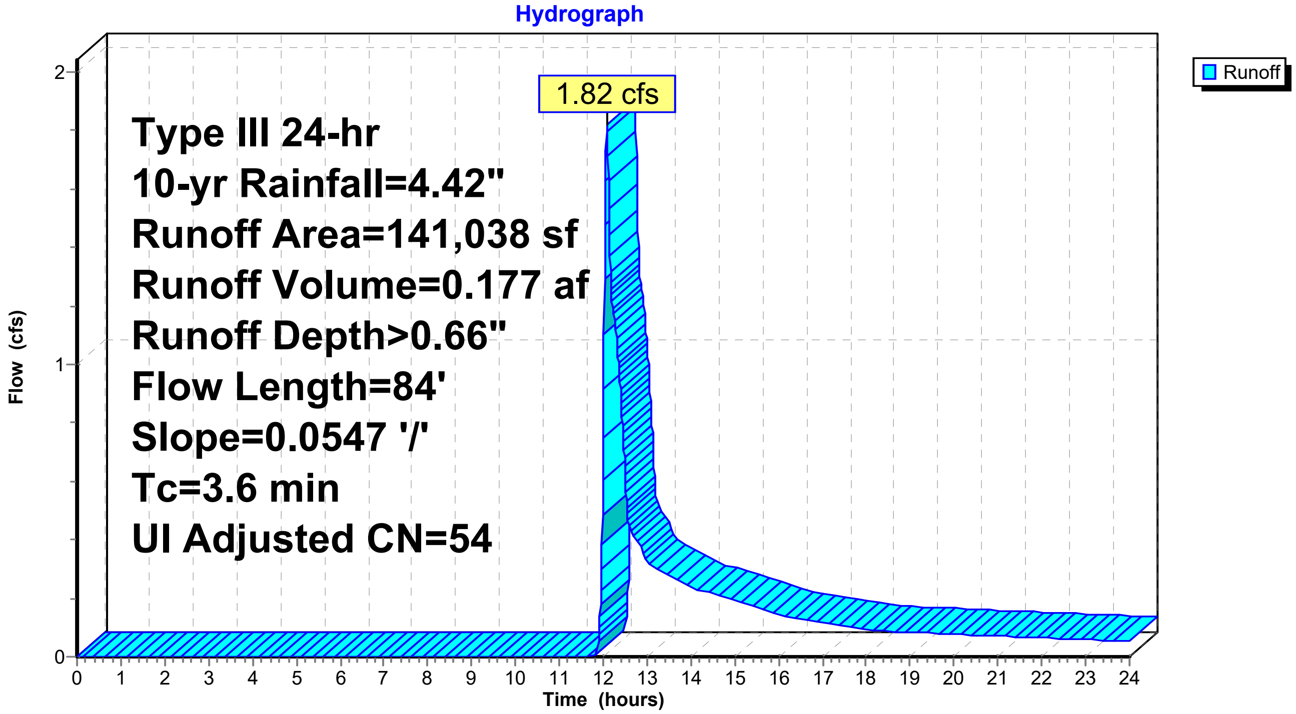
Runoff = 1.82 cfs @ 12.08 hrs, Volume= 0.177 af, Depth> 0.66"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
11,556	98		Unconnected pavement HSG C
1,043	74		>75% Grass cover, Good HSG C
5,785	89		Gravel roads HSG C
166	98		Unconnected pavement HSG A
2,800	30		Woods, Good HSG A
78,447	39		>75% Grass cover, Good HSG A
41,241	74		>75% Grass cover, Good HSG C
141,038	56	54	Weighted Average, UI Adjusted
129,316			91.69% Pervious Area
11,722			8.31% Impervious Area
11,722			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	84	0.0547	0.39		**Lag/CN Method,**

Subcatchment A'3.5: A'3.5



Summary for Subcatchment A'3.6: A'3.6

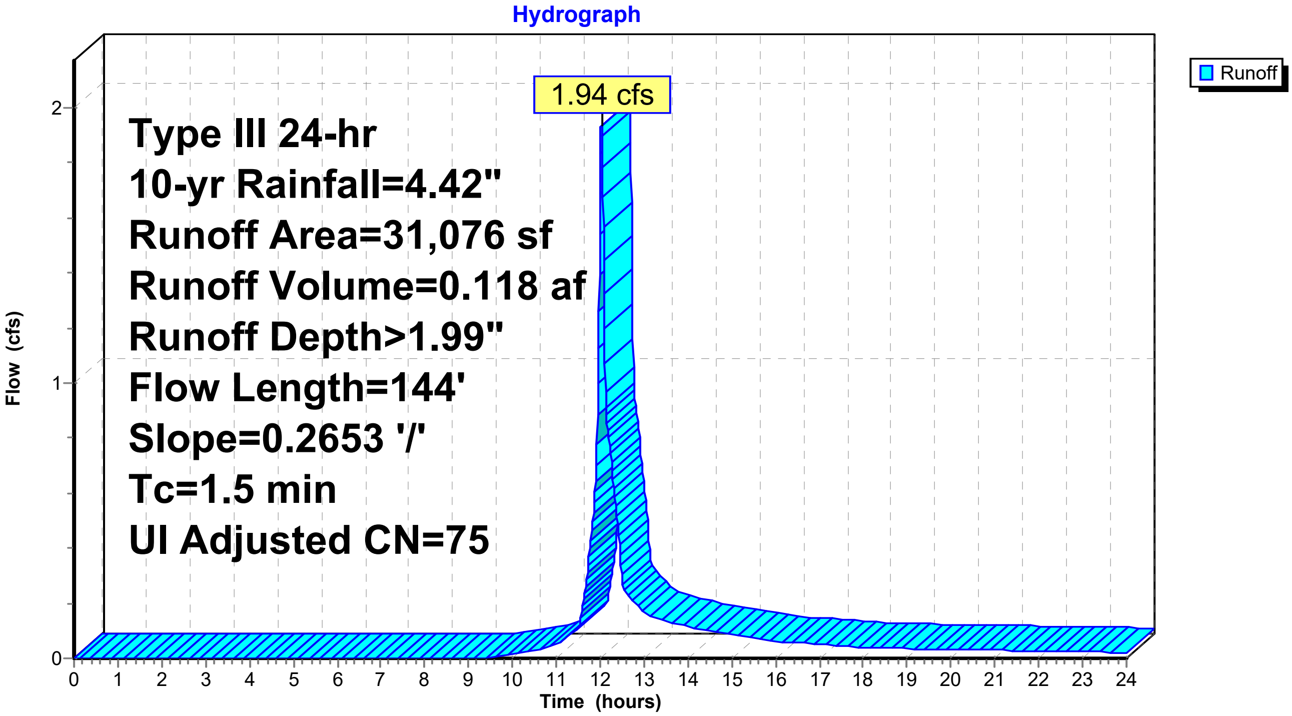
Runoff = 1.94 cfs @ 12.03 hrs, Volume= 0.118 af, Depth> 1.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
23,729	74		>75% Grass cover, Good HSG C
2,061	98		Unconnected pavement HSG C
5,286	74		>75% Grass cover, Good HSG C
31,076	76	75	Weighted Average, UI Adjusted
29,015			93.37% Pervious Area
2,061			6.63% Impervious Area
2,061			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.5	144	0.2653	1.63		**Lag/CN Method,**

Subcatchment A'3.6: A'3.6



Summary for Subcatchment A'3.7: A'3.7

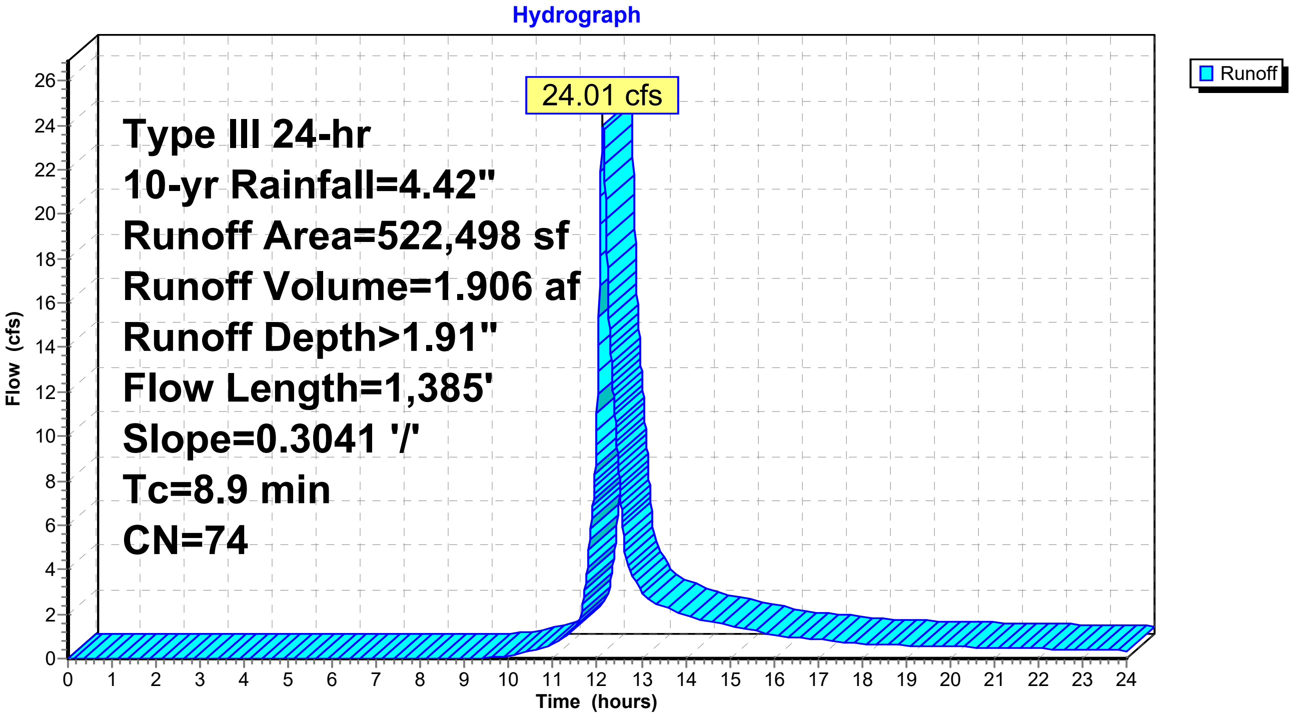
Runoff = 24.01 cfs @ 12.13 hrs, Volume= 1.906 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
205,958	74	>75% Grass cover, Good HSG C
316,540	74	>75% Grass cover, Good HSG C
522,498	74	Weighted Average
522,498		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.9	1,385	0.3041	2.58		**Lag/CN Method,**

Subcatchment A'3.7: A'3.7



Summary for Subcatchment A'4: A'4

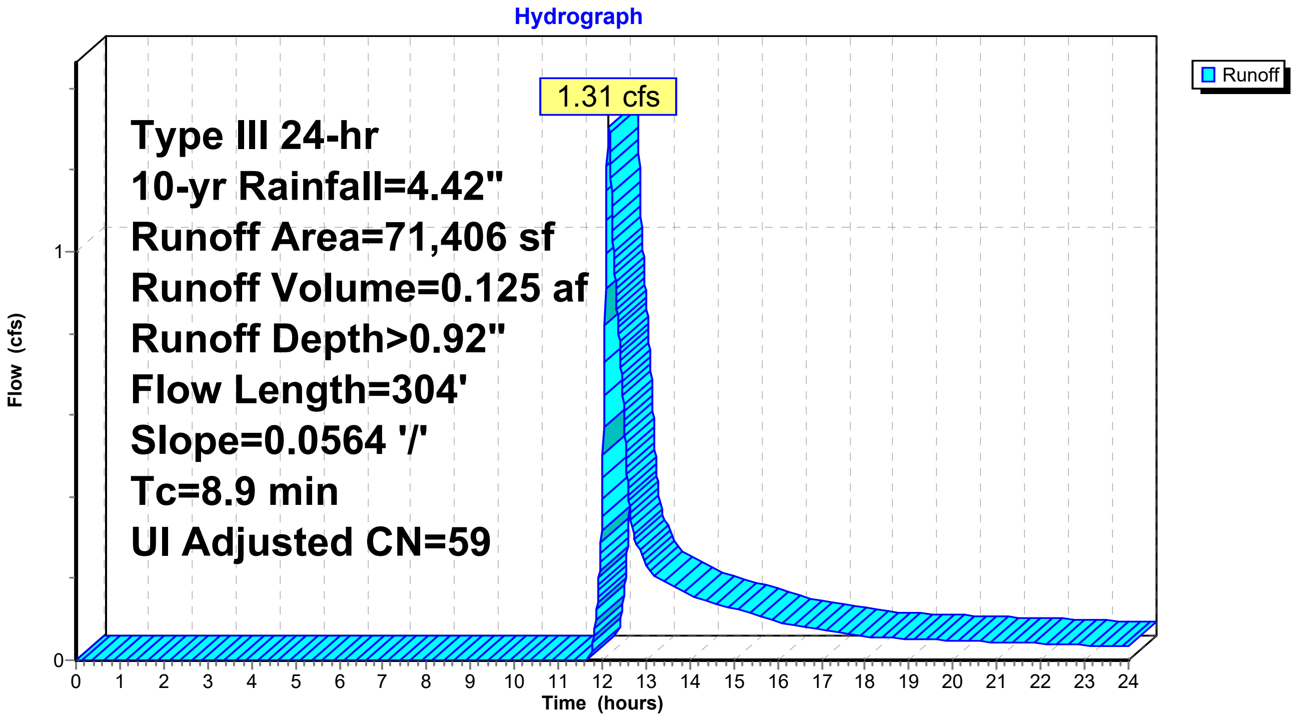
Runoff = 1.31 cfs @ 12.15 hrs, Volume= 0.125 af, Depth> 0.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Adj	Description
2,773	70		Woods, Good HSG C
4,240	89		Gravel roads HSG C
1,927	76		Gravel roads HSG A
5,080	98		Unconnected pavement HSG A
8,540	30		Woods, Good HSG A
2,046	73		Woods, Fair HSG C
22,175	39		>75% Grass cover, Good HSG A
24,627	74		>75% Grass cover, Good HSG C
71,406	60	59	Weighted Average, UI Adjusted
66,327			92.89% Pervious Area
5,080			7.11% Impervious Area
5,080			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.9	304	0.0564	0.57		**Lag/CN Method,**

Subcatchment A'4: A'4



Summary for Subcatchment C'1.1: C'1.1

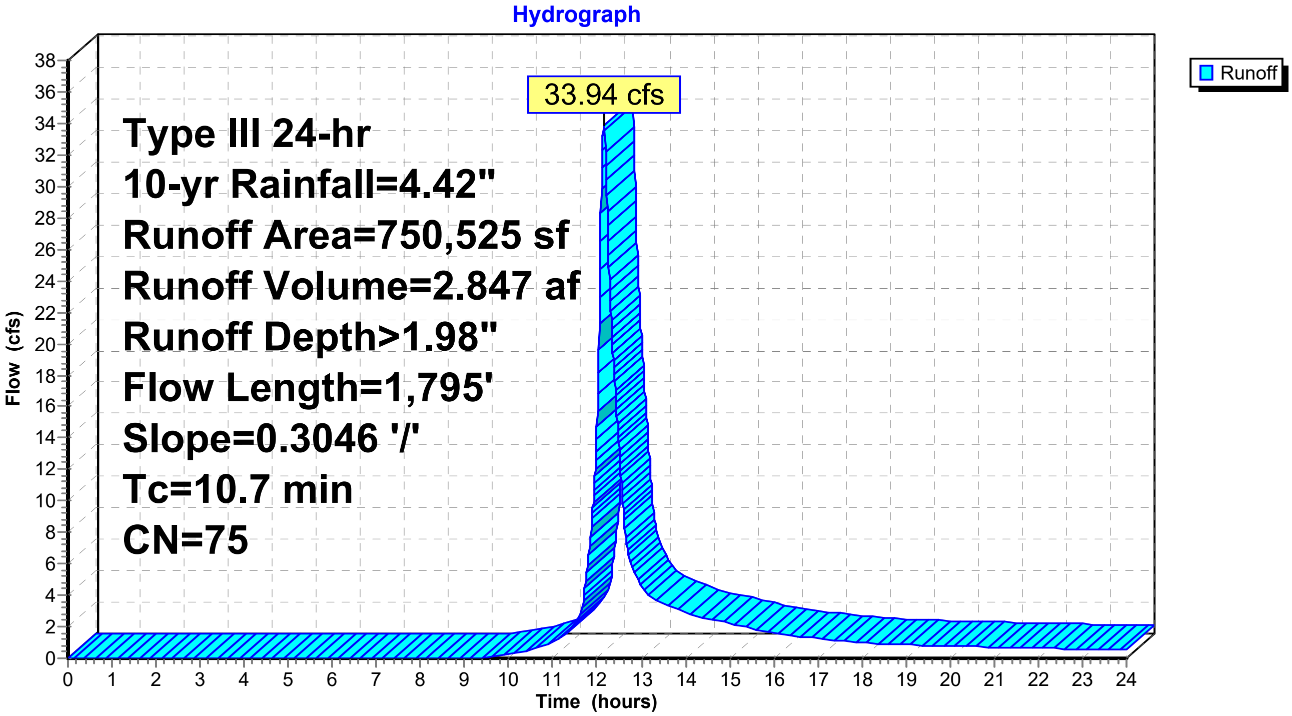
Runoff = 33.94 cfs @ 12.15 hrs, Volume= 2.847 af, Depth> 1.98"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
26,158	89	Gravel roads HSG C
370,991	74	>75% Grass cover, Good HSG C
353,376	74	>75% Grass cover, Good HSG C
750,525	75	Weighted Average
750,525		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.7	1,795	0.3046	2.80		**Lag/CN Method,**

Subcatchment C'1.1: C'1.1



Summary for Subcatchment C'1.2: C'1.2

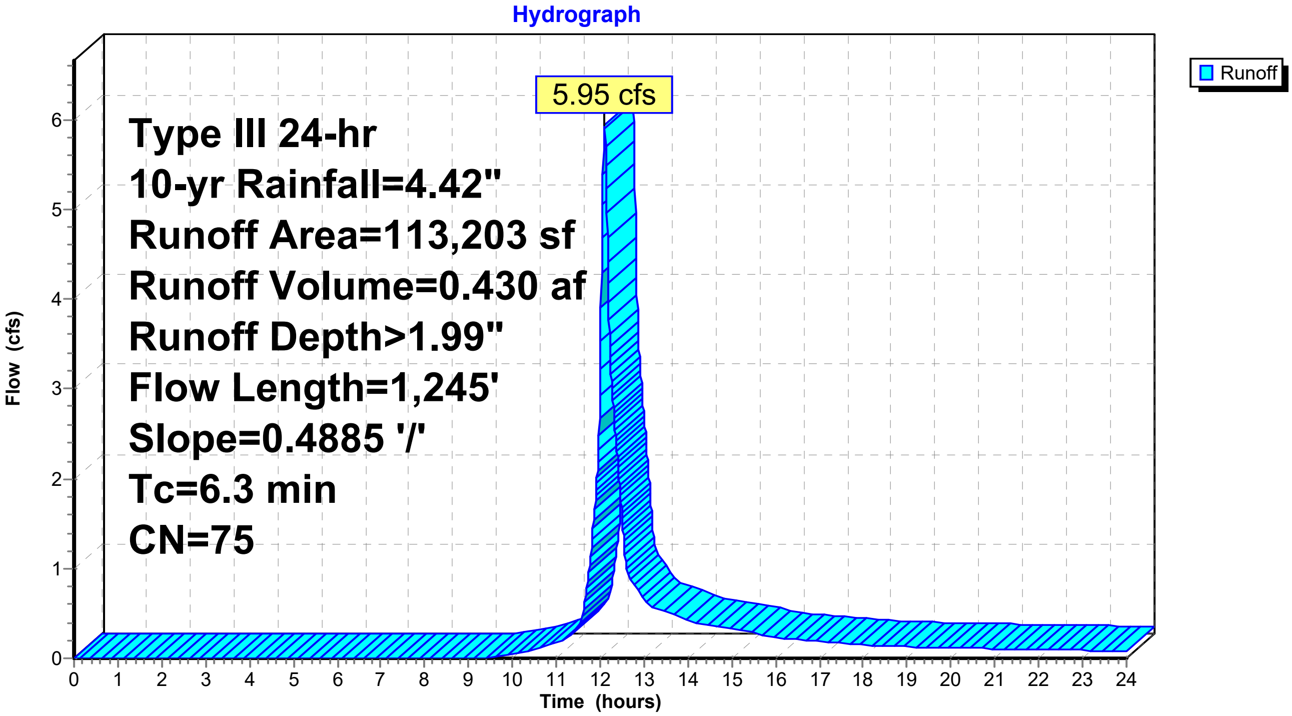
Runoff = 5.95 cfs @ 12.10 hrs, Volume= 0.430 af, Depth> 1.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
8,955	89	Gravel roads HSG C
84,135	74	>75% Grass cover, Good HSG C
20,113	74	>75% Grass cover, Good HSG C
113,203	75	Weighted Average
113,203		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.3	1,245	0.4885	3.30		**Lag/CN Method,**

Subcatchment C'1.2: C'1.2



Summary for Subcatchment C'1.3: C'1.3

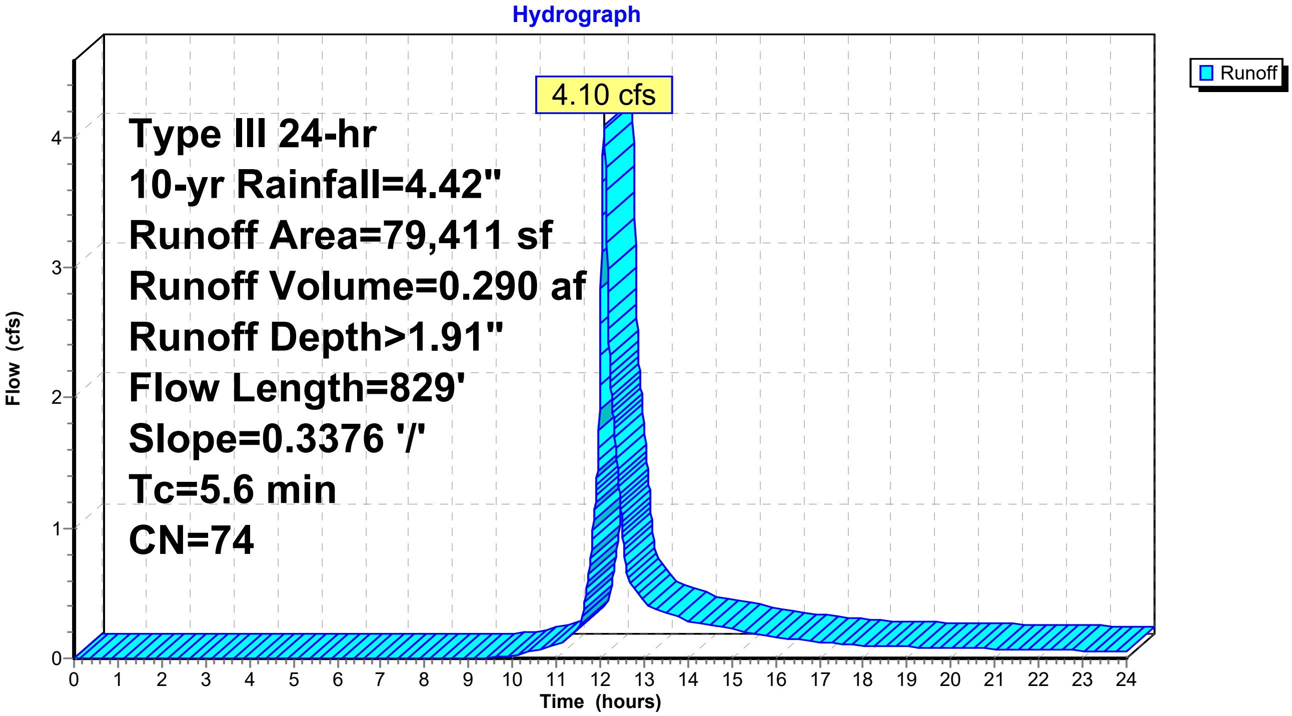
Runoff = 4.10 cfs @ 12.09 hrs, Volume= 0.290 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
79,411	74	>75% Grass cover, Good HSG C
79,411		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.6	829	0.3376	2.46		**Lag/CN Method,**

Subcatchment C'1.3: C'1.3



Summary for Subcatchment C'1.4: C'1.4

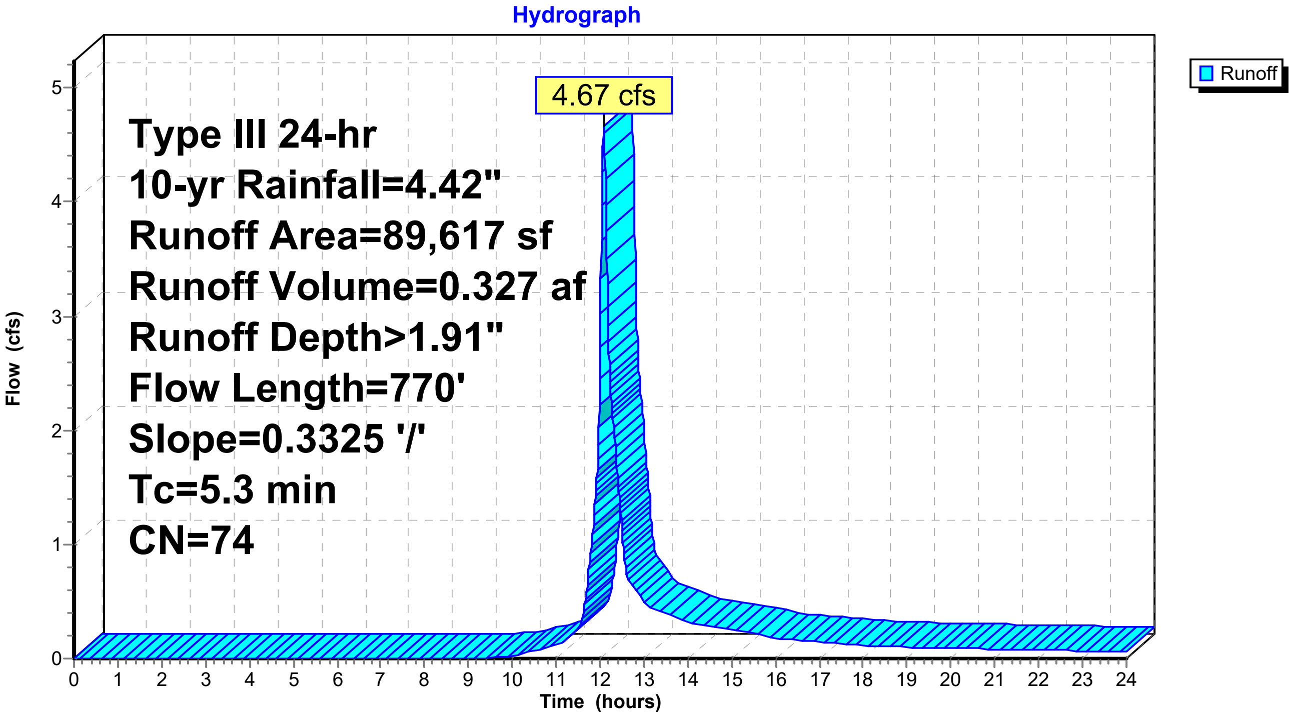
Runoff = 4.67 cfs @ 12.08 hrs, Volume= 0.327 af, Depth> 1.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
643	74	>75% Grass cover, Good HSG C
88,974	74	>75% Grass cover, Good HSG C
89,617	74	Weighted Average
89,617		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.3	770	0.3325	2.40		**Lag/CN Method,**

Subcatchment C'1.4: C'1.4



Summary for Subcatchment C'1.5: C'1.5

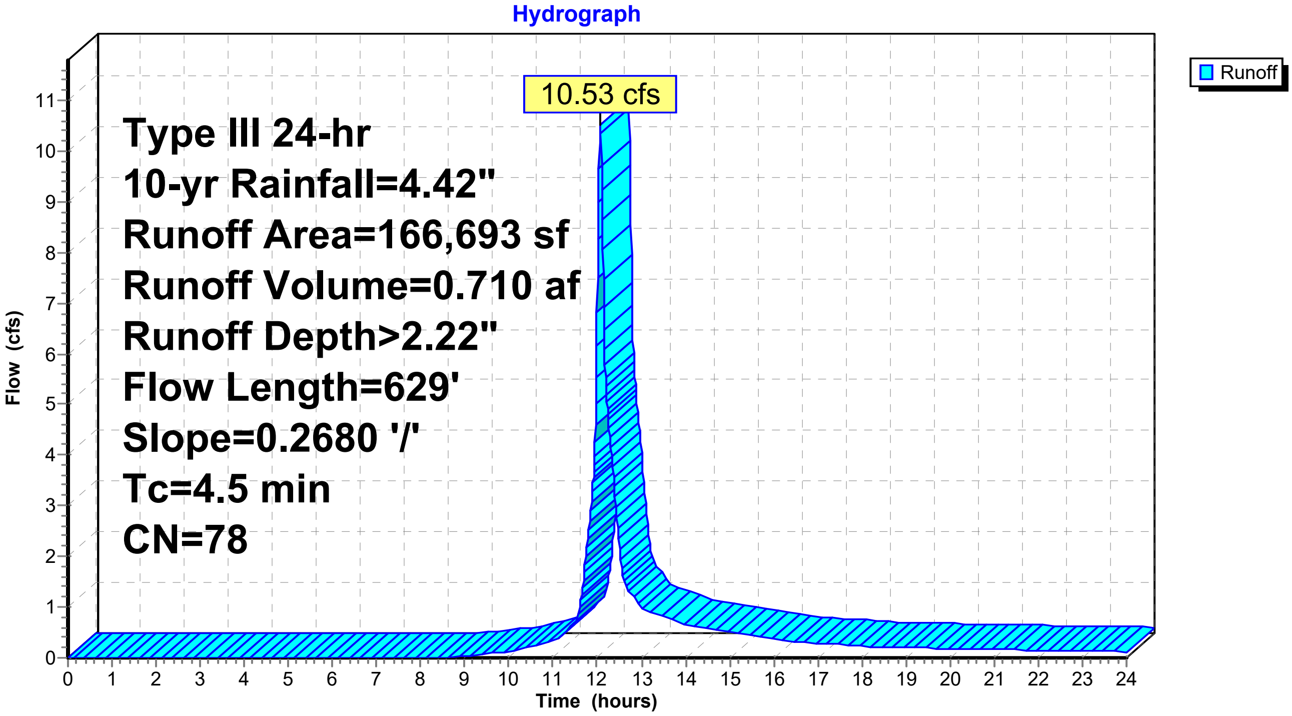
Runoff = 10.53 cfs @ 12.07 hrs, Volume= 0.710 af, Depth> 2.22"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.42"

Area (sf)	CN	Description
23,733	89	Gravel roads HSG C
14,125	70	Woods, Good HSG C
14,584	98	Water Surface HSG C
1,200	98	Roofs HSG C
113,050	74	>75% Grass cover, Good HSG C
166,693	78	Weighted Average
150,909		90.53% Pervious Area
15,784		9.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.5	629	0.2680	2.33		**Lag/CN Method,**

Subcatchment C'1.5: C'1.5



Summary for Reach 3R: Existing Swale

Inflow Area = 28.286 ac, 1.06% Impervious, Inflow Depth > 2.03" for 10-yr event
Inflow = 50.39 cfs @ 12.14 hrs, Volume= 4.777 af
Outflow = 49.39 cfs @ 12.17 hrs, Volume= 4.767 af, Atten= 2%, Lag= 1.7 min

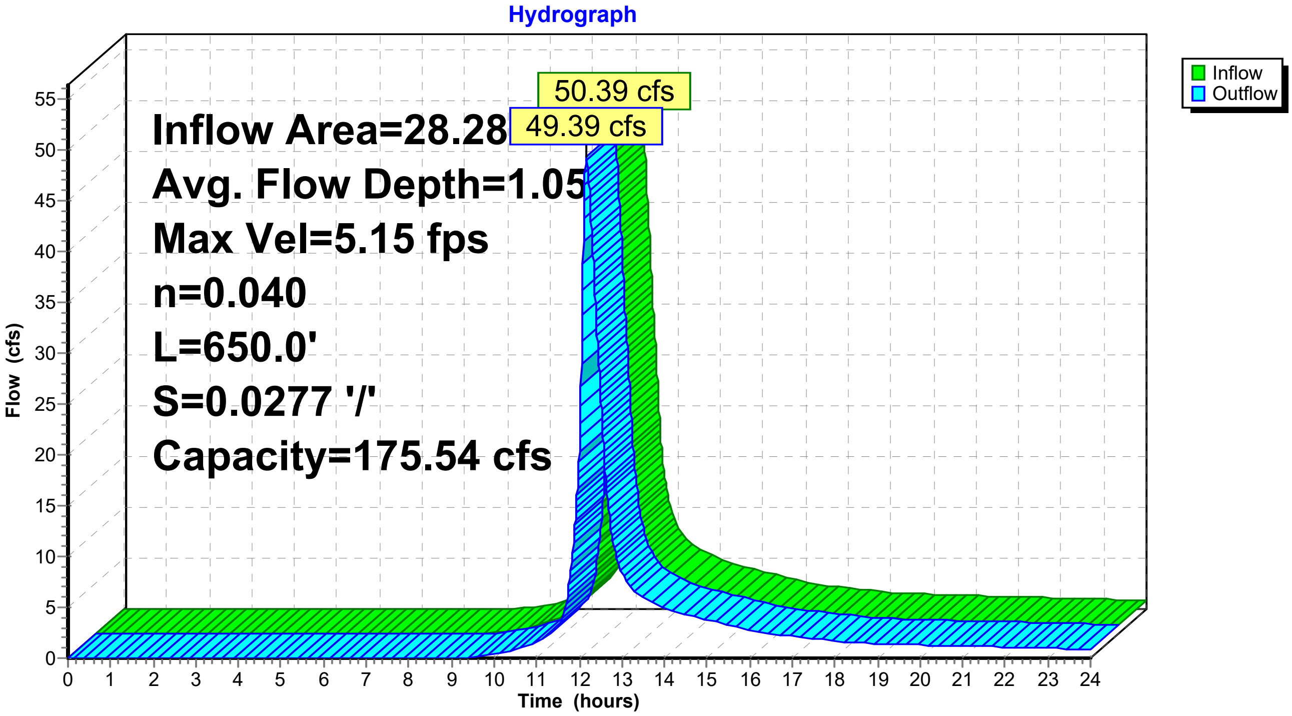
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.15 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 1.86 fps, Avg. Travel Time= 5.8 min

Peak Storage= 6,238 cf @ 12.17 hrs
Average Depth at Peak Storage= 1.05'
Bank-Full Depth= 2.00' Flow Area= 24.0 sf, Capacity= 175.54 cfs

6.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 650.0' Slope= 0.0277 '/'
Inlet Invert= 198.00', Outlet Invert= 180.00'

‡

Reach 3R: Existing Swale



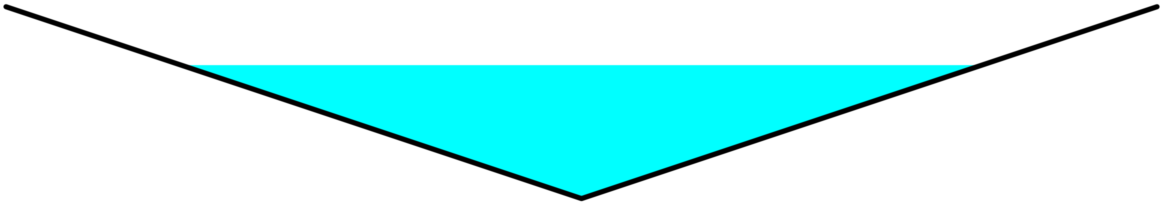
Summary for Reach 4R: Existing Swale

Inflow Area = 12.032 ac, 0.96% Impervious, Inflow Depth > 1.97" for 10-yr event
Inflow = 22.22 cfs @ 12.16 hrs, Volume= 1.976 af
Outflow = 18.25 cfs @ 12.26 hrs, Volume= 1.964 af, Atten= 18%, Lag= 6.1 min

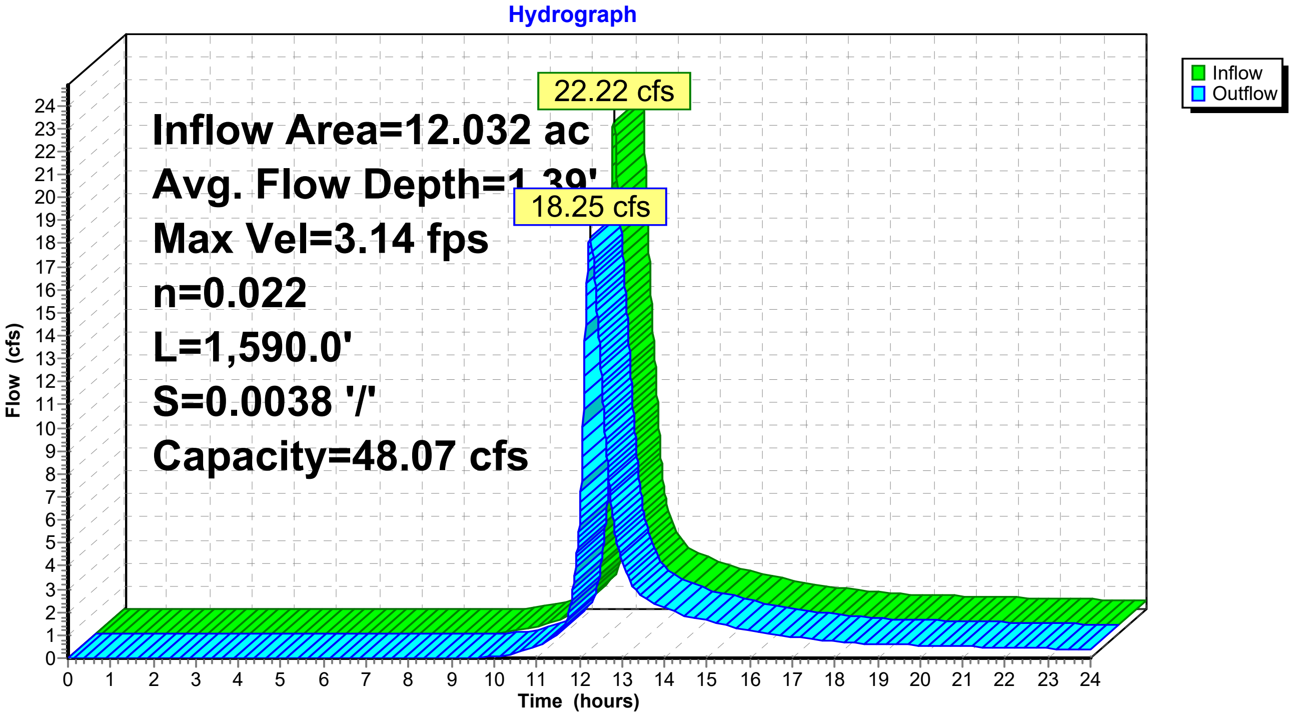
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.14 fps, Min. Travel Time= 8.4 min
Avg. Velocity = 1.47 fps, Avg. Travel Time= 18.0 min

Peak Storage= 9,228 cf @ 12.26 hrs
Average Depth at Peak Storage= 1.39'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 48.07 cfs

0.00' x 2.00' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 1,590.0' Slope= 0.0038 '/'
Inlet Invert= 184.00', Outlet Invert= 178.00'



Reach 4R: Existing Swale



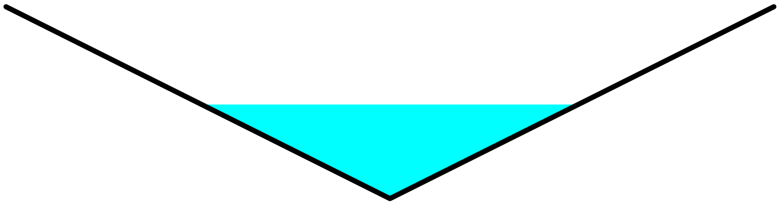
Summary for Reach 15R: Existing Roadside Swale

```
Inflow Area =         6.926 ac,   0.00% Impervious,  Inflow Depth >   1.91"   for  10-yr event
Inflow      =        12.71 cfs @   12.16 hrs,  Volume=            1.100 af
Outflow     =        12.28 cfs @   12.20 hrs,  Volume=            1.098 af,  Atten= 3%,  Lag= 2.0 min
```

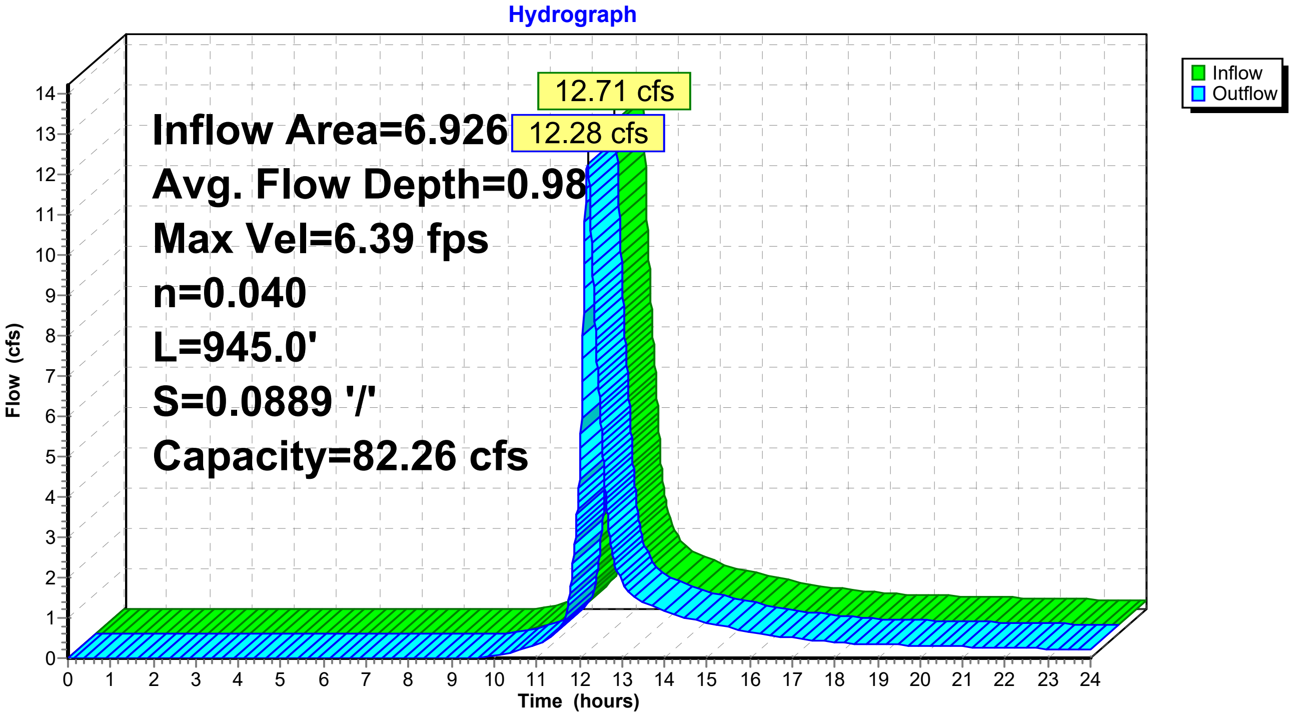
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 6.39 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 2.91 fps, Avg. Travel Time= 5.4 min

Peak Storage= 1,816 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.98'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 82.26 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 945.0' Slope= 0.0889 '/'
Inlet Invert= 288.00', Outlet Invert= 204.00'



Reach 15R: Existing Roadside Swale



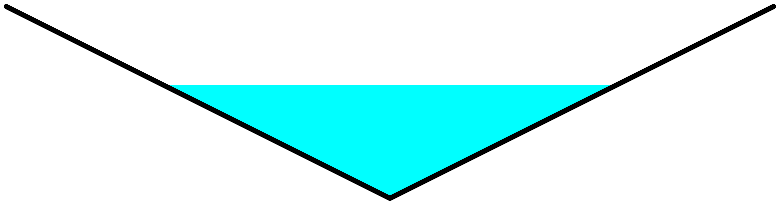
Summary for Reach 16R: Proposed Roadside Swale

Inflow Area = 10.804 ac, 0.00% Impervious, Inflow Depth > 2.14" for 10-yr event
Inflow = 21.14 cfs @ 12.19 hrs, Volume= 1.926 af
Outflow = 19.72 cfs @ 12.25 hrs, Volume= 1.921 af, Atten= 7%, Lag= 3.3 min

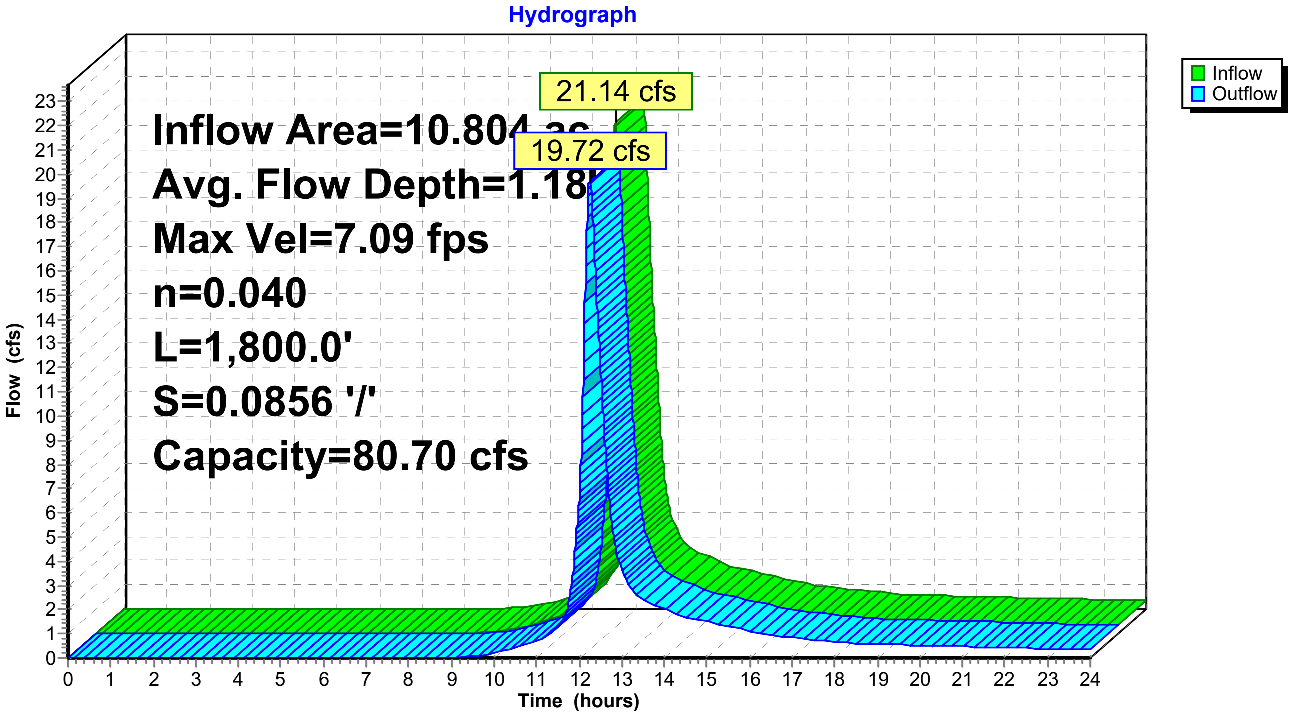
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.09 fps, Min. Travel Time= 4.2 min
Avg. Velocity = 3.24 fps, Avg. Travel Time= 9.3 min

Peak Storage= 5,006 cf @ 12.25 hrs
Average Depth at Peak Storage= 1.18'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 80.70 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 1,800.0' Slope= 0.0856 '/'
Inlet Invert= 366.00', Outlet Invert= 212.00'



Reach 16R: Proposed Roadside Swale



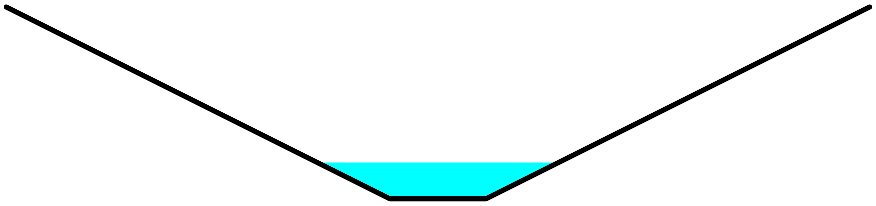
Summary for Reach 17R: Proposed Perimeter Swale

Inflow Area = 1.469 ac, 0.00% Impervious, Inflow Depth > 1.91" for 10-yr event
Inflow = 3.45 cfs @ 12.07 hrs, Volume= 0.234 af
Outflow = 3.28 cfs @ 12.09 hrs, Volume= 0.233 af, Atten= 5%, Lag= 1.5 min

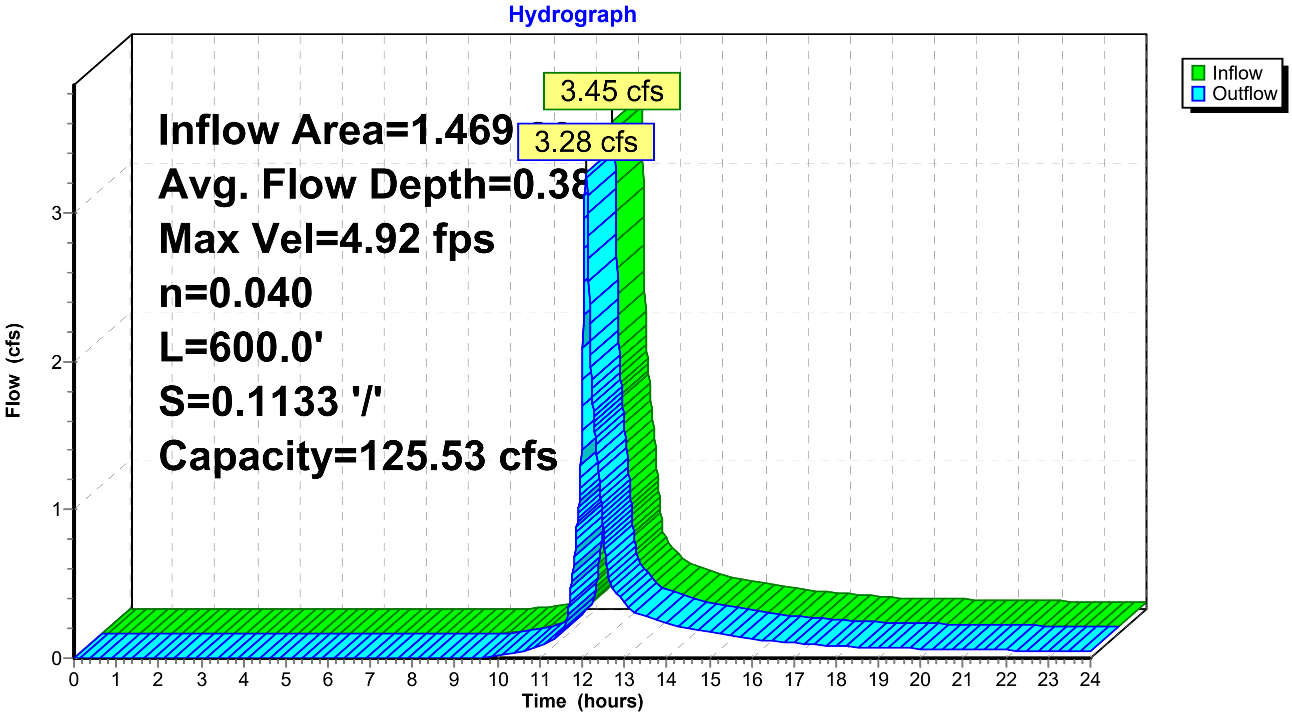
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.92 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 1.77 fps, Avg. Travel Time= 5.7 min

Peak Storage= 399 cf @ 12.09 hrs
Average Depth at Peak Storage= 0.38'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 125.53 cfs

1.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 600.0' Slope= 0.1133 '/'
Inlet Invert= 320.00', Outlet Invert= 252.00'



Reach 17R: Proposed Perimeter Swale



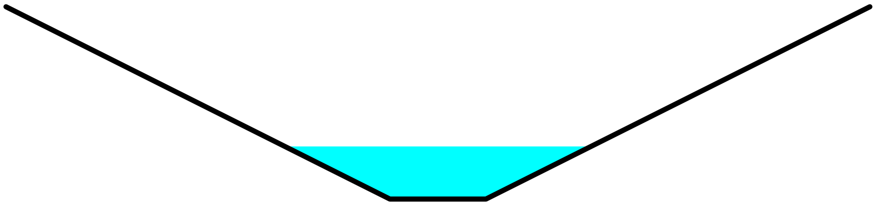
Summary for Reach 18R: Proposed Perimeter Swale

Inflow Area = 1.823 ac, 0.00% Impervious, Inflow Depth > 1.91" for 10-yr event
Inflow = 4.10 cfs @ 12.09 hrs, Volume= 0.290 af
Outflow = 3.53 cfs @ 12.13 hrs, Volume= 0.289 af, Atten= 14%, Lag= 2.8 min

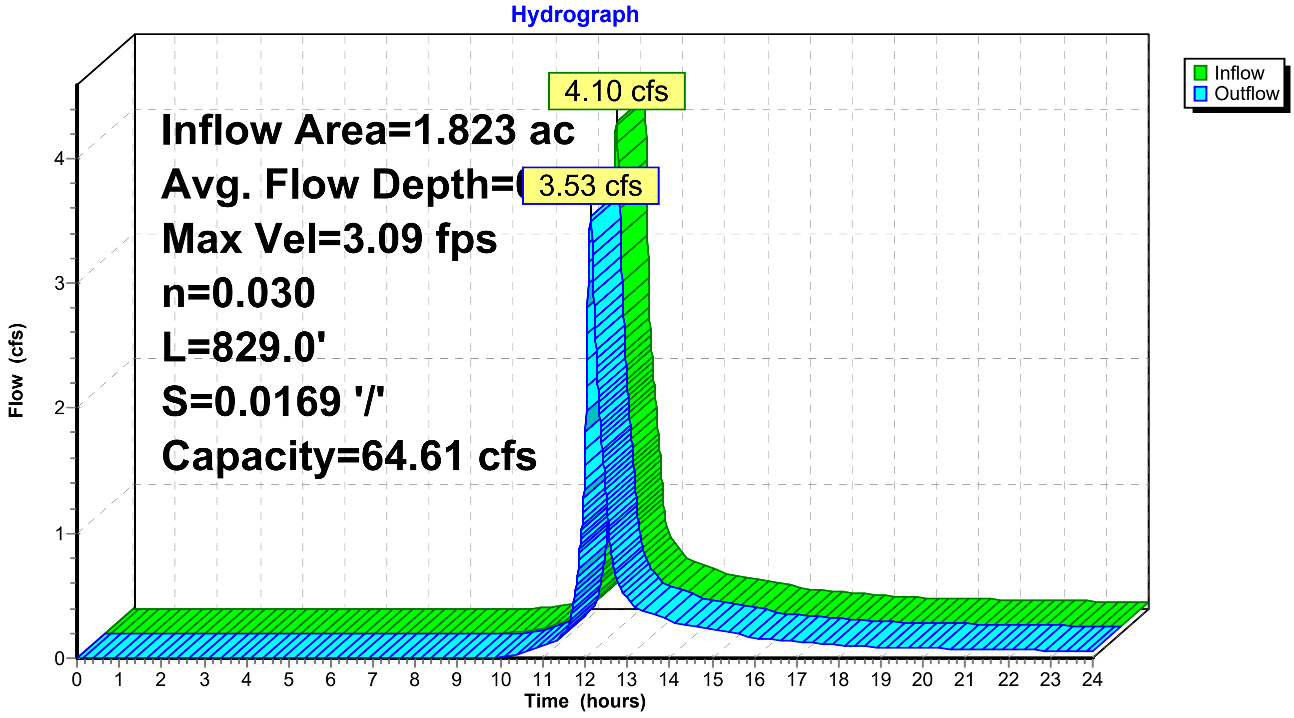
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.09 fps, Min. Travel Time= 4.5 min
Avg. Velocity = 1.21 fps, Avg. Travel Time= 11.4 min

Peak Storage= 948 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.55'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 64.61 cfs

1.00' x 2.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 829.0' Slope= 0.0169 '/'
Inlet Invert= 320.00', Outlet Invert= 306.00'



Reach 18R: Proposed Perimeter Swale



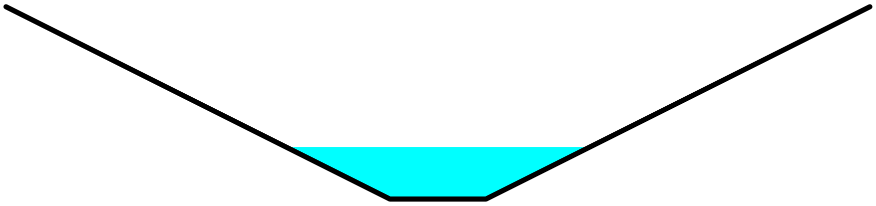
Summary for Reach 19R: Proposed Perimeter Swale

Inflow Area = 3.880 ac, 0.00% Impervious, Inflow Depth > 1.91" for 10-yr event
Inflow = 7.88 cfs @ 12.10 hrs, Volume= 0.616 af
Outflow = 7.84 cfs @ 12.11 hrs, Volume= 0.616 af, Atten= 1%, Lag= 0.6 min

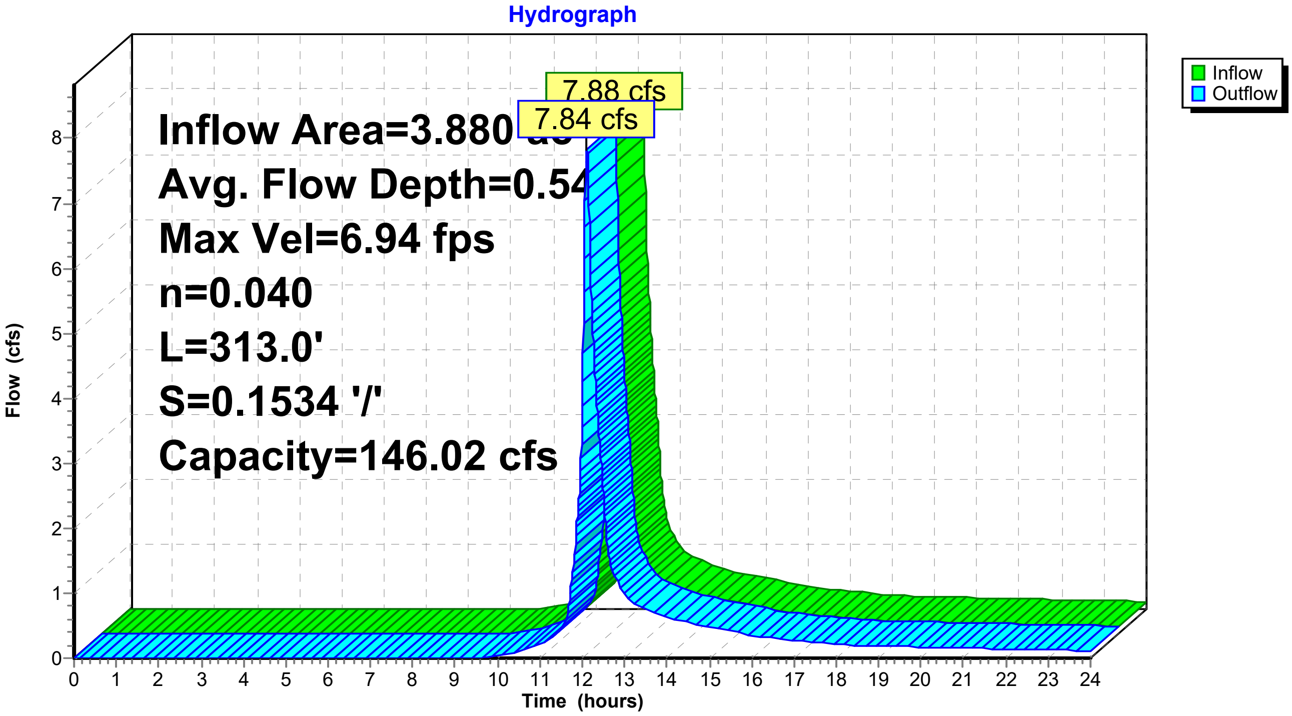
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 6.94 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 2.68 fps, Avg. Travel Time= 1.9 min

Peak Storage= 353 cf @ 12.11 hrs
Average Depth at Peak Storage= 0.54'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 146.02 cfs

1.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 313.0' Slope= 0.1534 '/'
Inlet Invert= 288.00', Outlet Invert= 240.00'



Reach 19R: Proposed Perimeter Swale



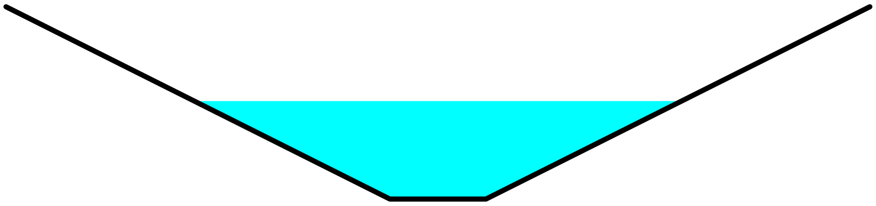
Summary for Reach 20R: Proposed Perimeter Swale (Bottom of Slope Portion)

Inflow Area = 3.880 ac, 0.00% Impervious, Inflow Depth > 1.90" for 10-yr event
Inflow = 7.84 cfs @ 12.11 hrs, Volume= 0.616 af
Outflow = 7.80 cfs @ 12.12 hrs, Volume= 0.615 af, Atten= 0%, Lag= 0.5 min

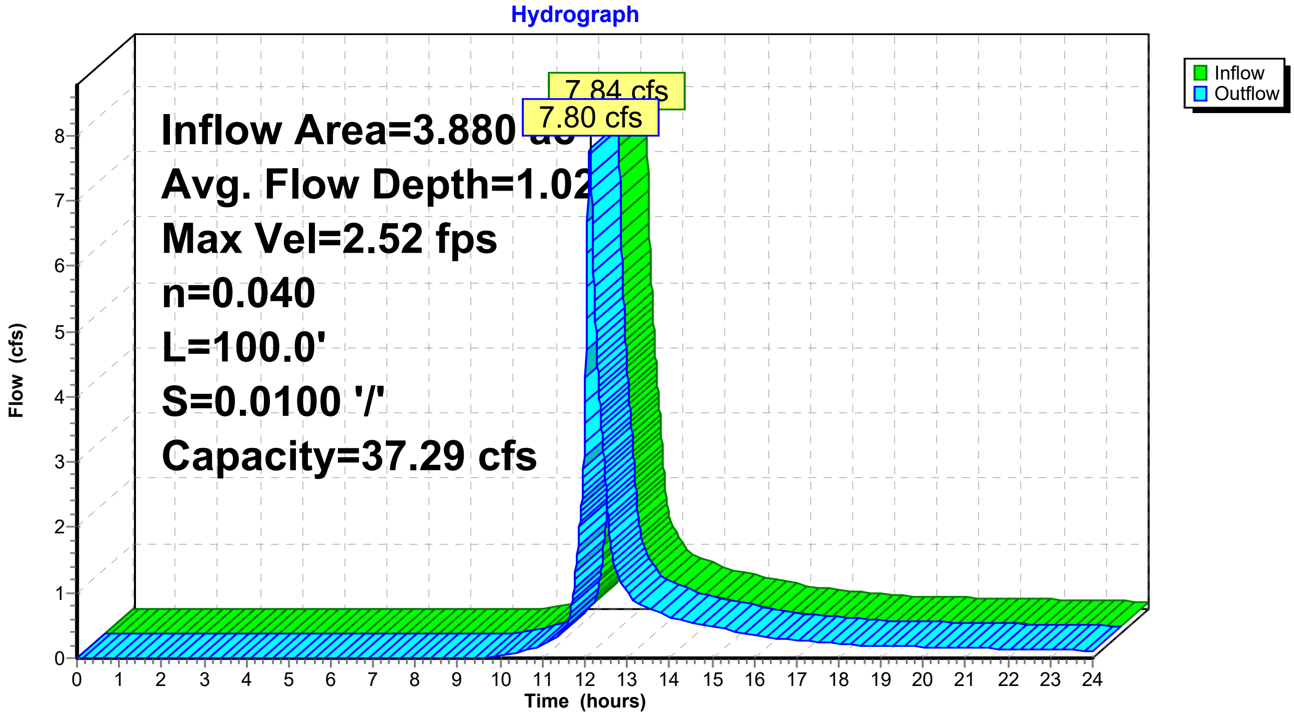
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.52 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.04 fps, Avg. Travel Time= 1.6 min

Peak Storage= 310 cf @ 12.12 hrs
Average Depth at Peak Storage= 1.02'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 37.29 cfs

1.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 100.0' Slope= 0.0100 '/'
Inlet Invert= 240.00', Outlet Invert= 239.00'



Reach 20R: Proposed Perimeter Swale (Bottom of Slope Portion)



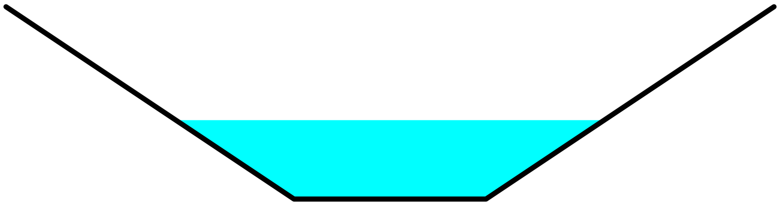
Summary for Reach 22R: Proposed Gabion-Lined Swale (Bottom of Slope Portion)

Inflow Area = 13.464 ac, 0.00% Impervious, Inflow Depth > 1.91" for 10-yr event
Inflow = 27.04 cfs @ 12.13 hrs, Volume= 2.140 af
Outflow = 27.01 cfs @ 12.13 hrs, Volume= 2.139 af, Atten= 0%, Lag= 0.3 min

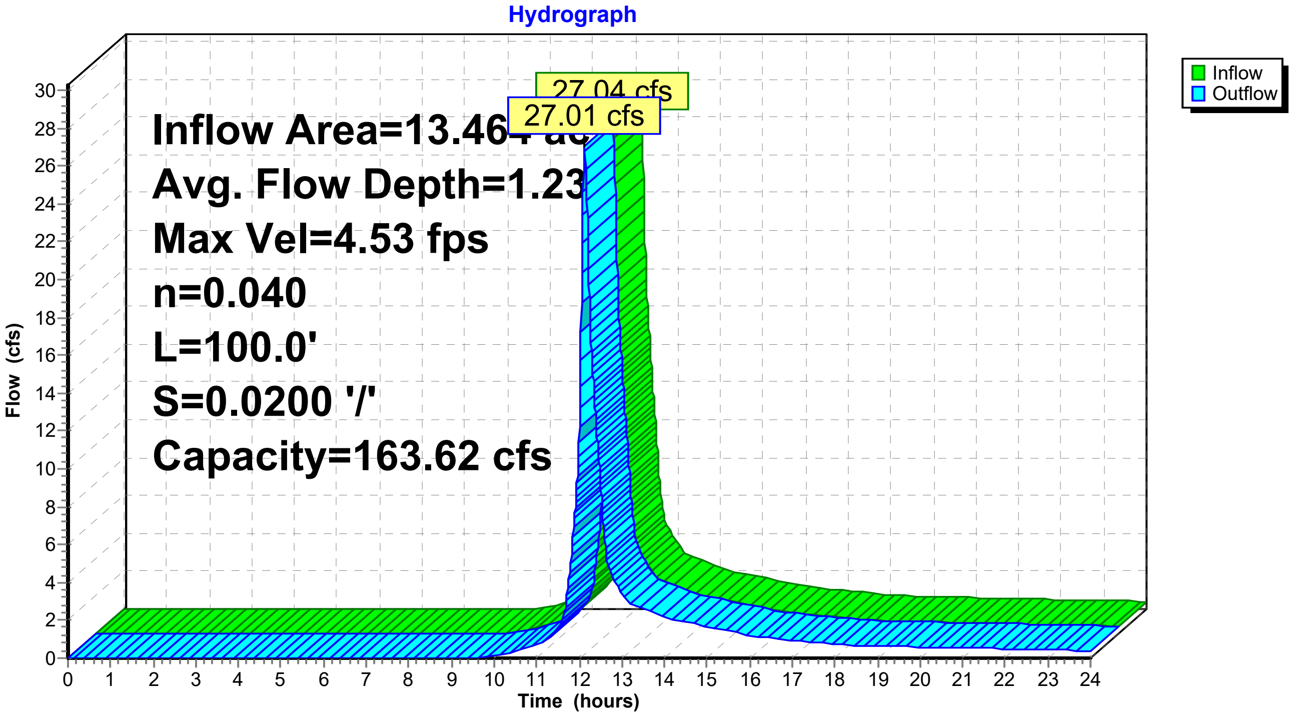
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.53 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.64 fps, Avg. Travel Time= 1.0 min

Peak Storage= 596 cf @ 12.13 hrs
Average Depth at Peak Storage= 1.23'
Bank-Full Depth= 3.00' Flow Area= 22.5 sf, Capacity= 163.62 cfs

3.00' x 3.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 1.5 '/' Top Width= 12.00'
Length= 100.0' Slope= 0.0200 '/'
Inlet Invert= 212.00', Outlet Invert= 210.00'



Reach 22R: Proposed Gabion-Lined Swale (Bottom of Slope Portion)



Summary for Pond 2P: Existing Pond 2 w/ Modified Outlet

```
Inflow Area =      64.678 ac,   1.49% Impervious,  Inflow Depth >   1.71"    for  10-yr event
Inflow      =     87.94 cfs @   12.18 hrs,  Volume=          9.214 af
Outflow     =      8.03 cfs @   14.78 hrs,  Volume=          6.429 af,  Atten= 91%,  Lag= 156.3 min
Primary     =      8.03 cfs @   14.78 hrs,  Volume=          6.429 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Starting Elev= 176.90'   Surf.Area= 0 sf   Storage= 123,527 cf
Peak Elev= 179.17' @ 14.78 hrs   Surf.Area= 0 sf   Storage= 339,747 cf   (216,220 cf above start)
Flood Elev= 181.50'   Surf.Area= 0 sf   Storage= 654,228 cf   (530,701 cf above start)

Plug-Flow detention time= 472.3 min calculated for 3.592 af (39% of inflow)
Center-of-Mass det. time= 197.2 min ( 1,051.2 - 854.0 )

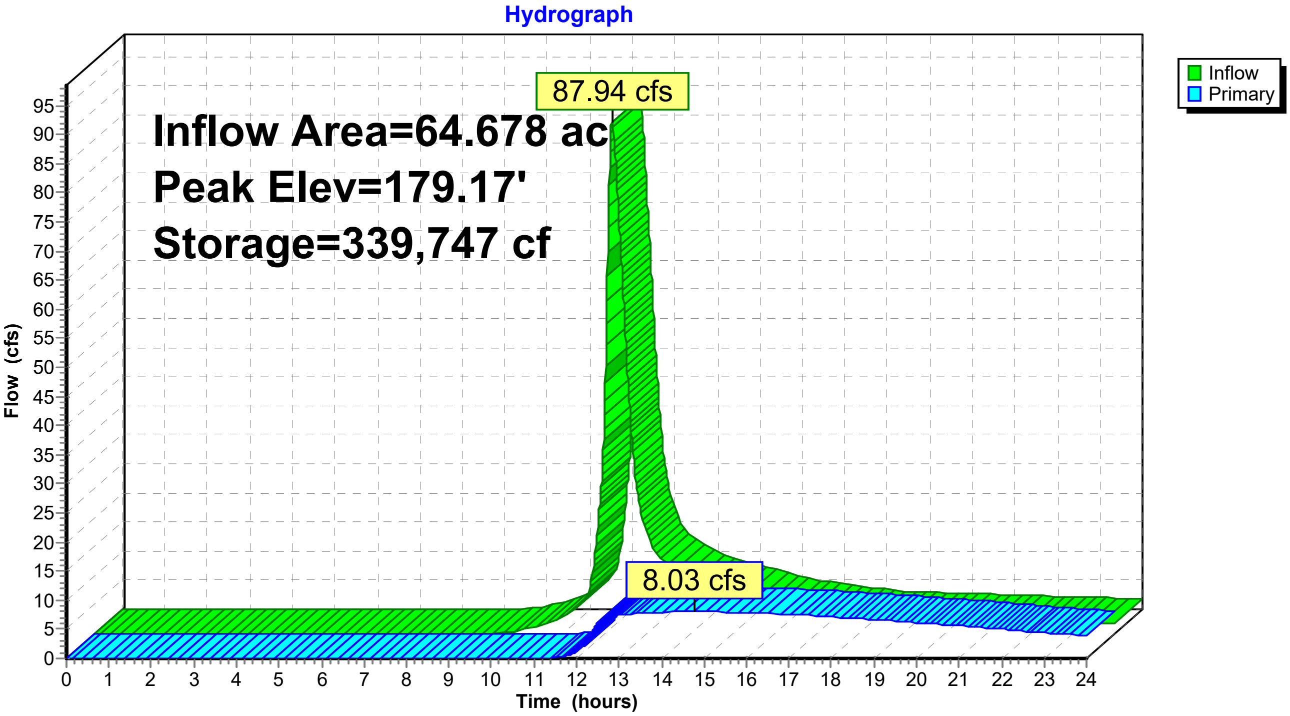
Volume         Invert      Avail.Storage    Storage Description
   #1          174.00'       654,228 cf     Custom Stage Data Listed below

 Elevation      Cum.Store
    (feet)    (cubic-feet)
    174.00              0
    176.75        113,517
    177.25        146,884
    177.75        183,300
    178.25        234,440
    179.00        319,208
    179.50        379,233
    180.00        438,083
    181.00        579,522
    181.50        654,228

Device   Routing          Invert   Outlet Devices
   #1    Primary         176.90'   24.0"  Round Culvert   L= 137.0'   CPP, square edge headwall,  Ke= 0.500
                                   Inlet / Outlet Invert= 176.90' / 176.20'   S= 0.0051 '/'   Cc= 0.900
                                   n= 0.012,  Flow Area= 3.14 sf
   #2    Device 1        176.90'   12.0" W x 6.0" H Vert. Orifice/Grate    C= 0.600
   #3    Device 1        178.00'   12.0" W x 6.0" H Vert. Orifice/Grate X 2.00    C= 0.600
   #4    Device 1        181.25'   48.0" Horiz. Orifice/Grate    C= 0.600   Limited to weir flow at low heads

Primary OutFlow  Max=8.03 cfs @ 14.78 hrs  HW=179.17'   (Free Discharge)
└─1=Culvert  (Passes 8.03 cfs of 15.90 cfs potential flow)
   ├─2=Orifice/Grate  (Orifice Controls 3.42 cfs @ 6.84 fps)
   ├─3=Orifice/Grate  (Orifice Controls 4.61 cfs @ 4.61 fps)
   └─4=Orifice/Grate  ( Controls 0.00 cfs)
```

Pond 2P: Existing Pond 2 w/ Modified Outlet



Summary for Pond 4P: Existing Pond 4 w/ Modified Outlet

Inflow Area = 27.536 ac, 1.32% Impervious, Inflow Depth > 2.01" for 10-yr event
Inflow = 54.55 cfs @ 12.12 hrs, Volume= 4.602 af
Outflow = 4.93 cfs @ 13.84 hrs, Volume= 3.433 af, Atten= 91%, Lag= 102.9 min
Primary = 4.93 cfs @ 13.84 hrs, Volume= 3.433 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Starting Elev= 196.50' Surf.Area= 14,584 sf Storage= 21,627 cf
Peak Elev= 201.18' @ 13.84 hrs Surf.Area= 27,468 sf Storage= 123,767 cf (102,140 cf above start)
Flood Elev= 208.00' Surf.Area= 41,741 sf Storage= 358,071 cf (336,443 cf above start)

Plug-Flow detention time= 322.4 min calculated for 2.936 af (64% of inflow)
Center-of-Mass det. time= 171.5 min (1,013.4 - 842.0)

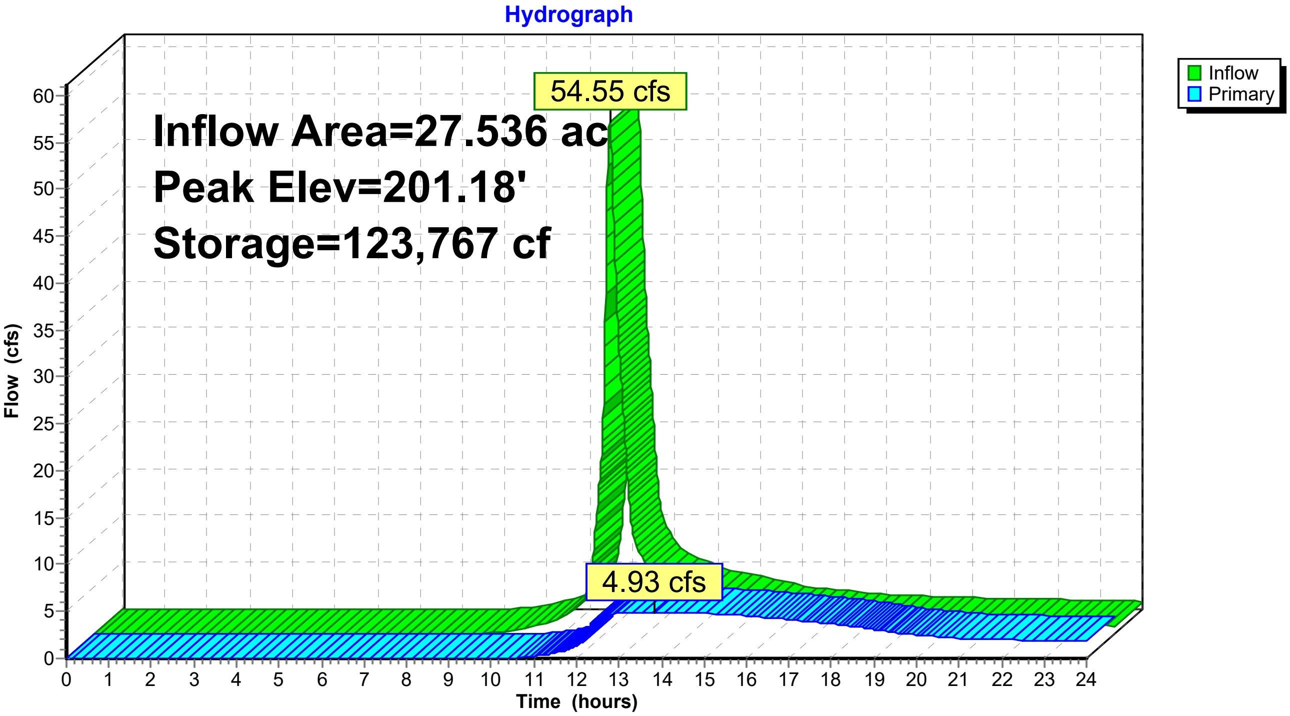
Volume	Invert	Avail.Storage	Storage Description
#1	194.00'	358,071 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
194.00	3,863	227.0	0	0	3,863
196.50	14,584	631.3	21,627	21,627	31,498
198.00	20,032	794.2	25,854	47,482	50,008
200.00	25,197	855.2	45,130	92,612	58,183
202.00	29,091	888.5	54,241	146,853	63,121
204.00	32,908	922.4	61,960	208,813	68,331
206.00	37,348	956.0	70,209	279,022	73,694
208.00	41,741	1,006.2	79,048	358,071	81,774

Device	Routing	Invert	Outlet Devices
#1	Primary	196.50'	**15.0" Round Culvert** L= 85.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 196.50' / 196.25' S= 0.0029 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 1.23 sf
#2	Device 1	196.50'	**6.0" W x 6.0" H Vert. Orifice/Grate** C= 0.600
#3	Device 1	199.50'	**10.0" W x 6.0" H Vert. Orifice/Grate** C= 0.600
#4	Device 1	205.00'	**48.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=4.93 cfs @ 13.84 hrs HW=201.18' (Free Discharge)
└─**1=Culvert** (Passes 4.93 cfs of 10.58 cfs potential flow)
  ├─**2=Orifice/Grate** (Orifice Controls 2.53 cfs @ 10.14 fps)
  ├─**3=Orifice/Grate** (Orifice Controls 2.40 cfs @ 5.76 fps)
  └─**4=Orifice/Grate** (Controls 0.00 cfs)

Pond 4P: Existing Pond 4 w/ Modified Outlet



Summary for Pond 6R: Proposed Culvert

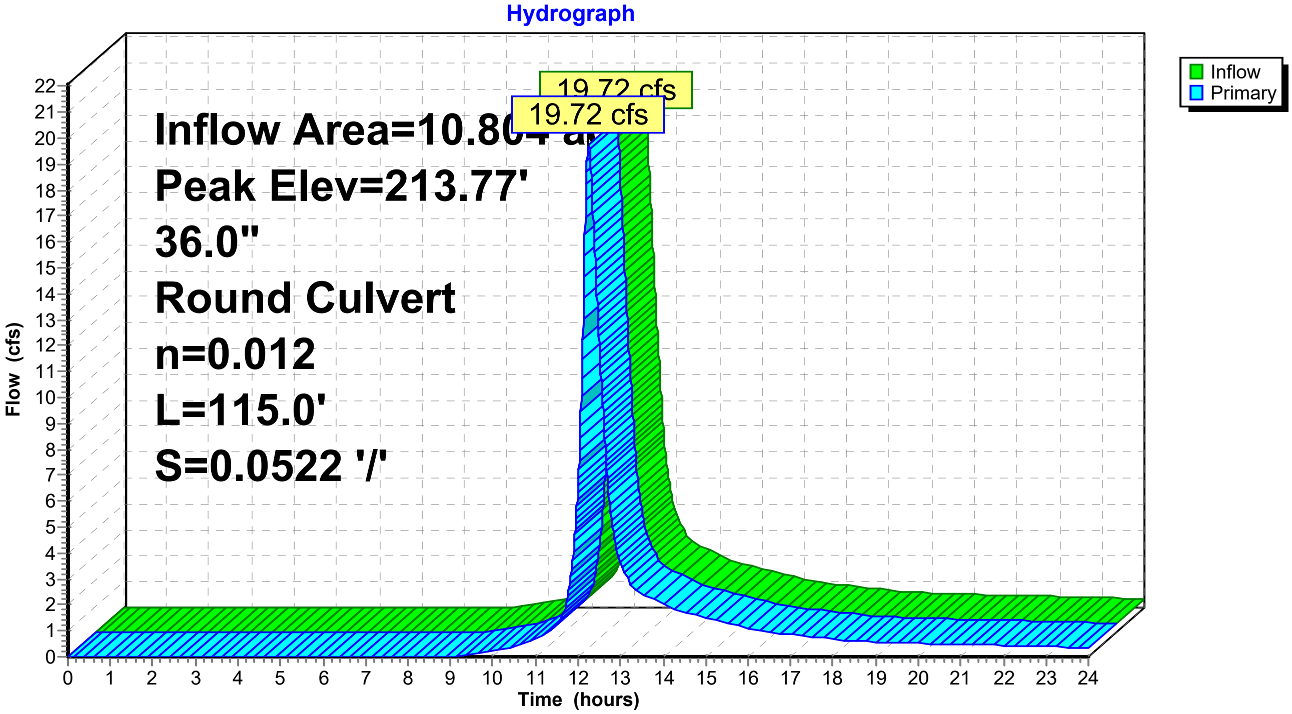
Inflow Area =	10.804 ac,	0.00% Impervious, Inflow Depth >	2.13"	for 10-yr event
Inflow =	19.72 cfs @	12.25 hrs, Volume=	1.921 af	
Outflow =	19.72 cfs @	12.25 hrs, Volume=	1.921 af, Atten= 0%, Lag= 0.0 min	
Primary =	19.72 cfs @	12.25 hrs, Volume=	1.921 af	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 213.77' @ 12.25 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	212.00'	**36.0" Round Culvert** L= 115.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 212.00' / 206.00' S= 0.0522 '/' Cc= 0.900 n= 0.012, Flow Area= 7.07 sf

Primary OutFlow Max=19.72 cfs @ 12.25 hrs HW=213.77' TW=199.00' (Dynamic Tailwater)
↳**1=Culvert** (Inlet Controls 19.72 cfs @ 4.53 fps)

Pond 6R: Proposed Culvert



Summary for Pond 21R: Proposed Dual Culverts

```
Inflow Area =       23.709 ac,   0.00% Impervious,  Inflow Depth >   1.97"   for  10-yr event
Inflow      =      46.58 cfs @  12.14 hrs,  Volume=            3.893 af
Outflow     =      46.58 cfs @  12.14 hrs,  Volume=            3.893 af,  Atten= 0%,  Lag= 0.0 min
Primary     =      46.58 cfs @  12.14 hrs,  Volume=            3.893 af
Secondary =         0.00 cfs @   0.00 hrs,  Volume=            0.000 af
```

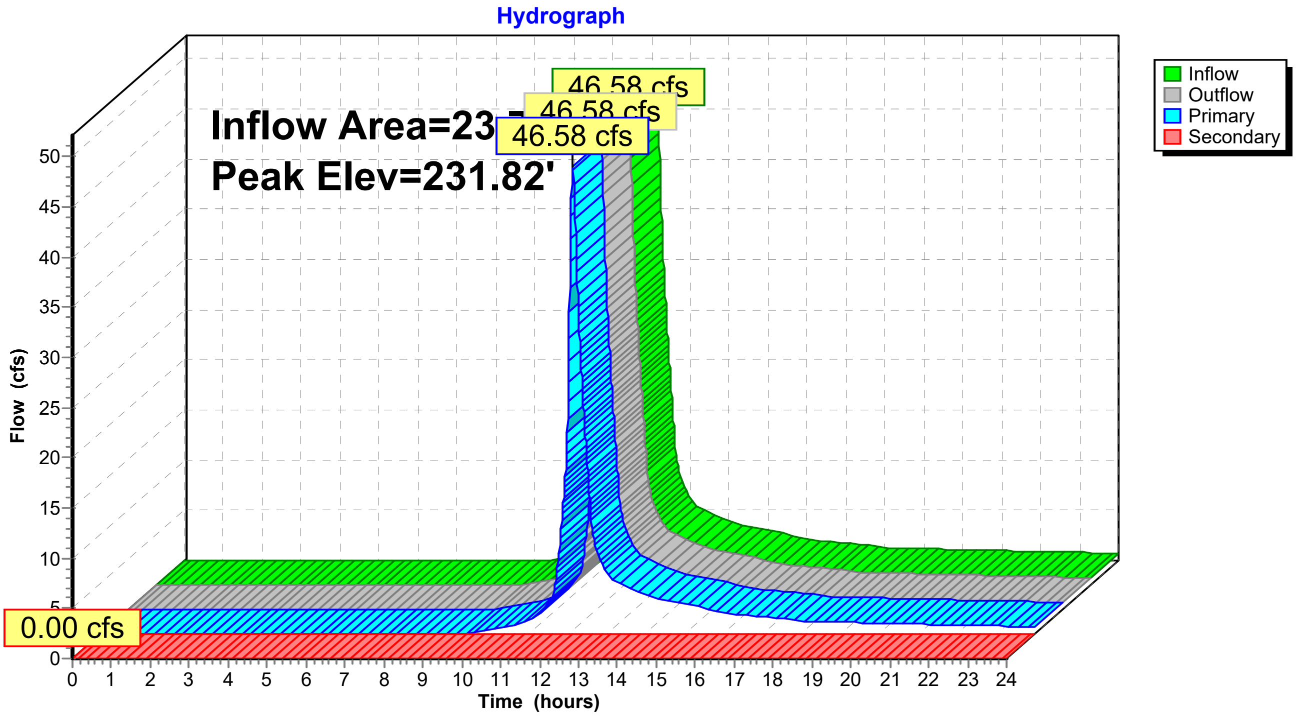
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 231.82' @ 12.14 hrs
Flood Elev= 233.50'

Device	Routing	Invert	Outlet Devices
#1	Primary	230.00'	**42.0" Round Dual Culverts X 2.00** L= 140.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 230.00' / 227.20' S= 0.0200 '/' Cc= 0.900 n= 0.012, Flow Area= 9.62 sf
#2	Secondary	233.00'	**10.0' long x 40.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=46.56 cfs @ 12.14 hrs HW=231.82' TW=199.03' (Dynamic Tailwater)
↑**1=Dual Culverts** (Inlet Controls 46.56 cfs @ 4.60 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=230.00' (Free Discharge)
↑**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 21R: Proposed Dual Culverts



Summary for Pond 23R: Proposed Dual Culverts

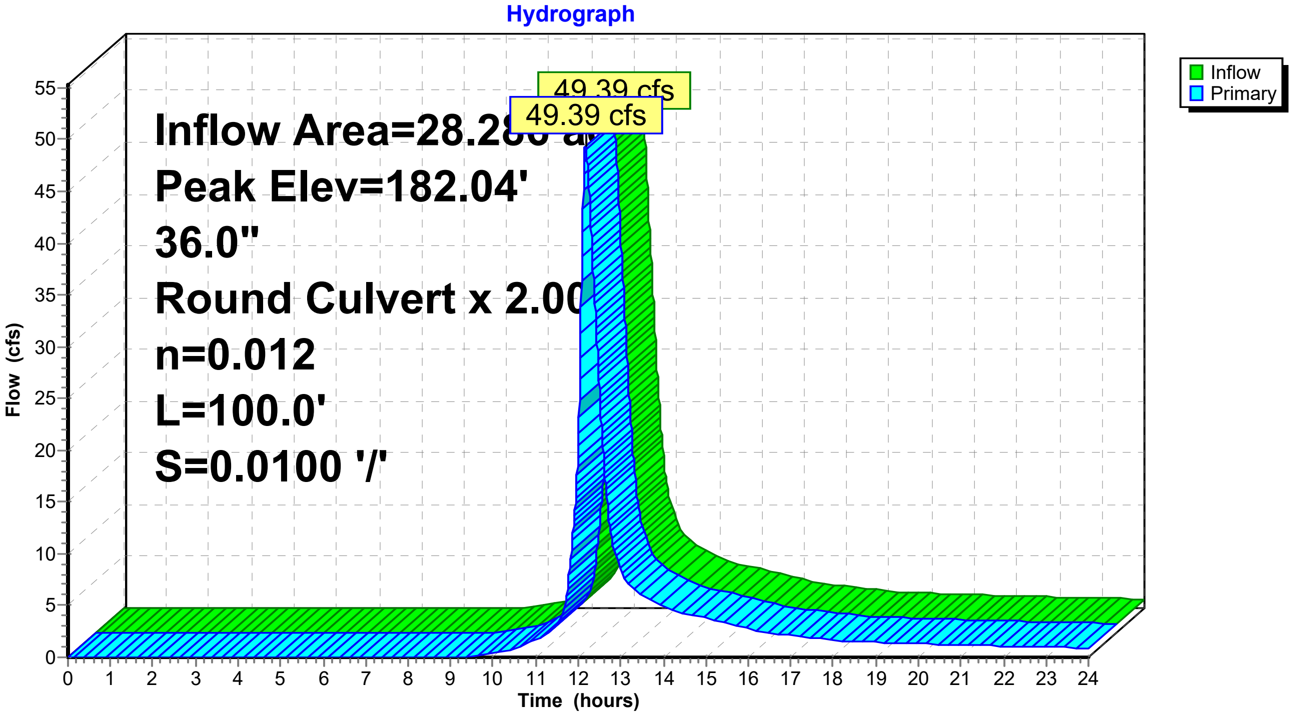
```
Inflow Area =      28.286 ac,   1.06% Impervious,  Inflow Depth >   2.02"    for  10-yr event
Inflow      =      49.39 cfs @   12.17 hrs,  Volume=           4.767 af
Outflow     =      49.39 cfs @   12.17 hrs,  Volume=           4.767 af,  Atten= 0%,  Lag= 0.0 min
Primary     =      49.39 cfs @   12.17 hrs,  Volume=           4.767 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 182.04' @ 12.17 hrs
Flood Elev= 184.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	180.00'	**36.0" Round Culvert X 2.00** L= 100.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 180.00' / 179.00' S= 0.0100 '/' Cc= 0.900 n= 0.012, Flow Area= 7.07 sf

Primary OutFlow Max=49.36 cfs @ 12.17 hrs HW=182.04' TW=177.94' (Dynamic Tailwater)
↑**1=Culvert** (Barrel Controls 49.36 cfs @ 6.79 fps)

Pond 23R: Proposed Dual Culverts



Summary for Pond CB3: Existing Catch Basin

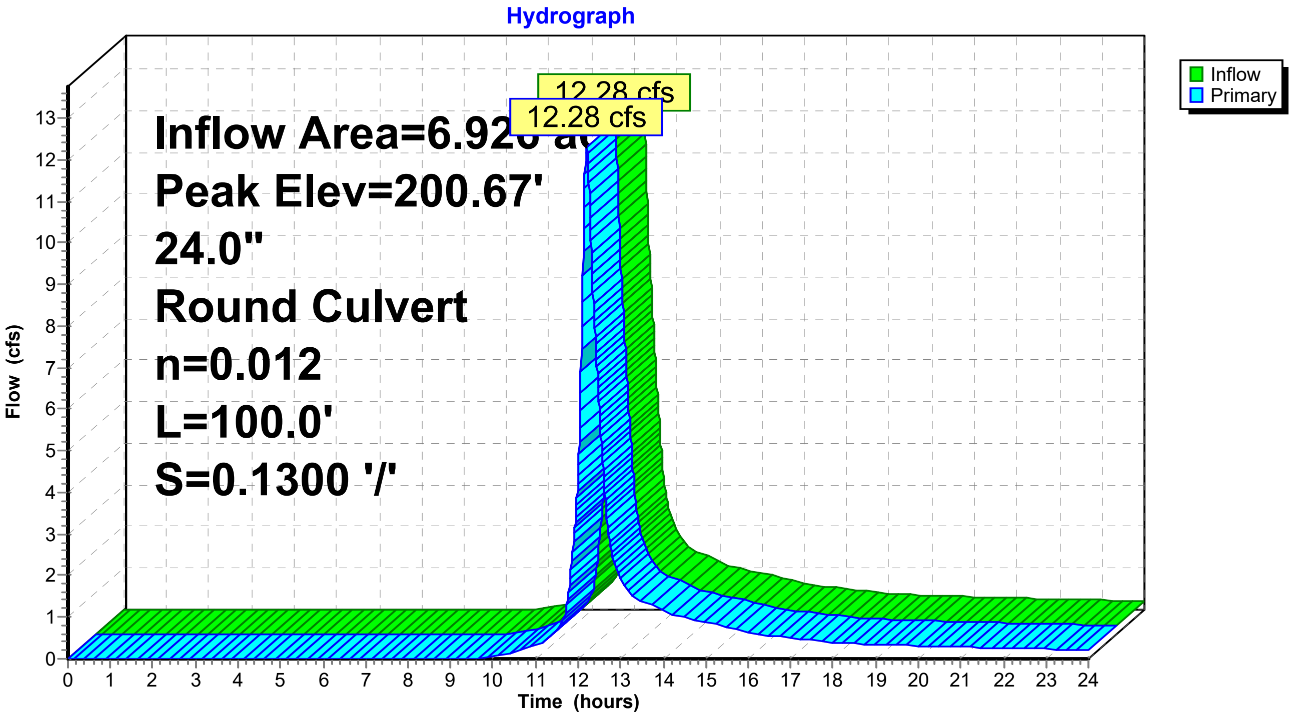
```
Inflow Area =       6.926 ac,   0.00% Impervious,  Inflow Depth >   1.90"   for  10-yr event
Inflow      =     12.28 cfs @  12.20 hrs,  Volume=           1.098 af
Outflow     =     12.28 cfs @  12.20 hrs,  Volume=           1.098 af,  Atten= 0%,  Lag= 0.0 min
Primary     =     12.28 cfs @  12.20 hrs,  Volume=           1.098 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 200.67' @ 12.20 hrs
Flood Elev= 201.50'

Device	Routing	Invert	Outlet Devices
#1	Primary	199.00'	**24.0" Round Culvert** L= 100.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 199.00' / 186.00' S= 0.1300 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=12.28 cfs @ 12.20 hrs HW=200.66' TW=185.36' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 12.28 cfs @ 4.39 fps)

Pond CB3: Existing Catch Basin



Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment A'2.0: A'2.0 Runoff Area=385,148 sf 0.00% Impervious Runoff Depth>1.12"
Flow Length=2,271' Slope=0.1851 '/' Tc=29.4 min CN=53 Runoff=5.48 cfs 0.823 af

Subcatchment A'2.1: A'2.1 Runoff Area=222,410 sf 2.27% Impervious Runoff Depth>2.99"
Flow Length=1,198' Slope=0.2381 '/' Tc=8.5 min CN=76 Runoff=16.46 cfs 1.272 af

Subcatchment A'2.2: A'2.2 Runoff Area=288,252 sf 1.72% Impervious Runoff Depth>2.90"
Flow Length=1,687' Slope=0.2495 '/' Tc=11.2 min CN=75 Runoff=18.94 cfs 1.597 af

Subcatchment A'2.3: A'2.3 Runoff Area=301,709 sf 0.00% Impervious Runoff Depth>2.80"
Flow Length=1,944' Slope=0.3126 '/' Tc=11.6 min CN=74 Runoff=18.93 cfs 1.618 af

Subcatchment A'3.1: A'3.1 Runoff Area=144,221 sf 0.00% Impervious Runoff Depth>2.81"
Flow Length=1,122' Slope=0.2295 '/' Tc=8.7 min CN=74 Runoff=9.92 cfs 0.774 af

Subcatchment A'3.2: A'3.2 Runoff Area=175,008 sf 7.49% Impervious Runoff Depth>3.09"
Flow Length=877' Slope=0.2144 '/' Tc=6.6 min UI Adjusted CN=77 Runoff=14.25 cfs 1.033 af

Subcatchment A'3.3: A'3.3 Runoff Area=470,611 sf 0.00% Impervious Runoff Depth>3.08"
Flow Length=2,403' Slope=0.2579 '/' Tc=13.8 min CN=77 Runoff=30.60 cfs 2.774 af

Subcatchment A'3.4: A'3.4 Runoff Area=64,004 sf 0.00% Impervious Runoff Depth>2.81"
Flow Length=606' Slope=0.3371 '/' Tc=4.4 min CN=74 Runoff=5.12 cfs 0.344 af

Subcatchment A'3.5: A'3.5 Runoff Area=141,038 sf 8.31% Impervious Runoff Depth>1.20"
Flow Length=84' Slope=0.0547 '/' Tc=3.6 min UI Adjusted CN=54 Runoff=4.15 cfs 0.322 af

Subcatchment A'3.6: A'3.6 Runoff Area=31,076 sf 6.63% Impervious Runoff Depth>2.90"
Flow Length=144' Slope=0.2653 '/' Tc=1.5 min UI Adjusted CN=75 Runoff=2.86 cfs 0.172 af

Subcatchment A'3.7: A'3.7 Runoff Area=522,498 sf 0.00% Impervious Runoff Depth>2.81"
Flow Length=1,385' Slope=0.3041 '/' Tc=8.9 min CN=74 Runoff=35.71 cfs 2.804 af

Subcatchment A'4: A'4 Runoff Area=71,406 sf 7.11% Impervious Runoff Depth>1.55"
Flow Length=304' Slope=0.0564 '/' Tc=8.9 min UI Adjusted CN=59 Runoff=2.47 cfs 0.212 af

Subcatchment C'1.1: C'1.1 Runoff Area=750,525 sf 0.00% Impervious Runoff Depth>2.90"
Flow Length=1,795' Slope=0.3046 '/' Tc=10.7 min CN=75 Runoff=50.01 cfs 4.158 af

Subcatchment C'1.2: C'1.2 Runoff Area=113,203 sf 0.00% Impervious Runoff Depth>2.90"
Flow Length=1,245' Slope=0.4885 '/' Tc=6.3 min CN=75 Runoff=8.75 cfs 0.628 af

Subcatchment C'1.3: C'1.3 Runoff Area=79,411 sf 0.00% Impervious Runoff Depth>2.81"
Flow Length=829' Slope=0.3376 '/' Tc=5.6 min CN=74 Runoff=6.09 cfs 0.426 af

Subcatchment C'1.4: C'1.4 Runoff Area=89,617 sf 0.00% Impervious Runoff Depth>2.81"
Flow Length=770' Slope=0.3325 '/' Tc=5.3 min CN=74 Runoff=6.94 cfs 0.481 af

```
Subcatchment C'1.5: C'1.5                  Runoff Area=166,693 sf  9.47% Impervious  Runoff Depth>3.18"
                           Flow Length=629'  Slope=0.2680 '/'  Tc=4.5 min  CN=78  Runoff=15.08 cfs  1.015 af

Reach 3R: Existing Swale                    Avg. Flow Depth=1.29'  Max Vel=5.76 fps  Inflow=74.74 cfs  6.946 af
                          n=0.040  L=650.0'  S=0.0277 '/'  Capacity=175.54 cfs  Outflow=73.47 cfs  6.934 af

Reach 4R: Existing Swale                    Avg. Flow Depth=1.63'  Max Vel=3.49 fps  Inflow=33.05 cfs  2.888 af
                        n=0.022  L=1,590.0'  S=0.0038 '/'  Capacity=48.07 cfs  Outflow=27.77 cfs  2.874 af

Reach 15R: Existing Roadside Swale          Avg. Flow Depth=1.14'  Max Vel=7.07 fps  Inflow=18.93 cfs  1.618 af
                           n=0.040  L=945.0'  S=0.0889 '/'  Capacity=82.26 cfs  Outflow=18.40 cfs  1.616 af

Reach 16R: Proposed Roadside Swale          Avg. Flow Depth=1.36'  Max Vel=7.80 fps  Inflow=30.60 cfs  2.774 af
                         n=0.040  L=1,800.0'  S=0.0856 '/'  Capacity=80.70 cfs  Outflow=28.84 cfs  2.767 af

Reach 17R: Proposed Perimeter Swale          Avg. Flow Depth=0.46'  Max Vel=5.49 fps  Inflow=5.12 cfs  0.344 af
                           n=0.040  L=600.0'  S=0.1133 '/'  Capacity=125.53 cfs  Outflow=4.91 cfs  0.343 af

Reach 18R: Proposed Perimeter Swale          Avg. Flow Depth=0.67'  Max Vel=3.44 fps  Inflow=6.09 cfs  0.426 af
                            n=0.030  L=829.0'  S=0.0169 '/'  Capacity=64.61 cfs  Outflow=5.36 cfs  0.425 af

Reach 19R: Proposed Perimeter Swale         Avg. Flow Depth=0.66'  Max Vel=7.73 fps  Inflow=11.87 cfs  0.906 af
                          n=0.040  L=313.0'  S=0.1534 '/'  Capacity=146.02 cfs  Outflow=11.82 cfs  0.906 af

Reach 20R: Proposed Perimeter Swale (Bottom  Avg. Flow Depth=1.22'  Max Vel=2.79 fps  Inflow=11.82 cfs  0.906 af
                           n=0.040  L=100.0'  S=0.0100 '/'  Capacity=37.29 cfs  Outflow=11.78 cfs  0.905 af

Reach 22R: Proposed Gabion-Lined Swale      Avg. Flow Depth=1.51'  Max Vel=5.05 fps  Inflow=40.20 cfs  3.147 af
                          n=0.040  L=100.0'  S=0.0200 '/'  Capacity=163.62 cfs  Outflow=40.17 cfs  3.146 af

Pond 2P: Existing Pond 2 w/ Modified Outlet    Peak Elev=180.16'  Storage=460,932 cf  Inflow=134.05 cfs  13.708 af
                                                                                   Outflow=10.83 cfs  9.427 af

Pond 4P: Existing Pond 4 w/ Modified Outlet       Peak Elev=203.00'  Storage=176,808 cf  Inflow=80.38 cfs  6.706 af
                                                                                      Outflow=6.62 cfs  5.221 af

Pond 6R: Proposed Culvert                                      Peak Elev=214.24'  Inflow=28.84 cfs  2.767 af
                       36.0"  Round Culvert  n=0.012  L=115.0'  S=0.0522 '/'  Outflow=28.84 cfs  2.767 af

Pond 21R: Proposed Dual Culverts                               Peak Elev=232.29'  Inflow=68.86 cfs  5.691 af
                  Primary=68.86 cfs  5.691 af  Secondary=0.00 cfs  0.000 af  Outflow=68.86 cfs  5.691 af

Pond 23R: Proposed Dual Culverts                               Peak Elev=182.67'  Inflow=73.47 cfs  6.934 af
               36.0"  Round Culvert x 2.00  n=0.012  L=100.0'  S=0.0100 '/'  Outflow=73.47 cfs  6.934 af

Pond CB3: Existing Catch Basin                                 Peak Elev=201.48'  Inflow=18.40 cfs  1.616 af
                       24.0"  Round Culvert  n=0.012  L=100.0'  S=0.1300 '/'  Outflow=18.40 cfs  1.616 af

          Total Runoff Area = 92.214 ac   Runoff Volume = 20.454 af   Average Runoff Depth = 2.66"
                                   98.56% Pervious = 90.888 ac    1.44% Impervious = 1.326 ac
```

Summary for Subcatchment A'2.0: A'2.0

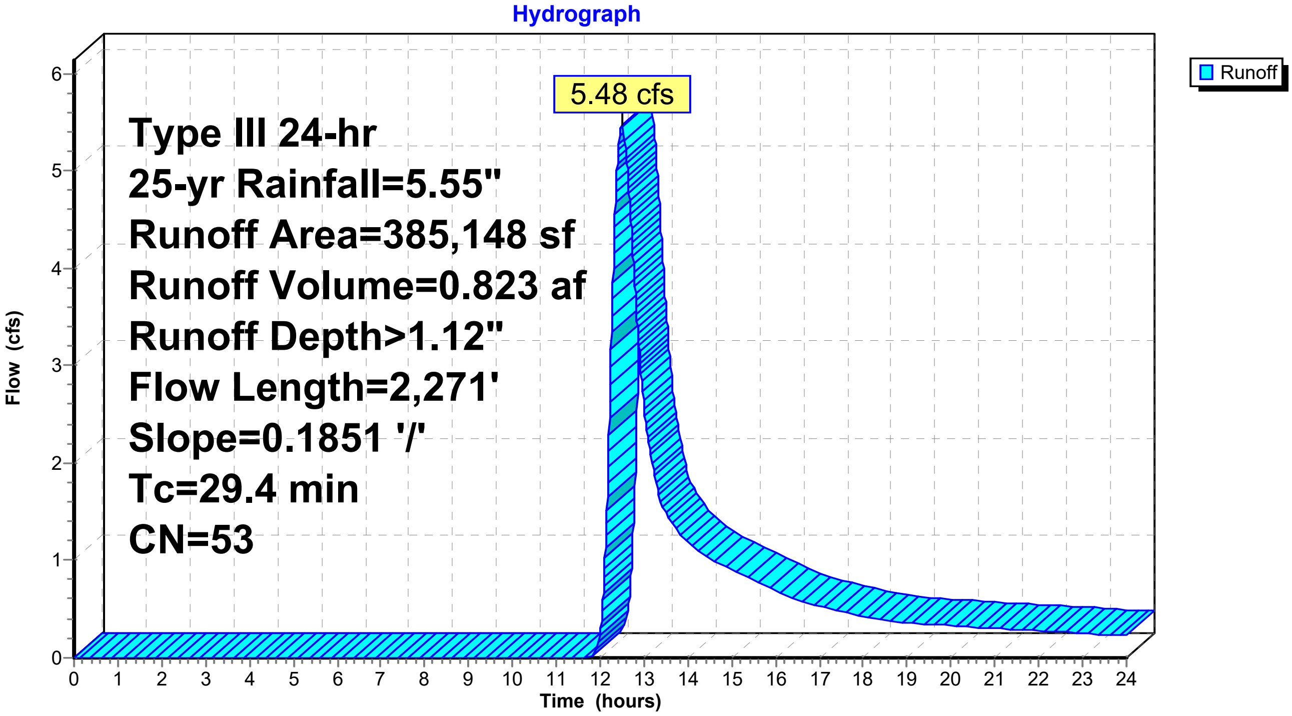
Runoff = 5.48 cfs @ 12.50 hrs, Volume= 0.823 af, Depth> 1.12"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
26,373	70	Woods, Good HSG C
18,788	89	Gravel roads HSG C
22,982	76	Gravel roads HSG A
72,099	30	Woods, Good HSG A
145,807	39	>75% Grass cover, Good HSG A
99,100	74	>75% Grass cover, Good HSG C
385,148	53	Weighted Average
385,148		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4	2,271	0.1851	1.29		**Lag/CN Method,**

Subcatchment A'2.0: A'2.0



Summary for Subcatchment A'2.1: A'2.1

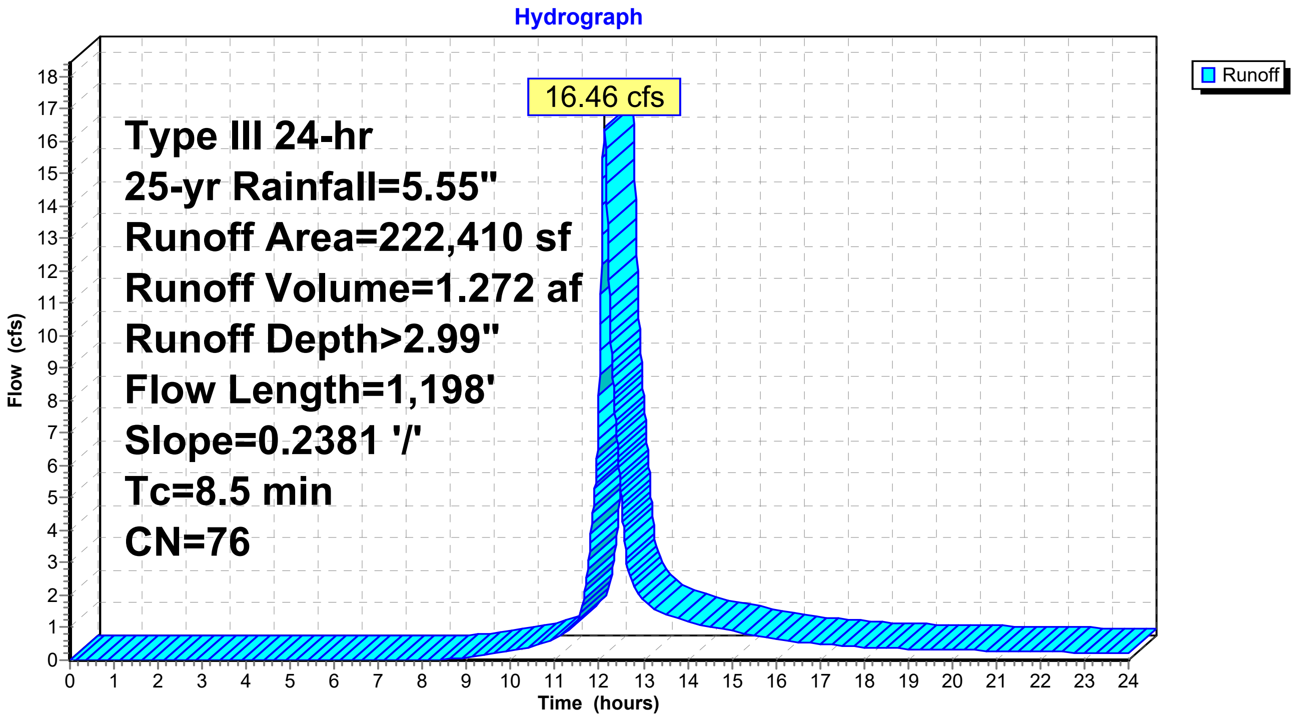
Runoff = 16.46 cfs @ 12.12 hrs, Volume= 1.272 af, Depth> 2.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
7,074	76	Gravel roads HSG A
24,840	89	Gravel roads HSG C
5,052	98	Unconnected pavement HSG C
2,607	39	>75% Grass cover, Good HSG A
182,835	74	>75% Grass cover, Good HSG C
222,410	76	Weighted Average
217,357		97.73% Pervious Area
5,052		2.27% Impervious Area
5,052		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.5	1,198	0.2381	2.35		**Lag/CN Method,**

Subcatchment A'2.1: A'2.1



Summary for Subcatchment A'2.2: A'2.2

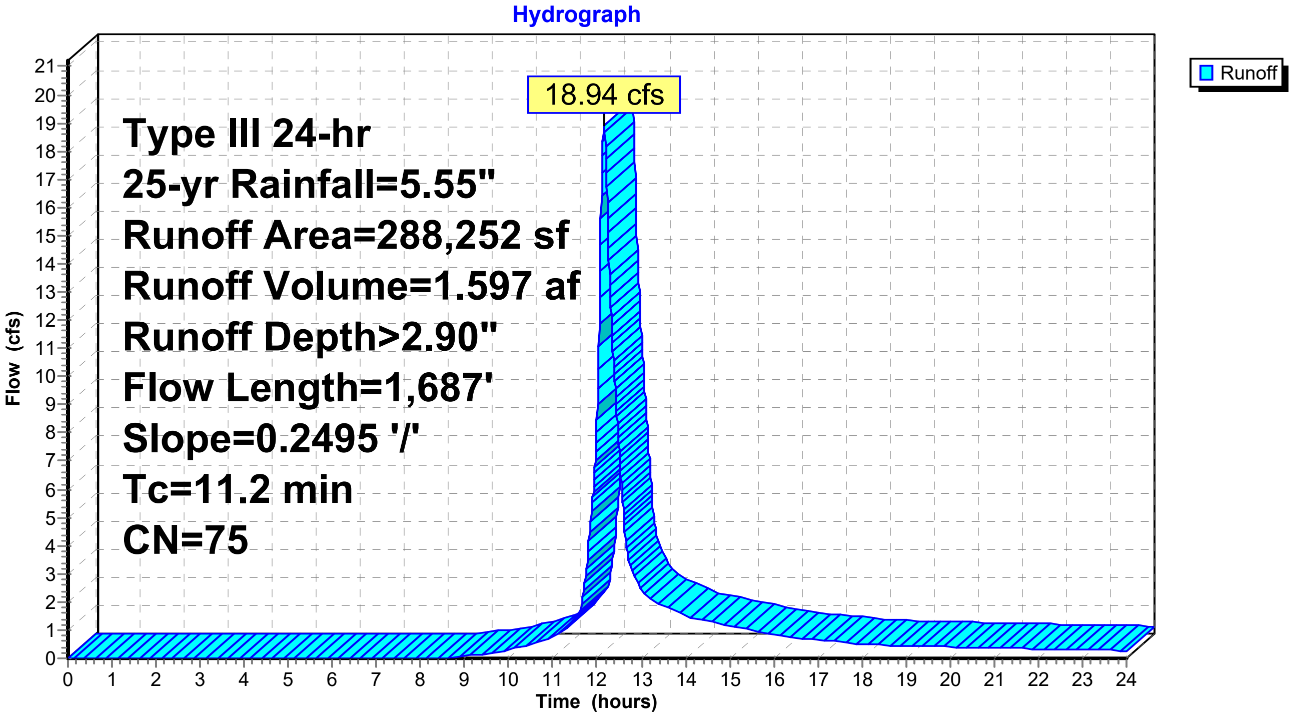
Runoff = 18.94 cfs @ 12.16 hrs, Volume= 1.597 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
15,419	89	Gravel roads HSG C
4,954	98	Unconnected pavement HSG C
267,880	74	>75% Grass cover, Good HSG C
288,252	75	Weighted Average
283,298		98.28% Pervious Area
4,954		1.72% Impervious Area
4,954		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	1,687	0.2495	2.50		**Lag/CN Method,**

Subcatchment A'2.2: A'2.2



Summary for Subcatchment A'2.3: A'2.3

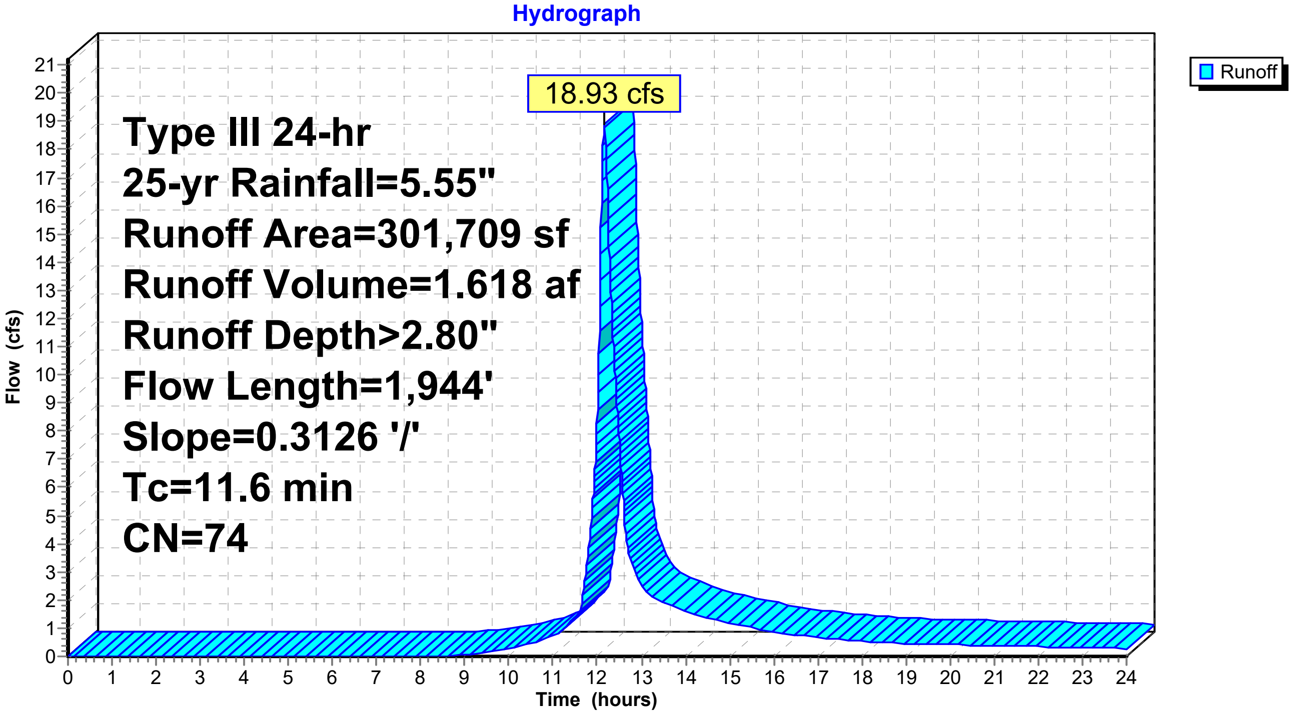
Runoff = 18.93 cfs @ 12.16 hrs, Volume= 1.618 af, Depth> 2.80"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
164	76	Gravel roads HSG A
4,164	89	Gravel roads HSG C
279,787	74	>75% Grass cover, Good HSG C
3,648	39	>75% Grass cover, Good HSG A
13,945	74	>75% Grass cover, Good HSG C
301,709	74	Weighted Average
301,709		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	1,944	0.3126	2.80		**Lag/CN Method,**

Subcatchment A'2.3: A'2.3



Summary for Subcatchment A'3.1: A'3.1

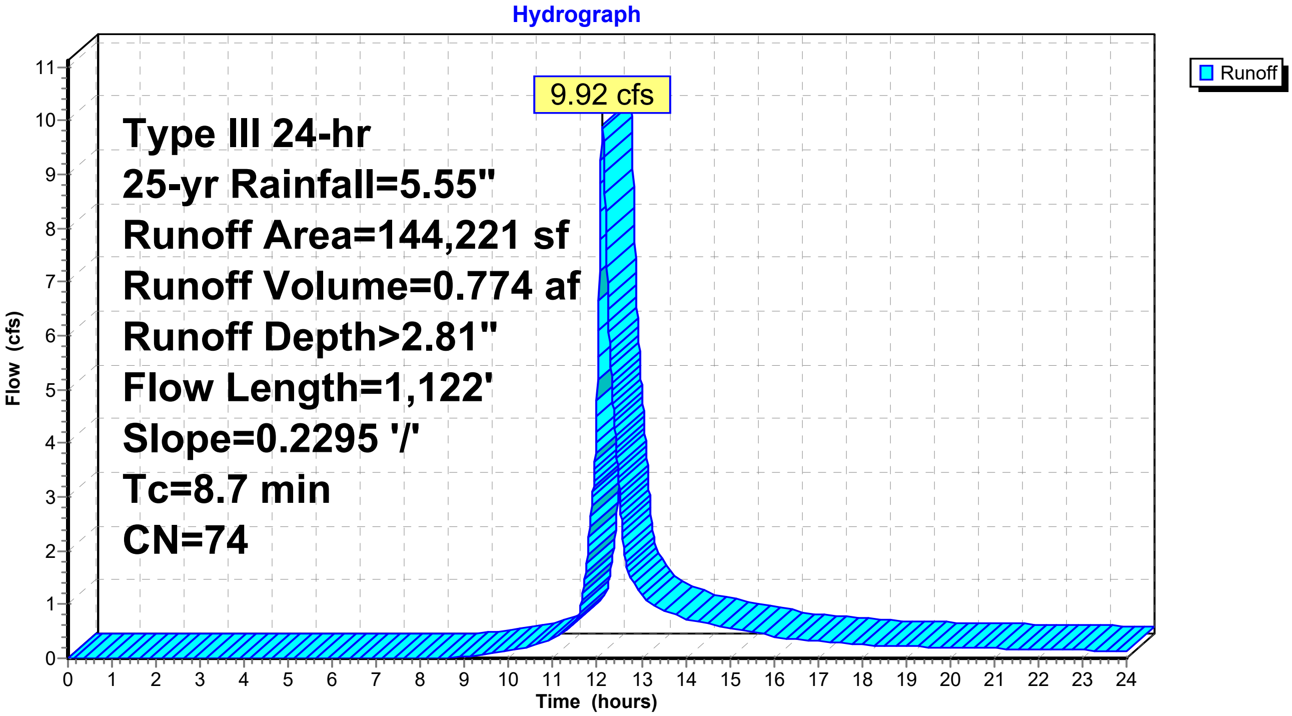
Runoff = 9.92 cfs @ 12.13 hrs, Volume= 0.774 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
139,893	74	>75% Grass cover, Good HSG C
2,604	89	Gravel roads HSG C
1,724	74	>75% Grass cover, Good HSG C
144,221	74	Weighted Average
144,221		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.7	1,122	0.2295	2.15		**Lag/CN Method,**

Subcatchment A'3.1: A'3.1



Summary for Subcatchment A'3.2: A'3.2

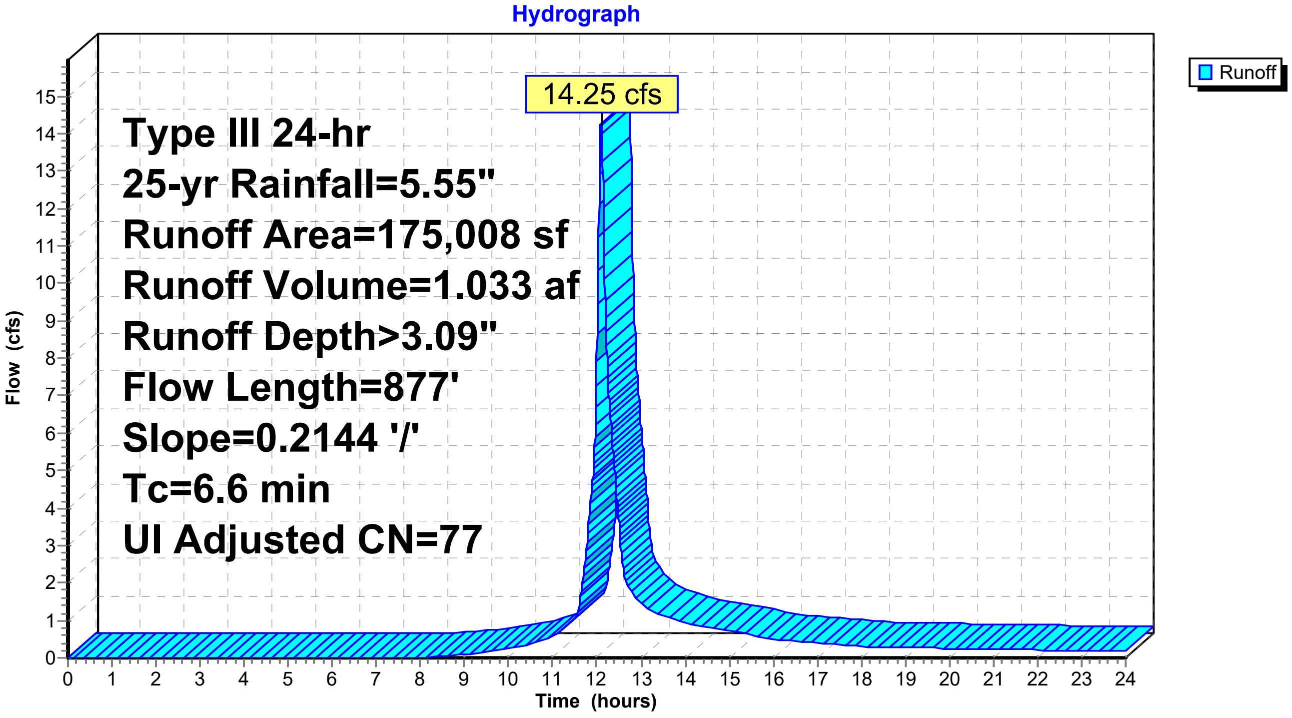
Runoff = 14.25 cfs @ 12.10 hrs, Volume= 1.033 af, Depth> 3.09"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
75,729	74		>75% Grass cover, Good HSG C
22,687	89		Gravel roads HSG C
13,108	98		Unconnected pavement HSG C
63,483	74		>75% Grass cover, Good HSG C
175,008	78	77	Weighted Average, UI Adjusted
161,899			92.51% Pervious Area
13,108			7.49% Impervious Area
13,108			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.6	877	0.2144	2.22		**Lag/CN Method,**

Subcatchment A'3.2: A'3.2



Summary for Subcatchment A'3.3: A'3.3

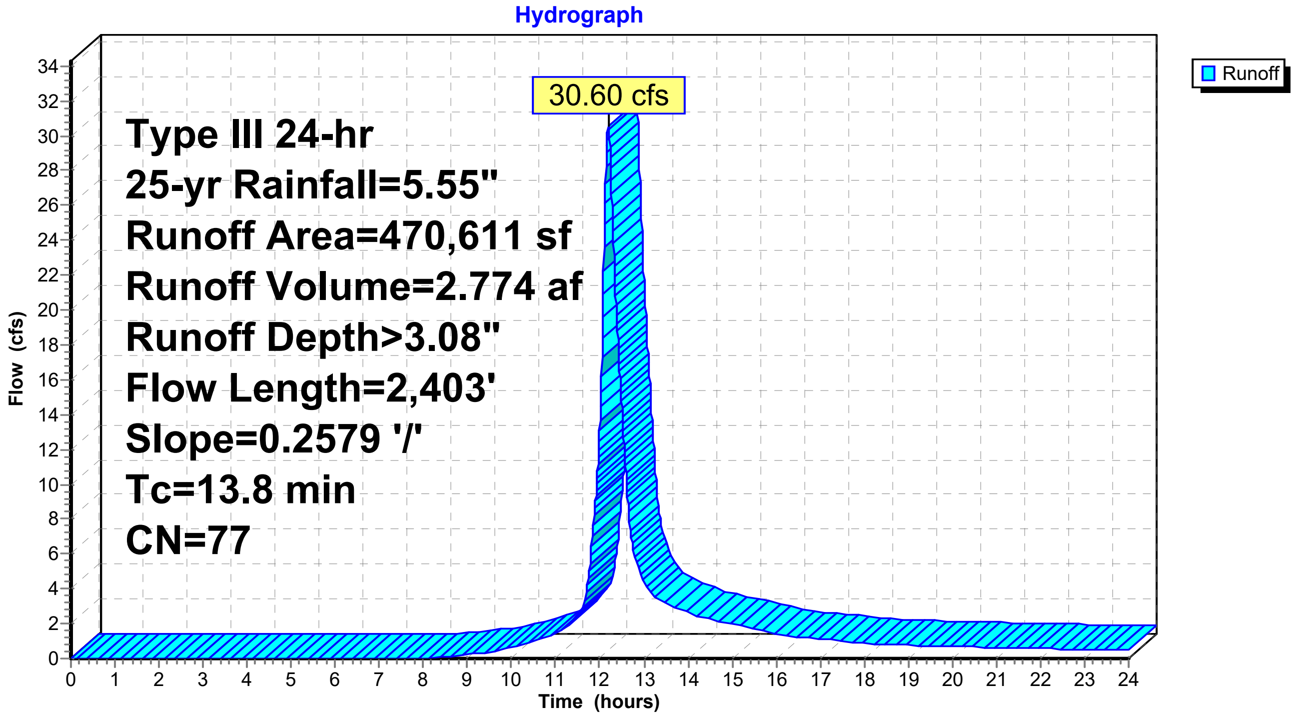
Runoff = 30.60 cfs @ 12.19 hrs, Volume= 2.774 af, Depth> 3.08"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
79,979	89	Gravel roads HSG C
390,633	74	>75% Grass cover, Good HSG C
470,611	77	Weighted Average
470,611		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.8	2,403	0.2579	2.90		**Lag/CN Method,**

Subcatchment A'3.3: A'3.3



Summary for Subcatchment A'3.4: A'3.4

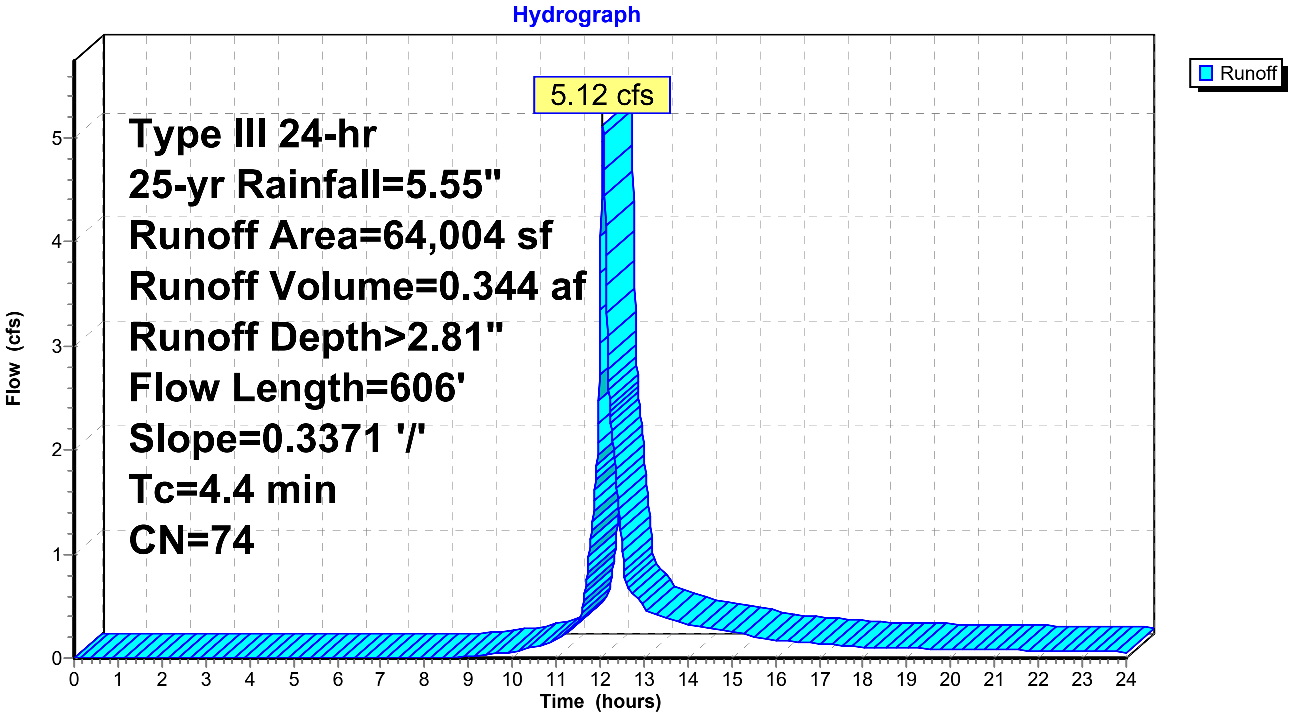
Runoff = 5.12 cfs @ 12.07 hrs, Volume= 0.344 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
64,004	74	>75% Grass cover, Good HSG C
64,004		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.4	606	0.3371	2.31		**Lag/CN Method,**

Subcatchment A'3.4: A'3.4



Summary for Subcatchment A'3.5: A'3.5

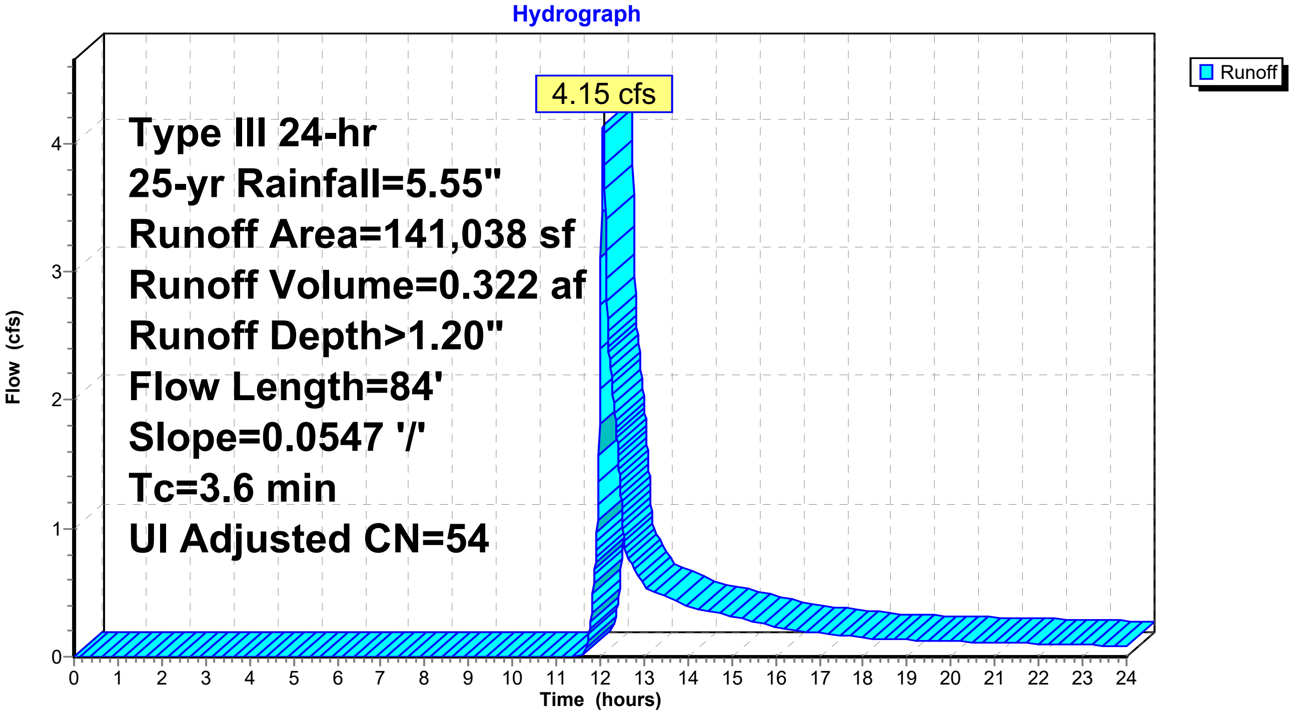
Runoff = 4.15 cfs @ 12.07 hrs, Volume= 0.322 af, Depth> 1.20"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
11,556	98		Unconnected pavement HSG C
1,043	74		>75% Grass cover, Good HSG C
5,785	89		Gravel roads HSG C
166	98		Unconnected pavement HSG A
2,800	30		Woods, Good HSG A
78,447	39		>75% Grass cover, Good HSG A
41,241	74		>75% Grass cover, Good HSG C
141,038	56	54	Weighted Average, UI Adjusted
129,316			91.69% Pervious Area
11,722			8.31% Impervious Area
11,722			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	84	0.0547	0.39		**Lag/CN Method,**

Subcatchment A'3.5: A'3.5



Summary for Subcatchment A'3.6: A'3.6

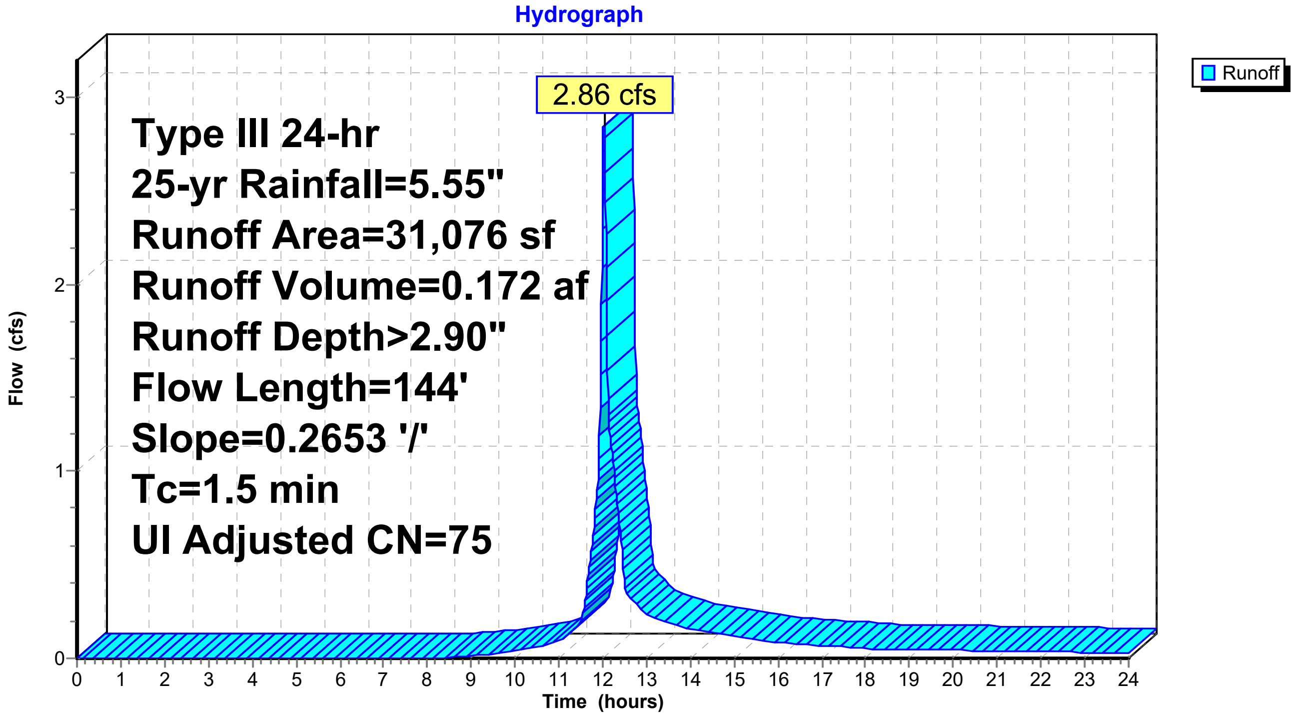
Runoff = 2.86 cfs @ 12.02 hrs, Volume= 0.172 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
23,729	74		>75% Grass cover, Good HSG C
2,061	98		Unconnected pavement HSG C
5,286	74		>75% Grass cover, Good HSG C
31,076	76	75	Weighted Average, UI Adjusted
29,015			93.37% Pervious Area
2,061			6.63% Impervious Area
2,061			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.5	144	0.2653	1.63		**Lag/CN Method,**

Subcatchment A'3.6: A'3.6



Summary for Subcatchment A'3.7: A'3.7

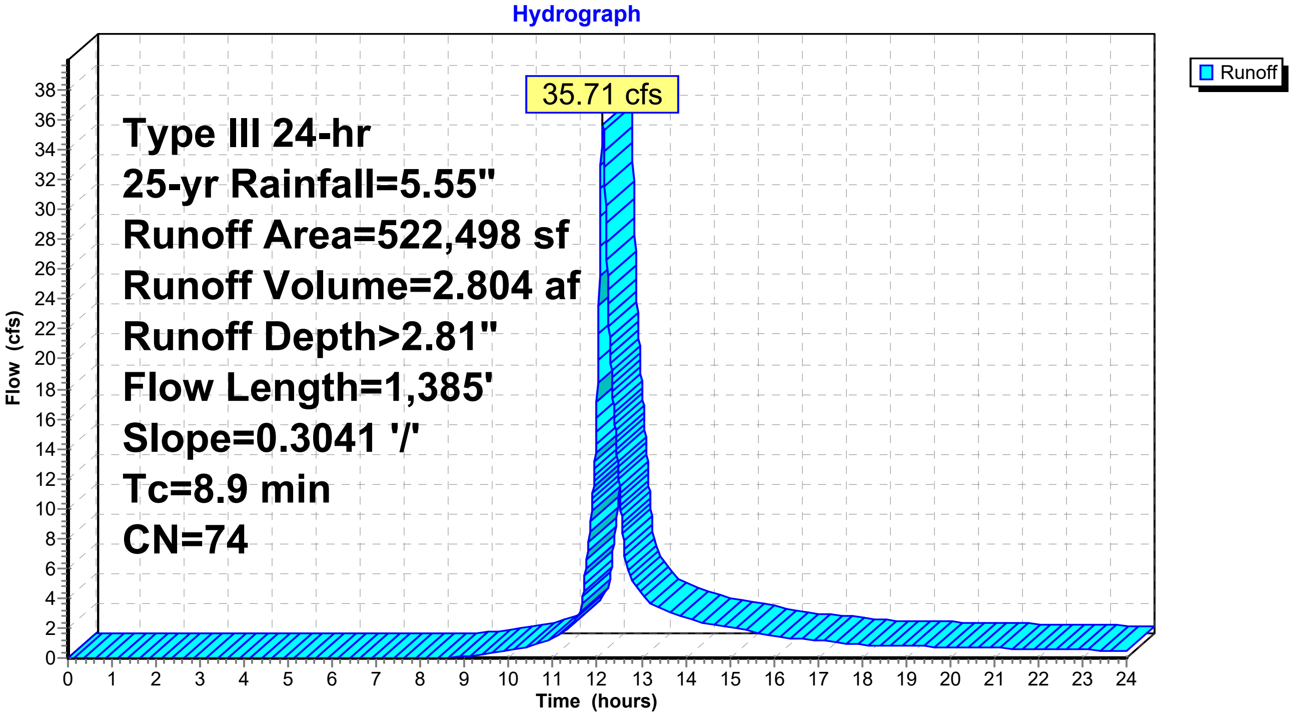
Runoff = 35.71 cfs @ 12.13 hrs, Volume= 2.804 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
205,958	74	>75% Grass cover, Good HSG C
316,540	74	>75% Grass cover, Good HSG C
522,498	74	Weighted Average
522,498		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.9	1,385	0.3041	2.58		**Lag/CN Method,**

Subcatchment A'3.7: A'3.7



Summary for Subcatchment A'4: A'4

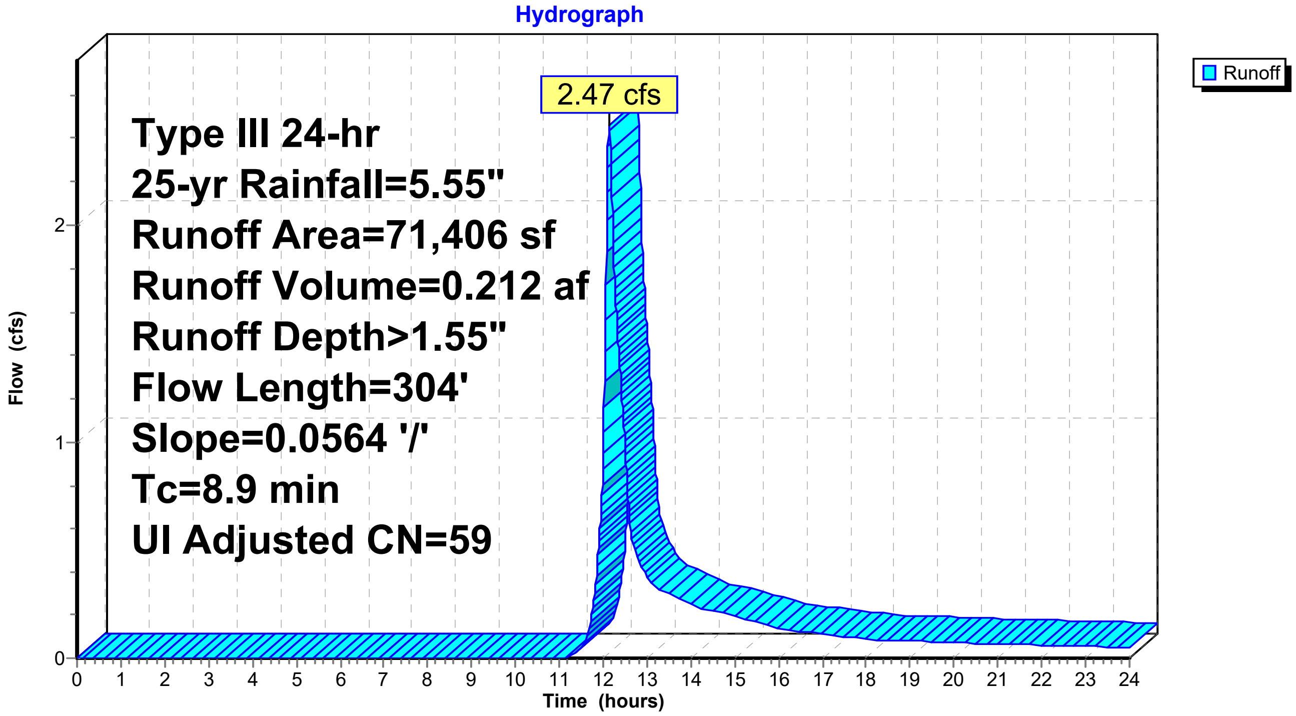
Runoff = 2.47 cfs @ 12.14 hrs, Volume= 0.212 af, Depth> 1.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Adj	Description
2,773	70		Woods, Good HSG C
4,240	89		Gravel roads HSG C
1,927	76		Gravel roads HSG A
5,080	98		Unconnected pavement HSG A
8,540	30		Woods, Good HSG A
2,046	73		Woods, Fair HSG C
22,175	39		>75% Grass cover, Good HSG A
24,627	74		>75% Grass cover, Good HSG C
71,406	60	59	Weighted Average, UI Adjusted
66,327			92.89% Pervious Area
5,080			7.11% Impervious Area
5,080			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.9	304	0.0564	0.57		**Lag/CN Method,**

Subcatchment A'4: A'4



Summary for Subcatchment C'1.1: C'1.1

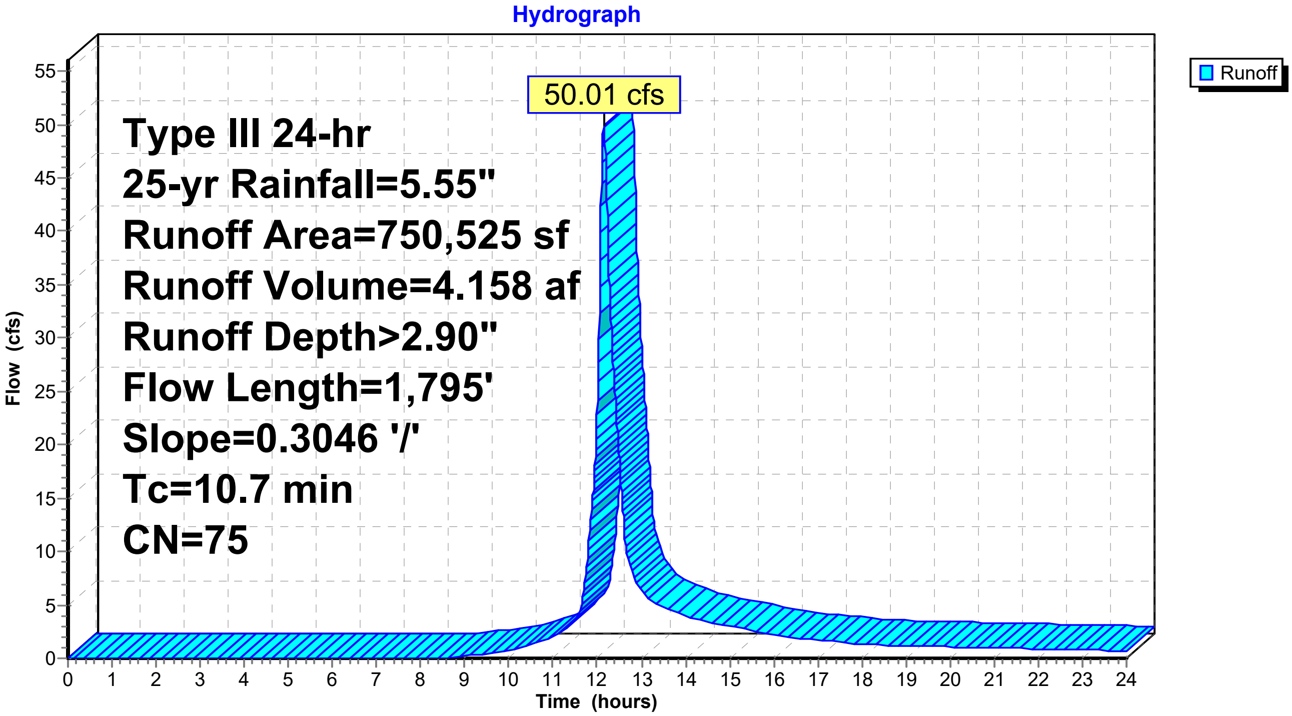
Runoff = 50.01 cfs @ 12.15 hrs, Volume= 4.158 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
26,158	89	Gravel roads HSG C
370,991	74	>75% Grass cover, Good HSG C
353,376	74	>75% Grass cover, Good HSG C
750,525	75	Weighted Average
750,525		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.7	1,795	0.3046	2.80		**Lag/CN Method,**

Subcatchment C'1.1: C'1.1



Summary for Subcatchment C'1.2: C'1.2

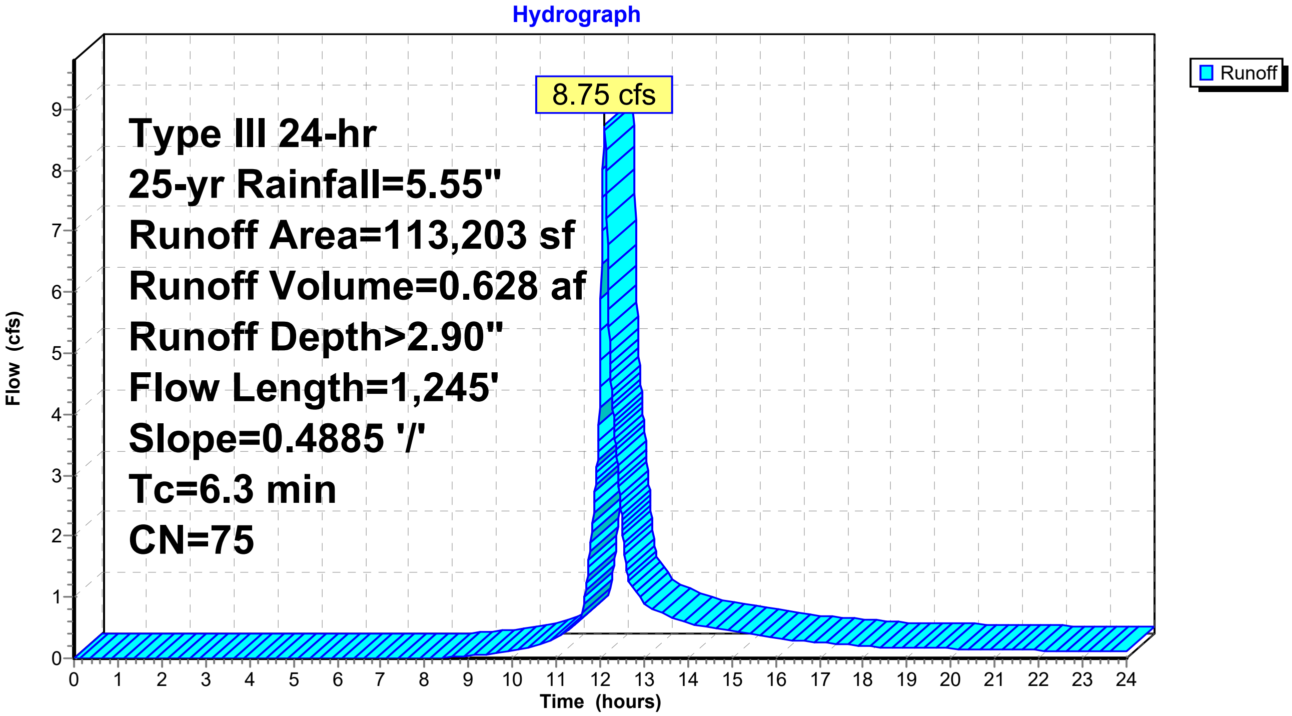
Runoff = 8.75 cfs @ 12.09 hrs, Volume= 0.628 af, Depth> 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
8,955	89	Gravel roads HSG C
84,135	74	>75% Grass cover, Good HSG C
20,113	74	>75% Grass cover, Good HSG C
113,203	75	Weighted Average
113,203		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.3	1,245	0.4885	3.30		**Lag/CN Method,**

Subcatchment C'1.2: C'1.2



Summary for Subcatchment C'1.3: C'1.3

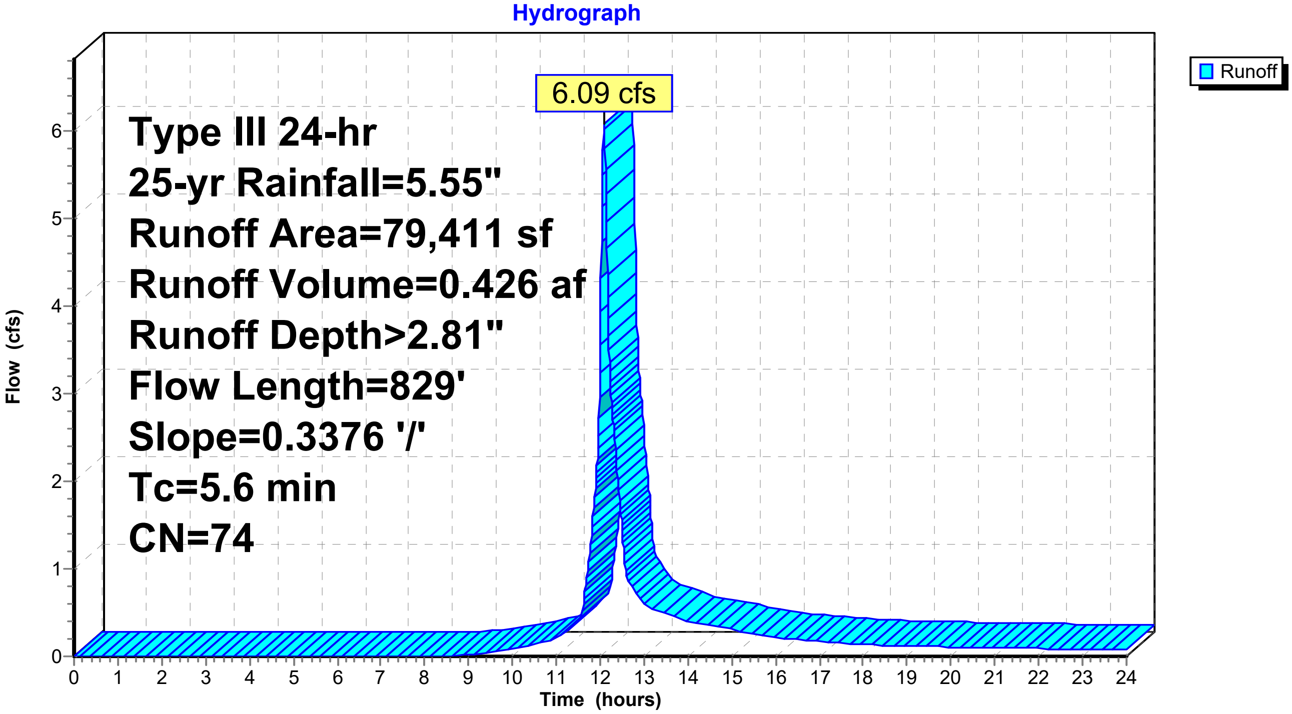
Runoff = 6.09 cfs @ 12.08 hrs, Volume= 0.426 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
79,411	74	>75% Grass cover, Good HSG C
79,411		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.6	829	0.3376	2.46		**Lag/CN Method,**

Subcatchment C'1.3: C'1.3



Summary for Subcatchment C'1.4: C'1.4

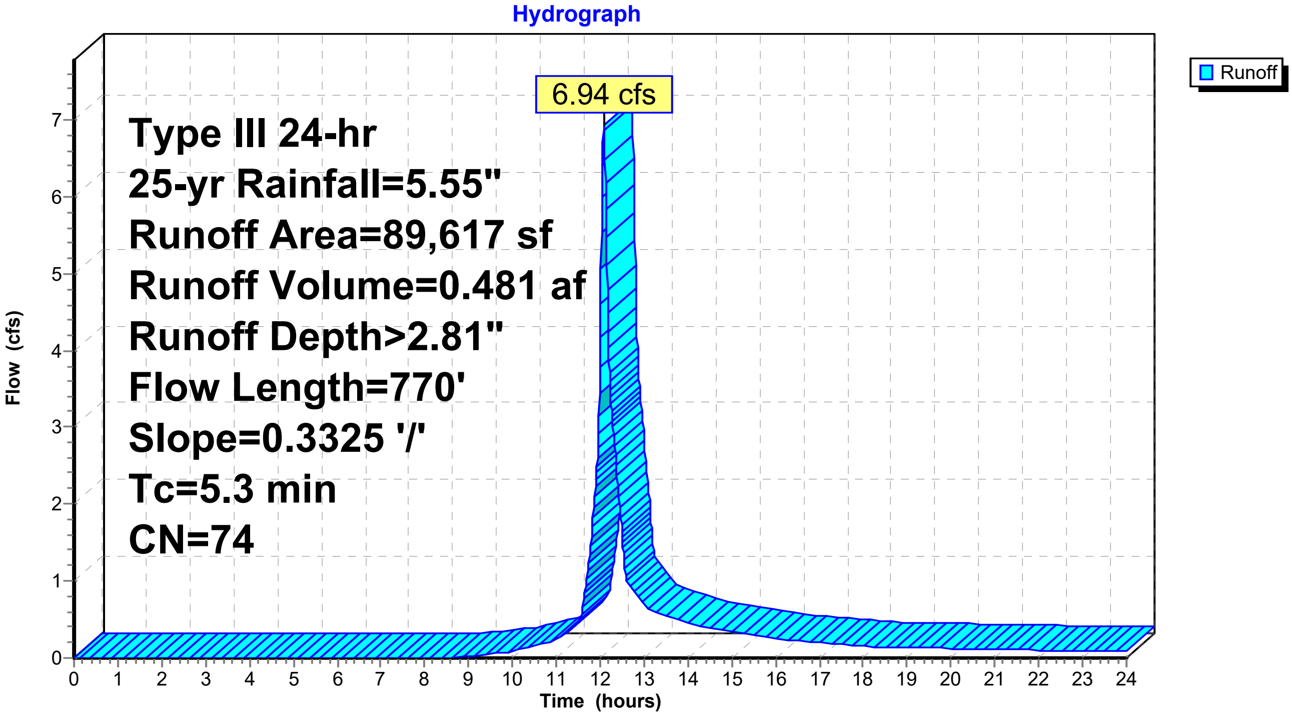
Runoff = 6.94 cfs @ 12.08 hrs, Volume= 0.481 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
643	74	>75% Grass cover, Good HSG C
88,974	74	>75% Grass cover, Good HSG C
89,617	74	Weighted Average
89,617		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.3	770	0.3325	2.40		**Lag/CN Method,**

Subcatchment C'1.4: C'1.4



Summary for Subcatchment C'1.5: C'1.5

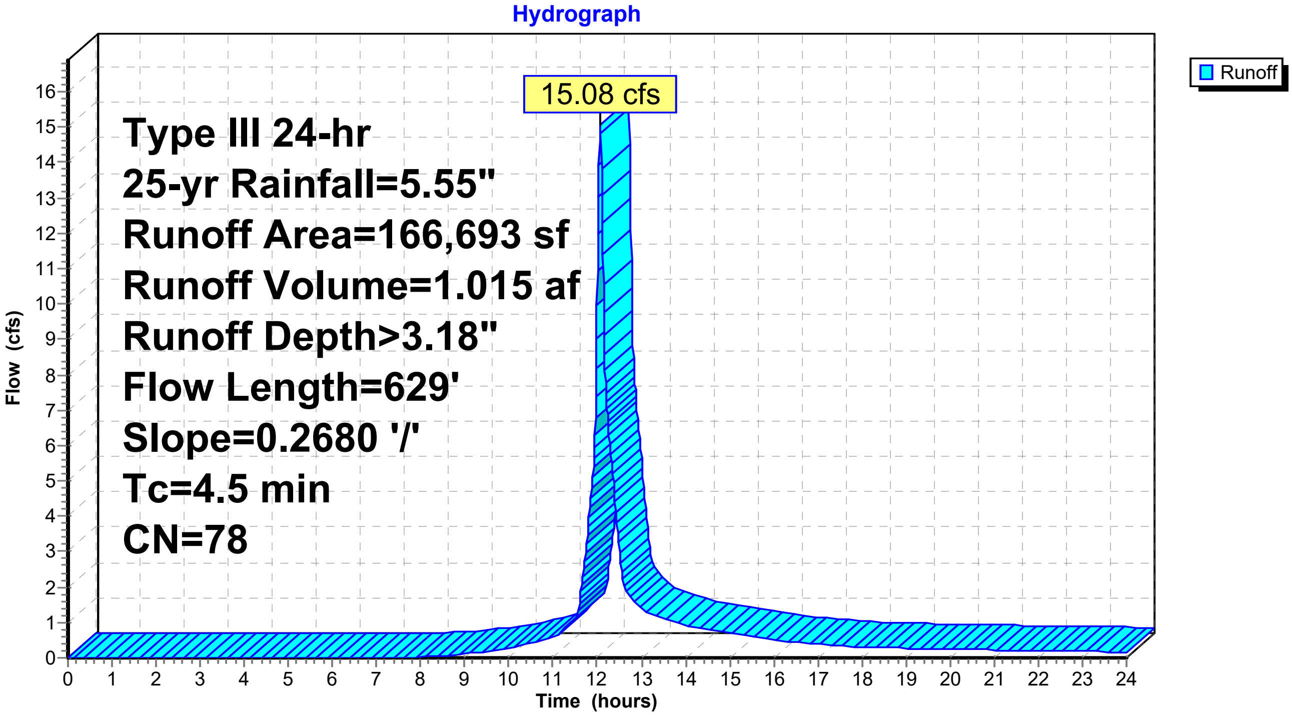
Runoff = 15.08 cfs @ 12.07 hrs, Volume= 1.015 af, Depth> 3.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
23,733	89	Gravel roads HSG C
14,125	70	Woods, Good HSG C
14,584	98	Water Surface HSG C
1,200	98	Roofs HSG C
113,050	74	>75% Grass cover, Good HSG C
166,693	78	Weighted Average
150,909		90.53% Pervious Area
15,784		9.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.5	629	0.2680	2.33		**Lag/CN Method,**

Subcatchment C'1.5: C'1.5



Summary for Reach 3R: Existing Swale

Inflow Area = 28.286 ac, 1.06% Impervious, Inflow Depth > 2.95" for 25-yr event
Inflow = 74.74 cfs @ 12.14 hrs, Volume= 6.946 af
Outflow = 73.47 cfs @ 12.17 hrs, Volume= 6.934 af, Atten= 2%, Lag= 1.5 min

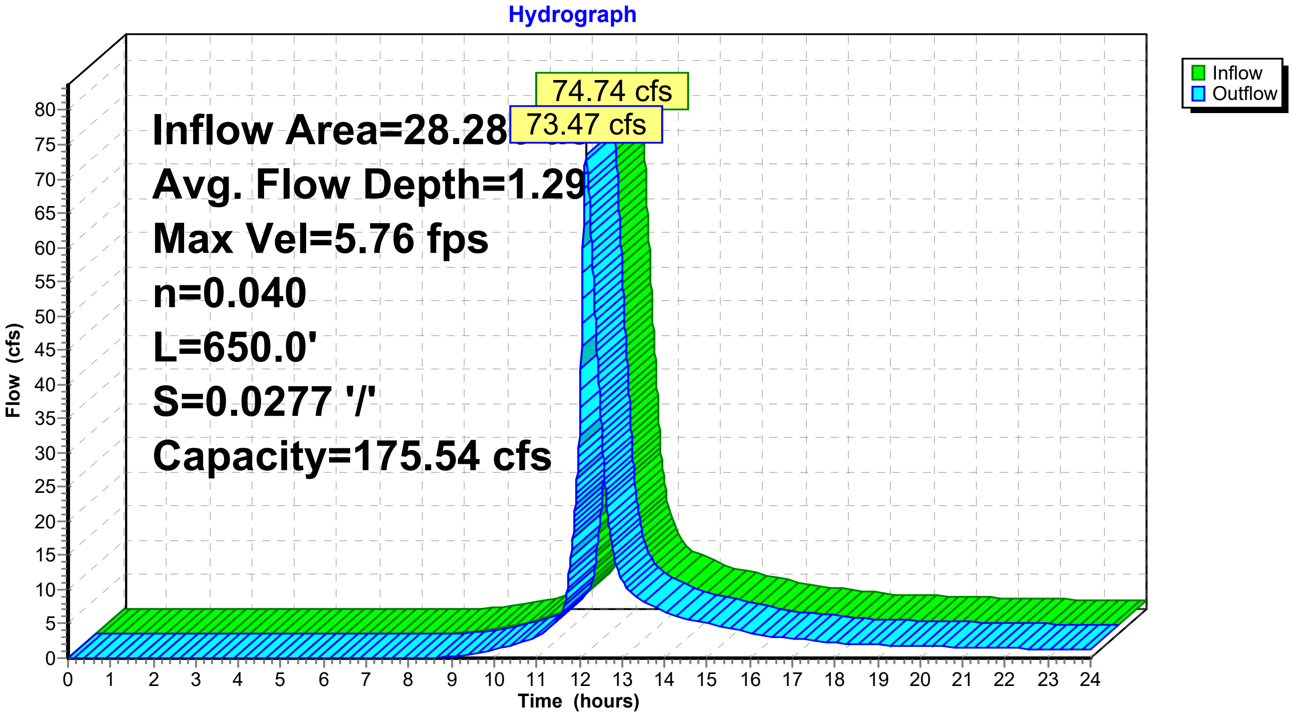
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.76 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 2.05 fps, Avg. Travel Time= 5.3 min

Peak Storage= 8,287 cf @ 12.17 hrs
Average Depth at Peak Storage= 1.29'
Bank-Full Depth= 2.00' Flow Area= 24.0 sf, Capacity= 175.54 cfs

6.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 650.0' Slope= 0.0277 '/'
Inlet Invert= 198.00', Outlet Invert= 180.00'

‡

Reach 3R: Existing Swale



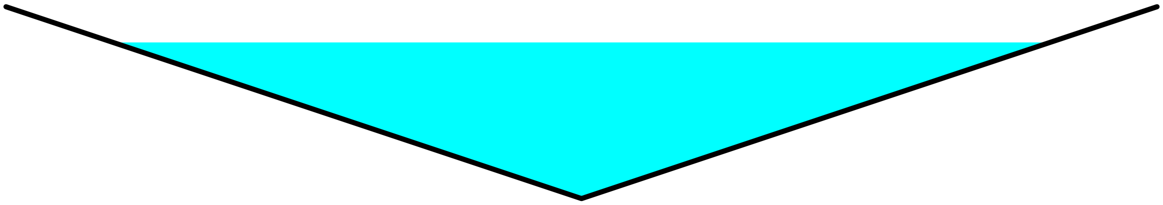
Summary for Reach 4R: Existing Swale

Inflow Area = 12.032 ac, 0.96% Impervious, Inflow Depth > 2.88" for 25-yr event
Inflow = 33.05 cfs @ 12.15 hrs, Volume= 2.888 af
Outflow = 27.77 cfs @ 12.24 hrs, Volume= 2.874 af, Atten= 16%, Lag= 5.4 min

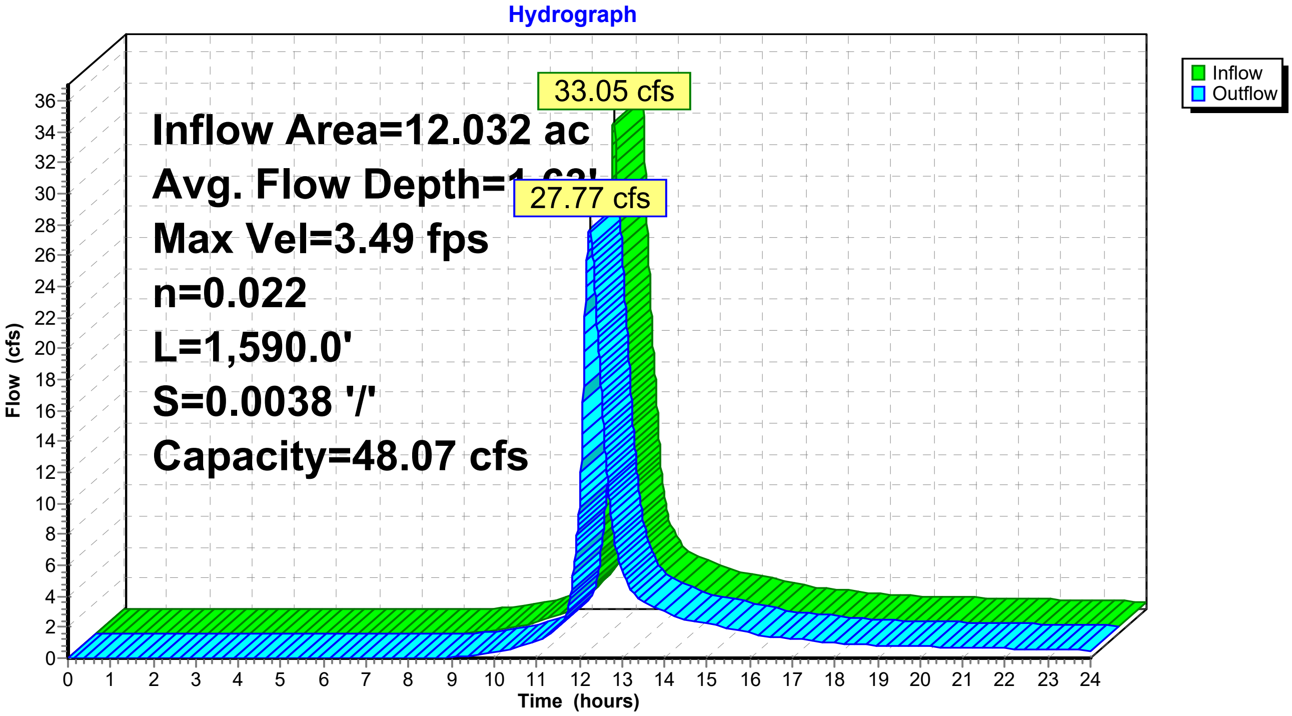
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.49 fps, Min. Travel Time= 7.6 min
Avg. Velocity = 1.58 fps, Avg. Travel Time= 16.8 min

Peak Storage= 12,641 cf @ 12.24 hrs
Average Depth at Peak Storage= 1.63'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 48.07 cfs

0.00' x 2.00' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 1,590.0' Slope= 0.0038 '/'
Inlet Invert= 184.00', Outlet Invert= 178.00'



Reach 4R: Existing Swale



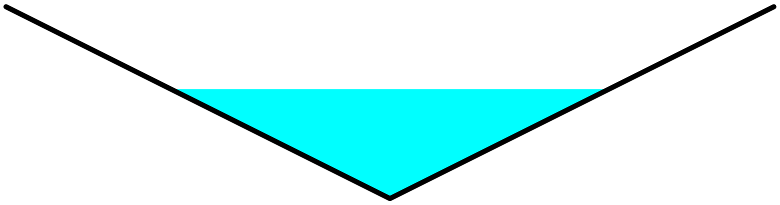
Summary for Reach 15R: Existing Roadside Swale

Inflow Area =	6.926 ac,	0.00% Impervious,	Inflow Depth > 2.80"	for 25-yr event	
Inflow =	18.93 cfs @	12.16 hrs,	Volume=	1.618 af	
Outflow =	18.40 cfs @	12.19 hrs,	Volume=	1.616 af,	Atten= 3%, Lag= 1.8 min

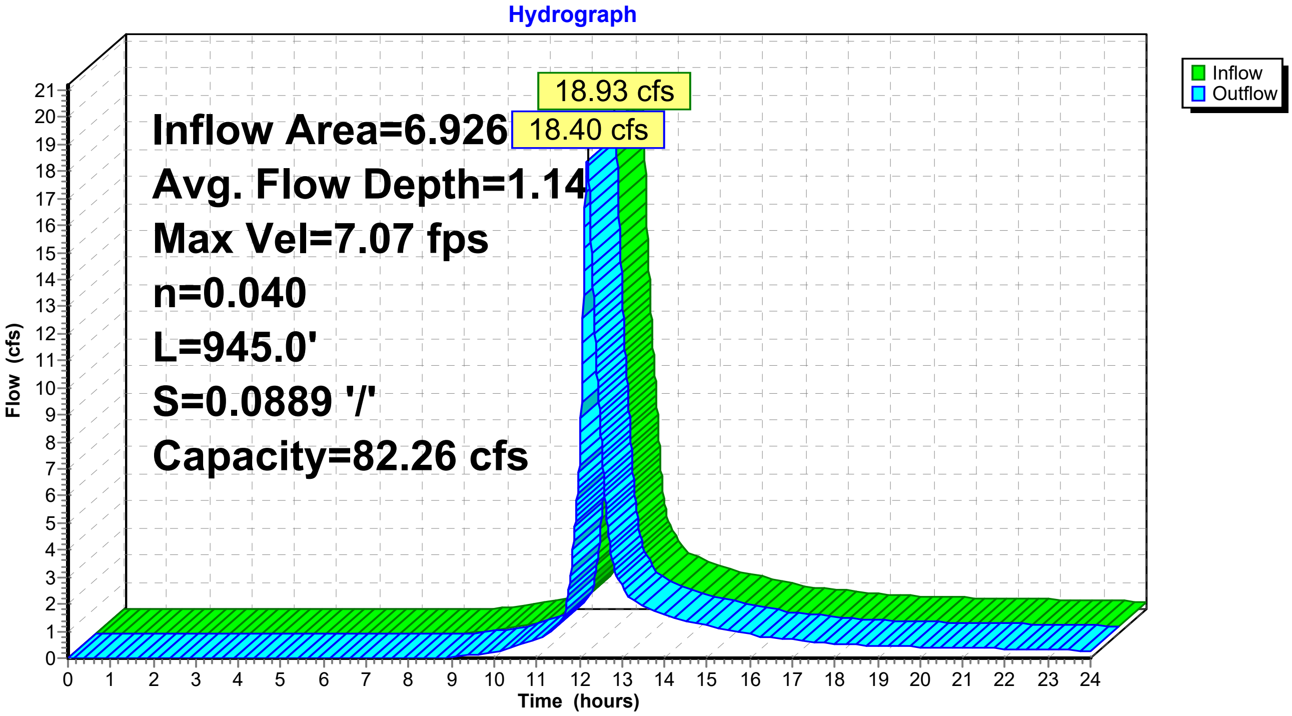
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.07 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 3.13 fps, Avg. Travel Time= 5.0 min

Peak Storage= 2,459 cf @ 12.19 hrs
Average Depth at Peak Storage= 1.14'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 82.26 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 945.0' Slope= 0.0889 '/'
Inlet Invert= 288.00', Outlet Invert= 204.00'



Reach 15R: Existing Roadside Swale



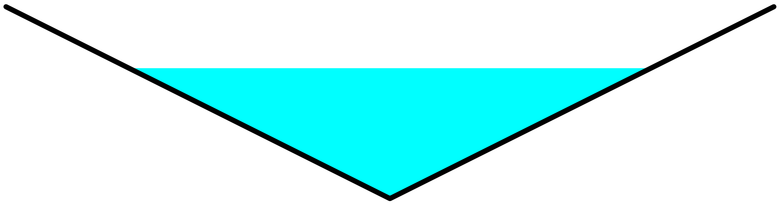
Summary for Reach 16R: Proposed Roadside Swale

Inflow Area = 10.804 ac, 0.00% Impervious, Inflow Depth > 3.08" for 25-yr event
Inflow = 30.60 cfs @ 12.19 hrs, Volume= 2.774 af
Outflow = 28.84 cfs @ 12.24 hrs, Volume= 2.767 af, Atten= 6%, Lag= 2.9 min

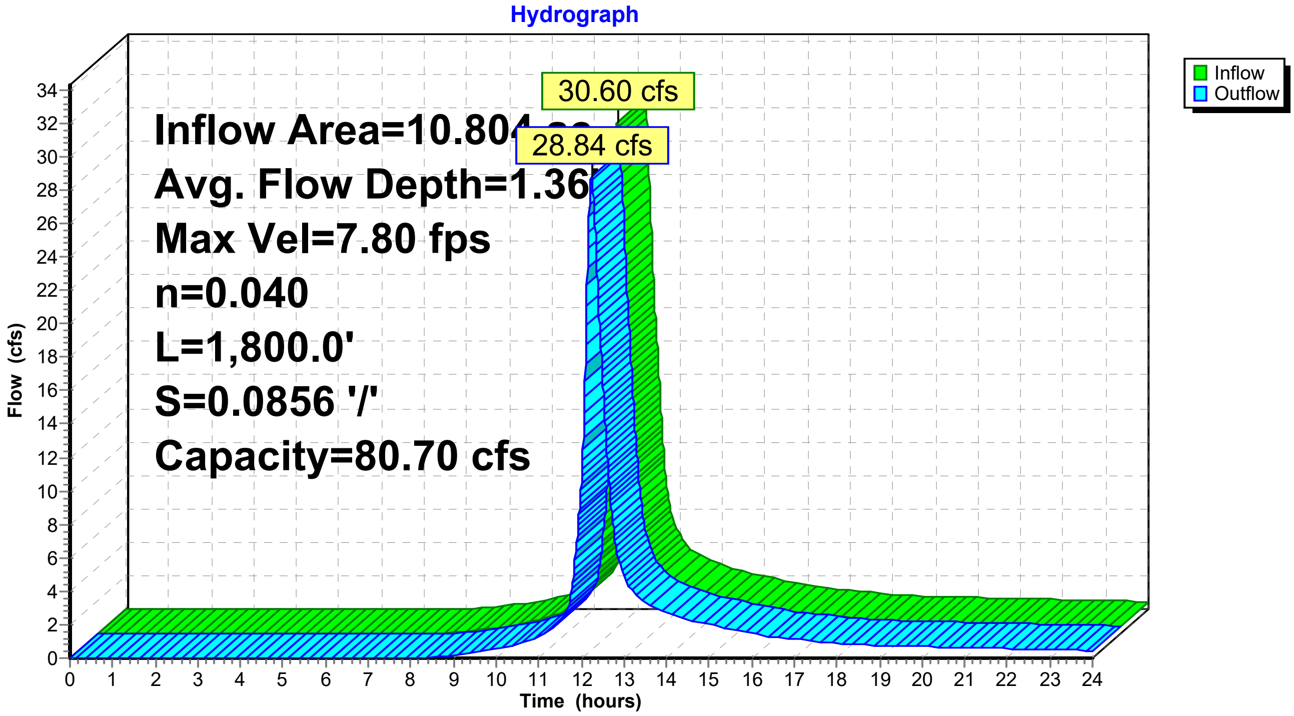
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.80 fps, Min. Travel Time= 3.8 min
Avg. Velocity = 3.46 fps, Avg. Travel Time= 8.7 min

Peak Storage= 6,656 cf @ 12.24 hrs
Average Depth at Peak Storage= 1.36'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 80.70 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 1,800.0' Slope= 0.0856 '/'
Inlet Invert= 366.00', Outlet Invert= 212.00'



Reach 16R: Proposed Roadside Swale



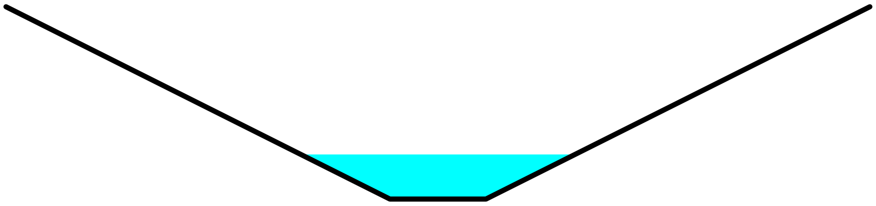
Summary for Reach 17R: Proposed Perimeter Swale

Inflow Area = 1.469 ac, 0.00% Impervious, Inflow Depth > 2.81" for 25-yr event
Inflow = 5.12 cfs @ 12.07 hrs, Volume= 0.344 af
Outflow = 4.91 cfs @ 12.09 hrs, Volume= 0.343 af, Atten= 4%, Lag= 1.3 min

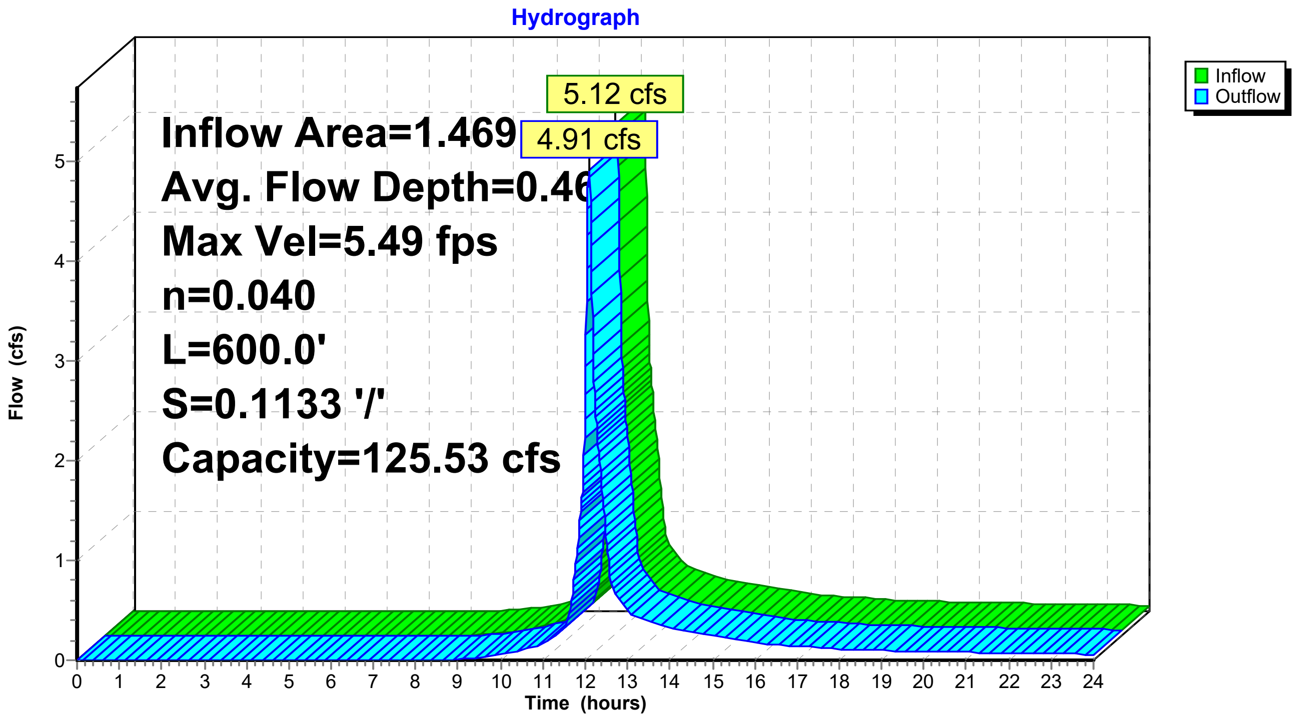
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.49 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.95 fps, Avg. Travel Time= 5.1 min

Peak Storage= 536 cf @ 12.09 hrs
Average Depth at Peak Storage= 0.46'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 125.53 cfs

1.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 600.0' Slope= 0.1133 '/'
Inlet Invert= 320.00', Outlet Invert= 252.00'



Reach 17R: Proposed Perimeter Swale



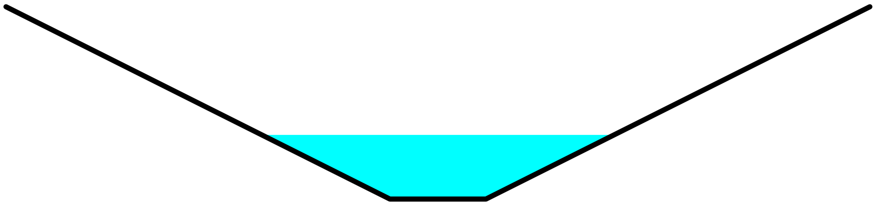
Summary for Reach 18R: Proposed Perimeter Swale

Inflow Area = 1.823 ac, 0.00% Impervious, Inflow Depth > 2.81" for 25-yr event
Inflow = 6.09 cfs @ 12.08 hrs, Volume= 0.426 af
Outflow = 5.36 cfs @ 12.13 hrs, Volume= 0.425 af, Atten= 12%, Lag= 2.6 min

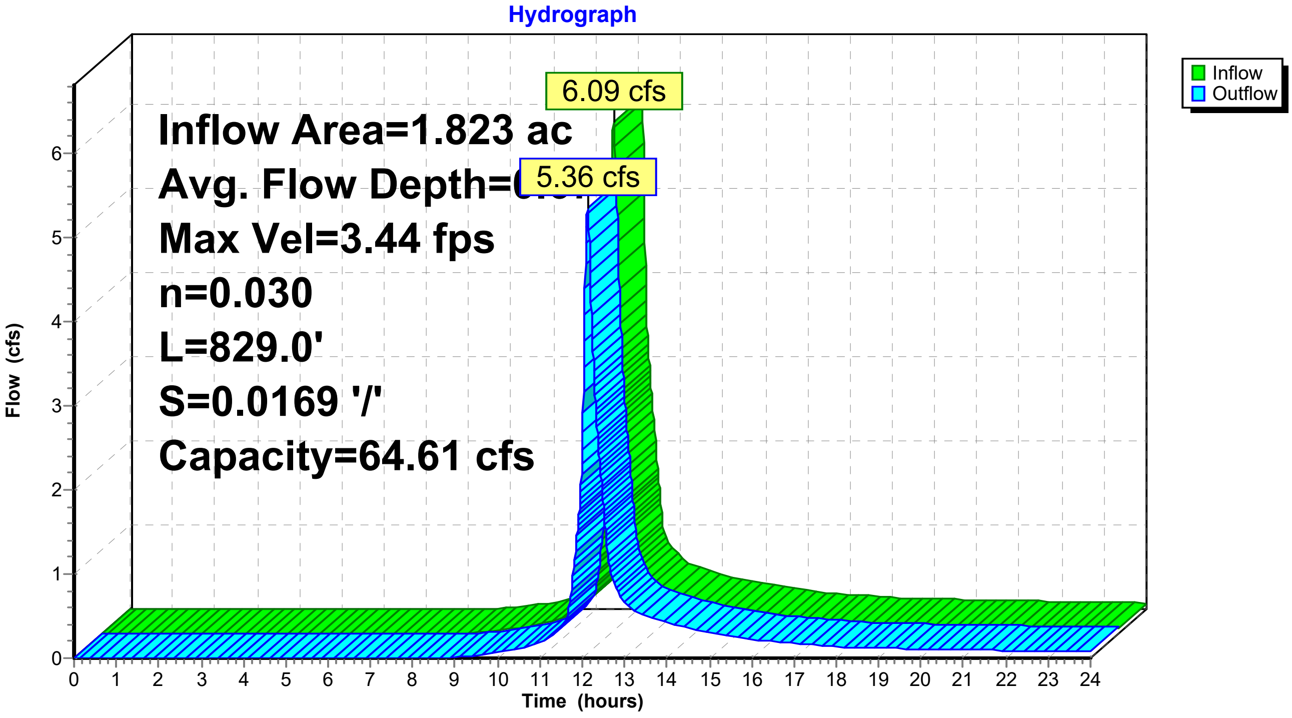
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.44 fps, Min. Travel Time= 4.0 min
Avg. Velocity = 1.33 fps, Avg. Travel Time= 10.4 min

Peak Storage= 1,291 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.67'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 64.61 cfs

1.00' x 2.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 829.0' Slope= 0.0169 '/'
Inlet Invert= 320.00', Outlet Invert= 306.00'



Reach 18R: Proposed Perimeter Swale



Summary for Reach 19R: Proposed Perimeter Swale

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Inflow Area =       3.880 ac,   0.00% Impervious,  Inflow Depth >   2.80"   for  25-yr event
Inflow      =      11.87 cfs @  12.10 hrs,  Volume=           0.906 af
Outflow     =      11.82 cfs @  12.11 hrs,  Volume=           0.906 af,  Atten= 0%,  Lag= 0.5 min
```
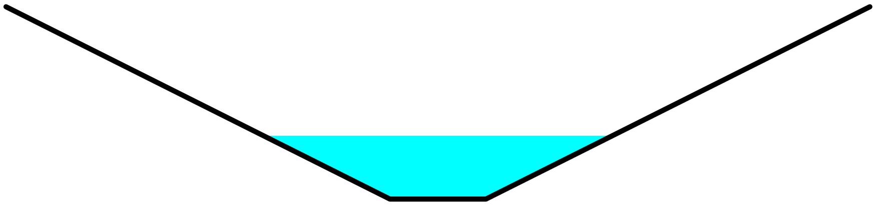
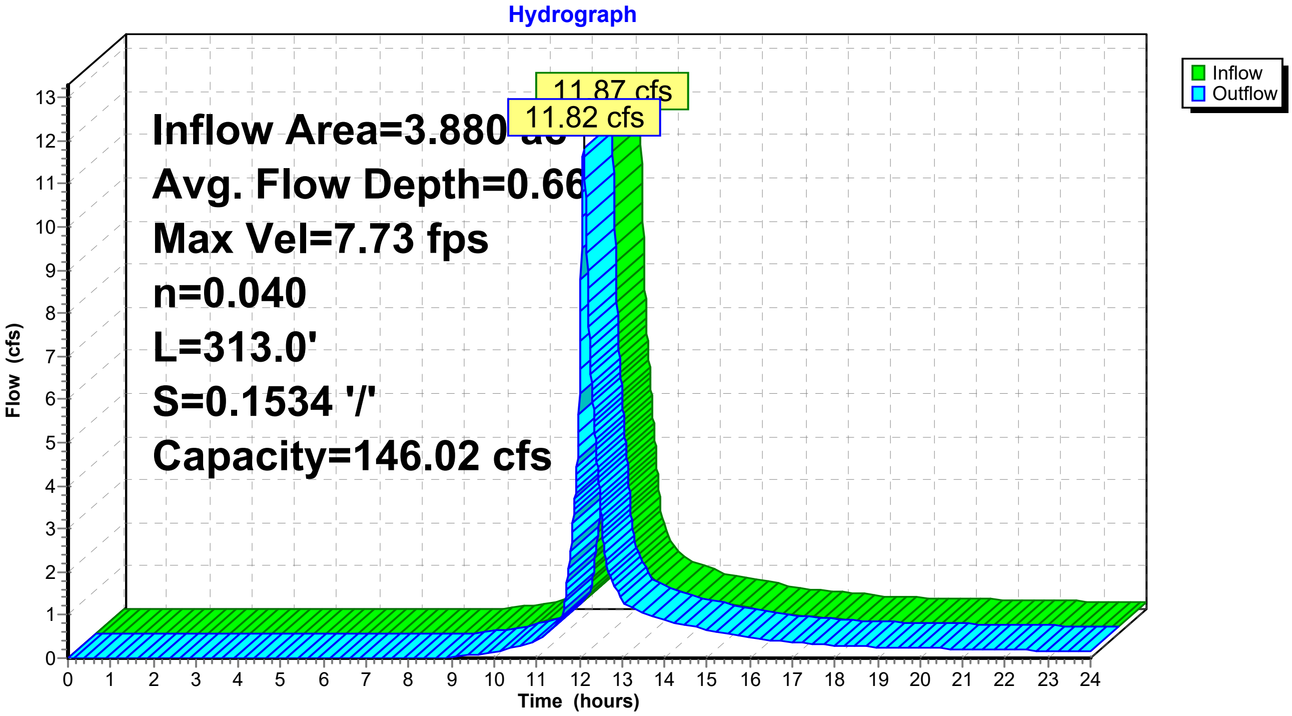

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.73 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 2.94 fps, Avg. Travel Time= 1.8 min

Peak Storage= 479 cf @ 12.11 hrs
Average Depth at Peak Storage= 0.66'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 146.02 cfs

1.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 313.0' Slope= 0.1534 '/'
Inlet Invert= 288.00', Outlet Invert= 240.00'



Reach 19R: Proposed Perimeter Swale



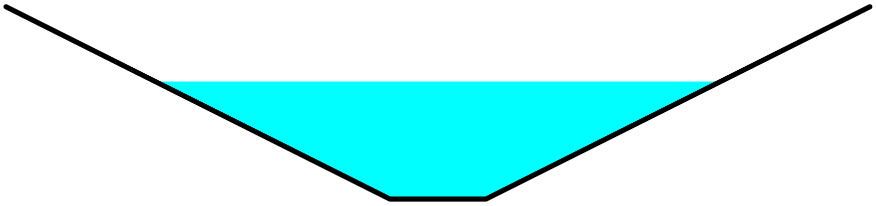
Summary for Reach 20R: Proposed Perimeter Swale (Bottom of Slope Portion)

Inflow Area =	3.880 ac,	0.00% Impervious, Inflow Depth >	2.80"	for 25-yr event
Inflow =	11.82 cfs @	12.11 hrs, Volume=	0.906 af	
Outflow =	11.78 cfs @	12.11 hrs, Volume=	0.905 af, Atten= 0%, Lag= 0.5 min	

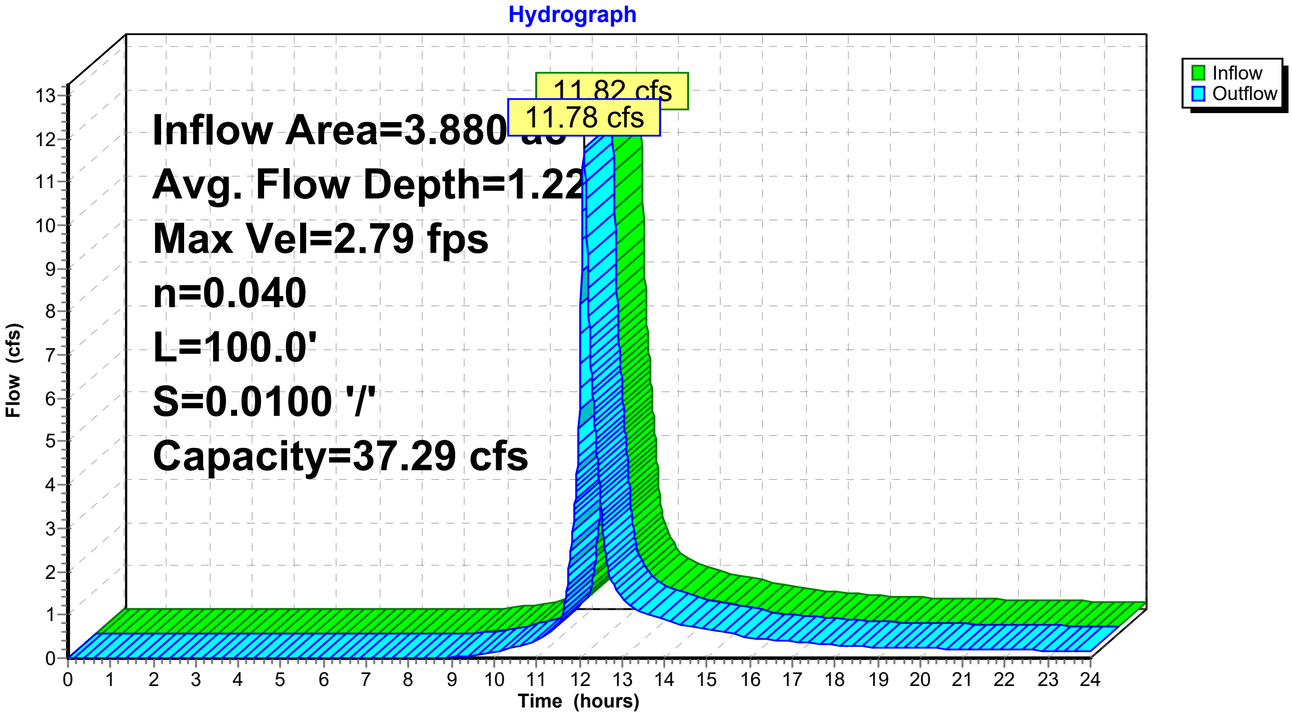
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.79 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.13 fps, Avg. Travel Time= 1.5 min

Peak Storage= 422 cf @ 12.11 hrs
Average Depth at Peak Storage= 1.22'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 37.29 cfs

1.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 100.0' Slope= 0.0100 '/'
Inlet Invert= 240.00', Outlet Invert= 239.00'



Reach 20R: Proposed Perimeter Swale (Bottom of Slope Portion)



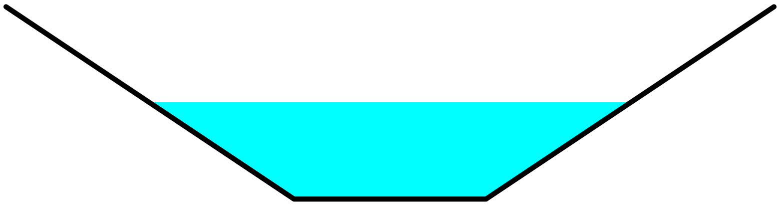
Summary for Reach 22R: Proposed Gabion-Lined Swale (Bottom of Slope Portion)

```
Inflow Area =        13.464 ac,   0.00% Impervious,  Inflow Depth >   2.80"    for  25-yr event
Inflow      =       40.20 cfs @   12.12 hrs,  Volume=           3.147 af
Outflow     =       40.17 cfs @   12.13 hrs,  Volume=           3.146 af,  Atten= 0%,  Lag= 0.2 min
```

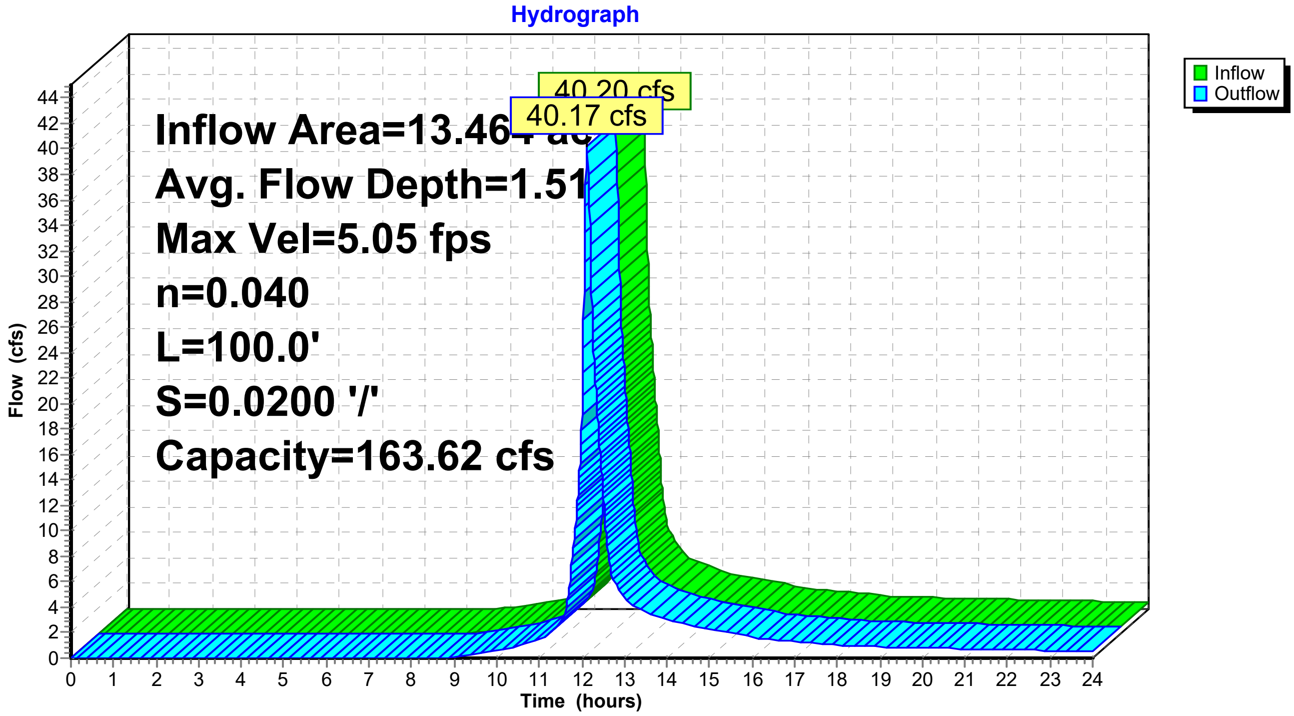
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.05 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.81 fps, Avg. Travel Time= 0.9 min

Peak Storage= 796 cf @ 12.13 hrs
Average Depth at Peak Storage= 1.51'
Bank-Full Depth= 3.00' Flow Area= 22.5 sf, Capacity= 163.62 cfs

3.00' x 3.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 1.5 '/' Top Width= 12.00'
Length= 100.0' Slope= 0.0200 '/'
Inlet Invert= 212.00', Outlet Invert= 210.00'



Reach 22R: Proposed Gabion-Lined Swale (Bottom of Slope Portion)



Summary for Pond 2P: Existing Pond 2 w/ Modified Outlet

Inflow Area = 64.678 ac, 1.49% Impervious, Inflow Depth > 2.54" for 25-yr event
Inflow = 134.05 cfs @ 12.17 hrs, Volume= 13.708 af
Outflow = 10.83 cfs @ 14.92 hrs, Volume= 9.427 af, Atten= 92%, Lag= 165.0 min
Primary = 10.83 cfs @ 14.92 hrs, Volume= 9.427 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Starting Elev= 176.90' Surf.Area= 0 sf Storage= 123,527 cf
Peak Elev= 180.16' @ 14.92 hrs Surf.Area= 0 sf Storage= 460,932 cf (337,405 cf above start)
Flood Elev= 181.50' Surf.Area= 0 sf Storage= 654,228 cf (530,701 cf above start)

Plug-Flow detention time= 440.9 min calculated for 6.588 af (48% of inflow)
Center-of-Mass det. time= 218.2 min (1,061.1 - 842.9)

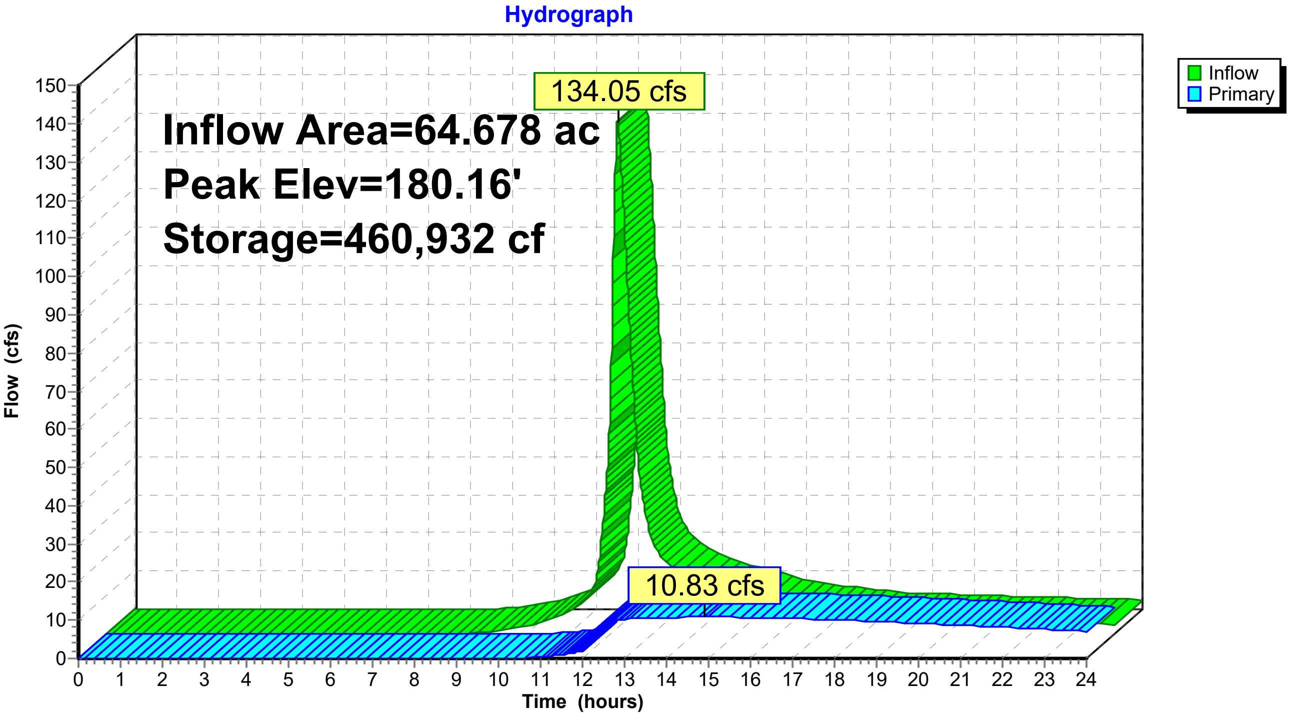
Volume	Invert	Avail.Storage	Storage Description
#1	174.00'	654,228 cf	**Custom Stage Data** Listed below

Elevation (feet)	Cum.Store (cubic-feet)
174.00	0
176.75	113,517
177.25	146,884
177.75	183,300
178.25	234,440
179.00	319,208
179.50	379,233
180.00	438,083
181.00	579,522
181.50	654,228

Device	Routing	Invert	Outlet Devices
#1	Primary	176.90'	**24.0" Round Culvert** L= 137.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 176.90' / 176.20' S= 0.0051 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf
#2	Device 1	176.90'	**12.0" W x 6.0" H Vert. Orifice/Grate** C= 0.600
#3	Device 1	178.00'	**12.0" W x 6.0" H Vert. Orifice/Grate X 2.00** C= 0.600
#4	Device 1	181.25'	**48.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=10.83 cfs @ 14.92 hrs HW=180.16' (Free Discharge)
└─**1=Culvert** (Passes 10.83 cfs of 20.54 cfs potential flow)
  ├─**2=Orifice/Grate** (Orifice Controls 4.18 cfs @ 8.35 fps)
  ├─**3=Orifice/Grate** (Orifice Controls 6.65 cfs @ 6.65 fps)
  └─**4=Orifice/Grate** (Controls 0.00 cfs)

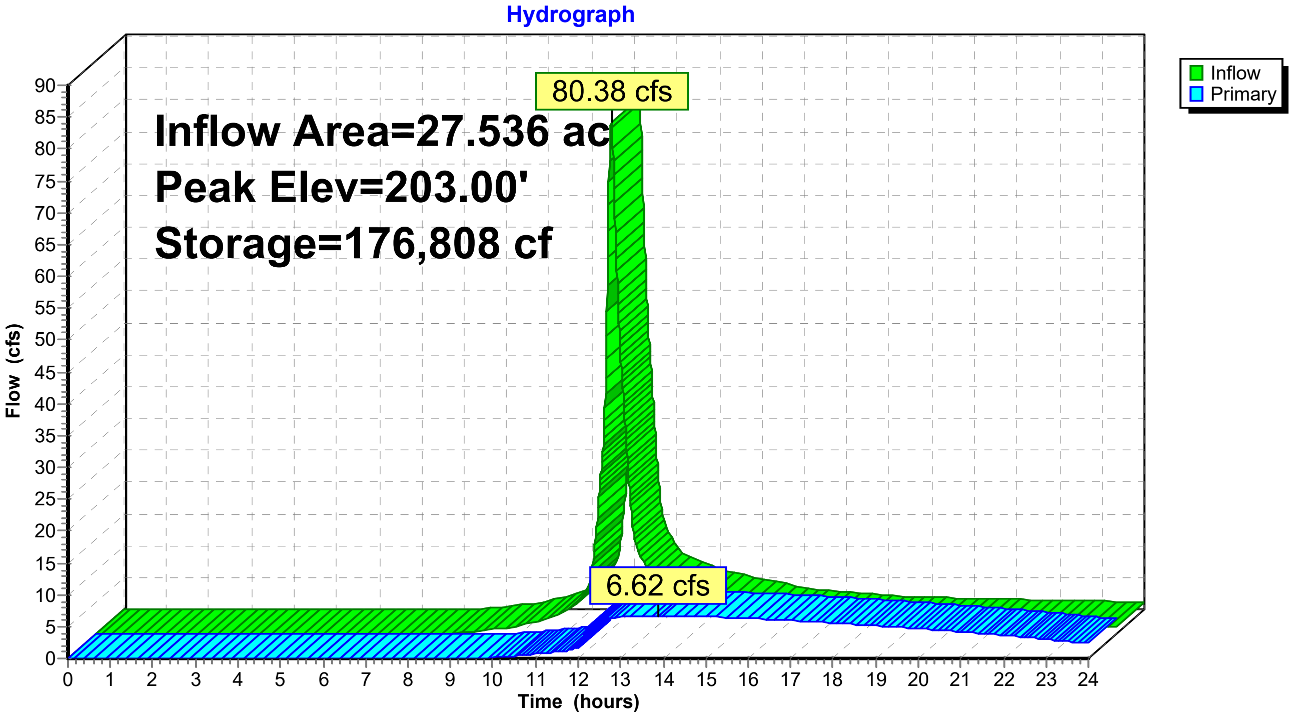
Pond 2P: Existing Pond 2 w/ Modified Outlet



Summary for Pond 4P: Existing Pond 4 w/ Modified Outlet

```
Inflow Area =      27.536 ac,   1.32% Impervious,  Inflow Depth >   2.92"    for  25-yr event
Inflow      =     80.38 cfs @   12.12 hrs,  Volume=           6.706 af
Outflow     =      6.62 cfs @   13.90 hrs,  Volume=           5.221 af,  Atten= 92%,  Lag= 106.6 min
Primary     =      6.62 cfs @   13.90 hrs,  Volume=           5.221 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Starting Elev= 196.50'   Surf.Area= 14,584 sf   Storage= 21,627 cf
Peak Elev= 203.00' @ 13.90 hrs   Surf.Area= 30,966 sf   Storage= 176,808 cf   (155,181 cf above start)
Flood Elev= 208.00'   Surf.Area= 41,741 sf   Storage= 358,071 cf   (336,443 cf above start)

Plug-Flow detention time= 322.0 min calculated for 4.723 af (70% of inflow)
Center-of-Mass det. time= 195.3 min ( 1,026.4 - 831.1 )

Volume       Invert     Avail.Storage   Storage Description
   #1       194.00'       358,071 cf    Custom Stage Data (Irregular) Listed below (Recalc)

 Elevation        Surf.Area     Perim.        Inc.Store        Cum.Store          Wet.Area
    (feet)          (sq-ft)     (feet)     (cubic-feet)     (cubic-feet)           (sq-ft)
    194.00            3,863      227.0                0                0             3,863
    196.50           14,584      631.3           21,627           21,627            31,498
    198.00           20,032      794.2           25,854           47,482            50,008
    200.00           25,197      855.2           45,130           92,612            58,183
    202.00           29,091      888.5           54,241          146,853            63,121
    204.00           32,908      922.4           61,960          208,813            68,331
    206.00           37,348      956.0           70,209          279,022            73,694
    208.00           41,741    1,006.2           79,048          358,071            81,774

Device   Routing          Invert    Outlet Devices
   #1    Primary         196.50'    15.0"  Round Culvert   L= 85.0'   CPP, square edge headwall,  Ke= 0.500
                                    Inlet / Outlet Invert= 196.50' / 196.25'   S= 0.0029 '/'   Cc= 0.900
                                    n= 0.012  Concrete pipe, finished,  Flow Area= 1.23 sf
   #2    Device 1        196.50'    6.0" W x 6.0" H Vert. Orifice/Grate    C= 0.600
   #3    Device 1        199.50'    10.0" W x 6.0" H Vert. Orifice/Grate    C= 0.600
   #4    Device 1        205.00'    48.0" Horiz. Orifice/Grate    C= 0.600   Limited to weir flow at low heads

Primary OutFlow  Max=6.62 cfs @ 13.90 hrs  HW=203.00'   (Free Discharge)
└─1=Culvert  (Passes 6.62 cfs of 12.93 cfs potential flow)
   ├─2=Orifice/Grate  (Orifice Controls 3.01 cfs @ 12.03 fps)
   ├─3=Orifice/Grate  (Orifice Controls 3.61 cfs @ 8.68 fps)
   └─4=Orifice/Grate  ( Controls 0.00 cfs)
```

Pond 4P: Existing Pond 4 w/ Modified Outlet



Summary for Pond 6R: Proposed Culvert

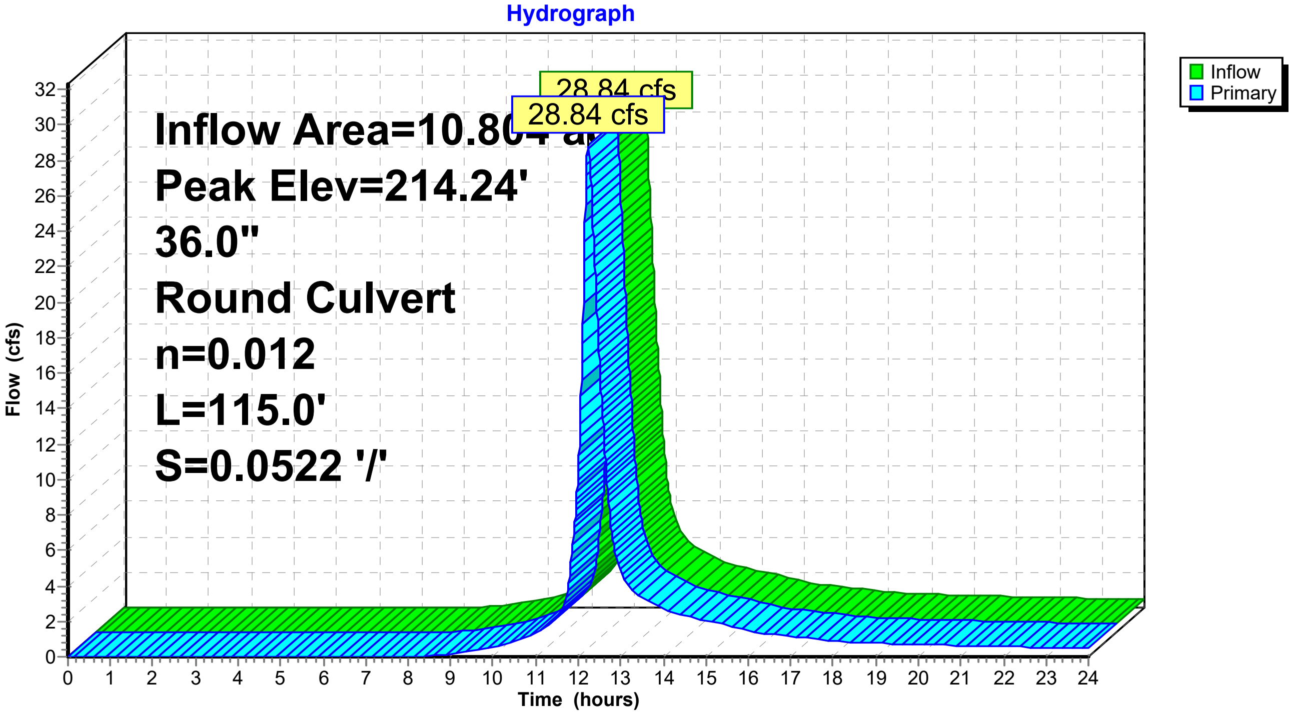
```
Inflow Area =      10.804 ac,  0.00% Impervious,  Inflow Depth >  3.07"   for  25-yr event
Inflow      =     28.84 cfs @  12.24 hrs,  Volume=          2.767 af
Outflow     =     28.84 cfs @  12.24 hrs,  Volume=          2.767 af,  Atten= 0%,  Lag= 0.0 min
Primary     =     28.84 cfs @  12.24 hrs,  Volume=          2.767 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 214.24' @ 12.24 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	212.00'	**36.0" Round Culvert** L= 115.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 212.00' / 206.00' S= 0.0522 '/' Cc= 0.900 n= 0.012, Flow Area= 7.07 sf

Primary OutFlow Max=28.83 cfs @ 12.24 hrs HW=214.24' TW=199.23' (Dynamic Tailwater)
└**1=Culvert** (Inlet Controls 28.83 cfs @ 5.10 fps)

Pond 6R: Proposed Culvert



Summary for Pond 21R: Proposed Dual Culverts

Inflow Area = 23.709 ac, 0.00% Impervious, Inflow Depth > 2.88" for 25-yr event
Inflow = 68.86 cfs @ 12.14 hrs, Volume= 5.691 af
Outflow = 68.86 cfs @ 12.14 hrs, Volume= 5.691 af, Atten= 0%, Lag= 0.0 min
Primary = 68.86 cfs @ 12.14 hrs, Volume= 5.691 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

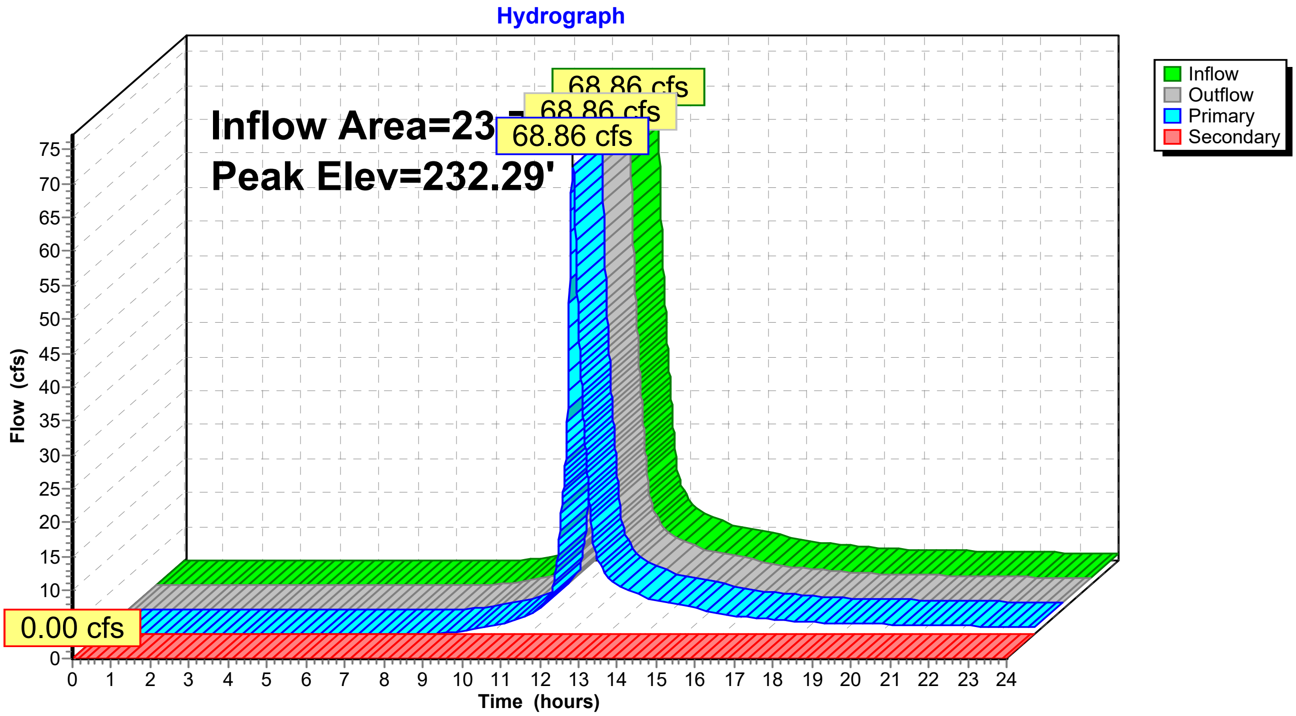
Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 232.29' @ 12.14 hrs
Flood Elev= 233.50'

Device	Routing	Invert	Outlet Devices
#1	Primary	230.00'	**42.0" Round Dual Culverts X 2.00** L= 140.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 230.00' / 227.20' S= 0.0200 '/' Cc= 0.900 n= 0.012, Flow Area= 9.62 sf
#2	Secondary	233.00'	**10.0' long x 40.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=68.78 cfs @ 12.14 hrs HW=232.29' TW=200.25' (Dynamic Tailwater)
↳**1=Dual Culverts** (Inlet Controls 68.78 cfs @ 5.15 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=230.00' (Free Discharge)
↳**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 21R: Proposed Dual Culverts



Summary for Pond 23R: Proposed Dual Culverts

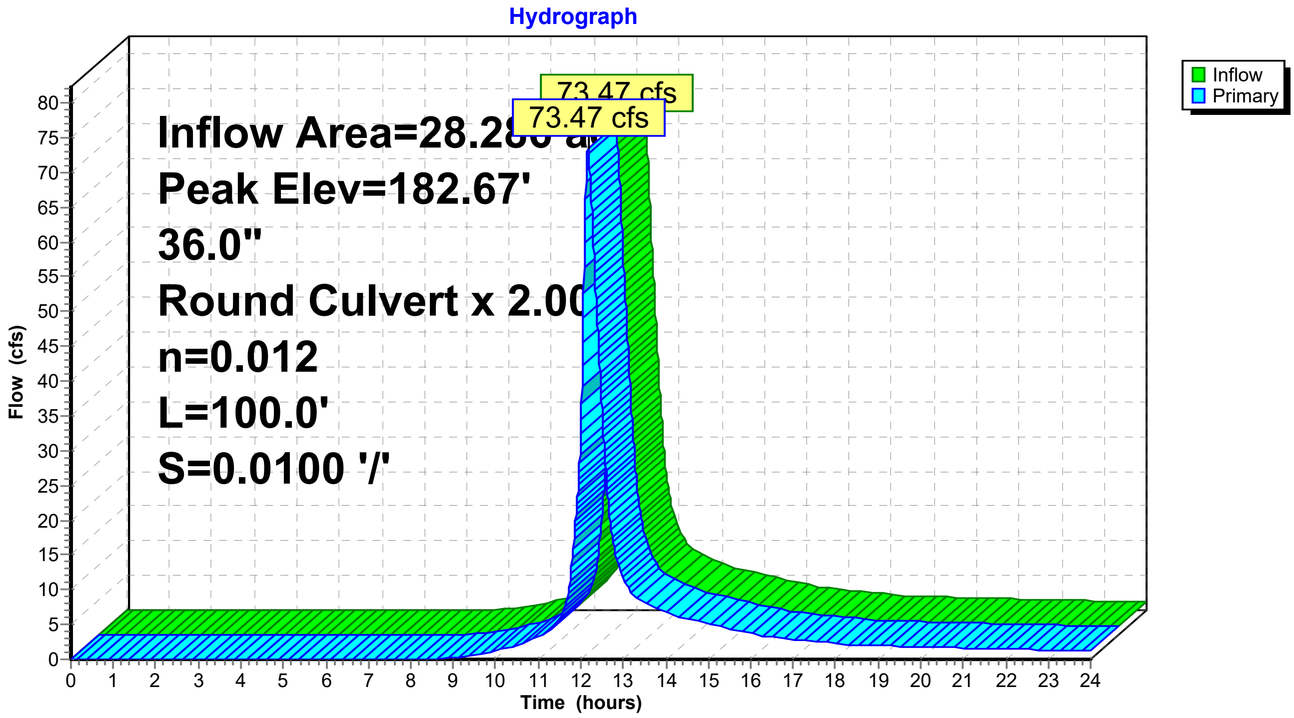
Inflow Area = 28.286 ac, 1.06% Impervious, Inflow Depth > 2.94" for 25-yr event
Inflow = 73.47 cfs @ 12.17 hrs, Volume= 6.934 af
Outflow = 73.47 cfs @ 12.17 hrs, Volume= 6.934 af, Atten= 0%, Lag= 0.0 min
Primary = 73.47 cfs @ 12.17 hrs, Volume= 6.934 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 182.67' @ 12.17 hrs
Flood Elev= 184.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	180.00'	**36.0" Round Culvert X 2.00** L= 100.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 180.00' / 179.00' S= 0.0100 '/' Cc= 0.900 n= 0.012, Flow Area= 7.07 sf

Primary OutFlow Max=73.43 cfs @ 12.17 hrs HW=182.67' TW=178.44' (Dynamic Tailwater)
└**1=Culvert** (Barrel Controls 73.43 cfs @ 7.32 fps)

Pond 23R: Proposed Dual Culverts



Summary for Pond CB3: Existing Catch Basin

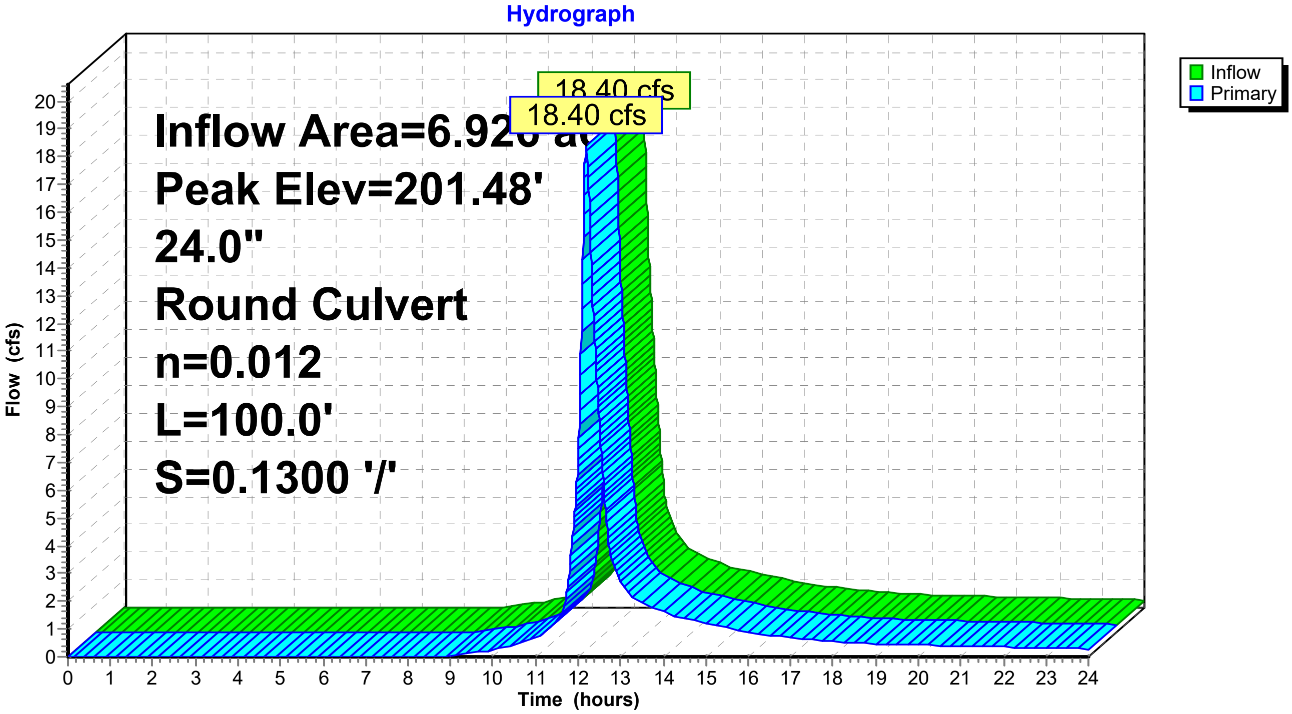
```
Inflow Area =       6.926 ac,   0.00% Impervious,  Inflow Depth >   2.80"   for  25-yr event
Inflow      =      18.40 cfs @  12.19 hrs,  Volume=          1.616 af
Outflow     =      18.40 cfs @  12.19 hrs,  Volume=          1.616 af,  Atten= 0%,  Lag= 0.0 min
Primary     =      18.40 cfs @  12.19 hrs,  Volume=          1.616 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 201.48' @ 12.19 hrs
Flood Elev= 201.50'

Device	Routing	Invert	Outlet Devices
#1	Primary	199.00'	**24.0" Round Culvert** L= 100.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 199.00' / 186.00' S= 0.1300 '/' Cc= 0.900 n= 0.012, Flow Area= 3.14 sf

Primary OutFlow Max=18.39 cfs @ 12.19 hrs HW=201.48' TW=185.60' (Dynamic Tailwater)
└─**1=Culvert** (Inlet Controls 18.39 cfs @ 5.85 fps)

Pond CB3: Existing Catch Basin



ATTACHMENT D
BMP WORKSHEETS

STORMWATER POND DESIGN CRITERIA

Env-Wq 1508.03

Type/Node Name: **Pond 2 (Node 2P)(Wet Pond)**

Enter the type of stormwater pond (e.g., Wet Pond) and the node name in the drainage analysis, if applicable

64.68	ac	A = Area draining to the practice	
0.96	ac	A_I = Impervious area draining to the practice	
0.01	decimal	I = percent impervious area draining to the practice, in decimal form	
0.06	unitless	Rv = Runoff coefficient = 0.05 + (0.9 x I)	
4.10	ac-in	WQV= 1” x Rv x A	
14,875	cf	WQV conversion (ac-in x 43,560 sf/ac x 1ft/12”)	
1,488	cf	10% x WQV (check calc for sediment forebay and micropool volume)	
7,438	cf	50% x WQV (check calc for extended detention volume)	
-	cf	V_{SED} = sediment forebay volume	← ≥ 10%WQV
116,000	cf	V_{PP} = permanent pool volume (volume below the lowest invert of the outlet structure) Attach stage-storage table.	
no	cf	Extended Detention?[1]	← ≤ 50% WQV
-		V_{ED} = Volume of Extended detention (if "yes is given in box above)	
		E_{ED} = elevation of WQV if "yes" is given in box above[2]	
-	cfs	$2Q_{avg}$ = 2* V_{ED} / 24 hrs * (1hr / 3600 sec) (used to check against Q_{EDmax} below)	
	cfs	Q_{EDmax} = discharge at the E_{ED} (attach stage-discharge table)	← <$2Q_{avg}$
-	hours	T_{ED} = drawdown time of extended detention = $2V_{ED}/Q_{EDmax}$	← ≥ 24-hrs
3.00	:1	Pond side slopes	← ≥3:1
167.00	ft	Elevation of seasonal high water table	
176.90	ft	Elevation of lowest pond outlet	
162.00	ft	Max floor = maximum elevation of pond bottom (ft)	
159.00	ft	Minimum floor (to maintain depth at less than 8')	← ≤ 8 ft
174.00	ft	Elevation of pond floor[3]	← ≤ Max floor and > Min floor
550.00	ft	Length of the flow path between the inlet and outlet at mid-depth	
135.00	ft	Average Width ([average of the top width + average bottom width]/2)	
4.07	:1	Length to Average Width ratio	← ≥ 3:1
Yes	Yes/No	The perimeter should be curvilinear.	
Yes	Yes/No	The inlet and outlet should be located as far apart as possible.	
No	Yes/No	Is there a manually-controlled drain to dewater the pond over a 24hr period?	
If no state why:		Pond 2 is an existing pond with wet pool below elevation of the discharge culvert	
Grate		What mechanism is proposed to prevent the outlet structure from clogging (applicable for orifices/weirs with a dimension of <6”)?	
181.08	ft	Peak elevation of the 50-year storm event	
181.50	ft	Berm elevation of the pond	
YES		50 peak elevation ≤ the berm elevation?	← yes

1. If the entire WQV is stored in the perm. pool, there is no extended det., and the following five lines do not apply.
2. This is the elevation of WQV if the hydrologic analysis is set up to include the permanent pool storage in the node description.
3. If the pond floor elevation is above the max floor elev., a hydrologic budget must be submitted to demonstrate that a minimum depth of 3 feet can be maintained. (First check whether a revised "lowest pond outlet" elev. will resolve the issue.)

Designer's Notes:

Pond 2 is an existing drainage basin with outlet modified as part of this project.

Stage-Area-Storage for Pond 2P: Existing Pond 2 w/ Modified Outlet

Elevation (feet)	Storage (cubic-feet)
174.00	0
174.04	1,651
174.08	3,302
174.12	4,953
174.16	6,605
174.20	8,256
174.24	9,907
174.28	11,558
174.32	13,209
174.36	14,860
174.40	16,512
174.44	18,163
174.48	19,814
174.52	21,465
174.56	23,116
174.60	24,767
174.64	26,419
174.68	28,070
174.72	29,721
174.76	31,372
174.80	33,023
174.84	34,674
174.88	36,325
174.92	37,977
174.96	39,628
175.00	41,279
175.04	42,930
175.08	44,581
175.12	46,232
175.16	47,884
175.20	49,535
175.24	51,186
175.28	52,837
175.32	54,488
175.36	56,139
175.40	57,790
175.44	59,442
175.48	61,093
175.52	62,744
175.56	64,395
175.60	66,046
175.64	67,697
175.68	69,349
175.72	71,000
175.76	72,651
175.80	74,302
175.84	75,953
175.88	77,604
175.92	79,256
175.96	80,907
176.00	82,558
176.04	84,209
176.08	85,860
176.12	87,511
176.16	89,162
176.20	90,814
176.24	92,465
176.28	94,116
176.32	95,767
176.36	97,418
176.40	99,069
176.44	100,721
176.48	102,372
176.52	104,023
176.56	105,674
176.60	107,325
176.64	108,976
176.68	110,627
176.72	112,279
176.76	114,184
176.80	116,854
176.84	119,523
176.88	122,192
176.92	124,862
176.96	127,531
177.00	130,201
177.04	132,870
177.08	135,539
177.12	138,209
177.16	140,878
177.20	143,547
177.24	146,217
177.28	149,069
177.32	151,982
177.36	154,896
177.40	157,809
177.44	160,722
177.48	163,635
177.52	166,549
177.56	169,462
177.60	172,375
177.64	175,288
177.68	178,202
177.72	181,115
177.76	184,323
177.80	188,414
177.84	192,505
177.88	196,596
177.92	200,688
177.96	204,779
178.00	208,870
178.04	212,961
178.08	217,052
178.12	221,144
178.16	225,235
178.20	229,326
178.24	233,417
178.28	237,831
178.32	242,352
178.36	246,873
178.40	251,394
178.44	255,915
178.48	260,436
178.52	264,956
178.56	269,477
178.60	273,998
178.64	278,519
178.68	283,040
178.72	287,561
178.76	292,082
178.80	296,603
178.84	301,124
178.88	305,645
178.92	310,166
178.96	314,687
179.00	319,208
179.04	324,010
179.08	328,812
179.12	333,614
179.16	338,416
179.20	343,218
179.24	348,020
179.28	352,822
179.32	357,624
179.36	362,426
179.40	367,228
179.44	372,030
179.48	376,832
179.52	381,587
179.56	386,295
179.60	391,003
179.64	395,711
179.68	400,419
179.72	405,127
179.76	409,835
179.80	414,543
179.84	419,251
179.88	423,959
179.92	428,667
179.96	433,375
180.00	438,083
180.04	443,741
180.08	449,398
180.12	455,056
180.16	460,713
180.20	466,371
180.24	472,028
180.28	477,686
180.32	483,343
180.36	489,001
180.40	494,659
180.44	500,316
180.48	505,974
180.52	511,631
180.56	517,289
180.60	522,946
180.64	528,604
180.68	534,262
180.72	539,919
180.76	545,577
180.80	551,234
180.84	556,892
180.88	562,549
180.92	568,207
180.96	573,864
181.00	579,522
181.04	585,498
181.08	591,475
181.12	597,451
181.16	603,428
181.20	609,404
181.24	615,381
181.28	621,357
181.32	627,334
181.36	633,310
181.40	639,287
181.44	645,263
181.48	**651,240**

NEW HAMPSHIRE DEPARTMENT OF
Environmental Services

STORMWATER POND DESIGN CRITERIA

Env-Wq 1508.03

Type/Node Name: **Pond 4 (Node 4P)(Wet Pond)**

Enter the type of stormwater pond (e.g., Wet Pond) and the node name in the drainage analysis, if applicable

27.54	ac	A = Area draining to the practice	
0.36	ac	A_I = Impervious area draining to the practice	
0.01	decimal	I = percent impervious area draining to the practice, in decimal form	
0.06	unitless	Rv = Runoff coefficient = 0.05 + (0.9 x I)	
1.70	ac-in	WQV= 1” x Rv x A	
6,174	cf	WQV conversion (ac-in x 43,560 sf/ac x 1ft/12”)	
617	cf	10% x WQV (check calc for sediment forebay and micropool volume)	
3,087	cf	50% x WQV (check calc for extended detention volume)	
4,500	cf	V_{SED} = sediment forebay volume	← **≥ 10%WQV**
20,000	cf	V_{PP} = permanent pool volume (volume below the lowest invert of the outlet structure) Attach stage-storage table.	
no	cf	Extended Detention?[1]	← **≤ 50% WQV**
-		V_{ED} = Volume of Extended detention (if "yes is given in box above)	
		E_{ED} = elevation of WQV if "yes" is given in box above[2]	
-	cfs	$2Q_{avg}$ = 2* V_{ED} / 24 hrs * (1hr / 3600 sec) (used to check against Q_{EDmax} below)	
	cfs	Q_{EDmax} = discharge at the E_{ED} (attach stage-discharge table)	← **<$2Q_{avg}$**
-	hours	T_{ED} = drawdown time of extended detention = $2V_{ED}/Q_{EDmax}$	← **≥ 24-hrs**
2.50	:1	Pond side slopes	← **≥3:1**
196.00	ft	Elevation of seasonal high water table	
196.50	ft	Elevation of lowest pond outlet	
191.00	ft	Max floor = maximum elevation of pond bottom (ft)	
188.00	ft	Minimum floor (to maintain depth at less than 8')	← **≤ 8 ft**
194.00	ft	Elevation of pond floor[3]	← **≤ Max floor and > Min floor**
350.00	ft	Length of the flow path between the inlet and outlet at mid-depth	
60.00	ft	Average Width ([average of the top width + average bottom width]/2)	
5.83	:1	Length to Average Width ratio	← **≥ 3:1**
Yes	Yes/No	The perimeter should be curvilinear.	
Yes	Yes/No	The inlet and outlet should be located as far apart as possible.	
No	Yes/No	Is there a manually-controlled drain to dewater the pond over a 24hr period?	
If no state why:		Pond 4 wet pool must be maintained for existing dry hydrant (for fire suppression)	
Grate		What mechanism is proposed to prevent the outlet structure from clogging (applicable for orifices/weirs with a dimension of <6”)?	
204.71	ft	Peak elevation of the 50-year storm event	
208.00	ft	Berm elevation of the pond	
YES		50 peak elevation ≤ the berm elevation?	← **yes**

1. If the entire WQV is stored in the perm. pool, there is no extended det., and the following five lines do not apply.
2. This is the elevation of WQV if the hydrologic analysis is set up to include the permanent pool storage in the node description.
3. If the pond floor elevation is above the max floor elev., a hydrologic budget must be submitted to demonstrate that a minimum depth of 3 feet can be maintained. (First check whether a revised "lowest pond outlet" elev. will resolve the issue.)

Designer's Notes:

Pond 4 is an existing drainage basin with outlet modified as part of this project.

Stage-Area-Storage for Pond 4P: Existing Pond 4 w/ Modified Outlet

Elevation (feet)	Surface (sq-ft)	Storage (cubic-feet)
194.00	3,863	0
194.15	4,313	613
194.30	4,787	1,295
194.45	5,286	2,050
194.60	5,809	2,882
194.75	6,358	3,794
194.90	6,931	4,791
195.05	7,529	5,875
195.20	8,152	7,050
195.35	8,799	8,321
195.50	9,471	9,691
195.65	10,168	11,164
195.80	10,890	12,743
195.95	11,636	14,432
196.10	12,407	16,235
196.25	13,203	18,155
196.40	14,023	20,197
196.55	14,752	22,361
196.70	15,261	24,612
196.85	15,778	26,939
197.00	16,304	29,345
197.15	16,839	31,831
197.30	17,382	34,398
197.45	17,934	37,046
197.60	18,495	39,778
197.75	19,064	42,595
197.90	19,642	45,498
198.05	20,154	48,486
198.20	20,522	51,537
198.35	20,893	54,643
198.50	21,268	57,805
198.65	21,646	61,023
198.80	22,027	64,299
198.95	22,412	67,632
199.10	22,800	71,022
199.25	23,191	74,472
199.40	23,585	77,980
199.55	23,983	81,547
199.70	24,385	85,175
199.85	24,789	88,863
200.00	25,197	92,612
200.15	25,479	96,413
200.30	25,763	100,256
200.45	26,049	104,142
200.60	26,336	108,071
200.75	26,624	112,043
200.90	26,915	116,058
201.05	27,206	120,117
201.20	27,500	124,220
201.35	27,795	128,367
201.50	28,091	132,558
201.65	28,389	136,794
201.80	28,689	141,075
201.95	28,990	145,401
202.10	29,276	149,772
202.25	29,555	154,184
202.40	29,836	158,638
202.55	30,117	163,135
202.70	30,400	167,674
202.85	30,684	172,255
203.00	30,970	176,879
203.15	31,257	181,546
203.30	31,545	186,256
203.45	31,835	191,010
203.60	32,126	195,807
203.75	32,418	200,647
203.90	32,712	205,532
204.05	33,016	210,461
204.20	33,339	215,438
204.35	33,665	220,463
204.50	33,992	225,537
204.65	34,320	230,661
204.80	34,650	235,833
204.95	34,982	241,056
205.10	35,315	246,328
205.25	35,650	251,650
205.40	35,987	257,023
205.55	36,325	262,446
205.70	36,664	267,921
205.85	37,005	273,446
206.00	37,348	279,022
206.15	37,669	284,649
206.30	37,991	290,323
206.45	38,315	296,046
206.60	38,640	301,818
206.75	38,967	307,638
206.90	39,295	313,508
207.05	39,624	319,427
207.20	39,954	325,395
207.35	40,286	331,413
207.50	40,620	337,481
207.65	40,955	343,599
207.80	41,291	349,767
207.95	**41,628**	**355,986**

Groundwater Recharge Volume (GRV) Calculation

	ac	Area of HSG A soil that was replaced by impervious cover	0.40"
	ac	Area of HSG B soil that was replaced by impervious cover	0.25"
	ac	Area of HSG C soil that was replaced by impervious cover	0.10"
	ac	Area of HSG D soil or impervious cover that was replaced by impervious cover	0.0"
-	inches	Rd = weighted groundwater recharge depth	
-	ac-in	GRV = AI * Rd	
-	cf	GRV conversion (ac-in x 43,560 sf/ac x 1ft/12")	

Provide calculations below showing that the project meets the groundwater recharge requirements (Env-Wq 1507.04):

Phase IV is an expansion to an active landfill, and is within a groundwater management zone.

Therefore, the City of Nashua does not intend to infiltrate stormwater coming off of the landfill.

ATTACHMENT C
RIPRAP SIZING CALCULATIONS

SANBORN | HEAD

File No. 3066.11 Page 1 of 3
Project Phase IV Expansion
Location Four Hills Landfill, Nashua, New Hampshire
Subject Riprap Swale Lining – Stone Sizing
Calculated By O. Hernandez Date 6/17/20
Checked By R. Clay Date 6/19/20
P:\3000s\3066.11\Source Files\Calculations\Stormwater\Att E - Riprap Sizing\20200617 Riprap Sizing (Trapezoidal).docx

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PURPOSE: Select size of riprap lining for Reach 3R based upon 25-year 24-hour peak flows.

METHOD:

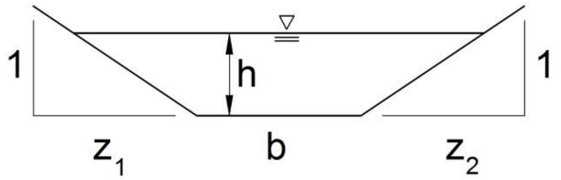
1. Design using method outlined in "Erosion & Sediment Control Handbook" by Goldman, Jackson, & Bursztynsky, Section 7.7b, pages 7.38-7.41. (Exhibit A)

DATA:

1. Estimated flow in channel for 25-yr storm event, Q = 74.74 ft^3/s (Exhibit B)
2. Trapezoidal swale with 3H:1V sideslopes, and 6-ft base (Exhibit B)
3. Slope of swale = 0.0277 ft/ft (Exhibit B)
4. h = Depth of flow for 25-yr storm event = 1.29 ft (Exhibit B)

CALCULATION:

1. Calculate the wetted perimeter, P, of the trapezoidal section,



$$\mathrm{P} = \mathrm{b} + \{[(h)^2 + (z_1 \times h)^2]^{0.5} + \ [(h)^2 + (z_2 \times h)^2]^{0.5}\}$$

$$\mathrm{P} = 6\ \mathrm{ft} + \{[(1.29ft)^2 + (3 \times 1.29ft)^2]^{0.5} + \ [(1.29ft)^2 + (3 \times 1.29ft)^2]^{0.5}\}$$

$$\mathrm{P} = 6\ \mathrm{ft} + 4.08\ \mathrm{ft} + 4.08\ \mathrm{ft} = 14.16\ \mathrm{ft}$$

2. Calculate the flow area, A:

$$\mathrm{A_{left}} = \frac{\mathrm{base} \times \mathrm{height}}{2} = \left(\frac{(1.29\ \mathrm{ft}\ \times\ 3) \times 1.29\ \mathrm{ft}}{2}\right) = 2.50\ \mathrm{ft}^2$$

$$\mathrm{A_{center}} = \mathrm{base} \times \mathrm{height} = 6\ \mathrm{ft} \times 1.29\ \mathrm{ft}\ = = 7.74\ \mathrm{ft}^2$$

$$\mathrm{A_{right}} = \left(\frac{(1.29\ \mathrm{ft}\ \times\ 3) \times 1.29\ \mathrm{ft}}{2}\right) = 2.50\ \mathrm{ft}^2$$

$$\mathrm{A} = \mathrm{A_{left}} +\ \mathrm{A_{center}} +\ \mathrm{A_{right}}$$

$$\mathrm{A} = 2.50\ \mathrm{ft}^2 +\ 7.74\ \mathrm{ft}^2 +\ 2.50\ \mathrm{ft}^2 = 12.74\ \mathrm{ft}^2$$

3. Calculate the hydraulic radius, R:

$$R = \frac{A}{P}$$

$$R = \frac{12.74\ ft^2}{14.16\ ft} = 0.900\ ft$$

4. Calculate the median riprap diameter (d_{50}) for the trapezoidal swale:

$$\mathrm{d_{50}} = 12(118\mathrm{QS_b}^{13/6}\mathrm{R/P})^{2/5} \quad \text{[REF. 1](Exhibit A)}$$

where:

Q = flow (ft^3/s)
S_b = channel bottom slope (ft/ft)
R = Hydraulic radius (ft)
P = Wetted Perimeter (ft)

$$\mathrm{d_{50}} = 12\left\{118(74.74\ \mathrm{ft}^3/\mathrm{s})(.0277^{13/6})\left(\frac{0.900\ \mathrm{ft}}{14.16\ \mathrm{ft}}\right)\right\}^{2/5} = 6.74\ \mathrm{in.}$$

5. Calculate the velocity, V, in the channel:

$$\mathrm{V} = \frac{\mathrm{Q}}{\mathrm{A}} = \frac{74.74\ \mathrm{ft}^3/\mathrm{s}}{12.74\ \mathrm{ft}^2} = 5.87\ \mathrm{ft/s}$$

6. Specify the riprap lining based on the following criteria:

If…	Then…
V < 5 ft/s	No Lining Required
$d_{50} \leq 6$ in.	Specify $d_{50} = 6$ in
6 in. $> d_{50} \leq 8$ in.	Specify $d_{50} = 8$ in
8 in. $> d_{50} \leq 12$ in.	Specify $d_{50} = 12$ in
$d_{50} > 12$ in.	Gabion Recommended

CONCLUSION:

Because the calculated d_{50} is greater than 6 inches and less than 8 inches, a d_{50} of 8 inches is recommended.

REFERENCES:

1. Goldman, Steven J., Katherine Jackson, and Taras A. Bursztynsky. *Erosion and Sediment Control Handbook. McGraw-Hill, Inc., 1986.*

EXHIBIT A (1 of 2)

cost, and need for permanence. Calculate velocity and depth of flow as described in Chap. 4. Common lining materials include:

- Earth
- Rock
- Grass
- Grass and rock combination
- Fabric
- Pavement

7.7a Unlined Channels

Table 7.1 lists the maximum permissible velocities in unlined channels according to soil type. Generally, sandy, noncohesive soils tend to be very erodible, mixtures of sand, clay, and colloids are moderately erodible, and large-grained gravel, clay, and silt mixtures are erosion-resistant.

Channels with slopes less than 3 percent may remain unlined; but unless the channel is a small swale, a lining is advisable if the channel is expected to serve throughout an entire season. Figure 7.28 shows an unlined diversion that became a deep channel in the course of an average rainy season.

7.7b Rock Linings

Gravel or rock is the simplest kind of lining. Rock linings can be made to withstand most velocities if the proper size of rock is selected. Basically, the sequence of construction is to place a filter layer on the soil and then place a layer of riprap on top of the filter layer. The filter layer is important to prevent soil movement out through the riprap, which would result in the settling and eventual failure of the lining. The filter may be a special filter cloth or properly graded layers of sand and gravel.

Sample Design Procedure to Determine Stone Size for Riprap-Lined Channels (14)

The design procedure for riprap-lined channels is adapted from the National Cooperative Highway Research Program Report No. 108, entitled *Tentative Design Procedure for Riprap-Lined Channels* (14). It is based on the tractive force method and covers the design of riprap in two basic channel shapes: trapezoidal and triangular.

Note: This procedure is for uniform flow in channels and is *not* to be used for design of riprap energy dissipators. See Sec. 7.8 for design guidelines for outlet protection and energy dissipators.

The procedure is based on the assumption that the channel is already designed and the remaining problem is to determine the riprap size that would be stable in the channel. The designer first determines the channel dimensions by the use of Manning's equation. The n value for use in Manning's equation is determined by first estimating a riprap size and then determining the corresponding n value for the riprapped channel from Fig. 7.29.

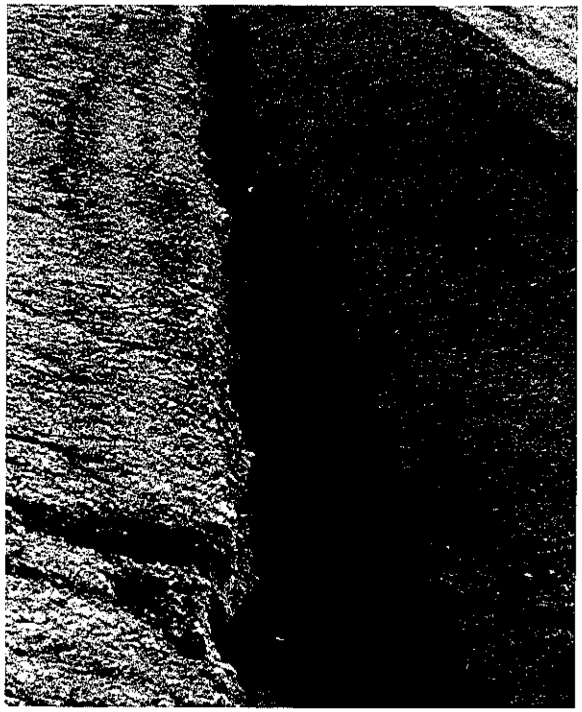


Fig. 7.28 Eroding swale/dike; lining is needed.

TRAPEZOIDAL CHANNELS

1. Calculate the bottom width-to-depth (b/d) ratio and enter Fig. 7.30 to find the ratio P/R of the wetted perimeter to the hydraulic radius.
2. Enter Fig. 7.31 with the channel bottom slope S_b, Q, and P/R to find the median riprap diameter d_{50} for straight channels. (By definition, 50 percent by weight of a rock mixture is greater than or less than the d_{50} size.)
3. Enter Fig. 7.29 to find the actual n value corresponding to the d_{50} from step 2. If the estimated and actual n values are not in reasonable agreement, another trial must be made. Recalculate the channel size by assuming a larger or smaller riprap, as appropriate, assign a new n value from Fig. 7.29, and return to step 1.

EXHIBIT A (2 of 2)

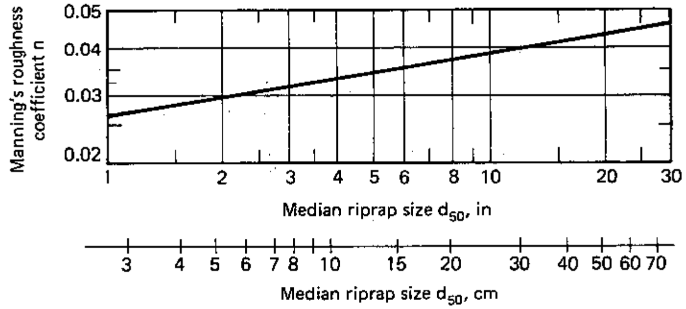


Fig. 7.29 Manning's *n* value for riprap-lined channels. (14)

4. For channels with bends, calculate the ratio B_s/R_o, where B_s is the channel surface width and R_o is the radius of the bend. Enter Fig. 7.32 and find the bend factor F_B. Multiply the d_{50} for straight channels by the bend factor to determine the riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for the straight channel, then the size for the straight channel may be used in the bend. Otherwise, the larger stone size calculated for the bend should be used. The riprap should extend across the full channel section and extend upstream and downstream from the ends of the bend a distance equal to 5 times the bottom width.

5. Enter Fig. 7.33 to determine the maximum stable side slope of the riprap surface.

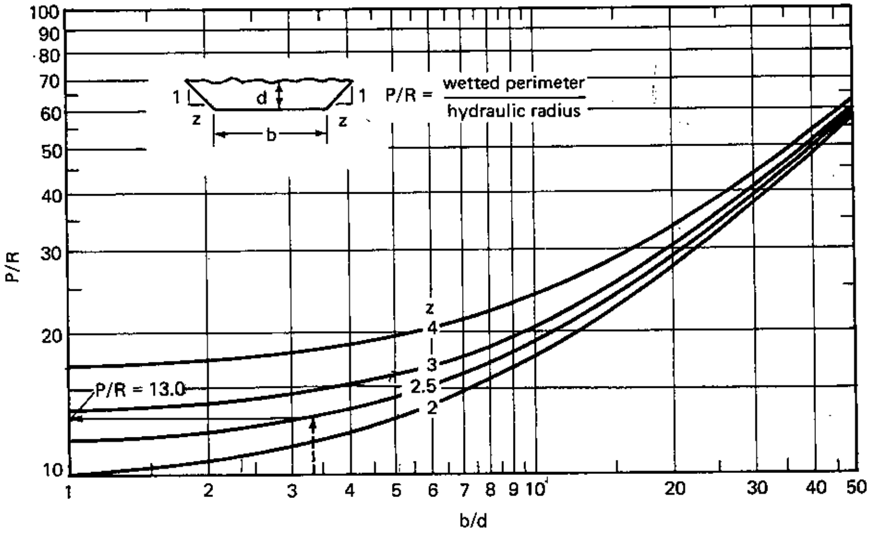


Fig. 7.30 Relation of *P/R* to *B/D* in trapezoidal channels. (14)

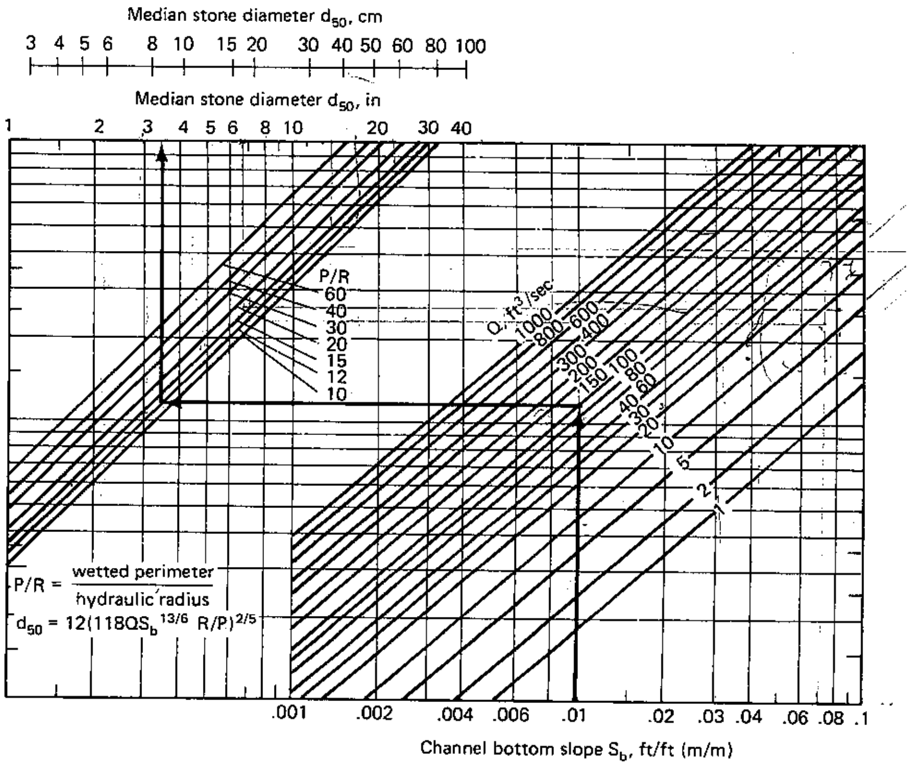


Fig. 7.31 Median riprap diameter for straight trapezoidal channels. (14)

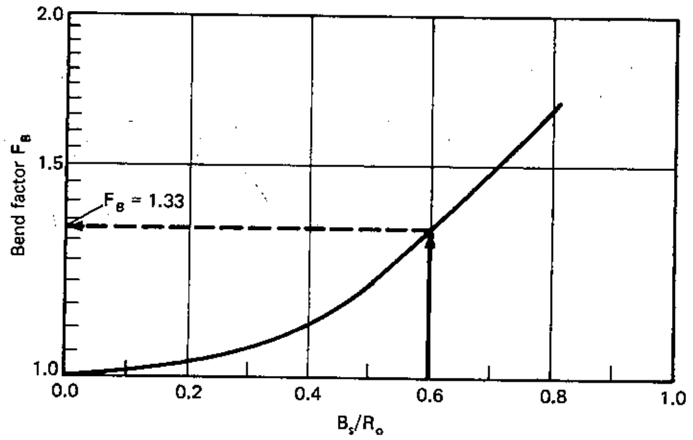


Fig. 7.32 Riprap size correction factor for flow in channel bends.
d_{50} (for bend) = d_{50} (for straight) × F_B
B_s = channel surface width
R_o = mean radius of bend

EXHIBIT B

Summary for Reach 3R: Existing Swale

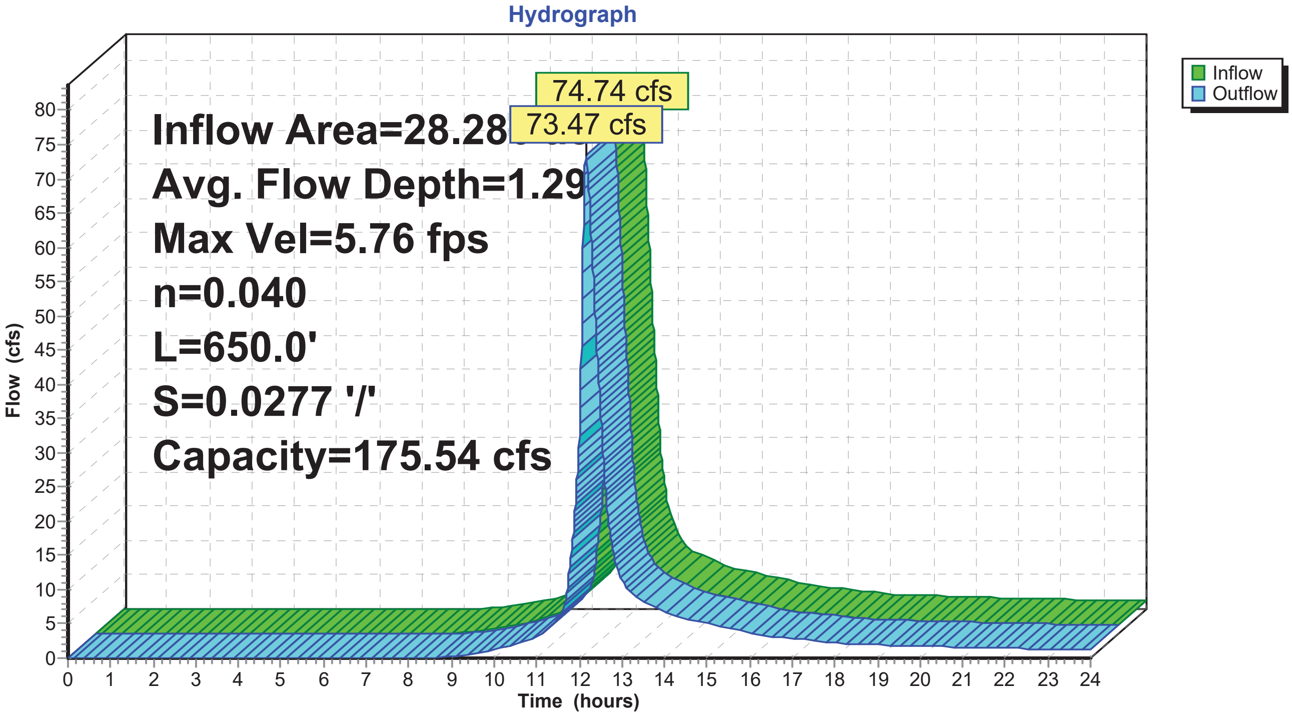
Inflow Area = 28.286 ac, 1.06% Impervious, Inflow Depth > 2.95" for 25-yr event
Inflow = 74.74 cfs @ 12.14 hrs, Volume= 6.946 af
Outflow = 73.47 cfs @ 12.17 hrs, Volume= 6.934 af, Atten= 2%, Lag= 1.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.76 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 2.05 fps, Avg. Travel Time= 5.3 min

Peak Storage= 8,287 cf @ 12.17 hrs
Average Depth at Peak Storage= 1.29'
Bank-Full Depth= 2.00' Flow Area= 24.0 sf, Capacity= 175.54 cfs

6.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 650.0' Slope= 0.0277 '/'
Inlet Invert= 198.00', Outlet Invert= 180.00'

Reach 3R: Existing Swale



File No. 3066.11 Page 1 of 3
Project Phase IV Expansion
Location Four Hills Landfill, Nashua, New Hampshire
Subject Riprap Swale Lining – Stone Sizing
Calculated By O. Hernandez Date 6/17/20
Checked By R. Clay Date 6/19/20
P:\3000s\3066.11\Source Files\Calculations\Stormwater\Att E - Riprap Sizing\20200617 Riprap Sizing Calc (Triangular).docx

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PURPOSE: Select size of riprap lining for the temporary access road triangular swale (Reach 16R) for the 25-year, 24 hour storm peak flow.

METHOD:

1. Design using method outlined in "Erosion & Sediment Control Handbook" by Goldman, Jackson, & Bursztynsky, Section 7.7b, pages 7.42-7.43. (Exhibit A)

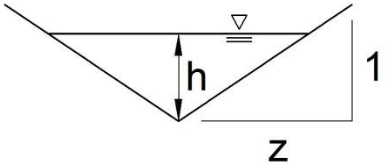
DATA:

<u>Reach 5R</u>

1. Estimated Flow in channel for 25-yr storm event, Q = 30.6 ft^3/s (See Exhibit B)
2. Triangular swale with 2H:1V sideslopes (See Exhibit B)
3. Slope of swale = 0.0856 ft/ft (See Exhibit B)
4. h = Depth of flow for 2-yr storm event = 1.36 ft (See Exhibit B)

CALCULATION:

1. Calculate the wetted perimeter, P, of the triangular section,



[REF. 2](See Attachment C)

$$P = 2h \times [1 + z^2]^{0.5}$$

$$P = 2(1.36\text{ ft}) \times [1 + 2^2]^{0.5}$$

$$P = 6.08\text{ ft}$$

2. Calculate the flow area of a triangular channel, A [REF. 2](See Exhibit C):

$$A = zh^2 = 2 \times (1.36\text{ft})^2 = 3.70\text{ ft}^2$$

3. Calculate the hydraulic radius, R:

$$R = \frac{A}{P}$$

$$R = \frac{3.70\ ft^2}{6.08\ ft} = 0.609\ ft$$

4. Calculate the median riprap diameter (d_{50}) for the triangular swale [REF. 1](Exhibit A):

$$d_{50} = 12(64.4QS_b{}^{13/6}\frac{z}{z^2 + 1})^{2/5}$$

where:

Q = flow (ft^3/s)
S_b = channel bottom slope (ft/ft)
z = sideslope ratio

$$d_{50} = 12\left\{64.4(30.6\ ft^3/s)(.0856^{13/6})\left(\frac{2}{2^2 + 1}\right)\right\}^{2/5} = 20.5\ in.$$

5. Calculate the velocity, V, in the channel:

$$V = \frac{Q}{A} = \frac{30.6\ ft^3/s}{3.70\ ft^2} = 8.27\ ft/s$$

6. Specify the riprap lining based on the following criteria:

If…	Then…
$V < 5$ ft/s	No Lining Required
$d_{50} \leq 6$ in.	Specify $d_{50} = 6$ in
6 in. $> d_{50} \leq 8$ in.	Specify $d_{50} = 8$ in
8 in. $> d_{50} \leq 12$ in.	Specify $d_{50} = 12$ in
$d_{50} > 12$ in.	Gabion Recommended

CONCLUSION:

Because the calculated d_{50} > 12 inches, a gabion is recommended.

REFERENCES:

1. Goldman, Steven J., Katherine Jackson, and Taras A. Bursztynsky. *Erosion and Sediment Control Handbook. McGraw-Hill, Inc., 1986.*

2. Engineeringtoolbox.com, “Flow Section Channels - Geometric Relationships,” http://www.engineeringtoolbox.com/flow-section-channels-d_965.html

EXHIBIT A

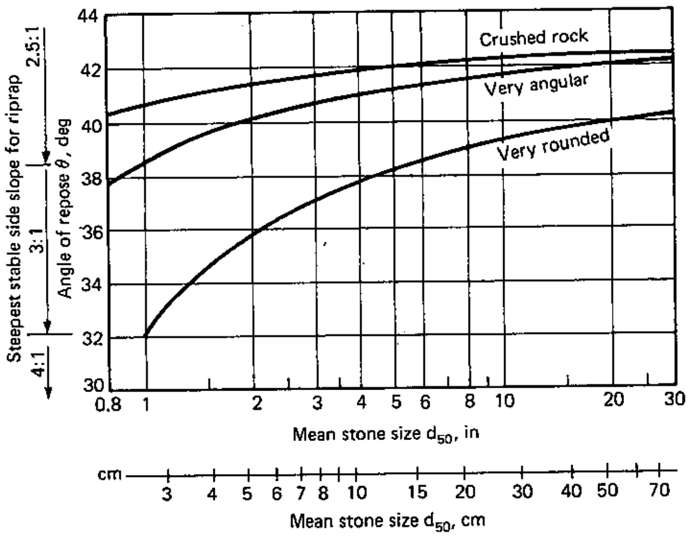


Fig. 7.33 Maximum riprap side slope for given riprap size. (14)

TRIANGULAR CHANNELS

1. Enter Fig. 7.34 with S_b, Q, and Z and find the median riprap diameter d_{50} for straight channels.
2. Enter Fig. 7.29 to find the actual n value. If the estimated and actual n values are not in reasonable agreement, another trial must be made.
3. For channels with bends, see step 4 under "Trapezoidal Channels."

Since temporary drainage channels on construction sites are generally small ditches with flows of less than 1 ft^3/sec (0.028 m^3/sec), Fig. 7.35 was developed as a handy riprap sizing chart for them. Figure 7.35 was derived from Fig. 7.34. When writing plan specifications, specify stones 1.5 times the d_{50} as the maximum stone size in the mixture. The thickness of the riprap layer should be 1.5 times the maximum stone size, but not less than 6 in (15 cm). Freeboard should be added to the channel depth and should not be less than 0.2 times the depth of flow or 0.3 ft (9 cm), whichever is greater.

EXAMPLE 7.3 Riprap Channel Lining Design Calculation (14)

Given: Trapezoidal channel with

Q = 75 ft^3/sec (1.2 m^3/sec) ← wrong

S_b = 0.01 ft/ft (m/m)

z = 2.5:1

Mean bend radius R_o = 25 ft (7.6 m)

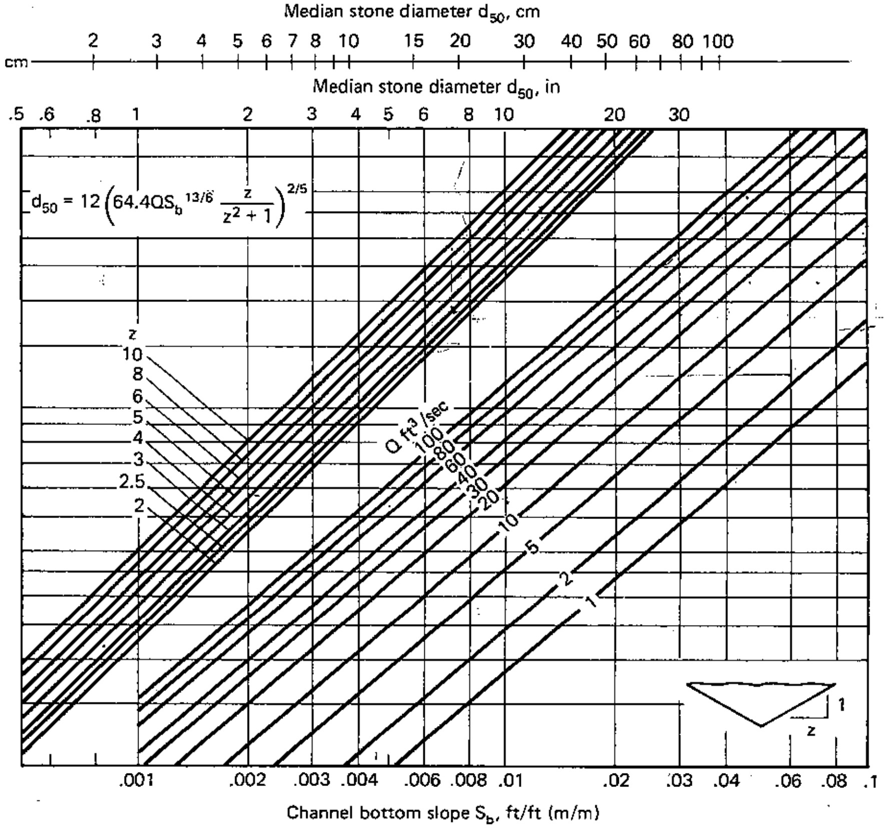


Fig. 7.34 Median riprap diameter for straight triangular channels. (14)

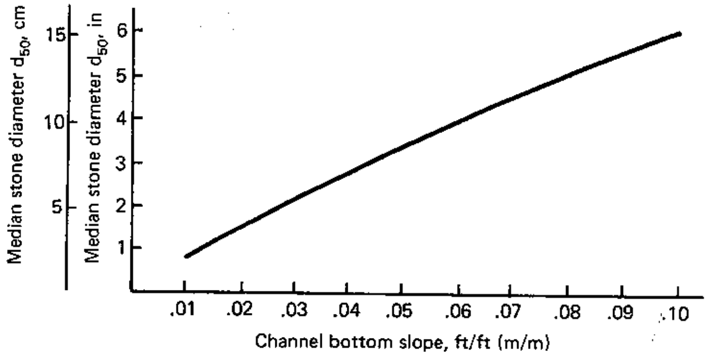


Fig. 7.35 Riprap sizing guide for lining triangular channels with flows of 1 ft^3/sec (0.028 m^3/sec) or less; assumes 2:1 side slopes.

EXHIBIT B

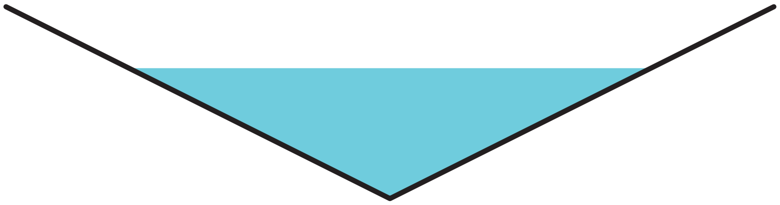
Summary for Reach 16R: Proposed Roadside Swale

Inflow Area = 10.804 ac, 0.00% Impervious, Inflow Depth > 3.08" for 25-yr event
Inflow = 30.60 cfs @ 12.19 hrs, Volume= 2.774 af
Outflow = 28.84 cfs @ 12.24 hrs, Volume= 2.767 af, Atten= 6%, Lag= 2.9 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.80 fps, Min. Travel Time= 3.8 min
Avg. Velocity = 3.46 fps, Avg. Travel Time= 8.7 min

Peak Storage= 6,656 cf @ 12.24 hrs
Average Depth at Peak Storage= 1.36'
Bank-Full Depth= 2.00' Flow Area= 8.0 sf, Capacity= 80.70 cfs

0.00' x 2.00' deep channel, n= 0.040 Earth, cobble bottom, clean sides
Side Slope Z-value= 2.0 '/' Top Width= 8.00'
Length= 1,800.0' Slope= 0.0856 '/'
Inlet Invert= 366.00', Outlet Invert= 212.00'



Reach 16R: Proposed Roadside Swale

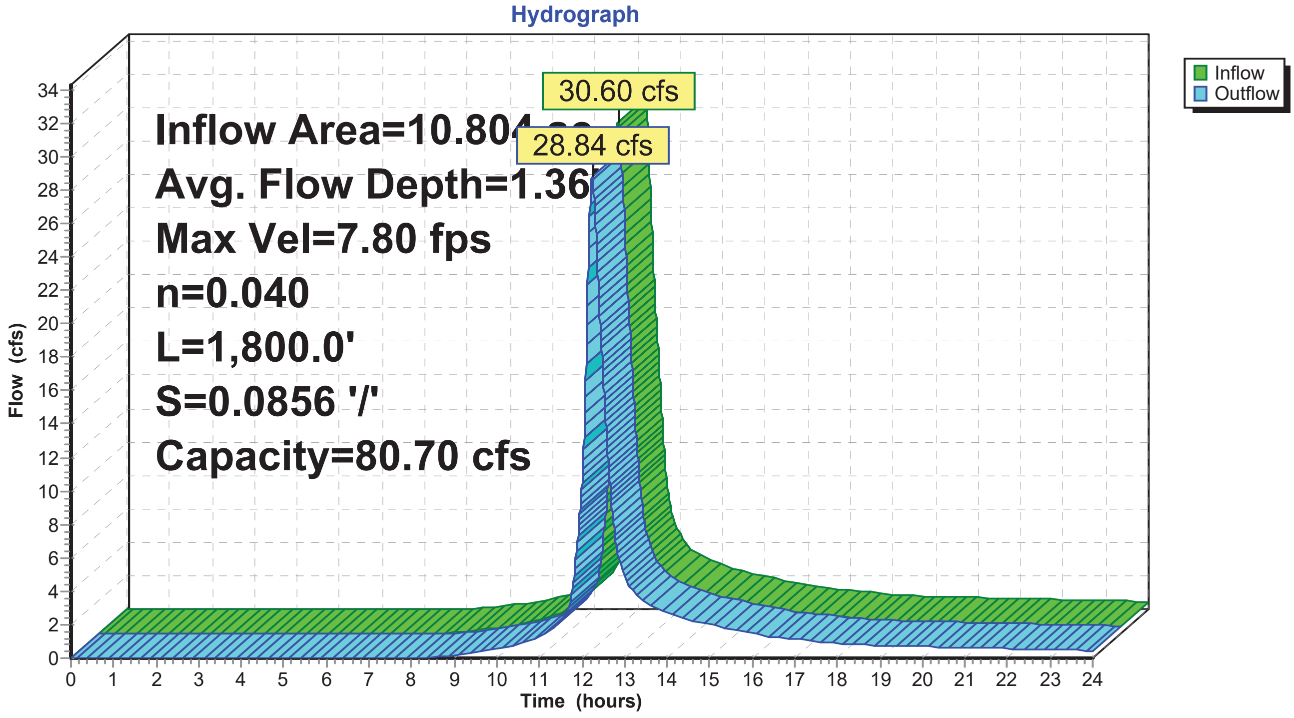


EXHIBIT C

Hydraulic Radius

Hydraulic radius of a rectangular channel can be expressed as

$R_h = b\,h / (b + 2\,h)$ (1c)

where

R_h = *hydraulic radius (m, in)*

- Hydraulic diameter

Trapezoidal Channel

Flow Area

Flow area of a trapezoidal channel can be expressed as

$A = h\,(b + T) / 2$ (2)

Wetted Perimeter

Wetted perimeter of a trapezoidal channel can be expressed as

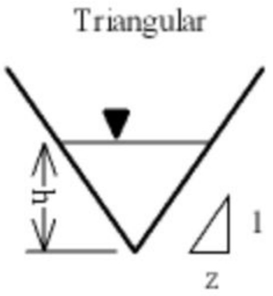
$P = b + 2\,(((T - b) / 2)^2 + h^2)^{1/2}$ (2b)

Hydraulic Radius

Hydraulic radius of a trapezoidal channel can be expressed as

$R_h = (h\,(b + T) / 2) / (b + 2\,(((T - b) / 2)^2 + h^2)^{1/2})$ (2c)

- Hydraulic diameter



Triangular Channel

Flow Area

Flow area of a triangular channel can be expressed as

$$\boxed{A = z\,h^2 \qquad (3)}$$

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a triangular channel can be expressed as

$P = 2\,h\,(1 + z^2)^{1/2}$ (3b)

Hydraulic Radius

Hydraulic radius of a triangular channel can be expressed as

$R_h = z\,h / 2\,(1 + z^2)^{1/2}$ (3c)

- Hydraulic diameter

Circular Channel

Flow Area

Flow area of a circular channel can be expressed as

$A = D^2/4\,(\alpha - \sin(2\,\alpha)/2)$ (4)

where

D = diameter of channel

$\alpha = \cos^{-1}(1 - h/r)$

Wetted Perimeter

Wetted perimeter of a circular channel can be expressed as

$P = \alpha\,D$ (4b)

Hydraulic Radius

Hydraulic radius of a circular channel can be expressed as

$R_h = D/4\,[1 - \sin(2\,\alpha) / (2\,\alpha)]$ (4c)

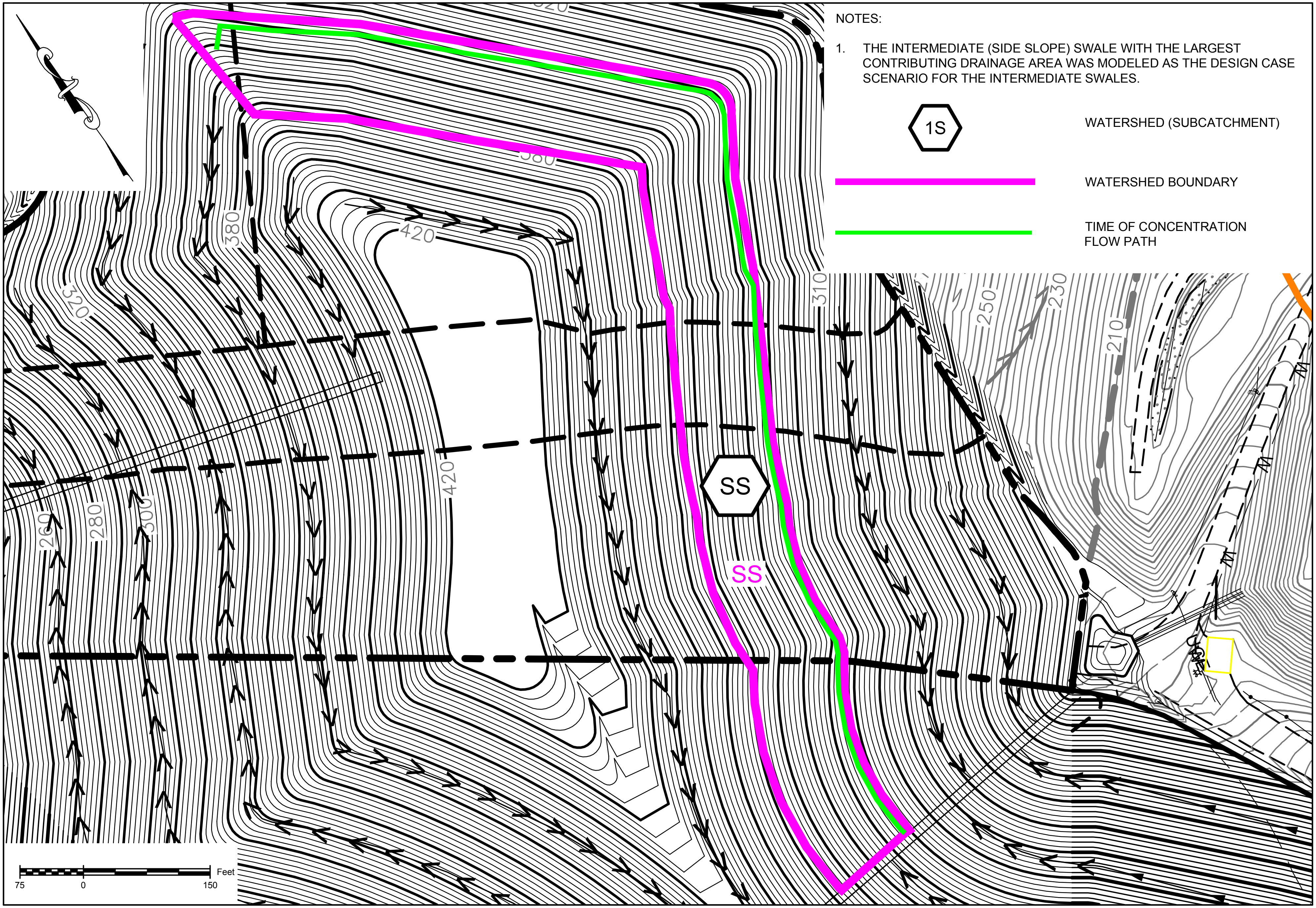
- Hydraulic diameter

Search the Engineering ToolBox

Related Topics

- Fluid Mechanics - The study of fluids - liquids and gases. Involves various properties of the fluid, such as velocity, pressure, density and temperature, as functions of space and time.

ATTACHMENT F
SIDESLOPE SWALE SIZING CHECK



NOTES:

1. THE INTERMEDIATE (SIDE SLOPE) SWALE WITH THE LARGEST CONTRIBUTING DRAINAGE AREA WAS MODELED AS THE DESIGN CASE SCENARIO FOR THE INTERMEDIATE SWALES.

1S	WATERSHED (SUBCATCHMENT)
🟪	WATERSHED BOUNDARY
🟩	TIME OF CONCENTRATION FLOW PATH

SANBORN | HEAD

DRAWN BY: O. HERNANDEZ
DESIGNED BY: O. HERNANDEZ
REVIEWED BY: R. CLAY
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV EXPANSION - FOUR HILLS LANDFILL
CITY OF NASHUA, NEW HAMPSHIRE
NASHUA, NEW HAMPSHIRE

SIDESLOPE SWALE SIZING CHECK

PROJECT NUMBER: 3066.11

SHEET NUMBER: 1 OF 1

FILE: P:\3000s\3066.11\Graphics Files\CAD\Stormwater\Post-Development Model - Phase IV (SWALE CHECK).dwg
LAYOUT: 8.5 x 11 (L)
USER: ohemandezpaz
PLOT DATE: 7-10-20 10:54 AM

Summary for Subcatchment SS: SS

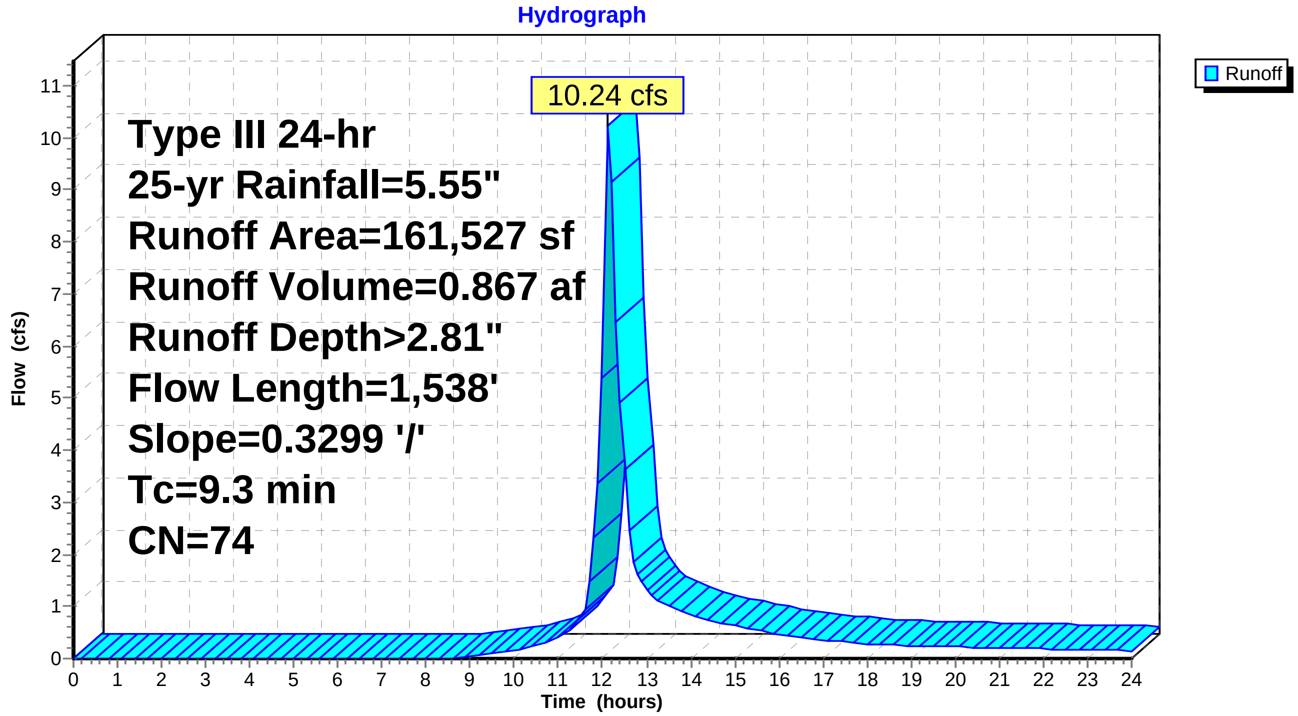
Runoff = 10.24 cfs @ 12.14 hrs, Volume= 0.867 af, Depth> 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.10 hrs
Type III 24-hr 25-yr Rainfall=5.55"

Area (sf)	CN	Description
27,892	74	>75% Grass cover, Good HSG C
133,636	74	>75% Grass cover, Good HSG C
161,527	74	Weighted Average
161,527		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.3	1,538	0.3299	2.75		**Lag/CN Method,**

Subcatchment SS: SS



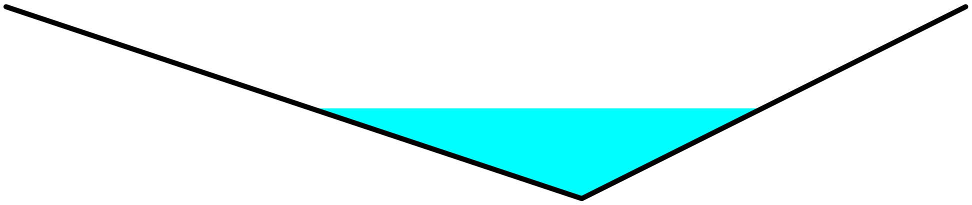
Summary for Reach 1R: Swale

Inflow Area = 3.708 ac, 0.00% Impervious, Inflow Depth > 2.81" for 25-yr event
Inflow = 10.24 cfs @ 12.14 hrs, Volume= 0.867 af
Outflow = 8.89 cfs @ 12.22 hrs, Volume= 0.864 af, Atten= 13%, Lag= 5.3 min

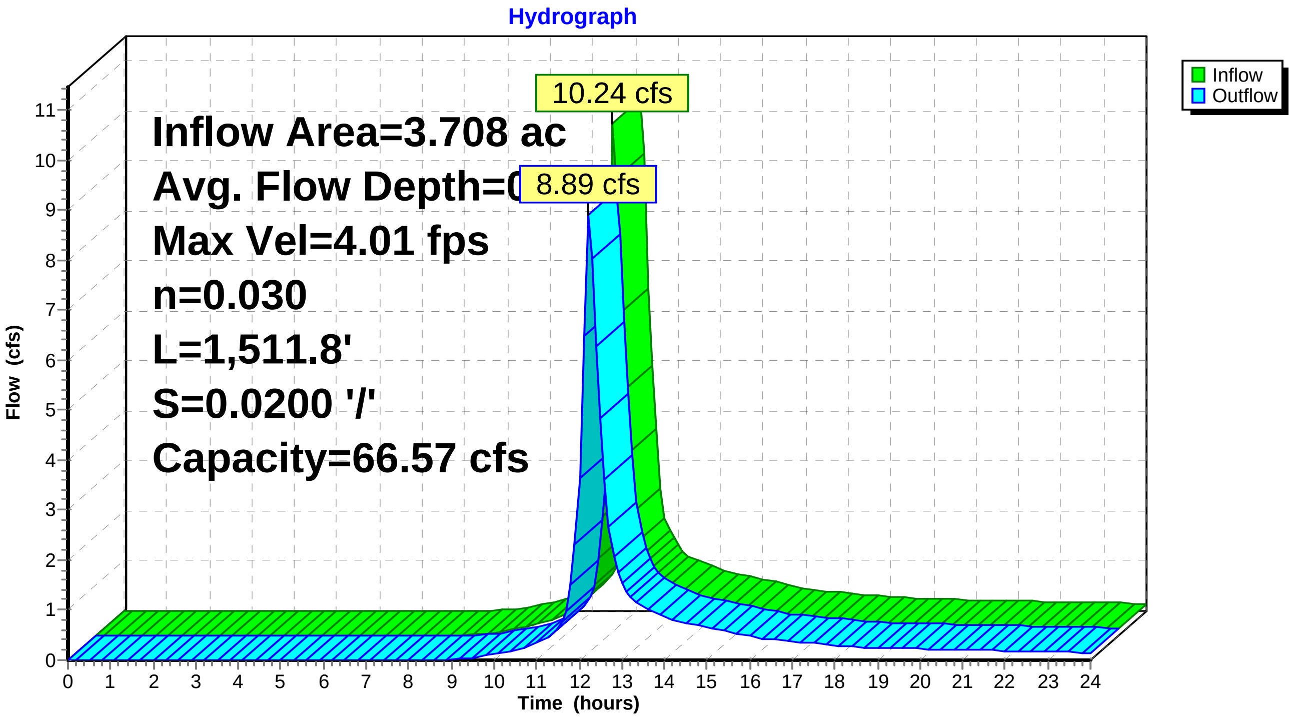
Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.10 hrs
Max. Velocity= 4.01 fps, Min. Travel Time= 6.3 min
Avg. Velocity = 1.82 fps, Avg. Travel Time= 13.8 min

Peak Storage= 3,343 cf @ 12.23 hrs
Average Depth at Peak Storage= 0.94' , Surface Width= 4.70'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 66.57 cfs

0.00' x 2.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 3.0 2.0 '/' Top Width= 10.00'
Length= 1,511.8' Slope= 0.0200 '/'
Inlet Invert= 352.00', Outlet Invert= 321.76'



Reach 1R: Swale



ATTACHMENT B

TECHNICAL SPECIFICATIONS

SANBORN HEAD
Building Trust. Engineering Success.

TECHNICAL SPECIFICATIONS

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Prepared for the City of Nashua
File No. 3066.11
July 2020

SANBORN, HEAD & ASSOCIATES, INC.
www.sanbornhead.com

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Section 02520 – Drainage Geocomposite
Section 02530 – Geosynthetic Clay Liner
Section 02550 – Geomembrane
Section 02560 – Interface Strength Testing
Section 02710 – Culverts
Section 02830 – Topsoil, Hydroseeding, and Turf Establishment

Division 15 – Mechanical

Section 15210 – High Density Polyethylene Pipe, Fittings, and Appurtenances
Section 15310 – Sump Riser Building Pipe, Fittings, and Appurtenances

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Section 02830 – Topsoil, Hydroseeding, and Turf Establishment

SECTION 02000

EROSION AND SEDIMENTATION CONTROL

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall furnish all labor, materials, tools and equipment, and perform all operations necessary to provide erosion and sedimentation control measures in accordance with the Drawings and Specifications.

1.2 PROJECT CONDITIONS

A. CONTRACTOR shall perform the Work in such a manner as to prevent erosion and the resulting sedimentation. The work area shall be graded, shaped, and otherwise drained in a manner that limits soil erosion, siltation of drainage swales, damage to vegetation, and damage to areas outside the work area. CONTRACTOR shall implement and maintain erosion and sedimentation control measures in accordance with all pertinent site and project stormwater permit requirements, or as directed by OWNER or ENGINEER for the duration of construction and until vegetative cover is provisionally accepted and such measures are no longer required.

B. Erosion control methods shall be installed, maintained, and removed in accordance with the Drawings, this specification, and the latest version of the New Hampshire Stormwater Manual.

C. CONTRACTOR shall follow all aspects of the Alteration of Terrain Permit and the Stormwater Pollution Prevention Plan for this project.

1.3 SUBMITTALS

A. At least 15 days prior to delivery to the project site, CONTRACTOR shall submit certifications that the Sediment Filter Logs and Erosion Control Blankets meet the required specifications.

B. At least 15 days prior to seeding, CONTRACTOR shall submit to ENGINEER the proposed seed mix including the manufacturer's certificate of compliance.

C. CONTRACTOR shall submit to ENGINEER a certified statement of the number of pounds of materials (e.g., seed, lime, fertilizer, etc.) to be used per 100 gallons of water. This statement shall specify the number of square feet of seeding that can be covered with the quantity of solution in the hydroseeder.

D. Prior to beginning the Work, CONTRACTOR shall submit to ENGINEER schedules for seeding and fertilizing.

1.4 GENERAL METHODOLOGY

A. Erosion and sedimentation control methods shall consider all factors that contribute to erosion and sedimentation including, but not limited to, the following:
   1. Topographic features of the project area.
   2. Types, depth, slope and areal extent of the various soil types.
   3. Proposed alteration of the area.
   4. Amount of runoff from the project area, borrow areas (if any), and the upgradient watershed areas.
   5. Staging of earthmoving activities.
   6. Temporary control measures and facilities for use during earthmoving.

PART 2 – PRODUCTS

2.1 MATERIALS

A. Sediment Filter Logs
   1. Sediment Filter Logs shall be a compost-filled bio- or photo-degradable tubular mesh product capable of trapping sediment before or within the device while allowing stormwater runoff to pass through.
   2. The mesh shall be of natural biodegradable materials to avoid problems with the sock trapping endangered snakes or lizards, such as biodegradable jute, sisal, burlap, or coir fiber fabric.
   3. The mesh fabric shall must be clean, evenly woven, and free of encrusted concrete or other contaminating materials and free from cuts, tears, broken or missing yarns and thin, open, or weak places.
   4. Each Sediment Filter Log shall have a diameter of no less than 8 inches.
   5. The mesh opening shall be no smaller than ⅛ inch.
   6. The compost shall be derived from green material consisting of chipped, shredded, or ground vegetation, or clean recycled wood products, and be reasonably free of visible contaminants.
   7. The compost shall NOT be derived from mixed municipal solid waste nor shall it contain paint, petroleum products, pesticides or any other chemical residues harmful to animal life or plant growth. The compost shall not possess objectionable odors.
   8. The Sediment Filter Log must have a minimum durability of one year after installation.

B. Erosion Control Blankets shall be a Rolled Erosion Control Product that complies with Temporary Slope Stabilization Type B as defined Section 645 of the NHDOT Specifications.

C. Mulch shall consist of cured straw free from primary noxious weed seeds, twigs, debris and rough or woody materials. Mulch shall be free from rot or mold and shall be acceptable to the ENGINEER or OWNER. Alternately, mulch shall be specially processed cellulose homogeneous fiber containing no growth or germination-inhibiting factors. Processed cellulose fiber shall be manufactured in such a manner that after addition and agitation in slurry tanks with water, the fibers in the material become uniformly suspended to form a slurry when sprayed on the ground. The material shall allow homogeneous absorption and percolation of moisture. Each package of the cellulose fiber shall be marked by the manufacturer to show the air dry weight content. Mulch shall be utilized on all newly-graded subgrade and topsoil areas that cannot be seeded within five (5) days.

PART 3 – EXECUTION

3.1 CONSTRUCTION SEQUENCE

A. Construction/installation of erosion control measures shall be completed prior to any site work.

B. Sediment barriers shall be used at storm drain inlets; across minor swales and ditches; and at other applications where the structure is of a temporary nature and structural strength is not required. Sediment barriers are temporary berms, diversions, or other barriers that are constructed to retain sediment on-site by retarding and filtering storm runoff.

C. All temporary erosion control measures shall be maintained throughout the course of construction activities until provisional acceptance of the site vegetation by ENGINEER or OWNER, at which time CONTRACTOR shall remove all remaining temporary erosion control structures, and properly dispose of accumulated sediment at temporary or permanent erosion control structures on-site in areas approved by OWNER.

D. OWNER, ENGINEER, or the CQA Consultant may require additional erosion and sediment controls be installed or that temporary erosion and sediment controls be replaced. CONTRACTOR shall comply with said request and immediately install the required controls.

3.2 CONSTRUCTION METHODS

A. All temporary erosion control measures shall be installed as shown on the Drawings or as directed by OWNER, ENGINEER, or the CQA Consultant in the field.

B. All temporary erosion control measures shall be installed in accordance with manufacturer's instructions.

C. Straw mulch shall be applied at a rate of 100 lbs/1000 ft^2.

D. CONTRACTOR shall provide protection against washouts by an approved method. Any washout that occurs either in the CONTRACTOR's work area or in areas topographically below the work shall be regraded and reseeded at CONTRACTOR's expense until an accepted vegetative stand is established.

3.3 MAINTENANCE AND INSPECTION

A. Contractor shall inspect and document all temporary erosion control measures as required by the Construction Stormwater Pollution Prevention Plan. Any damaged erosion control measure shall be repaired/replaced promptly.

[END OF SECTION 02000]

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SECTION 02100

GRUBBING AND TOPSOIL REMOVAL

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. This Work shall consist of grubbing, removing, and disposing of all vegetation and debris including stumps, branches, and shrubs, within the limits of Work shown on the Drawings or specified below.

PART 2 – PRODUCTS

Not used.

PART 3 – EXECUTION

3.1 CONSTRUCTION REQUIREMENTS

A. No trees shall be cut outside of the work area designated on the Drawings.

B. CONTRACTOR shall install erosion and sediment controls in areas topographically below areas, that will be disturbed and shall perform the Work in a manner that limits erosion and sedimentation. CONTRACTOR shall cease work and install additional erosion and sediment control measures if directed by OWNER, ENGINEER, or the CQA Consultant.

C. Grubbing shall include the removal of brush, stumps, and large roots to a depth of 2 feet below subgrade unless otherwise directed by ENGINEER or OWNER. In order to conserve topsoil, CONTRACTOR shall make use of rake teeth on bulldozers in the process of removing stumps and brush unless other equipment is allowed by OWNER.

D. Stumps, large roots, branches, other wood, brush, weeds, grass and other perishable material resulting from the clearing and grubbing operations shall be disposed of in an on-site area designated by OWNER.

E. CONTRACTOR shall strip topsoil for subsequent reuse. Topsoil shall be stockpiled on-site in an area approved by OWNER.

[END OF SECTION 02100]

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SECTION 02200

EARTHWORK

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall provide all labor, materials, equipment and incidentals necessary to perform the earthwork required to complete the Work shown on the Drawings and specified herein, including, but not limited to: excavation, placement, grading, and compaction of earth materials; sampling and testing (laboratory and field) earth materials; and disposal and stockpiling of surplus soil.

B. CONTRACTOR shall work with the Construction Quality Assurance (CQA) Consultant and provide assistance as needed so that the required CQA sampling and testing may be performed. CQA activities shall be considered germane to the Work and not be a cause for scheduling delays. CQA requirements are defined in the CQA Plan.

1.2 SUBMITTALS

A. CONTRACTOR shall provide the source(s) for Riprap at least 15 days prior to when the material will be required in the Work. The acceptability of the material will be determined by service records for similar stone and/or by suitable tests. If testing is required, suitable samples of stone shall be taken in the presence of the CQA Consultant at least fourteen (14) days in advance of the time when the placing of Riprap is expected to begin. The approval of some rock fragments from a particular quarry shall not be construed as constituting the approval of all rock fragments taken from the quarry.

B. Prior to initiating interface shear strength tests (See Specification Section 02560), CONTRACTOR shall provide the following information to ENGINEER:
   1. the proposed material source or sources (either on-site or off-site); and
   2. laboratory test data in conformance with the requirements of Part 2.2.

C. Following approval of materials by ENGINEER, CONTRACTOR shall provide the testing laboratory with samples of each type of soil to be tested for interface strength.

D. As soon as the information is available, CONTRACTOR shall provide ENGINEER the results of field and laboratory tests performed on soil.

E. If Work is interrupted for reasons other than inclement weather, then CONTRACTOR shall notify ENGINEER a minimum of 24 hours prior to the resumption of Work.

1.3 SOIL TESTING AND CONSTRUCTION MONITORING

A. Prior to and during placement of soil, the CQA Consultant may select areas within the work limits for field compaction testing. CONTRACTOR shall cooperate fully with the CQA Consultant during testing and shall allow the CQA Consultant sufficient time to make necessary observations and tests.

B. OWNER will pay the CQA Consultant for testing. However, if test results indicate inadequate compaction or earth materials not meeting the Specifications, CONTRACTOR shall bear all costs associated with correcting deficiencies in compacted materials to the satisfaction of the OWNER and the CQA Consultant.

PART 2 – PRODUCTS

2.1 GENERAL

A. The CQA Consultant shall collect soil samples for laboratory conformance testing at the frequency defined in the CQA Plan.

B. Soil materials not meeting the requirements of this Section shall not be used in the Work.

B. The final approval of a source for the soil will be at the sole discretion of ENGINEER.

C. All earth materials shall be substantially free from organic materials, wood, trash, and other objectionable materials that may be compressible or that cannot be properly compacted. Earth materials shall not contain stone blocks, broken concrete, masonry rubble, or other similar materials. Earth materials shall have the physical properties such that it can be readily spread and compacted to the specified permeability and/or density. Snow, ice, and frozen soil shall not be permitted.

2.2 MATERIALS

A. Structural Fill
  1. Structureal Fill shall be used for construction of embankments and general raises-in-grade.
  2. Structural Fill shall be friable soil and shall be free of trash, ice, snow, tree stumps, roots, and other organic material.
  3. Structural Fill shall contain no stone greater than 8 inches in diameter and contain no more than 50 percent of the material passing the No. 200 sieve.
  4. Structural Fill placed within 6 inches of geosynthetics shall contain no stone greater than 1-inch in diameter.

B. Screened Till

1. Screened Till shall be used to establish the landfill subgrade beneath the geomembrane in the secondary liner system and where otherwise indicated on the Drawings.
2. The Screened Till shall contain no stone greater than 1 inch in diameter. The Screened Till shall contain no sharp, angular stones, and shall be free from ice and snow, roots, sod, clay, rubbish and other deleterious or organic matter.
3. Screened Till shall exhibit a hydraulic conductivity of less than 1 x 10^{-4} cm/sec when tested in accordance with ASTM D5084. Test specimens shall be compacted at a moisture content that provides a density no less than 95 percent of the maximum dry density as determined by ASTM D698. Hydraulic conductivity testing shall be performed at a normal stress of 30 pounds per square inch (lb/in.^{2}).
4. Screened Till shall exhibit an internal shear strength represented by an angle of friction of no less than 30 degrees and a cohesion of 0 when tested in accordance with ASTM D3080. Test specimens shall be compacted at a moisture content and density matching that at which acceptable hydraulic conductivity tests were performed. Testing shall be performed at the following normal stresses of 15, 30, 60, and 120 lb/in.^{2}.

C. Drainage Sand

1. Drainage Sand shall be used as a soil component of the primary and secondary liner systems and where otherwise specified on the Drawings.
2. Drainage Sand shall be free from ice and snow, roots, sod, clay, rubbish and other deleterious or organic matter.
3. Drainage Sand shall be a well-graded material having no particle size greater than 1 inch and no more than 10 percent passing (by weight) the No. 200 sieve.
4. Drainage Sand shall exhibit a hydraulic conductivity greater than 1x10-^{4} cm/sec as measured by ASTM D2434.
5. Drainage Sand shall contain no more than 15 percent calcium carbonate as measured by ASTM D4373.

D. Crushed Stone

1. Crushed Stone to be placed around the secondary and primary leachate collection pipes shall meet the requirements of #467 aggregate as specified in Section 703 of the NHDOT Specifications.
2. Crushed Stone to be placed under buildings, manholes, and other similar structures shall meet the requirements of #67 aggregate as specified in Section 703 of the NHDOT Specifications.

E. Riprap

1. Riprap shall be hard, durable, angular in shape; resistant to weathering and to water action; free from overburden, spoil, and organic materials; and shall meet the gradation requirements specified.

2. Neither breadth nor thickness of a single stone should be less than one-third (⅓) its length. Rounded stone or boulders will not be accepted unless authorized by ENGINEER and OWNER.
3. If testing is required, the resistance to disintegration from the type of exposure to which the stone will be subjected will be determined by the following tests:
    a. The results of the abrasion test (ASTM C535) shall indicate a percentage loss of not more than forty (40) after five hundred (500) revolutions.
    b. The results of the sulfate soundness test (ASTM C88) shall indicate a loss not exceeding ten percent (10%) after five (5) cycles.
4. Riprap shall have a d_{50} of 8 inches.
5. Control of gradation will be by visual inspection. Any difference of opinion between the CQA Consultant and CONTRACTOR shall be resolved by dumping and checking the gradation of two (2) random truckloads of stone. Mechanical equipment, a sorting site, and labor needed to assist in checking gradation shall be provided by CONTRACTOR at no additional cost to OWNER.

PART 3 – EXECUTION

3.1 EQUIPMENT

A. CONTRACTOR shall only use equipment that has been approved by ENGINEER for this Work.

B. CONTRACTOR shall furnish, operate, and maintain grading equipment as is necessary to produce uniform layers, sections, and smoothness of grade for compaction and drainage.

C. CONTRACTOR shall furnish, operate and maintain compaction equipment as is necessary to produce the required in-place density and moisture content.

D. CONTRACTOR shall furnish, operate, and maintain tank trucks, pressure distributors, or other equipment designed to apply water uniformly and in controlled quantities to variable surface widths, if moisture conditioning is required to achieve the specified in-place density and moisture content.

E. CONTRACTOR shall furnish, operate, and maintain soil spreading equipment that travels on the material being spread without traveling directly on the surface of the underlying compacted soil surface layer.

F. CONTRACTOR shall furnish, operate, and maintain miscellaneous equipment such as scarifiers, disks, spring tooth or spike tooth harrows, earth hauling equipment, and other equipment necessary for earthwork construction.

3.2 GENERAL

A. CONTRACTOR shall plan and perform his operations so as to prevent damage to existing structures, safeguard people and property, limit disruptions to site traffic, protect the structures to be installed, and provide safe working conditions in compliance with local safety regulations and provisions of the Occupational Safety and Health Administration (OSHA).

B. Prior to excavating or placing and compacting soil, CONTRACTOR shall carefully inspect the installed Work of all other sections and verify that all Work is complete to the point where Work of this Section may properly commence without adverse impact. If CONTRACTOR has any concerns regarding the installed work of other sections, then CONTRACTOR shall immediately notify ENGINEER prior to the initiation of soil placement. Failure to notify ENGINEER in writing shall be construed as CONTRACTOR's acceptance of the relative Work of all other Sections.

C. Soil and aggregate shall <u>not</u> be stockpiled or stored within the limits of the area to be lined.

D. Soil shall be placed and compacted to the lines and grades shown on the Drawings.

E. Soil shall be placed only on dry, unfrozen subgrade surfaces.

F. Compaction shall be performed using a static smooth-drum roller or padded-foot compactors as specified elsewhere in this Section. Hand compaction of material shall be used in locations where larger compaction is inappropriate due to limited area.

G. CONTRACTOR shall finish each day's work with a smooth-drum roller to create a smooth surface, free from ruts or indentations, that will limit moisture penetration. The area shall be left in a manner to promote runoff at the end of each day.

H. Prior to continuing construction from the previous day's work, CONTRACTOR shall scarify the surface to provide a bond between the layers.

3.3 EXCAVATION BELOW GRADE

A. Excavations shall be made to the elevations and dimensions shown on the Drawings. Excavate sufficient material to provide suitable room for construction providing bracing and support as required. The bottom of the excavations shall be rendered firm and dry and in all respects acceptable to the CQA Consultant.

B. Remove water accumulated in excavations by pumping or other means to maintain a dry and stable subgrade until earthwork operations are complete. All dewatering shall be performed at CONTRACTOR's cost. Pumped water shall be treated using a sediment control system such as DIRTBAG® by ACF

Environmental or other system approved by ENGINEER. Treated water shall be directed to the stormwater basins.

C. Where the soil subgrade has been softened, eroded, or otherwise disturbed by flooding, exposure during unfavorable weather, or other causes, it shall be over-excavated and replaced with suitable material at no cost to OWNER.

D. When the required excavation depth is reached, ENGINEER shall be notified and will observe conditions. If, in the opinion of the CQA Consultant, the material in its undisturbed natural condition, at or below the normal grade of the excavation as indicated on the Drawings is unsuitable, then it shall be removed and be replaced with suitable material as directed by ENGINEER. CONTRACTOR shall be responsible for the removal, relocation, and stockpiling of unsuitable material. Unsuitable material is classified here as stumps, excessively wet soil, ledge rock, ice, topsoil, subsoil, organics, existing fill, or other deleterious material.

E. CONTRACTOR shall exercise care to preserve the material below and beyond the lines of excavation. If the bottom of an excavation is extended below the limits shown on the Drawings or specified or directed by ENGINEER, then it shall be refilled and compacted in accordance with these specifications at CONTRACTOR's expense with fill approved by ENGINEER.

3.4 EXCAVATION FOR UTILITY TRENCHES

A. Excavate as necessary for installation of utilities including, culverts, conduits, leachate collection and transmission system pipe, and for related structures and appurtenances.

B. Excavations for utilities shall be carried out in a manner that will preserve the undisturbed state of the subgrade soils. Dewatering shall be performed as needed to provide a dry excavation.

C. Excavation of trenches required for the installation of subsurface utilities shall be made to the depths indicated on the Drawings and in such a manner and to such widths as will give suitable room for laying the pipe within the trenches, for bracing and supporting, and for drainage facilities. CONTRACTOR shall render the bottom of the excavations firm and dry, and acceptable to the CQA Consultant.

3.5 MISCELLANEOUS EARTHWORK

A. CONTRACTOR shall perform earthwork as necessary for constructing access roads and any other miscellaneous earth excavation required.

3.6 SUBGRADE PREPARATION

A. Prior to placing earth materials, the subgrade should be compact, dry, and free from debris, ice, and snow. Earth materials shall not be placed over frozen soil unless otherwise approved by ENGINEER.

B. CONTRACTOR shall excavate in such a manner as to limit disturbance of the underlying natural ground. Deterioration of the subgrade between the time of excavation and initial fill placement shall be the responsibility of CONTRACTOR and shall be repaired at CONTRACTOR's expense.

C. All subgrade surfaces shall be observed by the CQA Consultant prior to earth placement. Sufficient time must be given to the CQA Consultant to observe and perform tests on the subgrade.

D. Subgrade for pavement or geosynthetic placement shall be proof-rolled by at least four (4) passes of a 10,000-pound vibratory, smooth-drum roller. Rolled areas shall be firm and shall not display soft spots or deflections (e.g., pumping) as the roller passes. Soft spots and areas of deflection shall be remediated to achieve a firm subgrade.

E. The subgrade shall be smooth and uniformly graded and shall be prepared to the grades indicated on the Drawings. All objects capable of penetrating the overlying geosynthetics, including, but not limited to, stones, sticks, and debris shall be removed by hand and replaced with compacted earth material as indicated on the Drawings.

F. Deterioration of the subgrade surface between acceptance of the CQA Consultant and deployment of the geosynthetic materials is the responsibility of CONTRACTOR and shall be repaired at no cost to OWNER.

3.7 SOIL PLACEMENT AND COMPACTION

A. Soil shall be placed in loose continuous layers and compacted to the specified compaction criteria. The loose lift fill thickness shall not exceed 12 inches. Smaller lift heights may be required to achieve the specified compaction.

B. Compaction shall be by mechanical means designed specifically for soil compaction. The CQA Consultant, ENGINEER, or OWNER reserves the right to reject any device of inadequate capacity or, in their opinion of a type unsuited to the character of material being compacted.

C. Placed and compacted soil shall be graded to drain and provide a smooth surface that will readily shed water.

D. Earth materials containing ice, snow, frozen soil, large rocks, roots, sod, rubbish and other deleterious or organic material shall not be placed. Frozen soil shall not be placed as fill, nor shall fill or utilities be placed on frozen soil.

E. Earth materials shall not be placed during weather conditions that do not allow for proper moisture and density control. CONTRACTOR shall not resume earthwork operations until the moisture content and the density of the previously placed soil are as specified. During freezing conditions, subgrades and each lift of fill must be compacted before the water in the subgrade or the fill can freeze.

F. Soil that is too wet for proper compaction shall be removed or disced, harrowed, rototilled, or otherwise dried to proper moisture content for compaction to the required density.

G. Soil that is too dry for proper compaction shall receive water uniformly applied over the surface of the loose layer. Compaction shall not be performed until the moisture content of the fill material is uniform. Sufficient water shall be added to allow for compaction to the required density.

H. The degree of soil compaction shall be based on a maximum dry density as determined by the ASTM D698. The minimum degree of compaction required, unless otherwise noted in plans or directed and approved by ENGINEER, shall be 95 percent. The moisture content, unless otherwise specified or directed by ENGINEER, shall be between -2 and +2 percent of the optimum moisture content determined by ASTM D698.

I. For Screened Till the degree of soil compaction shall be governed by the in-place hydraulic conductivity, which shall be no greater than 1×10^{-4} cm/sec when tested in accordance with ASTM D5084.

3.8 UTILITY TRENCH BACKFILL

A. CONTRACTOR shall backfill utility trenches as soon as practicable after the utility placed and tested in accordance with the appropriate section(s) of the Specifications and has been observed and approved by the CQA Consultant. CONTRACTOR is responsible for the satisfactory construction of the utility. If subsequent testing shows defects in materials or workmanship, then the necessary repairs and replacements shall be made by CONTRACTOR to the satisfaction of the CQA Consultant at no additional cost to OWNER.

B. Trench bedding and backfill shall be as specified on the Drawings. Trench backfill shall be placed simultaneously on either side of the pipe and compacted in such a manner as to avoid displacement of the utility. CONTRACTOR shall place and compact the backfill such that stones do not strike or remain in contact with the utility.

C. Trench bedding shall be placed to the spring line of the pipe and shaped so that the pipe is firmly supported across its diameter for its entire length. Particular care shall be taken to provide recesses in the bedding or trench bottom, as required, to relieve each bell of any load.

D. Placement of trench bedding shall be performed by skilled personnel and shall precede the laying of pipe by a reasonable distance.

E. From the top of the bedding to a minimum of 6 inches above the pipe crown, the trench shall be backfilled with the specified material placed evenly on both sides of the pipe with care being taken not to raise or otherwise dislodge the pipe. Backfill to this depth shall be thoroughly compacted with approved hand-operated devices.

F. No stone or rock fragment greater than 1 inch shall be placed into the trench nor shall large masses of backfilling material be dropped into the tamped layers of backfill until a minimum of 6 inches of backfill has been placed over the top of the pipe.

G. Wet backfill shall not be placed in the trench or compacted. CONTRACTOR shall suspend compacting activities until the backfill materials exhibit a moisture content sufficient to allow for proper compaction.

3.9 DRAINAGE SAND

A. The Drainage Sand shall be installed as shown on the Drawings.

B. Drainage Sand shall not be placed until the CQA Consultant approves the installation of the underlying geosynthetics.

C. Drainage Sand over drainage geocomposite shall only occur under the observation of the CQA Consultant.

D. CONTRACTOR shall use extreme care in placing Drainage Sand over the geosynthetics. The Drainage Sand shall be placed in a manner that will maintain a minimum thickness of 12 inches of material at all times between the geosynthetics and the bottom of construction equipment spreading material. Unless otherwise specified by ENGINEER, all equipment operating on earthen materials overlying the geosynthetics shall comply with the following.

Allowable Equipment Ground Pressure (psi)	Thickness of Overlying Compacted Soil (ft)
<5	1.0
<10	1.5
<20	2.0
>20	3.0

E. Lightweight, non-earthwork moving equipment with ground pressures less than 5 psi such as ATV and tracked backhoes may travel directly on the Drainage Geocomposite provided that the equipment does not turn or abruptly start and/or stop. The CQA Consultant shall observe the Drainage

Geocomposite for damage. Damaged drainage geocomposite shall be replaced by CONTRACTOR at no cost to OWNER.

F. CONTRACTOR shall control grades using a method which will not damage the geosynthetics. Grade stakes shall not be used in areas where geosynthetics are placed. Materials that may be used to control grades include, but are not limited to, sections of cardboard tubes or Styrofoam.

G. CONTRACTOR shall ensure that:
1. The geosynthetics remain intact during the installation of the overlying soil; and
2. No foreign material is mixed into the soil.

3.10 RIPRAP

A. Riprap shall be placed on top of a nonwoven geotextile.

B. Riprap shall be placed to its full thickness in one operation and in such a manner as to avoid displacing the underlying material or damaging the geotextile.

C. The larger stones shall be well distributed such that there are no large accumulations of either the larger or smaller sizes of stone.

D. CONTRACTOR shall place the Riprap such that a dense section is produced. Hand-placing or rearranging of individual stones by mechanical equipment may be required to secure the results specified.

E. Unless otherwise authorized by ENGINEER, Riprap shall be placed in conjunction with the dressing and preparation of the drainage channels. CONTRACTOR shall not delay placement of Riprap.

F. The edge of Riprap areas shall be blended into existing slope contours.

3.11 PENETRATIONS

A. Penetrations in the compacted soil that must be filled shall include, but not be limited to:
1. nuclear density test probe locations; and
2. test probes.

B. Penetrations in the compacted soil shall be backfilled with similar soil and compacted. The filled penetrations shall be to the satisfaction of the CQA Consultant.

3.12 DEFECTIVE AREAS

A. If a defective area is discovered in the compacted soil, then the CQA Consultant will notify CONTRACTOR who shall proceed to determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, then CONTRACTOR will determine the extent of the defective area by additional tests, observations, a review of records, or other means that CONTRACTOR deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, then CONTRACTOR will define the limits and nature of the defect.

B. After the extent and nature of a defect has been determined, CONTRACTOR shall correct the deficiency to the satisfaction of the CQA Consultant. The cost of corrective actions shall be borne by CONTRACTOR.

C. Additional testing will be performed, CONTRACTOR to verify that the defect has been corrected. The additional testing will be performed before any additional work is allowed in the area of deficiency.

3.13 FIELD QUALITY ASSURANCE

A. The CQA Consultant will monitor the placement and compaction of earth materials.

B. The CQA Consultant will perform quality testing as outlined in the CQA Plan.

C. The CQA Consultant shall select locations to observe construction and perform moisture content, gradation, and compaction tests. Where tests indicate that the soil tested does not conform to the specified compaction requirements, CONTRACTOR shall remove and recompact the material to the specified density at no additional cost to OWNER.

D. The presence of the OWNER, ENGINEER, or the CQA Consultant does not include supervision or direction of the Work by CONTRACTOR, his employees, or agents. Neither the presence of OWNER, ENGINEER, or the CQA Consultant, nor any observations and testing performed by them shall excuse CONTRACTOR from defects discovered in the Work.

E. Soil materials not meeting the Specification requirements shall not be used in the Work.

3.14 GRADING TOLERANCE

A. Disturbed areas shall be graded so that water sheds and no ponding of surface water runoff.

B. Finished grades shall be within ½ inch of the required elevations in areas where the geomembrane will be placed.

C. Finished grades shall be within 1 inch of the required elevations in areas beyond where geomembrane is placed.

[END OF SECTION 02200]

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SECTION 02510

NONWOVEN GEOTEXTILES

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall provide all labor, materials, tools, and equipment and perform all operations necessary to furnish, deploy, and install the nonwoven geotextiles in the areas indicated on the Drawings or as required by ENGINEER or OWNER.

1.2 QUALITY ASSURANCE

A. Experience
   1. CONTRACTOR shall be trained and experienced in field handling, storing, deploying, installing, and protecting the nonwoven geotextiles.
   2. CONTRACTOR shall demonstrate at least four years of experience in sewing nonwoven geotextiles and shall have completed at least four projects that required nonwoven geotextile sewing. Alternatively, CONTRACTOR shall engage an experienced subcontractor or manufacturer's agent who shall meet the experience requirements.

B. Submittals
   1. At least 15 days prior to delivery of the nonwoven geotextiles to the project site, CONTRACTOR shall submit to ENGINEER certifications that the nonwoven geotextile and thread meet the required specifications, and a description of the proposed sewn seam types.
   2. CONTRACTOR shall submit the qualifications of the person(s) who will be sewing the nonwoven geotextile prior to performing the related Work.

1.3 MATERIALS STORAGE AND HANDLING

A. CONTRACTOR shall be responsible for the handling, storage, and care of nonwoven geotextile from the time of delivery to the project site until final acceptance of the completed Work by OWNER. CONTRACTOR shall be liable for all damages to the materials during such time.

PART 2 – PRODUCTS

2.1 GENERAL

A. The nonwoven geotextile provided shall meet or exceed the property values specified herein. The nonwoven geotextile shall be comprised of polymeric yarns of fibers or weld or drawn strands oriented into a stable network that will retain its structure during handling, placement, and long-term service.

nonwoven geotextile shall be capable of withstanding direct exposure to the sunlight for 30 days with no measurable deterioration.

B. The nonwoven geotextile fabrics shall be non-biodegradable. CONTRACTOR shall follow the manufacturer's recommendations regarding handling and installation of such materials.

2.2 GEOTEXTILES

A. The nonwoven geotextile shall be installed as indicated in the Drawings.

B. The nonwoven geotextile shall be manufactured of polypropylene or polyester material exhibiting the following Minimum Average Roll Values (MARV).

Property	Test Method	MARV	
		10 oz/yd^2	16 oz/yd^2
Mass per Unit Area (oz/yd^2)	ASTM D5261	10	16
Grab Tensile Strength (lbs)	ASTM D4632	250	380
Trapezoidal Tear Strength (psi)	ASTM D4533	100	150
Apparent Opening Size (mm)	ASTM D4751	<0.15	<0.15
Puncture Resistance (lbs)	ASTM D6241	700	1100
Permittivity (sec^{-1})	ASTM D4491	1.2	0.7

PART 3 – EXECUTION

3.1 INSTALLATION

A. The nonwoven geotextile shall be installed in accordance with the manufacturer's recommendations, as shown on the Drawings and specified herein.

B. Where the use of adjacent sheets of a nonwoven geotextile are required and are not to be sewn, a minimum overlap of 18 inches shall be maintained.

C. Sheets of nonwoven geotextile used in drainage swales, or areas subject to concentrated stormwater flow, shall be shingled such that the upslope nonwoven geotextile overlies the adjacent downgradient sheet.

D. All holes and tears in the nonwoven geotextile shall be noted and repaired as specified by the CQA Consultant .

[END OF SECTION 02510]

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SECTION 02520

DRAINAGE GEOCOMPOSITE

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall provide all labor, materials, tools, and equipment and perform all operations necessary to furnish, deploy, and install Drainage Geocomposite in the areas indicated on the Drawings or as required by ENGINEER or OWNER.

1.2 QUALITY ASSURANCE

A. CONTRACTOR shall be trained and experienced in field handling, storing, deploying, and installing Drainage Geocomposite. Alternatively, CONTRACTOR shall engage an experienced Subcontractor who shall meet the experience requirements.

B. Drainage geocomposite shall be sampled and tested in accordance with the approved Construction Quality Assurance (CQA) plan.

C. At least 10 days prior to beginning geosynthetic installation, CONTRACTOR shall submit to ENGINEER the results of the laboratory tests for all the interfaces to be tested (see also Specification Section 02560).

1.3 MATERIAL STORAGE AND HANDLING

A. CONTRACTOR shall be responsible for the handling, storage, and care of the Drainage Geocomposite from the time of delivery to the site until final acceptance of the completed work by the CQA Consultant, ENGINEER, and OWNER. CONTRACTOR shall be liable for all damages to the materials during such time.

1.4 SUBMITTALS

A. CONTRACTOR shall submit manufacturer's data indicating conformance with these Specifications.

B. At least 15 days prior to delivery of materials, CONTRACTOR shall submit to ENGINEER the following:

1. Certification that the material meets the required Specifications;
2. Drawings showing geocomposite sheet layout, location of seams, direction of overlap, and sewn seams;

3. Description of proposed method of deployment, sewing equipment, sewing methods, and provisions for holding geocomposite temporarily in place until permanently secured.

PART 2 – PRODUCTS

2.1 GENERAL

A. The Drainage Geocomposite shall meet the performance requirements of this section. CONTRACTOR may select from either a geonet geocomposite or a multi-liner geocomposite for the primary liner system. A geonet geocomposite must be used within the secondary liner system.

2.2 MULTI-LINEAR DRAINAGE GEOCOMPOSITE

A. Material Description
   1. Multi-Linear Drainage Geocomposite shall consist of two geotextile layers comprised of short synthetic staple fibers of 100% polypropylene or polyester needle-punched together with perforated corrugated polypropylene pipes (mini-pipes) regularly spaced inside.
   2. The perforated polypropylene pipes shall function as the primary fluid conveyance. The pipes shall be corrugated with two perforations per corrugation at 180° and alternating at 90°.
   3. Multi-Linear Drainage Geocomposite may only be used in the primary liner system.

B. Multi-Linear Drainage Geocomposite Properties
   1. The components of the Multi-Linear Drainage Geocomposite specified shall meet or exceed the values provided in the table below.

MANUFACTURING QUALITY CONTROL TEST REQUIREMENTS			
CHARACTERISTIC	**STANDARD**	**UNIT**	**MARV(1)**
Mini-pipe Properties			
Outside diameter	ASTM D2122	in.	1.0
Stiffness at 5% deflection	ASTM D2412	psi	435
Geotextile Properties (each component)			
Mass Per Unit Area	ASTM D5261	oz/yd^2	10
Grab Tensile Strength	ASTM D4632	lb	160
Trapezoidal Tear Strength	ASTM D4533	lb	65
Puncture CBR	ASTM D6241	lb	450
AOS	ASTM D4751	mm	≤0.12
Permittivity	ASTM D4491	sec^{-1}	≥1.80
Geocomposite Properties			
Transmissivity (2)	ASTM D4716	m^2/sec	2.0×10^{-3}

Notes:
(1) Maximum Average Value.
(2) Measured at a minimum seating time of 100 hours, with a test section including Drainage Sand above the Drainage Geocomposite and textured 60-mil textured HDPE below, using a gradient of 0.1 under a compressive stress of 12,000 psf for 100 hours.

2.3 GEONET DRAINAGE GEOCOMPOSITE

A. Material Description

1. Geonet Drainage Geocomposite shall consist of a geonet to which a geotextile has been heat-bonded to both sides.
2. The geonet shall be manufactured of high-density polyethylene.
3. The geotextile shall be needle-punched, nonwoven, short synthetic staple polypropylene or polyester fibers

B. Geonet Drainage Geocomposite Properties

1. The components of the Geonet Drainage Geocomposite specified shall meet or exceed the values provided in the table below.

MANUFACTURING QUALITY CONTROL TEST REQUIREMENTS			
CHARACTERISTIC	**STANDARD**	**UNIT**	**MARV(1)**
Geonet Properties			
Core Net Thickness	ASTM D5199	mils	≥330
Resin Specific Gravity	ASTM D1505	g/cm^3	0.94
Resin Melt Index	ASTM D1238	g/10 min	< 1.1
Tensile Strength	ASTM D7179	lb/in.	100
Carbon Black Content	ASTM D4218	%	2 to 3
Geotextile Properties (each component)			
Mass Per Unit Area	ASTM D5261	oz/yd^2	10
Grab Tensile Strength	ASTM D4632	lb	260
Trapezoidal Tear Strength	ASTM D4533	lb	100
Puncture CBR	ASTM D6241	lb	725
AOS	ASTM D4751	mm	≤0.150
Permittivity	ASTM D4491	sec^{-1}	1.0
Geocomposite Properties			
Transmissivity(2)	ASTM D4716	m^2/sec	$2×10^{-3}$
Ply Adhesion	ASTM D7005	lb/in.	1.0

Notes:
(1) Maximum Average Value.
(2) Measured at a minimum seating time of 100 hours, with a test section including Drainage Sand above the Drainage Geocomposite and textured 60-mil textured HDPE below, using a gradient of 0.1 under a compressive stress of 12,000 psf for 100 hours.

2.4 TIES (for Geonet Drainage Geocomposite only)

A. Ties used to secure adjacent sheets of geonet shall be plastic fasteners or polymer braid and shall meet the approval of ENGINEER. Metallic ties shall not be allowed. Ties shall be yellow or white to facilitate inspection.

2.5 THREAD

A. Thread used to seam the geotextile shall be polymer material with chemical resistance properties equal to or exceeding those of the geotextile. The thread shall be different color than the geotextile.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Drainage Geocomposite shall <u>not</u> be stockpiled or stored within the limits of the area to be lined.

B. Drainage Geocomposite shall be installed in accordance with manufacturer's recommendations, and as shown on the Drawings and specified herein. If a Drainage Geocomposite with a preferential flow direction is used, it shall be installed oriented with the preferential flow direction perpendicular to the contours unless otherwise approved by ENGINEER.

C. Care shall be taken to keep the Drainage Geocomposite clean prior to installation.

D. Folds or excessive wrinkling of deployed Drainage Geocomposite shall be removed to the extent practicable. CONTRACTOR shall exercise care not to entrap stones, excessive dust, or foreign objects in the material. Drainage Geocomposite shall be adequately weighted, using sand bags or equivalent until the Drainage Sand and Crushed Gravel cover is placed.

E. Adjacent sheets of Drainage Geocomposite shall be overlapped a minimum of 4 inches, and shall be secured using ties, if appropriate for the material used, placed at intervals no greater than 5 feet. Additional ties spaced at intervals not exceeding 2 feet shall be used on seams running across slopes and located in anchor trenches. Spot welding of the Drainage Geocomposite to the geomembrane shall not be allowed.

F. The upper geotextile on adjacent panels of Drainage Geocomposite shall be sewn together with a continuous seam in the field prior to placement of overlying soil. All seams on sideslopes shall be oriented parallel to the slope. The adjacent sheets of geotextile shall be overlapped a minimum of 6 inches prior to seaming. All overlaps shall be such that the upslope sheet is placed over the downslope sheet. No holes in the upper geotextile will be allowed. All tie holes at horizontal seams shall be covered with a leistered nonwoven geotextile patch.

G. Drainage Geocomposite shall not be exposed to ultraviolet rays for more than fourteen (14) days before being covered. CONTRACTOR shall place Drainage Sand over the Drainage Geocomposite as specified in Section 02200 and in such a manner as to ensure the Drainage Geocomposite is not damaged.

[END OF SECTION 02520]

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SECTION 02530

GEOSYNTHETIC CLAY LINER

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, tools, and equipment and perform all operations necessary to furnish, deploy, and install Geosynthetic Clay Liner (GCL) in the areas indicated on the Drawings or as required by the ENGINEER or OWNER.

1.2 SUBMITTALS

A. CONTRACTOR shall submit to ENGINEER certification that the materials meet the required specifications and the manufacturer's instructions for handling and installing the material, at least ten days prior to delivery of materials to the site.

B. At least 10 days prior to beginning geosynthetic installation, CONTRACTOR shall submit to ENGINEER the results of the laboratory tests for all the interfaces to be tested (see also Specification Section 02560).

1.4 QUALITY ASSURANCE

A. CONTRACTOR shall be trained and experienced in field handling, storing, deploying, and installing GCL. Alternatively, CONTRACTOR shall engage an experienced subcontractor who shall meet the experience requirements.

B. GCL shall be sampled and testing in accordance with the approved Construction Quality Assurance (CQA) plan.

1.5 MATERIAL STORAGE AND HANDLING

A. All rolls shall be labeled and bagged in packaging that is resistant to degradation by ultraviolet (UV) light.

B. CONTRACTOR shall be responsible for the handling, storage, and care of the GCL from the time of delivery to the site until final acceptance of the completed work by OWNER. CONTRACTOR shall be liable for all damages to the materials during such time.

C. The GCL shall be stored in a dry location and off the ground.

PART 2 – PRODUCTS

2.1 GCL

A. The GCL shall consist of a continuous layer of sodium bentonite sandwiched between two geotextiles and reinforced with needle punched fibers.

B. The sodium bentonite components shall be 90 percent montmorillonite (from Wyoming).

C. The GCL Manufacturer shall deliver CCL Geomembrane that conforms with the properties below.

Property	Test Method	Value
Bentonite Mass/Unit Area (MARV)	ASTM D5993	0.75 lbs/ft^2
Geotextile Mass/Unit Area (MARV)	ASTM D5261	Top/cap onwoven = 6.0 oz/yd^2 Carrier woven = 3.1 oz/yd^2
Permeability (max.)	ASTM D5887	5x10^{-9} cm/sec at 5 psi confining pressure and 2 psi head
Tensile Strength (MARV)	ASTM D6768	30 lbs/in
Fluid Loss, max. (bentonite property)	ASTM D5891	18 milliliters
Peel Strength (min.)	ASTM D6496	3.5 lbs/in.
Internal Shear Strength (min.)	ASTM D6243	500 psf

MARV = minimum average roll value

PART 3 – EXECUTION

3.1 INSTALLATION

A. GCL shall be installed in accordance with the manufacturer's recommendations, and as shown on the Drawings and specified herein.

B. GCL shall be deployed over prepared and approved subgrade as soon as practicable after completion of subgrade preparation. The material shall be placed so as not to cause subgrade disturbance with the carrier side in contact with the Drainage Sand. GCL shall not be deployed through standing water or during rainfall. Care shall be exercised to ensure that no large stones or foreign objects are trapped beneath the GCL.

C. CONTRACTOR shall only deploy GCL in an area that can be completed in one day. Completion includes deploying, seaming, and covering with Geomembrane. If inclement weather is approaching or is present, no additional GCL shall be placed until the previously placed GCL is covered with Geomembrane and seamed. GCL that becomes wet and hydrates shall be removed and replaced at the discretion of ENGINEER at no additional cost to OWNER.

D. Adjacent sheets of GCL shall be overlapped a minimum of 6 inches. A continuous bead of granular sodium bentonite shall be applied between all overlapping edges of material. On sideslopes, seams shall be perpendicular to the contours. Seams shall be made in accordance with the manufacturer's recommendations. Wrinkles and creases shall be removed from a sheet prior to deploying and overlapping the adjacent sheet. CONTRACTOR shall clean all dirt and debris from contacting surfaces.

E. Where cuts are required during installation, the exposed surfaces shall receive powdered bentonite and be slightly hydrated.

F. All holes, tears, and cuts in the GCL shall be recorded and repaired in accordance with the manufacturer's recommendations or as specified by ENGINEER.

[END OF SECTION 02530]

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SECTION 02550

GEOMEMBRANE

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall furnish all labor, materials, tools, equipment, and incidentals, and perform all operations necessary to furnish, deploy, seam, and test the textured, high-density polyethylene (HDPE) Geomembrane (Geomembrane) as described in this Specification and where indicated in the Drawings.

1.2 DEFINITIONS

A. *Geomembrane Manufacturer*: The party responsible for the manufacturing of the Geomembrane liner material.

B. *Installation Contractor*: The Installation Contractor shall be the Geomembrane Manufacturer or a contractor approved by the manufacturer to install the Geomembrane Manufacturer's Geomembrane and who is trained and experienced in field handling, storing, deploying, seaming, and QC testing of Geomembrane for landfill applications.

C. *Lot*: A quantity of resin (usually the capacity of one rail car) used by the Geomembrane Manufacturer. Each finished roll of Geomembrane will be identified by a roll number traceable to the resin lot used.

D. *Panel*: Unit of Geomembrane seamed in the field and is larger than 100 square feet (ft^2).

E. *Patch*: Unit of Geomembrane seamed in the field and is smaller than 100 ft^2.

F. *CQA Consultant*: OWNER will engage a CQA Consultant to verify the quality of raw materials, the integrity and quality of seams and seaming processes performed on-site, and the locations and results of all testing and repair work performed. The CQA Consultant will observe and document the work, and in particular, the quality control testing performed by the Installation Contractor.

H. *Quality Control (QC)*: The Geomembrane Manufacturer shall implement QC measures to ensure that the Geomembrane provided meets the Specifications provided herein. The Installation Contractor shall implement QC measures to ensure Geomembrane installation is complete and is in compliance with the Specifications contained herein. QC procedures include, but are not limited to providing the Geomembrane Manufacturer's material QC certifications; providing experienced and competent field staff; performing adequate personnel training; performing QC testing during Geomembrane installation; and maintaining records documenting QC items, such as, as-built panel layout, locations and identifications of all repairs, locations and results of all destructive and non-destructive field tests, as specified herein.

G. *Subgrade Surface*: The soil surface that immediately underlies geosynthetic material.

1.3 SUBMITTALS

A. With the Bid, CONTRACTOR shall submit the following information:

1. Installation Contractor qualifications, including project descriptions with references.
2. Brand of Geomembrane to be used, and a statement from the Geomembrane Manufacturer detailing its properties and composition, and a description of the Geomembrane Manufacturer's QC program.
3. Draft warranties regarding quality of workmanship, materials, and long-term performance of the Geomembrane.

B. No more than 15 days after the Notice of Award, the Installation Contractor shall submit the following:

1. Shop Drawings showing extent, sizes, panel identification numbers, and details of the Geomembrane installation, including recommendations for terminating the material and proposed methods of sealing around penetrations if different from those shown on the Drawings. Except for special requirements due to configuration and/or terminating the Geomembrane, maximum use of large-size panels shall be made.
2. Superintendent qualifications.
3. QC plans detailing proposed QC procedures.
4. The Geomembrane Manufacturer's certification that the resin used meets the Specifications. The QA/QC certificates issued by the Geomembrane Manufacturer and the resin supplier shall be provided.
5. Samples of all materials shall be submitted for inspection and acceptance.

C. At least 15 days prior to manufacturing the proposed Geomembrane, CONTRACTOR or Geomembrane Manufacturer shall submit the proposed manufacturing dates for the rolls to be utilized.

D. CONTRACTOR shall advise the CQA Consultant promptly upon placing orders for Geomembrane, so that arrangements may be made, if desired, for inspection of the proposed geomembrane during manufacturing.

E. Prior to shipping the Geomembrane from the factory, CONTRACTOR shall provide the roll certifications to the CQA Consultant.

F. Prior to deploying Geomembrane, the Installation Contractor shall provide a letter to the CQA Consultant indicating the acceptance of the Subgrade Surface.

G. At least 10 days prior to beginning geosynthetic installation, CONTRACTOR shall submit to ENGINEER the results of the laboratory tests for all the interfaces to be tested (see also Specification Section 02560).

H. During the course of the work, the Installation Contractor shall maintain as-built drawings showing, but not limited to, panel layout and identification, seam type and identification, repair locations and identifications, and destructive test sample locations and identification. The Installation Contractor shall submit working copies of the as-built drawings to the CQA Consultant upon request, and shall submit a final copy to ENGINEER prior to moving off the site.

1.4 QUALIFICATIONS OF INSTALLATION CONTRACTOR AND MANUFACTURER

A. To perform the work of this Specification, the Installation Contractor shall have demonstrated by previous experience its ability to do the Work. The required previous experience shall consist of the following:
   1. The Installation Contractor shall be approved and/or licensed to install the products by the Geomembrane Manufacturer.
   2. The Installation Contractor shall have successfully installed Geomembrane for not less than ten projects, or Geomembranes totaling a minimum of 2,000,000 ft^2 similar in type to that specified herein, now giving satisfactory service in the United States.
   3. The Installation Contractor shall provide documentation for at least three similar Geomembrane projects of at least 200,000 ft^2 in continuous area.

B. The Geomembrane Manufacturer shall have manufactured and fabricated not less than 10,000,000 ft^2 of Geomembrane similar to that specified herein.

C. The Installation Contractor shall provide the services of a competent field technical representative throughout the installation of the Geomembrane and all appurtenant structures and soils contacting the Geomembrane. The field technical representative shall remain on-site and be responsible throughout the installation of the Geomembrane for Geomembrane layout, seaming, patching, testing, repairs, and other activities of the Installation Contractor. The field technical representative shall have personally supervised and directed the installation of a minimum of 2,000,000 ft2 of Geomembrane.

D. All personnel performing seaming operations shall be qualified by experience and by successfully passing seaming tests. At least one seamer shall have experience seaming a minimum of 1,000,000 ft2 of Geomembrane with a similar method. This “Master Seamer” will provide direct supervision over less experienced seamers; no seaming will take place without a Master Seamer present.

E. All field seams shall be inspected over their full length in accordance with these Specifications by the Installation Contractor in the presence of the CQA Consultant or the CQA Consultant's representative.

F. The manufacturer shall furnish complete written instructions for storage, handling, installation, seaming, repair, and inspection of the Geomembrane material in compliance with this Specification and conforming to the conditions of the warranty. A copy of all manufacturer's literature shall be submitted to the CQA Consultant upon request.

1.5 PROJECT MEETINGS

A. A preconstruction meeting is required between Owner, Engineer, Contractor, the CQA Consultant, and the Installation Contractor, prior to the start of Geomembrane installation work on-site. The intent of the meeting is to discuss the requirements of these Specifications to ensure that all parties involved are familiar with their respective responsibilities.

B. The Installation Contractor shall attend other construction meetings that may be held during the installation of the geosynthetics associated with the project. These meetings will be held to review work activities, discuss the project schedule, provide clarifications, and review possible questions.

1.6 QUALITY ASSURANCE

A. OWNER will retain a the CQA Consultant to perform construction quality assurance services during the Geomembrane installation. The CQA Consultant shall be on-site for observation of Geomembrane handling, deploying, seaming, testing, and repair work.

B. The Installation Contractor shall cooperate with the CQA Consultant, and furnish tools, samples of materials, and assistance as requested.

C. The Installation Contractor shall apprise the CQA Consultant of the proposed work schedule on a daily basis, and shall inform the CQA Consultant of schedule changes in a timely manner.

D. The Installation Contractor shall advise ENGINEER and the CQA Consultant before placing orders for Geomembrane, so that arrangements may be made, if desired, for inspection of the Geomembrane during manufacturing. The Installation Contractor shall at all times furnish the CQA Consultant and its representatives facilities, including labor, and allow proper time for observing and testing materials and workmanship. The Installation Contractor shall allow time in the schedule for possible delays due to the necessity of materials and workmanship being observed, tested and accepted for use. The Installation Contractor shall furnish, at his/her own expense, all samples of materials required by ENGINEER or the CQA Consultant for testing.

E. Geomembrane shall be sampled and tested in accordance with the approved Construction Quality Assurance (CQA) Plan.

PART 2 – PRODUCTS

2.1 GEOMEMBRANE

A. Membrane Resin Specifications

1. Geomembrane shall be from first-quality resin containing no recycled polymer (product run may be recycled). The resin shall be the same for the Geomembrane and the extrudite rod or bead and shall meet the following specifications:

Property	Test Method	Value
Melt Index	ASTM D1238 Condition 190/2.16	<1.0 grams (g)/10 min.
Specific Gravity	ASTM D4883	0.94 g/cm^3

B. Geomembrane Specifications

1. The Geomembrane Manufacturer shall deliver Geomembrane that is in conformance with the specifications below.

Property	Test Method	Value
Thickness (min. ave.): Lowest individual of 8 out of 10 values Lowest individual for any of the 10 values	ASTM D5994	57 mil 54 mil 51 mil
Asperity Height (min. ave.)	ASTM D7466	16 mil
Formulated Density	ASTM D792	0.94 g/cc
Tensile strength (min. ave.)$^{(A)}$ Yield strength Break strength Yield elongation Break elongation	ASTM D6693	 126 lb/in. width 90 lb/in. width 12 percent 100 percent
Tear resistance (min. ave.)	ASTM D1004	42 lbs
Puncture resistance (min. ave.)	ASTM D4833	90 lbs
Stress Crack Resistance (min. ave.)$^{(B)}$	ASTM D5397	≥ 500 hours
Carbon Black Content (range)	ASTM D4218	2 to 3 percent
Carbon Black Dispersion	ASTM D5596	(see Note C)
Oxidative Induction Time (min. ave.)	ASTM D3895	≥ 100 minutes

Notes:

A. Test in Machine direction and cross machine direction. The average values should be based on 5 test specimens each direction.
   - Yield elongation is calculated using a gage length of 1.3 inches.

- Break elongation is calculated using a gage length of 2.0 inches.

B. This test is not appropriate for testing geomembranes with textured or irregular rough surfaces. The test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the test should be the manufacturer's mean value obtained from the manufacturer's quality control testing of the same sample.

C. Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2; and
- 1 in Category 3.

2. The Geomembrane Liner shall consist of a base sheet meeting the specifications below with texturing applied to both sides of the sheet. The texturing of the Geomembrane Liner shall be regular and uniform. Rolls of Geomembrane Liner containing irregular texturing (bald areas or clumps of texturing material) may be rejected by the CQA Consultant and shall be removed from the site by the Contractor.

3. The Geomembrane roll shall have 6 inches of smooth, non-textured material along both edges of the roll.

4. The Geomembrane shall consist of unreinforced HDPE containing 3 percent by weight maximum additives, fillers, or extenders, including carbon black.

5. The Geomembrane shall have no striations, pinholes, or bubbles and shall be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.

6. The Geomembrane delivered to the site shall be accompanied by a QC Certificate for each roll (roll Certificates must be provided to the CQA Consultant prior to shipment to the job site), and shall be identified with a distinctive code that will serve as the identification number on the as-built drawing.

7. Samples shall be taken from the delivered material by the CQA Consultant for testing as outlined in the CQA Plan.

PART 3 – EXECUTION

3.1 DELIVERY, STORAGE, AND HANDLING

A. Transportation to, and unloading and storage at, the projet site shall be the responsibility of the Installation Contractor. Damaged Geomembrane or Geomembrane not meeting these Specifications shall be immediately removed from the project site and replaced, at no cost to OWNER. Once delivered and accepted by the CQA Consultant, the Geomembrane rolls shall be stored on a prepared surface approved by the CQA Consultant, no more than three rolls high, and protected from dirt, grease, water, abrasions, excessive heat or cold, or other damage.

B. Geomembrane rolls shall be handled with appropriate equipment to prevent damaging or stressing of the Geomembrane. Loading and unloading shall be performed using equipment such as spreader bars and cloth chokers. Deployment shall be performed using equipment such as roll bars and vise-grip pliers designed to handle sheet materials. Any damaged Geomembrane shall be repaired or replaced immediately, at the discretion of the CQA Consultant, and at no cost to Owner.

C. Geomembrane shall not be stockpiled or stored within the limits of the area to be lined.

3.2 WEATHER CONDITIONS

A. Geomembrane panels shall not be installed, seamed, or repaired during periods of precipitation, excessively high winds, or in areas of ponded water or excessive moisture. Geomembrane panels may be installed and seamed only if the ambient air temperature, measured 6-inches above the Geomembrane, is less than 110 degrees (°) Fahrenheit (F). Installation and seaming of Geomembrane panels in ambient temperatures below 40°F shall only be performed with approval of ENGINEER, and only if trial seams demonstrate the ability to meet seaming specifications. The Installation Contractor shall submit for ENGINEER's review and approval a plan for installation and seaming Geomembrane in temperatures between 0°F and 32°F.

B. If allowed by ENGINEER, installation and seaming in temperatures below 40°F shall follow the guidelines of GRI Test Method GM9.

3.3 GENERAL INSTALLATION

A. The Installation Contractor shall be responsible for field handling, storing, placing, and seaming, plus any other processes required to assemble a continuous secure Geomembrane.

B. Installation shall be performed under the direction of a competent field technical representative. The technical representative shall be in charge of the installation and shall be responsible for the work performed.

C. Smoking is prohibited on the Geomembrane or other geosynthetics associated with the project. Installation Contractor personnel who are reminded by CONTRACTOR, ENGINEER, OWNER, or the CQA Consultant more than three (3) times of the no smoking requirements will be asked to leave the site.

D. Subgrade preparation and bedding placement shall be performed in accordance with Section 02200. Surfaces to be lined shall be smooth and free of all rocks, stones, sticks, roots, sharp objects, or debris of any kind. The surface should be smooth and provide a firm, unyielding foundation for the Geomembrane with no sudden, sharp, or abrupt changes or breaks in grade.

No standing water or excessive moisture shall be allowed. Prior to the installation of any Geomembrane, the Installation Contractor and the CQA Consultant shall observe the surface that the Geomembrane will be installed. The Installation Contractor will direct any remedial work required to bring the surface into compliance with the Specifications required for Geomembrane installation. Upon satisfactory surface preparation, the Installation Contractor and the CQA Consultant will issue a letter to Owner indicating acceptance of the subgrade.

E. The Geomembrane shall be placed over the prepared surfaces in a manner that results in minimum handling. Any portion of Geomembrane damaged during installation by any cause shall be removed or repaired at no additional cost to Owner.

F. Geomembrane panels to be installed on slopes shall be oriented such that seams are parallel to the line of slope. The seams shall be terminated or extended a minimum of 25 feet from the toe of slope.

G. Each Geomembrane panel shall be assigned a simple and logical identification number or letter. In addition, the Installation Contractor shall record the roll number, location, and date of installation of each panel placed. The panels shall be marked by their identification number or letters, and shall be recorded on the as-built drawings by the Installation Contractor. Upon completion of the Work, the Installation Contractor shall submit as-built drawings with panel identifications to the CQA Consultant.

H. The panel layout pattern will be decided upon prior to placement in a meeting between Owner, ENGINEER, CONTRACTOR, the CQA Consultant, and the Installation Contractor. The panel overlap pattern should be similar to that used for shingles, to facilitate the drainage of water. No more panels shall be deployed during a single day than can be seamed or tack-welded together that same day.

I. All deployed Geomembrane panels shall be protected from wind uplift by placing suitable ballast that will not damage the Geomembrane during its placement or removal.

J. All disturbed subgrade or other underlying material shall be repaired and observed by the CQA Consultant prior to deploying Geomembrane panels.

K. Vehicle traffic shall not be allowed directly on Geomembrane panels. Equipment shall not damage panels by handling, leakage, transporting across panels, or any other means. Personnel working on or with Geomembrane panels shall not wear shoes that may damage the panels.

L. Geomembrane panels shall be deployed using methods that will not stretch, crimp, abrade, or otherwise damage panels. Placement of panels shall employ methods that limit wrinkles and differential wrinkles between adjacent panels.

M. Placement of soil shall not occur on Geomembrane that is under stress due to thermal contraction or other causes, or that has large winkles that may fold over and crimp, or when the ambient air temperature, measured 6-inches above the Geomembrane, is greater than 104°F or lower than 40°F without prior approval of ENGINEER. Panels under tensile stress due to thermal contraction or any other cause shall be cut and a patch shall be placed to provide compensation for Geomembrane contraction. Equipment shall not be operated directly on the Geomembrane during placement of soil.

N. Geomembrane panels shall be secured in the anchor trench as indicated on the Drawings.

O. All pipe penetrations through the Geomembrane shall be sealed with a boot of the same material as the panels, meeting the same resin specifications, and installed in accordance with the Drawings.

3.4 TRIAL SEAMS

A. Trial seams shall be performed with each seam welder at the beginning (start of shift) of each day, and at the beginning of each period after which the welder has been turned off or disconnected from its power supply, or has been idle for 30 minutes (extrusion welder) or 60 minutes (hot wedge welder), and after any change in operator personnel on a welder, after 5 hours of continuous seaming, or at any other time deemed necessary by the CQA Consultant.

B. The Installation Contractor is responsible for providing and operating an on-site tensiometer and corresponding sample cutting equipment to perform all trial and field seam testing.

C. Trial seams shall be produced under the same physical conditions as production seaming.

D. Trial seam samples shall be a minimum of 5 feet long and 12 inches wide (perpendicular to the seam).

E. Trial seams samples shall be tested as defined in Paragraph 3.6 of this specification. If a trial seam test fails to meet the requirements of Paragraph 3.6 of this specification, then another trial seam shall be performed and tested. If the second trial seam fails, then the seam welding equipment shall not be used until it is repaired or faulty conditions are corrected, and two trial seams pass the requirements of Paragraph 3.6 of this specification.

F. A record of the date, time, ambient weather conditions, test results, operator, and equipment number shall be kept by the Installation Contractor, and submitted to the CQA Consultant on a weekly basis. A properly identified unused section of the trial weld seam will be retained by the OWNER.

3.5 GEOMEMBRANE SEAMING

A. Geomembrane seams shall be arranged so that the seams are oriented parallel to the line of maximum slope. Cross or butt seams on slopes, seams located in corners, and unusual geometric panel shapes shall be minimized and shall be installed such that the upgradient sheet is installed over the edge of the downgradient sheets.

B. The seam identification system shall be related to and be compatible with the panel identification system.

C. Seaming equipment shall be equipped with temperature gauges and readout devices that enable continuous monitoring of equipment temperatures during seaming. Electric generators shall be capable of providing constant voltage under load and shall be underlain with a splash pad to collect spilled fuel or oil when located on the Geomembrane.

D. Surfaces to be seamed shall be overlapped a minimum of 4 inches and cleaned of moisture, grease, dust, dirt, debris, and any other foreign material. No solvent or adhesive shall be used for seaming without approval from the manufacturer and ENGINEER.

E. Where moisture or dirt interferes with the seam, a protective sheet of plastic shall be placed below the seam overlap to protect the panels being seamed. This may consist of a “rub sheet” of plastic that is pulled along beneath the seaming apparatus.

F. Surfaces to be seamed using extrusion welding shall be cleaned of oxidation by disc grinder not more than one hour before extruding the seam. Abrasion of the seam area with the disc grinder shall not extend beyond the extrusion bead area unless inspected and approved by the CQA Consultant. Tack welding of the panels to be seamed shall not damage the Geomembrane or adversely affect the seaming operation. The top Geomembrane of the seam overlap shall be beveled and the extrusion apparatus shall be purged of heat-degraded extrudite before seaming.

G. Should wrinkles occur, a cut shall be made along the ridge of the wrinkle and laid flat so the edges of the material overlap. The overlap shall be extrusion-seamed and any portion of the seam with less than a 3-inch overlap shall be patched with a circular or oval patch extending a minimum of 6 inches beyond the cut in all directions.

H. All T-seams and air testing needle holes are to be capped with a circular or oval patch extending a minimum of 6 inches beyond the spot weld in all directions.

I. The Installation Contractor shall log the ambient air temperature 6 inches above the Geomembrane elevation, extruded temperatures in extrusion equipment barrels and nozzles, and operating temperatures of hot wedge seamers at intervals specified by the CQA Consultant.

J. The Installation Contractor shall visually inspect seams and panels for holes, crimps, abrasions, or defects, and shall mark each suspect location. All repair locations shall be assigned an appropriate identifying label that shall be clearly marked on the panel adjacent to the repair location and shall be shown on the as-built drawings. Each marked location shall be repaired, non-destructively tested, and recorded on the as-built drawings. No repairs shall be covered until passing results of non-destructive tests are achieved and accepted by the CQA Consultant.

K. Methods of repair shall consist of spot welding small tears or over-abraded areas where thickness of the Geomembrane was reduced by more than 6 mils (0.006 inches) abrading and re-welding small sections of defective extrusion welds and removing a defective seam and replacing with a new strip of material. The surface of the Geomembrane in the seam/repair area shall be abraded no more than one hour before the repair is made. All Geomembrane surfaces shall be cleaned and dried at the time of the repair. Patches over larger holes and other defects shall extend a minimum of 6 inches beyond the edges of the defect. All corners of patches shall be rounded with a radius of at least 3 inches.

3.6 GEOMEMBRANE SEAM TESTING

A. Seam strength testing shall be performed at a minimum frequency of one per 500 linear feet of seam. As the project continues and data on seam quality are gathered, this frequency may be varied at the discretion of the CQA Consultant and with the approval of the Owner based on the procedure outlined in GRI GM14 (Standard Guide for Selecting Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes). The CQA Consultant will select the locations for seam samples and reserves the right to increase the frequency of seam testing if deemed necessary. Seam strength testing shall be performed as work progresses to obtain test results before seams are covered.

B. The Installation Contractor shall cut seam samples at the locations designated by the CQA Consultant. The seam samples shall be 12 inches wide and 48 inches long with the seam centered lengthwise. Each seam sample shall be assigned an identification number and the locations shall be recorded on the As-Built drawings.

C. Sampling for destructive testing shall be performed on a daily basis as the seaming progresses to remain current with the amount of sheet deployed.

D. All holes resulting from seam sampling shall be repaired immediately and tested with the vacuum box in accordance with these specifications.

E. Field testing (peel and shear) of all seam samples shall be performed by the Installation Contractor and observed by the CQA Consultant prior to the shipment of the samples to an independent geosynthetics testing laboratory. Failed field tests may constitute a failed seam and further 3rd party testing may or may not be performed by the CQA Consultant. The Installation Contractor is responsible for providing and operating an on-site tensiometer and corresponding sample cutting apparatus to perform all field destructive seam testing.

F. Laboratory testing of each seam sample shall be coordinated by the CQA Consultant and performed by an independent geosynthetic testing laboratory paid for by the Owner.

G. Trial, field, and laboratory testing of seam samples shall be tested in accordance with ASTM D6392 and each specimen tested shall meet or exceed the following values and exhibit acceptable breaks. The elongation requirements are for laboratory tests only. ach sample failure must consist of a ductile break that is film tearing bond and must meet or exceed the following requirements:

Property	**Values**	
Peel Adhesion – Fusion	91 lb/in. (min.)	25% separation (max.)
Peel Adhesion – Extrusion	78 lb/in. (min.)	25% separation (max.)
Shear – Fusion and Extrusion	120 lb/in. (min.)	50% elongation (min.)

H. Acceptable seam breaks include the following ASTM D6392 designations provided the strength and elongation/separation properties are achieved d:

Fusion Welds	**Extrusion Welds**
BRK	AD-WLD
SE1	SE1
SE2	SE2
AD-BRK < 25%	SE3
SIP	BRK1
	BRK2
	BRK3
	AD-BRK
	HT
	SIP

I. If either the field or laboratory test seams do not pass, then the seam shall be reconstructed or capped between any two passing test seam locations. Alternatively, intermediate tests may be performed on both sides of the failed sample location to isolate the defective seam area. If intermediate field test seams pass, laboratory test seams shall be performed on samples from the same locations. If laboratory test seams also pass, then the seam shall be reconstructed or capped between the intermediate sample locations. If either of the test seams fail, then the process shall be repeated with intermediate samples further away from the original failing seam location to determine the defective seam area.

J. To be considered an acceptable seam, each seam shall be bounded by two locations where samples passed the laboratory destructive tests. Whenever a reconstructed seam exceeds 150 feet, an additional sample shall be obtained for destructive testing along the reconstructed seam. At the CQA Consultant's discretion, it may be necessary to take additional samples from seams welded on the same day by a seaming apparatus or seaming technician that welded a seam not passing seam specifications.

K. After large areas of geomembrane have been seamed and before they are covered, large wrinkles shall be cut, re-seamed, and tested. The deployed sheet shall be anchored by the installer as necessary to minimize movement of the panels on the subgrade.

L. If a seam is located where non-destructive testing cannot be performed, the seam shall, at the discretion of the CQA Consultant, be liner-stripped (capped) and the liner-stripping operation shall be observed by the CQA Consultant and Installation Contractor for completeness.

M. Results and locations of the destructive and non-destructive field testing shall be displayed by the Installation Contractor on the Record Drawing

3.7 INSTALLATION CONTRACTOR QC TESTING

A. The Installation Contractor shall non-destructively test the full length of all seams to ensure watertight, homogeneous seams. Test methods shall consist of vacuum box testing, air-pressure testing of double-fusion seams, or other methods approved by the manufacturer and the CQA Consultant. The test shall be performed as work progresses, rather than at the completion of all field seaming.

B. Vacuum Box Testing
   1. Vacuum box testing shall be performed on extrusion welds using a vacuum box with a rigid housing, transparent viewing window, a soft rubber gasket on the bottom edge, and a valve assembly with a vacuum gauge.

2. The vacuum box must be approved by the CQA Consultant prior to use. The CQA Consultant has the right to reject any vacuum box that he feels may not provide accurate results.
3. Vacuum testing shall be performed in accordance with ASTM D5641.
4. Vacuum box testing shall be performed by applying a soap-and-water solution to the seam and placing the box over the seam so a leak-tight seal is obtained, applying a vacuum of 5 psi to the box.
5. The seam shall be examined through the viewing window for at least 10 seconds by the CQA Consultant for the presence of soap bubbles. If soap bubbles are detected in the viewing window, the location will be marked and repaired in accordance with these Specifications.

C. Air pressure testing
   1. Air pressure testing shall be performed on double-fusion seams having an air channel between the seams.
   2. Air pressure testing shall be performed in accordance with ASTM D5820.
   3. Pressurize the air channel to between 30 and 35 psi.
   4. Test time is a minimum of 5 minutes.
   5. The maximum allow pressure drop 2 psi over the test time.
   6. The CQA Consultant shall witness the entire test, including the release of the pressurize air.

D. Seams failing either the vacuum box or air pressure testing of seam samples shall be repaired in accordance with this specification.

E. Results and locations for all laboratory and field destructive testing and non-destructive field testing shall be displayed by the Installation Contractor on the as-built drawing.

3.8 FINAL INSPECTION

A. A final inspection shall be performed by the Installation Contractor, the CQA Consultant, and OWNER prior to the Installer's crew demobilizing from the project site. All identified problem areas shall be repaired by the Installation Contractor and accepted by the CQA Consultant prior to the installation crew demobilizing from the site.

[END OF SECTION 02550]

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SECTION 02560

INTERFACE SHEAR STRENGTH TESTING

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. The work in this Section includes all labor, materials, tools, and equipment necessary to perform interface shear strength testing for the liner system components using either ASTM D5321 or D6243 (for testing involving the Geosynthetic Clay Liner [GCL]).

B. Liner system interfaces to be testing include:
   1. Drainage Sand/Drainage Geocomposite;
   2. Drainage Geocomposite/Geomembrane;
   3. Geomembrane/GCL;
   4. GCL/Drainage Sand; and
   5. Geomembrane/Screened Till.

C. If the Geomembrane used has a different texturing on the top from that on the bottom, then additional interface shear strength testing shall be performed so that all liner system interfaces are evaluated.

D. Interface shear testing shall be performed by an independent geosynthetic testing laboratory and paid for by CONTRACTOR.

1.2 QUALITY ASSURANCE

A. The Materials Testing Laboratory performing the interface shear shear strength testing shall be accredited by the Geosynthetics Accreditation Institute.

1.3 SUBMITTALS

A. At least 10 days prior to beginning geosynthetic installation, CONTRACTOR shall submit to ENGINEER the results of the laboratory tests for all the interfaces to be tested.

PART 2 – PRODUCTS

NOT USED

PART 3 – EXECUTION

2.1 MATERIAL SAMPLING

A. Materials to be tested shall be obtained in the presence of the CQA Consultant or his designated representative from materials that will be placed during construction. Sampling of geosynthetics may occur in the manufacturing facility.

B. The size of the geosynthetic sample to be obtained from each material type shall be determined by the needs of the test to be performed, and be no small than a 3-foot wide piece cut along the length of the geosynthetic roll.

C. Soil components used in the laboratory testing program shall be obtained from the borrow source or from soil stockpiles to be utilized in the construction of the soil components during construction.

2.2 INTERFACE STRENGTH TESTING REQUIREMENTS

A. The following interfaces shall be tested in a soaked condition:
   1. Drainage Geocomposite/Geomembrane;
   2. Geomembrane/GCL; and
   3. Geomembrane/Screened Till.

B. For the Geomembrane/Screened Till interface, the Screened Till shall be compacted to 95 percent of the maximum density as determined by ASTM D698 at a water content one to two percent above the optimum. The recompacted Screened Till shall be allowed to condition for no less than 36 hours prior to testing.

C. For geosynthetic/soil interface tests (including those with GCL), the geosynthetic shall be placed in the testing device first, and the soil placed/compacted above. Care shall be take not to damage the underlying geosynthetic.

D. The Geomembrane/GCL test setup shall be hydrated for 24 hours under a normal stress of 5 psi. After soaking, the sample should be loaded to the at least 10 psi and allowed to consolidate for 48 hours prior to testing.

E. The tests shall be run at the following normal stresses: 15, 30, 60, 120 psi.

F. Maximum shear displacement rates shall be as follows:
   1. Drainage Sand/Drainage Geocomposite – 0.04 in./minute
   2. Drainage Geocomposite/Geomembrane – 0.2 in./minute
   3. Geomembrane/GCL – 0.04 in./minute
   4. GCL/Drainage Sand – 0.04 in./minute
   5. Geomembrane/Screened Till – 0.04 in./minute.

2.3 REVIEW OF TEST RESULTS

A. The results of the interface strength tests shall be provided to ENGINEER for review. Test reports are to be prepared in accordance with the appropriate ASTM standards and, at a minimum, clearly identify the materials tested, the date of testing, the test conditioning procedures (including soil compaction and moisture content), the normal stresses applied, the rate of shear, the measured shear strengths, table and plot of shear force versus shear displacement and shear stress versus normal stress, Mohr-Coulomb shear strength enevelopes for peak and post-peak conditions, post-test observations of the tested materials, and any departure from the test standard.

B. ENGINEER shall review the interface shear strength testing reports to evaluate whether the test results meet the minimum requirements of the design.

C. CONTRACTOR may retest failed interfaces. Testing may be done at the same laboratory or another independent laboratory. Retesting shall be performed at CONTRACTOR's expense. Retest results shall be reviewed by ENGINEER.

D. Failed interface test results requires CONTRACTOR to obtain other materials that can be demonstrated to meet the project requirements.

[END OF SECTION 02560]

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SECTION 02710

CULVERTS

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall provide all labor, materials, tools, and equipment and perform all operations necessary to furnish, install culverts, including necessary joints and connections as required. Culverts shall consist of sections of pipe of the kinds and sizes shown on the Drawings and as specified, laid on a firm foundation in accordance with these Specifications.

1.2 SUBMITTALS

A. At least 15 days prior to delivery of materials, CONTRACTOR shall submit to ENGINEER manufacturer's technical product data and installation instructions for culvert piping and appurtenances.

1.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Inspection of Material
   1. When delivered to the project site and prior to unloading, CONTRACTOR shall inspect all pipe and accessories for loss, damage, or lack of specified identification and markings.
   2. Any defective or improper material shall be immediately marked and shall not be unloaded.

B. Storage
   1. In shipping, storing, and installing, pipe shall be kept in a sound, undamaged condition. It shall at all times be handled with care and shall not be dropped, dumped, or bumped against any other object. Any material(s) damaged shall be marked and immediately removed from the job site.

C. Defective Materials
   1. Materials found at any time during the progress of the work to have cracks, flaws, or other defects will be rejected and marked, and CONTRACTOR shall promptly remove such defective material from the project site.

PART 2 – PRODUCTS

2.1 PIPE

A. Corrugated Polyethylene Pipe (CPP)

1. The culvert pipe shall be made of high-density polyethylene material conforming to the requirements of cell classification 435400C as defined in ASTM D3350.
2. The culvert pipe be Type S – corrugated exterior and smooth interior.
3. The method of fabrication and materials used shall conform to the applicable requirements of AASHTO M294.
4. Coupling bands and gaskets shall be provided by the manufacturer of the pipe and shall meet the water-tight requirements of AASHTO M294.
5. Joints shall be rated for at leaste 5 psi when tested under ASTM D3212.

PART 3 – EXECUTION

3.1 GENERAL

A. Pipes and appurtenances shall be installed true to lines, grades, and locations indicated on the Drawings. Any deviations must be approved by ENGINEER before installation. CONTRACTOR shall furnish all labor, materials, and tools to establish and maintain all lines and grades. Benchmarks and reference points as required for control of the work are shown on the Drawings or will be provided to CONTRACTOR.

3.2 BACKFILL AND COMPACTION

A. Backfill and compaction shall be as specified in Specification Section 02200.

3.3 PIPE BEDDING CONDITIONS

A. Pipe laid in open trench excavations shall be bedded in and uniformly supported over their full length on compacted Drainage Sand.

3.4 INSTALLATION OF PIPE

A. After the trench bedding has been brought to the proper grade the pipe shall be laid. Pipe installation shall be done only in the presence of ENGINEER, and CONTRACTOR shall give ample notice of schedule of pipe laying operations to ENGINEER.

B. All pipe shall be carefully lowered into the trench by hand or with appropriate equipment. Pipe becoming cracked or otherwise damaged during or following installation shall be marked by CONTRACTOR or ENGINEER and removed from the project site.

C. Pipes shall be laid true to grades shown on the Drawings. Each section of pipe shall rest upon the pipe bed for the full length of its barrel, with recesses excavated to accommodate joints. Blocking will not be permitted. Any pipe that has its grade or joints disturbed after being laid shall be taken up and re-laid.

D. The pipe ends shall be thoroughly cleaned before the joint is made. All connections shall be made in accordance with instructions supplied by the manufacturer.

[END OF SECTION 02710]

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SECTION 02720

GABIONS

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall provide all labor, materials, tools, and equipment and perform all operations necessary for constructing the gabion reinforced slope. The gabion reinforced slope shall be constructed at the locations shown on the Drawings.

1.2 SUBMITTALS

A. at least 15 days prior to delivery of the gabion baskets to the PROJECT site, CONTRACTOR shall submit to ENGINEER manufacturer's data demonstrating compliance with these Technical Specifications, and manufacturer's instructions for installation of the gabions.

PART 2 – PRODUCTS

2.1 GABIONS

A. The gabions shall be constructed of galvanized wire baskets which shall be furnished in dimensions not less than 3-feet long, 12-inches thick, and 3-feet wide.

B. Steel wire used in the wire basket shall be galvanized steel with a zinc coating which complies with Federal Specifications QQ-W-461H. The nominal diameter of the wire used in the fabrication netting shall be at least 0.1181 inches. The mesh opening shall have dimensions no larger than 3¼ inches by 4¼ inches, with a maximum opening not to exceed 4¼ inches.

C. The basket edges, including end panels and diaphragms, shall be mechanically tied to prevent unraveling of the mesh. The tie method used shall be that recommended by the manufacturer.

2.2 ROCK FILL

A. Rock fill for the gabions shall consist of well-graded, clean rock with a minimum rock size of 4 inches and a maximum rock size of 8 inches.

PART 3 – EXECUTION

3.1 INSTALLATION

A. CONTRACTOR shall grade the area for placement of the gabions according to the Construction Drawings or as approved by ENGINEER.

B. CONTRACTOR shall place and erect the gabions in accordance with the manufacturer's recommendations from the low end to the high end.

C. The gabions shall be filled in one lift with rock fill placed to limit the amount of voids. The rock fill shall be leveled with the top of the gabion to provide a relatively even surface.

D. The rock fill adjacent to exposed faces shall be hand-placed to achieve an even face. Internal diaphragms within the wire basket shall be protected from damage during filling by a wooden or metal sleeve.

E. The zone between gabions shall be filled with rock fill.

[END OF SECTION 02720]

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SECTION 02830

TOPSOIL, HYDROSEEDING, AND TURF ESTABLISHMENT

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, equipment and incidentals required to place topsoil, finish grade, furnish and apply lime and fertilizer, furnish and hydraulically apply seed and mulch, and maintain all seeded areas as specified herein. Topsoil will be available for use by the CONTRACTOR on-site. CONTRACTOR shall load and haul topsoil to the project area.

B. CONTRACTOR shall seed all areas disturbed by his operations. All areas disturbed or not having sufficient vegetation to prevent erosion shall be seeded.

C. Topsoil, Hydrooseeding, and turf establishment shall comply with the requirements within the Alteration of Terrain Permit.

1.2 SUBMITTALS

A. At least 15 days prior to seeding, CONTRACTOR shall submit to ENGINEER the proposed seed mix including the manufacturer's certificate of compliance.

1.3 SAMPLES AND APPROVAL OF MATERIAL

A. Samples of all materials shall be submitted for inspection and acceptance upon ENGINEER’s request.

B. Seed bag tags shall be provided to the CQA Consultant at the time of seeding.

PART 2 – PRODUCTS

2.1 MATERIALS

A. TOPSOIL

1. Topsoil shall be used for areas beyond the geomembrane limits disturbed during construction. Topsoil shall be free of trash, ice, snow, tree stumps, roots, sticks, clay, peat, weeds, sod, and other non-soil based organic materials.
2. Topsoil shall be friable soil containing no stone greater than 2 inches in diameter and contain no more than 70 percent of the material passing the No. 200 sieve.
3. Topsoil shall be obtained from naturally well-drained areas.
4. Topsoil shall not be excessively acid or alkaline nor contain material harmful to plants.

B. Fertilizer and loam shall be commercial grade that is consistent with the State Cooperative Extension's recommendations for establishing a healthy vegetative cover as described herein. It shall be delivered to the project site in the original unopened containers, each showing the manufacturer's guaranteed analysis. Fertilizer shall be stored so that when used it shall be dry and free-flowing.

C. Seed shall be as specified on the Drawings

D. The seed shall be furnished and delivered premixed in the specified proportions. The manufacturer for each seed type shall provide a manufacturer's certificate of compliance to the specified mix. These certificates shall include the guaranteed percentages of purity, weed content, and germination of the seed, and also the net weight and date of shipment. No seed may be sown until CONTRACTOR has submitted the certificates to ENGINEER.

E. Mulch shall be specially processed cellulose fiber containing no growth or germination inhibiting factors. It shall be manufactured in such a manner that after agitation in slurry tanks with water, the fibers in the material become uniformly suspended to form a homogenous slurry. When sprayed on the ground, the material shall allow absorption and percolation of moisture.

F. Fertilizer, seed, and lime shall be furnished in new, clean, sealed, and properly labeled bags, with the following information clearly marked:
   1. Manufacturer name
   2. Type
   3. Weight
   4. Guaranteed analysis

PART 3 – EXECUTION

3.1 TOPSOIL

A. The subgrade of all areas to be covered with Topsoil shall be raked and all rubbish and sticks, roots, and stones larger than 3 inches shall be removed.

B. The subgrade surface in all areas shall be tracked immediately after fine grading and raking is completed. Tracking shall be performed with bulldozers; the tracks of the bulldozers shall have grousers of sufficient height to leave visible depressions in the subgrade. The depressions shall be perpendicular to the slope to reduce erosion potential. During the tracking, all depressions caused by settlement or tracking shall be filled with soil and the surface shall be regraded and tracked until an even finished grade is created.

C. Areas to receive Topsoil shall be inspected and approved by the CQA Consultant before Topsoil is placed. After Topsoil has been spread and fine-graded, CONTRACTOR shall remove and dispose of all rubbish, sticks, large stiff clods, lumps, brush, roots, stumps, litter, stones larger than 3 inches, and other foreign material from the area to be covered with topsoil.

D. Unless otherwise shown on the Drawings, Topsoil shall be placed to a minimum thickness of 4 inches. CONTRACTOR shall exercise care to ensure that the underlying soil remains intact and does not become mixed with the Topsoil during placement.

E. Topsoil shall be tracked in place but not compacted.

F. After spreading and fine grading the Topsoil, CONTRACTOR shall remove and dispose of all large stiff clods, lumps, brush, roots, stumps, litter and other foreign material.

G. The Topsoil surface shall be tracked immediately after fine grading and other preparation has been completed. Tracking is to be performed with bulldozers; the tracks of the bulldozers are to have grousers of sufficient height to leave visible depressions in the subgrade. The depressions are to be perpendicular to the slope flow to reduce erosion potential until topsoil is placed. During the tracking, all depressions caused by settlement or tacking shall be filled with Topsoil and the surface shall be regraded and tracked until an even finished grade is created.

3.2 APPLICATION

A. For all areas to be seeded:
   1. Lime and fertilizer shall be applied uniformly over the area at the rate noted on the Drawings. Modifications to the application rate and/or fertilizer type may be made based on recommendations from the State Cooperative Extension based on topsoil testing.
   2. Seed shall be applied uniformly over the area at the rate noted on the Drawings.

B. The application of fertilizer and lime shall be performed hydraulically in one operation with hydroseeding. CONTRACTOR will be responsible for cleaning all structures and paved areas of unwanted deposits.

C. The application of mulch is to be by pneumatic blower.

D. Applying fertilizer, lime, seed and mulch shall only be performed during those periods within the seasons that are normal for such work as determined by the weather and locally accepted practice, and as approved by ENGINEER. CONTRACTOR shall hydroseed and hay mulch only on a calm day.

E. CONTRACTOR shall schedule seeding and fertilizing activities with the CQA Consultant and OWNER.

F. Lime and fertilizer are to be spread hydraulically in one operation with the hydroseeding.

G. Seed shall be sown within five (5) days following soil preparation, unless otherwise approved by ENGINEER or OWNER. Seed shall be applied hydraulically at the rates and percentages indicated. The spraying equipment and mixture shall be designed so that when the mixture is sprayed over an area, the lime, fertilizer, and seed shall be equal in quantity to the specified rates. Prior to the start of Work, CONTRACTOR shall provide the CQA Consultant with a certified statement for approval as to the number of pounds of materials to be used per 100 gallons of water. This statement shall also specify the number of square feet of seeding that can be covered with the quantity of solution in the hydroseeder.

H. Hay or straw mulch shall be tracked as described in Paragraph 3.3.A.

I. When protection of newly graded areas is necessary at a time outside of the normal seeding season, CONTRACTOR shall protect those areas by whatever means necessary (such as straw) or by other measures as approved by ENGINEER and OWNER.

3.3 MAINTENANCE AND PROVISIONAL ACCEPTANCE

A. CONTRACTOR shall keep all seeded areas watered and in good condition, shall reseed if and when necessary until a good, healthy, uniform growth is established over the entire area seeded, and shall maintain these areas in an approved condition until provisional acceptance.

B. On slopes, CONTRACTOR shall protect against wash outs by an approved method. Any wash out that occurs shall be regraded and reseeded at CONTRACTOR's expense until a good sod cover is established.

C. ENGINEER or OWNER will observe work for provisional acceptance at the end of the eight (8) week grass maintenance period, and upon the written request of CONTRACTOR, which must be received at least ten (10) days before the anticipated date of observation.

D. A satisfactory stand will be defined as a section of grass of 10,000 square feet or larger that has:
1. No bare spots larger than three square feet.
2. No more than ten percent of total area with bare spots larger than one square foot.
3. No more than fifteen percent of total area with bare spots larger than 6 inches square.
4. The observations by ENGINEER or OWNER will determine whether maintenance shall continue in any area or manner.

E. After all necessary corrective work and cleanup has been completed, ENGINEER or OWNER will acknowledge the provisional acceptance of the seeded areas. CONTRACTOR's responsibility for maintenance of seeded areas, or parts of seeded areas shall cease on receipt of provisional acceptance.

3.4 GUARANTEE PERIOD AND FINAL ACCEPTANCE

A. All seeded areas shall be guaranteed by CONTRACTOR for not less than one full year from the time of provisional acceptance.

B. At the end of the guarantee period, ENGINEER or OWNER will make observations upon written request submitted by the CONTRACTOR at least ten days before the anticipated date. Seeded areas not demonstrating satisfactory stands as outlined above, as determined by ENGINEER or OWNER, shall be renovated, reseeded, and maintained meeting all requirements as specified herein.

C. After all necessary corrective work is complete, ENGINEER or OWNER shall acknowledge in writing the final acceptance of the seeded areas.

[END OF SECTION 02830]

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SECTION 15210

HIGH-DENSITY POLYETHYLENE
PIPE, FITTINGS, AND APPURTENANCES

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. Supply and install high-density polyethylene (HDPE) pipe, fittings, and appurtenance for the leachate collection and conveyance systems.

1.2 SUBMITTALS

A. CONTRACTOR shall submit to ENGINEER the following:
   1. Manufacturing data listing resin type, cell classification, stock density, melt flow, flexural modulus, tensile strength, and coloration.
   2. Pipe Dimensions:
      a. Average outside diameter.
      b. Average inside diameter.
      c. Minimum and average wall thickness.
      d. Approximate weight in pounds per foot.
   3. Manufacturer's instructions for fusing joints.

B. CONTRACTOR shall submit pipe welding certifications for pipe fusion machine operators prior to beginning fusion operations.

1.3 MANUFACTURER'S QUALITY ASSURANCE

A. The pipe, fittings, and valve manufacturers shall have an established quality assurance (QA) program responsible for inspecting incoming and outgoing materials. At a minimum, incoming polyethylene (PE) materials shall be inspected for density per ASTM D1505, melt flow rate per ASTM D1238, and contamination. The supplier shall certify all incoming PE materials.

B. The pipe and fittings manufacturer shall have an established QA program responsible for assuring the long-term performance of materials and products. Representative samples of PE materials shall be tested against the physical property requirements of this Specification. Each extrusion line and molding machine shall be qualified to produce pressure rated products by taking representative production samples and performing sustained pressure tests in accordance with ASTM D1598.

C. QA testing for representative pipe and fitting samples shall include:

Test	Standard	Pipe	Fittings
Ring ESCR	ASTM F1248	Yes	Not Applicable
Sustained pressure at 176°F / 725 psi hoop stress	ASTM D1598	Yes (f0>100 h)	Yes (f0>100 h)
Sustained pressure at 73°F / 1600 psi hoop stress	ASTM D1598	Yes (f0>1,000 h)	Yes (f0>1,000 h)

D. All outgoing materials shall be inspected for diameter, wall thickness, length, straightness, out-of-roundness, concentricity, toe-in, inside and outside surface finish, markings, and end cut. Quality control (QC) shall perform tests of density, melt flow rate, carbon content, and carbon dispersion. In addition, samples of the pipe provided shall be tested for hoop tensile strength and ductility by either quick burst per ASTM D1599 or ring tensile per ASTM D2290. Molded fittings shall be subject to x-ray inspection for voids, and tests for knit line strength. All fabricated fittings shall be inspected for fusion quality and alignment.

E. The pipe and fitting manufacturer shall maintain permanent QC and QA records.

F. If manufacturer’s test data is inadequate or unavailable, then OWNER reserves right to reject or require additional tests to satisfy material requirements. The cost of these tests shall be borne by CONTRACTOR.

G. Work shall comply with codes and standards of the Plastic Pipe Institute (PPI).

1.4 DELIVERY, STORAGE, AND HANDLING

A. The pipe and fitting manufacturer shall package products for shipment in a manner suitable for safe transport by commercial carrier. When delivered, a receiving inspection shall be performed by CONTRACTOR, and any shipping damage reported to the pipe and fittings manufacturer. Pipe and fittings shall be handled, installed, and tested in accordance with manufacturer’s recommendations, and the requirements of this Section.

B. Pipe Storage
   1. Store or stack pipe to prevent damage from marring, crushing or puncture. Limit maximum stacking height to 6 feet or manufacturer’s recommended maximum height, whichever is less.
   2. Store in accordance with manufacturer’s recommendations.

C. Pipe Handling
  1. Protect pipe from excessive heat or harmful chemicals.
  2. Handle pipe and use equipment needed to avoid gouging of the pipe surfaces.

PART 2 – PRODUCTS

2.1 PHYSICAL PROPERTIES

A. Materials used for the manufacture of HDPE pipe and fittings shall meet the following physical property requirements:

Property	**Unit**	**Test Procedure**	**Value**
Material Designation	-	PPI TR-4	PE 4710
Cell Classification	-	ASTM D3350	445574C
Density	g/cm^3	ASTM D1505	>0.940
Melt Index	g/10 min	ASTM D1238	<0.15
Flexural Modulus	psi	ASTM D790	110,000 to <160,000
Tensile Strength at yield	psi	ASTM D638	3,500 to <4,000
Slow Crack Resistance (PENT)	hours	ASTM F1473	>500
Hydraulic Design Basis	psi	ASTM D2837	1,600 @ 23°C 1,000 @ 60°C
Carbon Black Content	% Carbon Black	ASTM D1603	2 to 3
Elastic Modulus	psi	ASTM D638	>175,000
Brittleness Temperature	^{o}F	ASTM D746	<-103
Vicat Softening Temperature	^{o}F	ASTM D1525	255
Thermal Expansion	in/in/^{o}F	ASTM D696	1 x 10^{-4}
Hardness	Shore D	ASTM D2240	64

B. There shall be no evidence of splitting, cracking, or breaking when the pipe is tested.

C. Ring Stiffness Constant (RSC) values for the pipe shall be 90 percent of the nominal.

D. The pipe and fittings shall be homogenous throughout and free from visible cracks, holes, foreign inclusions, or other injurious defects. The pipe shall be as uniform as commercially practical in color, opacity, density, and other physical properties.

E. Clean rework or recycled material generated by the manufacturer's own production may be used so long as the pipe or fittings produced meet all the requirements of this Section.

2.2 PIPE AND FITTINGS

A. Dimensions
1. The nominal inside diameter of the pipe shall be true to the specified pipe size in accordance with ASTM D2513. Standard laying lengths shall be 40 feet (nominal).
2. Fittings such as couplings, wyes, tees, adaptors, etc. for use in laying pipe shall have standard dimensions that conform to ASTM D2513.
3. Pipe and fittings shall have the Standard Dimension Ratio (SDR) rating indicated on the Drawings.

B. Pipe and fittings shall be produced by the same manufacturer from identical materials meeting the requirements of this Section. Special or custom fittings may be exempted from this requirement.

C. Pipe and fittings shall be pressure rated to meet the service pressure requirements specified. Whether molded or fabricated, fittings shall be fully pressure rated to at least the same service pressure rating as the joining pipe.

D. Molded fittings shall meet the requirements of ASTM D3261 and this Specification. At the point of fusion, the outside diameter and minimum wall thickness of fitting butt fusion outlets shall meet the diameter and wall thickness specifications of the mating system pipe. Fitting markings shall include a production code from which the location and date of manufacture can be determined. Upon request, the manufacturer shall provide an explanation of his production code.

E. Perforated pipe shall meet the same physical properties and requirements of standard solid pipe. Hole spacing and orientation are presented on the Drawing. Sections of perforated pipe shall be fused together with perforations aligned between each section of pipe.

F. Marking
1. Each standard and random length of pipe and fitting in compliance with this standard shall be clearly marked with the following information:
   a. Manufacturer's Name or Trademark;
   b. ASTM Standard Designation;
   c. Nominal Pipe Size;
   d. Class & Profile Number;

e. Production Code, including Extrusion Date, and Lot or Batch Number; and

f. SDR.

2.3 SOURCE QUALITY CONTROL

A. The pipe and fitting manufacturer shall certify that samples of his production pipe have undergone stress regression testing, evaluation, and validation in accordance with ASTM D2837 and PPI TR-3. Under these procedures, the minimum hydrostatic design basis shall be certified by the pipe and fitting manufacturer to be 1600 psi at 73.4°F and 800 psi at 140°F.

B. Material shall be listed in the name of the pipe and fitting manufacturer by the Plastics Pipe Institute (PPI) in PPI TR-4 with the following Standard Grade ratings:

	73.4ºF	140ºF
Hydrostatic Design Basis (HDB)	1600 psi	1000 psi
Hydrostatic Design Stress (HDS)	1000 psi	500 psi

C. PPI material listing in the name of the resin supplier is not acceptable in meeting this requirement.

D. As the basis of the acceptance of the material, the manufacturer will furnish a certificate of conformance of these Specifications upon request. When prior agreement is being made in writing between the purchaser and the manufacturer, the manufacturer will furnish other conformance certification in the form of affidavit of conformance, test results, or copies of test reports.

E. Physical Test Requirements
   1. Sampling: The selection of the sample of pipe shall be as agreed upon by the purchaser and the manufacturer. In case of no prior agreement, any sample selected by the manufacturer shall be deemed adequate.
   2. Sample size for flattening test will be one sample per size and class of pipe per project.
   3. Conditioning: Conditioning of samples prior to and during test shall be as agreed upon by the purchaser and manufacturer. In case of no prior agreement, the conditioning procedure used by the manufacturer shall be deemed adequate.

F. Test Methods (to be completed by Manufacturer)
   1. Flattening: Three specimens of pipe, a minimum of 12 inches long, shall be flattened between parallel plates in a suitable press until the distance between the plates is 40 percent of the outside diameter of the pipe. The rate of loading shall be uniform and such that the compression is

completed within 2 to 5 minutes. Remove the load, and examine the specimens for splitting cracking or breaking.

2. Pipe Ring Stiffness Constant: The pipe ring stiffness constant shall be determined using procedures similar to those outlined in ASTM D2412. The stiffness of HDPE pipe is defined in terms of the load, applied between parallel plates, which causes 1 percent reduction of pipe diameter. Test specimens shall be a minimum of two pipe diameters or 4 feet in length, whichever is less.

2.4 GASKETS AND HARDWARE

A. All gaskets shall be ⅛-inch thick, full face Viton with a Shore A durometer rating between 60 and 80.

B. Below-grade joint hardware shall be Type 304 stainless steel.

C. Above-grade joint hardware shall be zinc-plated steel unless otherwise noted.

D. Hot-dipped galvanized fasteners are not allowed.

2.5 FITTINGS

A. Fittings shall be manufactured from polyethylene compound having cell classification equal to or exceeding compound used in pipe to ensure compatibility of polyethylene resins.

B. Provide factory-fabricated, dual containment fittings except as indicated below.

C. Fittings shall be from same manufacturer as pipe being provided. OWNER may allow substitution for approved material with use of flanged joint sections.

D. Dimensions of fittings conforming to standard dimensions and tolerances in accordance with ASTM F2206.

E. Fittings shall have the same or higher pressure rating as pipe.

F. Markings
   1. Manufacturer's name or trademark
   2. Nominal size
   3. Type of plastic pipe (i.e., PE 4710)
   4. Standard dimension ratio
   5. Extrusion date, lot number or batch number

G. The Drawings do not show all fittings that may be required. CONTRACTOR to provide all fittings required for a complete installation.

PART 3 – EXECUTION

3.1 FIELD QUALITY CONTROL

A. Pipe may be rejected for failure to conform to any of the following:
   1. Fractures or cracks passing through pipe wall, except single crack not exceeding 2 inches in length at either end of pipe which could be cut off and discarded. Pipes within one shipment shall be rejected if defects exist in more than 5 percent of shipment or delivery.
   2. Cracks sufficient to impair strength, durability or serviceability of pipe.
   3. Defects indicating improper proportioning, mixing, and molding.
   4. Damaged ends, where such damage prevents making satisfactory joint.
   5. Damage due to handling or installation. Scratches and gouges exceeding five (5) percent of the wall thickness shall be considered excessive, and may be rejected by OWNER or the CQA Consultant.

B. Acceptance of fittings, stubs or other specifically fabricated pipe sections shall be based on visual inspection at job site and documentation of conformance to this Section.

C. **Prior to backfilling, CONTRACTOR shall obtain as-built survey information (location and elevation) for the installed pipe at 50-foot intervals, any changes in grade, and the location of all installed fittings.**

3.2 INSTALLATION

A. Trench, backfill, and compact in accordance with Specification Section 02200.

B. Heat Fusion of Pipe
   1. Weld in accordance with manufacturer’s recommendation for butt fusion methods. The pipe manufacturer shall certify fusion operators.
   2. Butt fusion equipment for joining procedures shall be capable of meeting conditions recommended by pipe manufacturer including, but not limited to, temperature requirements, alignment, and fusion pressures.
   3. For cleaning pipe ends, solutions such as detergents and solvents, when required, shall be used in accordance with manufacturer's recommendations.
   4. Do not bend pipe to greater degree than minimum radius recommended by manufacturer for type and grade.
   5. Do not subject pipe to strains that will overstress or buckle piping or impose excessive stress on joints.

6. Branch saddle fusions shall be joined in accordance with manufacturer's recommendations and procedures. Branch saddle fusion equipment shall be of a size to facilitate saddle fusion within the trench.
7. Before butt fusing pipe, inspect each length for presence of dirt, sand, mud, shavings, and other debris or animals. Remove debris from pipe.
8. **Cover open ends of fused pipe at end of each working day. Cap to prevent entry by animals or debris**.
9. Use compatible fusion techniques when PEs of different melt indexes are fused together. Refer to manufacturer's specifications for compatible fusion.
10. Fusion welding shall not be performed when pipe ends are exposed to precipitation. CONTRACTOR shall provide temporary welding shelter if necessary.
11. All HDPE cuttings from pipe facing and drilling shall be removed from the pipe network by CONTRACTOR prior to turning the Project over to OWNER. CONTRACTOR shall clean the entire pipe network associated with the Project if HDPE cuttings are encountered in the pipe network by OWNER following completion of the project.
12. **All interior butt-fusion weld beads shall be removed from the pipe (i.e., all HDPE pipe must be de-beaded) in accordance with the manufacturer's recommendations**.

C. Flange Jointing
  1. Use on flanged pipe connection sections.
  2. Convoluted stainless steel backup rings shall be used for joining HDPE pipes below grade, and epoxy-coated carbon steel backup flanges shall be used above grade.
  3. Butt fuse fabricated flange adapters to pipe.
  4. Observe the following precautions in connection of flange joints.
     a. Use full-face Viton gaskets only.
     b. All fasteners shall be Type 304 stainless steel below grade, and zinc-plated steel above grade. Do not use hot-dipped galvanized fasteners.
     b. Align flanges or flange/valve connections to provide tight seal. Require nitrile-butadiene gaskets if needed to achieve seal. Gaskets are required for flange/valve connections. Flange adapters may require modification or special adapters when used against butterfly valves to provide clearance for disc to open fully.
     c. U.S. Standard round washers as may be required on some flanges in accordance with manufacturer's recommendations. Bolts shall be lubricated in accordance with manufacturer's recommendations.
     d. Tighten flange bolts using a torque wrench in sequence and accordance with manufacturer's recommendations. CAUTION: Do

not over-torque bolts. CONTRACTOR shall use a torque wrench to tighten all flange fasteners.

5. Pull bolts down by degrees to uniform torque in accordance with manufacturer's recommendation.
6. Protect below grade bolts and flanges by covering with a 6-mil thick PE wrap. Duct tape wrap to HDPE pipe.
7. Electrofusion couplers, where used, shall be installed per manufacturer's specifications. The outside diameter of the HDPE pipe and face shall be prepared in accordance with manufacturer's recommendations prior to installing the coupler.

D. Pipe Placement

1. Grade control equipment shall be of type to accurately maintain design grades and slopes during installation of pipe.
2. Remove all standing water in trench before pipe installation.
3. Unless otherwise specifically stated, install pipe in accordance with manufacturer's recommendations.
4. Maximum lengths of fused pipe to be handled as one section shall not exceed 400 feet and shall be placed according to manufacturer's recommendations as to pipe size, pipe SDR, and topography so as not to cause excessive gouging or surface abrasion. Pipe wall gouges deeper than 3/16-inch shall be cause for rejection of the pipe.
5. Cap pipe sections longer than single joining (usually 40 feet or less) on both ends during placement except during fusing operations.
6. Remove dirt or debris from inside of pipe before backfilling.
7. Notify the CQA Consultant prior to installing pipe into trench and allow time for the CQA Consultant's inspection.
7. Correct irregularities found during inspection.
8. Complete connections within trench whenever possible to prevent overstressed connections.
9. Allow pipe sufficient time to adjust to trench temperature prior to testing, segment tie-ins, or backfilling activity.
10. Install reducers adjacent to laterals and tees.
11. To reduce branch saddle stress, install saddles at slope equal to and continuous with lateral piping.
12. Place in trench by allowing minimum 12 inches/100 feet for thermal contraction and expansion.
13. Coordinate construction of pipes near/in access roads with OWNER to limit impediment of OWNER's operations or operations of other contractors.

3.3 PIPE TESTING

A. General
   1. The Contractor shall perform hydrostatic pressure tests after placement in trench, in accordance with these specifications.
   2. The total test time, including initial pressurization, initial expansion, and time at test pressure shall not exceed eight hours. If the test is not completed in eight hours, the pressure in the test section shall be released and the section allowed to “relax” for at least eight hours before initiating another test.
   3. Pipe lines shall be pressure tested in presence of the CQA Consultant. CONTRACTOR to provide the CQA Consultant with a minimum of 7 days’ notice before performing the test.
   4. Provide necessary connections between section of pipe being tested and nearest available source of water or air supply, together with test pressure equipment, meters, pressure gauge, other equipment, materials and facilities necessary to make specified tests.
   5. OWNER will provide a source of water for testing.
   6. Provide bulkheads, flanges, valves, bracing, blocking, or other temporary sectionalizing devices as required to perform the tests safely.
   7. Pipe to be tested shall be exposed in the trench, except that bends, reduced pressure rated fittings and components should be buried or restrained. Flange connections shall be visible to check for leaks.
   8. Contractor shall notify on-site personnel of the testing schedule, and only allow personnel required to perform the test in the test area for the duration of the test.
   9. Contractor shall provide a system without leaks.

B. Test all non-perforated HDPE leachate force main pipe and fittings.

C. Preparation
   1. Remove or isolate valves, flow meters, and instruments that may not withstand the required test pressure from within the test sections. Reconnect pipes with temporary fittings. Vent isolated equipment.
   2. Flush pipe with clean water until pipe section to be tested is clean and free of dirt, sand, pipe shavings, or other foreign material.
   3. Plug pipe outlets with test plugs, blind flanges or other devices suitable for the test pressure. Brace securely to prevent blowouts. Verify test pressure does not exceed any component of the pipe system.
   4. Restrain or remove expansion joints.
   5. Pressurizing equipment shall include a pressure regulator, set to avoid over-pressurizing and damaging otherwise acceptable pipe.

D. Hydrostatic Pressure Testing

1. Contractor shall use a hydrostatic test pump specifically designed for performing hydrostatic pressure tests on pipe.
2. Clean potable water shall be used as the testing medium to fill the pipes.
3. Pipe shall be tested at a pressure of 100 psi or the lowest rated pressure of any component of the system being tested. In no case exceed maximum allowable pressure for any pipeline component, including valves, fittings, and instruments.
4. Apply test pressure slowly, and once the test pressure has been reached, allow the pressure to stabilize, without adding additional pressure. This may take 2 to 3 hours.
5. Once pressure has stabilized, add additional water to achieve the test pressure and begin the test.
6. After 1 hour, additional water shall be added to return to the test pressure. If the volume of water required to achieve the test pressure after 1 hour is less than shown in the table, then the pipe has passed the pressure test.
7. The total test time, including the initial pressurization, initial expansion and time at test pressure, shall not exceed eight hours. If the test is not completed within that time, the test pressure shall be removed for at least eight hours, prior to performing the test again.
8. If pressure test is not accepted, correct leaks or defects in the pipe and retest.
9. Remove temporary sectionalizing devices after tests are complete.

E. Pneumatic Testing

WARNING: Compressed air or any pressurized gas used as a test medium may present severe hazards to personnel in the vicinity of pipelines being tested. Personnel protection precautions must be observed when a gas under pressure is used as the test medium.

WARNING: Explosive Failure. Pipe system rupture during pneumatic pressure tests may result in explosive, uncontrolled movement of system pipe, or components, or parts of components. Keep personnel a safe distance away from the test section during testing.

1. The test period at the test pressure shall last no more than 10 minutes.
2. Provide all necessary connections, bulkheads, flanges, bracing, and blocking, as well as all required test equipment.
3. Test pressure gauge shall have a maximum range of no more than 20 psig, with minor gradations no greater than 0.1 psig.

4. Pipe to be tested shall be exposed in the trench, except bends, reduced pressure rated fittings and components, which shall be buried or restrained. Flange connections shall be visible to check for leaks.
5. Test pressure shall be 5 psig.
6. Test shall be accepted if the pressure drop over 10 minutes is less than 5 percent of the pressure at the beginning of the test period.

F. Test Report
1. Pressure testing shall be documented using one of the test logs provided as Attachment 1 and 2 to this Specification depending on the test method utilized by the CONTRACTOR .
2. CQA Consultant shall record the following information for each test.
    a. Date of test.
    b. Description and identification of piping system tested.
    c. Type of test performed.
    d. Test fluid.
    e. Test pressure.
    f. Results of test.
    g. Type and location of leaks detected.
    h. Corrective action taken to repair leaks.
    i. Results of retesting.
    j. Name of person performing test.

[END OF SECTION 15210]

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ATTACHMENT 1 TO SECTION 15210

HYDROSTATIC PIPE PRESSURE TEST LOG

SANBORN HEAD
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Project No.:
Project Name:
Project Location:
Weather

Contractor:
Test No.
Sanborn Head Personnel:
Person/Company Performing the Test:
Date of Test:
Time of Test: Start: Finish:
Pipe Length: ft. Pipe Diameter: in. Pipe Material: Pipe SDR/Sch.:
Rated Working Pressure: Test Pressure:
Location/designation of pipe tested:

t Time (hours)	P_t Pressure Gauge Reading (psig)	P_C Pressure Drop (%)	Amount of Make-Up Water Added (gal.)
0			
1			
2			
3			
4			
5			
6			

Pass Fail
Retest? Yes No

Description/location of defects for failed test:

Test Procedure:

1. Pressurize to 100 psi;
2. Add make-up water each hour for three hours to maintain pressure;
3. Test phase begins after the initial three-hour phase;
4. After one, two or three hours add a measured amount of makeup water to return to the test pressure; and
5. The amount of makeup water added to return to the test pressure must not exceed the amount in the makeup water test values table on the back of this sheet.

Comments:

Signature:

MAXIMUM ALLOWABLE MAKE-UP WATER VOLUME

Nominal Pipe Size (inches)	Make-Up Water Allowance (U.S. Gallons per 100 ft. of Pipe)		
	1 Hour Test	2 Hour Test	3 Hour Test
1-1/4	0.06	0.10	0.16
1-1/2	0.07	0.10	0.17
2	0.07	0.11	0.19
3	0.10	0.15	0.25
4	0.13	0.25	0.40
5	0.19	0.38	0.58
5-3/8	0.21	0.41	0.62
6	0.3	0.6	0.9
7-1/8	0.4	0.7	1.0
8	0.5	1.0	1.5
10	0.8	1.3	2.1
12	1.1	2.3	3.4
13-3/8	1.2	2.5	3.7
14	1.4	2.8	4.2
16	1.7	3.3	5.0
18	2.0	4.3	6.5
20	2.8	5.5	8.0
22	3.5	7.0	10.5
24	4.5	8.9	13.3
26	5.0	10.0	15.0
28	5.5	11.1	16.8
30	6.3	12.7	19.2
32	7.0	14.3	21.5
34	8.0	16.2	24.3
36	9.0	18.0	27.0
42	12.0	23.1	35.3
48	15.0	27.0	43.0
54	18.5	31.4	51.7

ATTACHMENT 2 TO SECTION 15210

PIPE PRESSURE AIR TEST LOG

SANBORN HEAD

Project No.:

Project Name:

Project Location:

Weather:

Contractor:

Test No.:

SHA Personnel:

Person/Company Performing the Test:

Date of Test:

Time of Test: Finish:

Pipe Length: ~ ft. Pipe Diameter: in.

Pipe Material: Pipe SDR/Sch.:

Rated Working Pressure:

Test Pressure: psi

Location/designation of pipe tested:

t Time (min.)	T Pipe Temperature (ºC)	P_t Pressure Gauge Reading (psig)	P_c Pressure Drop (%)
0			
5			
10			
15			
30			
60			

Pass Fail

Retest? Yes No

Description of leaks and repairs of retested pipe segments:

P_c = Percent Pressure Drop $\frac{P_o - P_t}{P_o} \times 100$

P_o = Initial Pressure Gauge Reading

P_t = Pressure Gauge Reading at Time t

Comments:

Signature:

SECTION 15310

SUMP RISER BUILDING PIPE, FITTINGS, AND APPURTENANCES

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. Furnish and install all pipe, valves, and appurtenances in the Sump Riser Building, including:
   1. Polyvinyl chloride (PVC) pipe and fittings.
   2. Check valves, regulating valves, shutoff valves, air release/vacuum relief valves.
   3. Labels.

B. Furnish and install blind flanges to sideslope risers.

C. Furnish and install vent piping.

D. Perform hydrostatic testing.

1.2 PRODUCT HANDLING

A. CONTRACTOR is responsible for the handling, storage, and care of the materials from the time of delivery to the site until final acceptance of the completed Work by Owner. Contractor shall be liable for all damages to the materials during such time.

B. CONTRACTOR shall ship, store, and install material and equipment in a manner which does not degrade quality, serviceability or appearance. Store in clean, dry location.

C. Do not spill or cause release of any chemicals used to clean or bond piping materials.

1.3 SUBMITTALS

A. At least 15 days priot ro material delivery, CONTRACTOR shall submit to ENGINEER the manufacturer's technical product data and the installation instructions that meets the requirements of this Section.

1.4 WORKMANSHIP

A. All pipe shall be installed by qualified workmen, with minimum 5 years' experience in industrial process plumbing.

PART 2 – PRODUCTS

2.1 PIPE AND FITTINGS

A. Pipe and fittings shall be manufactured from a PVC compound that meets the requirements of Cell Classification 12454-B polyvinyl chloride as outlined in ASTM D1784. Pipe and fittings materials shall be specially formulated with sufficient ultraviolet screeners to provide for longer term outdoor exposure with no deleterious effects.

B. PVC pipe shall meet the requirements of ASTM D1784 and ASTM D1785.

C. PVC fittings shall meet the requirements of ASTM D2464 and ASTM D2467.

D. All PVC cements shall meet the requirements of ASTM D2564.

E. Clean rework or recycle material generated by the manufacturer's own production may be used so long as the pipe or fittings produced meet all the requirements of this Section.

F. Fittings shall be industrial, heavy duty, hub style.

G. Socket fittings shall be pressure rated the same as the corresponding size pipe prescribed by ASTM D1785. Threaded fittings shall be pressure rated to at least 150 percent of the rating for socket fittings.

2.2 PVC VALVES

A. PVC for pressure applications shall be Schedule 80, ASTM D1785, Type 1, Grade 1. Fittings shall be socket type, ASTM D2467.

B. PVC valve bodies and fittings shall be Schedule 80, ASTM D1785, Type 1, Grade 1. Fittings shall be socket ends, ASTM D2467.

C. All flange hardware shall be stainless steel. Flange gaskets shall be ⅛-inch Viton, full face.

2.3 VALVES

A. Ball valves shall be true union design with socketed connections. Pressure rating shall be 150 psig, Type I, Grade I PVC construction with Viton or PVDF seats and seals. Full port opening.

B. Butterfly valves shall be wafer or flange type, constructed of stainless steel or PVC. Valves shall have Viton seats and Viton packing. CONTRACTOR shall provide inserts, as required, to allow for full opening of the valve. Pressure rating shall be 150 psig at 75°F.

C. Flanged check valves shall be ANSI Class 150, swing-check style, with PVC body, bonnet, and counterweight. Fasteners shall be Type 18-8, 304, or 316 stainless steel. Seals shall be FKM. Check valves shall include an external stainless steel spring assist.

D. Wafer-style check valves shall be ANSI Class 150, wafer style, with PVC body, valve plates, and trim. Seals shall be Viton or Teflon. Check valves shall provide leak-tight seal at 2 psi back pressure.

E. PVC Gate valves shall be flanged or socketed. Stainless steel gate valves shall be threaded. Rated for 150 psig to full vacuum. Seals shall be Viton or PVDF.

F. Sample ports shall be nominal ½-inch diameter stainless steel ball valves with threaded connection to PVC leachate pipe. Seats and seals shall be PTFE. The free end of the valve shall be supplied with a ⅛-inch inner dimension hose barb fitting.

2.4 VACUUM, AIR, AND PRESSURE VALVES

A. All valves shall be dual air release/vacuum release valves. Air release and vacuum relief valve shall be Crispin Model US20SB with an orifice diameter of 0.25 inches designed for domestic sewer use for inflow/outflow of up to 98 scfm.

B. Air release and vacuum relief valves shall allow entry of air when operating pressure is below atmospheric pressure. The valve shall also allow release of air from the pipe when the pipe is filling and under pressure. The valve shall close leak-tight when the pipe is full, and provide a drip-tight seal at 2 psig and above. Provide suitable seat material to assure drip-tight seal.

C. Valve body shall be constructed of cast iron. Float rod, float guide, and float shall be stainless steel. Furnish valve body with factory applied epoxy lining.

D. Valve shall be equipped with 2-inch diameter NPT inlet and 2-inch diameter NPT outlet.

E. Valve body pressure rating shall be 150 psig.

2.5 FLEXIBLE HOSE

A. Furnish flexible hose for leachate discharge manifold connections where indicated on the Drawings. Hose shall be constructed of ultra high molecular weight polyethylene tube, with fabric/wire reinforcement, and abrasion resistant outer cover. Inner surface of hose shall be smooth. Hose shall be designed for minimum operating pressure of 200 psig.

B. Furnish sufficient length of hose to allow connection to rigid piping without placing strain on any components.

2.6 QUICK CONNECT COUPLINGS, CLAMPS

A. Standard couplings shall be quick-disconnect type. Couplings shall be constructed entirely of stainless steel and use a cam mechanism to secure the adapter to the coupler, providing a leak-tight connection. No springs, ball bearings, or snaps shall be used. Engagement levers shall be stainless steel. Gaskets shall be Viton. Couplings shall be designed to operate at working pressure of 200 psig. Hose clamps shall be non-reusable stainless steel, "Band-It" type.

B. Dry-style couplings shall be dry disconnect style. Couplings shall be constructed entirely of stainless steel. Couplings shall use a locking cam and groove mechanism to secure the adapter to the coupler and lever actuation to prevent flow of liquid until the coupling is secured. Coupling shall provide automatic closure from both directions. Ring seal shall be Viton. Couplings shall be designed to operate at working pressure of 200 psig. Hose clamps shall be non-reusable stainless steel, "Band-It" type.

C. Size as indicated on the Drawings.

2.7 PIPE SUPPORTS

A. Pipe supports shall conform to requirements of Chapter 1, Section 6 of the ANSI Code for Pressure Piping (B-31.1).

B. All concrete and masonry anchors shall be drilled expansion bolt type; power driven fasteners will not be allowed. Expansion bolts shall be stainless steel. Rawl-Bolt, Hilti or approved equal.

C. Pipe supports shall be fabricated from stainless steel. Supports shall generally conform to the typical details shown on the Drawings. The dimensions shall be modified as required to accommodate specific conditions.

2.8 LABELS

A. Labels shall be determined at time of construction.

2.9 SIDESLOPE RISER BULKHEAD AND HARDWARE

A. Fabricate sideslope riser bulkhead from HDPE, 1-inch-thick flatstock.

B. For sideslope riser pipe connection, provide Type 304 stainless steel flanges, nipple, and hardware, size as indicated on the Drawings.

C. Provide Type 18-8, 304, or 316 stainless steel, self-tapping threaded inserts with ¼-inch-20 internal threads and minimum depth of $^{7}/_{16}$-inch.

D. Provide bulkhead bolts and flat washers of matching material to threaded inserts. Bolts shall have sufficient length to span bulkhead flatstock, bulkhead gasket, and flat washer while still engaging at least ⅜-inches into threaded insert.

E. Fabricate Bulkhead Gasket from ¼-inch thick Viton sheet gasket material, 40 durometer hardness.

PART 3 – EXECUTION

3.1 GENERAL

A. Do not damage pipe, valves, gauges or other equipment during loading, hauling or handling. Provide all lifting and loading equipment required.

B. Furnish all tools and materials required to join pipes in accordance with manufacturer's instructions.

C. Install all piping and appurtenances in a neat and workmanlike manner. Pipe shall be aligned true to line and grade and rigidly supported. Pipe shall be installed at constant slope, and in alignment with fittings, equipment and structures.

D. Install adequate unions and flanges to allow convenient removal of valves, meters, and other equipment from the pipe system.

E. Pipe and fittings shall be cleaned before being installed to remove foreign material.

F. Screwed connections shall be made with thread compound applied to male thread only. Teflon tape or compound may be used for PVC, steel, or copper.

G. Proper fittings shall be used for changes in direction. Pipe shall be installed at right angles or parallel to walls and floors. Provide low points and union connections where needed to allow drainage.

H. All penetrations through structures shall be sealed weather-tight.

I. Check layout of pipe prior to final installation, and verify adequate clearance between valves, fittings, instruments, and structural components can be achieved.

3.2 PVC PIPE INSTALLATION

A. PVC pipe and pipe fittings shall be handled carefully in loading and unloading. They shall be lifted by hoists and lowered on skidways in such a manner as to avoid shock. Pipe and pipe fittings shall not be dropped or dumped.

B. PVC pipe installation shall conform to the requirements of this Section, the manufacturer's recommendations, and as outlined in ASTM D2774V.

C. Pipes shall be joined in accordance with ASTM D2855.

D. All pipe shall be inspected for cuts, scratches, or other damages prior to installation. Pipe with imperfections shall not be used.

E. All burrs, chips, etc., shall be removed from pipe interior and exterior.

F. All loose dirt and moisture shall be wiped from the interior and exterior of the pipe end and the interior of the fitting.

G. All pipe cuts shall be square and perpendicular to the center line of pipe.

H. Pipe ends shall be beveled prior to applying primer and solvent cement so that the cement does not get wiped off during insertion into the fitting socket.

I. A coating of CPS primer, as recommended by pipe supplier, shall be applied to the entire interior surface of the fitting socket, and to an equivalent area on the exterior of the pipe prior to applying solvent cement.

J. The solvent cement shall comply with the requirements of ASTM D2564 and shall be applied in strict accordance with manufacturer's specifications.

K. Pipe shall not be primed or solvent welded when it is raining, or when atmospheric temperature is below 40°F, or above 90°F when under direct exposure to the sun.

L. After solvent welding, the pipe shall remain undisturbed until cement has reached initial set. As a guideline for joint setting time, use 1 hour for ambient temperatures between 60°F and 100°F, or 2 hours when ambient temperature is between 40°F and 60°F.

M. Pipe and pipe fittings shall be selected so that there will be as small a deviation as possible at the joints, and so that inverts present a smooth surface. Pipe and fittings that do not fit together to form a tight fitting shall be rejected.

3.3 VALVES

A. Locate and orient valves and flow meters to allow unobstructed manual operation, and access for maintenance.

B. Verify correct orientation of check valves and butterfly valves with flow direction.

3.4 FLEXIBLE HOSES

A. Flexible hoses shall have female couplings at both ends of hose. Male adapters shall be installed on pipe system.

B. Lay hose neatly in vault between end connections. Install in a manner to prevent kinking, or straining of connections.

C. Secure quick disconnect fittings to flexible hose using clamps specified above. Follow manufacturer's installation instructions.

3.5 PIPE SUPPORTS

A. Pipe supports shall be independent of equipment to which pipe is connected. Equipment shall be removable without affecting pipe supports.

B. At a minimum, pipe supports shall be spaced to conform to requirements of Chapter 1, Section 6 of the ANSI Code for Pressure Piping (B-31.1).

C. Install pipe supports for rigid pipe within 4 inches of connections with flexible hose. Install pipe supports within 4 inches both sides of all valves and flow meters. Pipe supports shall be located so that access in the Sump Riser Building, and removal of equipment from the sideslope risers is not restricted.

D. Install pipe supports at maximum 4-foot intervals along straight runs of pipe.

E. Piping shall be supported and restrained to prevent excessive stress on pipe, fittings, or equipment to which piping is connected. Supports shall provide required pitch for proper drainage. Supports shall prevent excessive variation in supporting force. Supports shall allow free expansion and contraction.

3.6 SIDESLOPE RISER BULKHEAD

A. Install sideslope riser bulkhead to sideslope riser pipe. Cut pipe square to long axis of pipe after pipe temperature has reached equilibrium after burial. Prevent cuttings from entering the sideslope riser.

B. Neatly shave or grind cut pipe end to within $\frac{1}{32}$-inch of true planar surface. Maintain square edges.

C. Field drill holes for lag screws in pipe wall and in bulkhead. Holes shall be square to pipe end.

D. Install gasket and bulkhead. Evenly tighten lag screws until gasket forms an airtight seal.

E. Install hardware on and through bulkhead face as indicated with airtight penetrations.

3.7 TESTING

A. General
   1. Pipe lines shall be pressure tested in presence of the CQA Consultant. CONTRACTOR to provide ENGINEER with a minimum 7-day notice before performing test.
   2. Provide necessary pipe connections between section of pipe being tested and nearest available source of water or air supply, together with test pressure equipment, meters, pressure gauge, and other equipment, materials, and facilities necessary to perform test.
   3. OWNER will provide water for testing.
   4. Provide bulkheads, flanges, valves, bracing, blocking, or other temporary sectionalizing devices required.

B. Test all PVC pipe and fittings, and flexible hose inside the Sump Riser Building.

C. Presure testing shall follow the procedures outlined in Specifciation Section 01510, Part 3.3.

D. Visual Testing of Valves, Flow Meters, and Instruments
   1. During initial startup of the sump riser building equipment, valves, flow meters, and instruments removed from the pipe during pressure testing shall be visually inspected for leaks from the item itself and from its connection points with adjacent pipe.

[END OF SECTION 15310]

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ATTACHMENT C

CONSTRUCTION QUALITY ASSURANCE PLAN

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CONSTRUCTION QUALITY ASSURANCE PLAN

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Nashua
NEW HAMPSHIRE'S GATE CITY

Prepared for the City of Nashua
File No. 3066.11
July 2020

SANBORN, HEAD & ASSOCIATES, INC.
www.sanbornhead.com

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APPENDIX A – TESTING FORMS

Subgrade Acceptance Certificate
Geosynthetic Clay Liner (GCL) Roll ID and Certification
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Geomembrane Defect Log
Geomembrane Panel Deployment
Geomembrane Trial Seam Log
Geomembrane Seam Log
Geomembrane Seam Location Log
Geomembrane Destructive Sample Log
Geomembrane Destructive Test Log
Geocomposite Roll Identification and Certification
Geotextile Roll Identification and Certification
Pipe Hydrostatic Pressure Test Log
Low Pressure Pneumatic Pressure Test Log
Daily Field Report
Geosynthetics Installation Field Report

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ERRATA SHEET

This Errata Sheet defines the roles and responsibilities of the Construction Quality Assurance (CQA) personnel presented in this CQA Plan. The following outlines the minimum qualifications and specific duties of the Project and Residential Engineer, respectively:

Project Engineer

The Project Engineer, denoted as the CQA Managing Engineer in this CQA Plan, shall comply with the requirements of Env-Sw 1104.06. The roles and responsibilities of the CQA Managing Engineer are outlined in this CQA Plan. The CQA Managing Engineer may delegate tasks to the CQA Site Manager, but all certifications will be signed and stamped by the CQA Managing Engineer. Depending on the CQA Consultant, the roles of the CQA Managing Engineer and to the CQA Site Manager may be fulfilled by the same person.

Resident Engineer

The Resident Engineer, denoted as the CQA Monitor in this CQA Plan, shall comply with the requirements of Env-Sw 1104.06. The roles and responsibilities of the CQA Site Monitor are outlined in this CQA Plan and shall conform to Env-Sw- 805.16(d). Depending on the CQA Consultant, the roles of the CQA Site Manager and the CQA Monitor may be fulfilled by the same person.

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1.0 INTRODUCTION

This Construction Quality Assurance (CQA) Plan addresses the quality assurance activities specific to the construction of Phase IV at the Four Hills Landfill in Nashua, New Hampshire. The purpose of this CQA Plan is to establish the roles and responsibilities of the parties involved with the project, lines of communications between parties, and procedures to document that construction was performed in accordance with the Construction Drawings (Drawings) and Specifications. In the context of this plan, quality assurance refers to means and actions employed to assure that the components of the Phase IV construction project are constructed in accordance with the Drawings and Specifications. Quality assurance is provided by a party independent of the Contractor.

Quality Control refers to those actions taken by the Contractor, its subcontractors, and the manufacturers to ensure that materials and workmanship meet the requirements of the Drawings and Specifications, and applies to manufacturing, shipment, handling, and installation of manufactured components. This CQA Plan does not address design guidelines, installation specifications, or selection of the components. The Specifications define the quality of materials and workmanship to be used and employed. The CQA Plan defines the means to assure the level of material and workmanship used in the construction meets or exceeds the requirements of the Drawings and Specifications.

2.0 PARTIES

The project organization chart depicting the key roles and lines of communication for the Phase IV construction project is presented below, followed by the duties and responsibilities of each of the parties.

2.1 Owner

In this CQA Plan and the Drawings and Specifications, the term “Owner” refers specifically to the City of Nashua, New Hampshire.

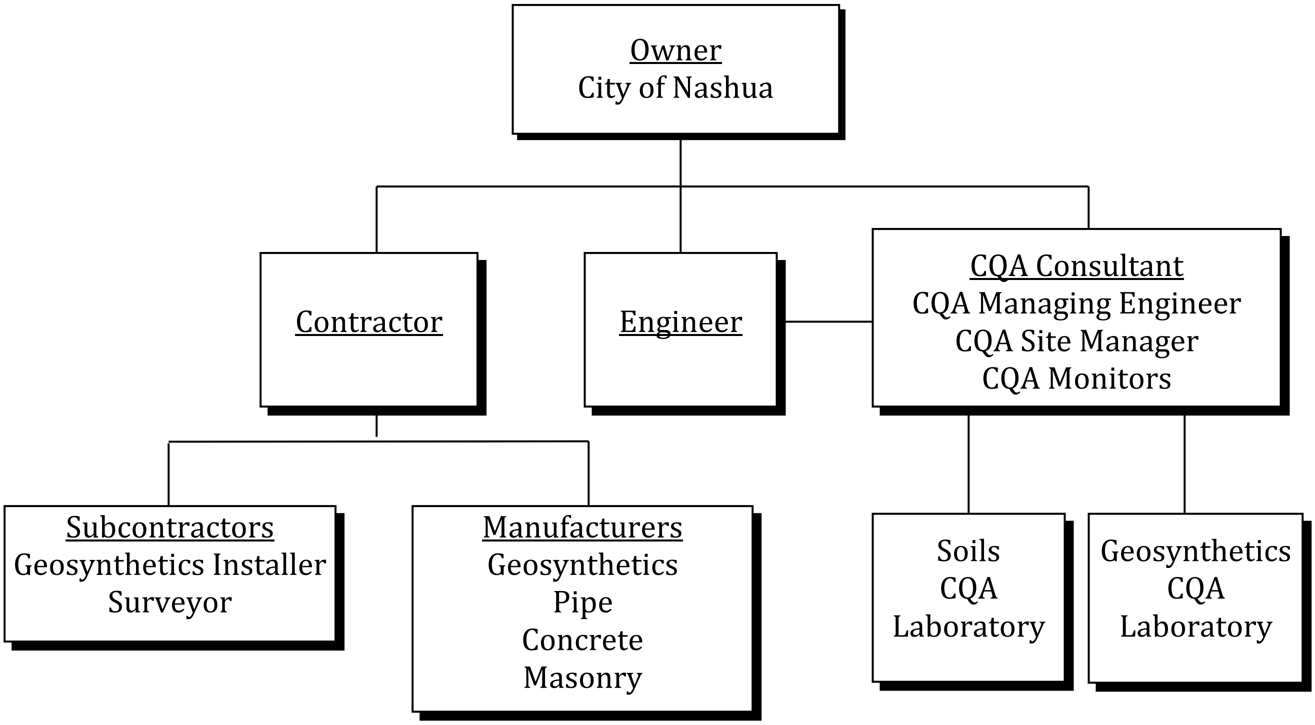
2.2 Project Manager

The Project Manager is the official representative of the Owner (i.e., Owner’s Representative) and is responsible for the coordination and management of activities associated with construction of the Project.

2.3 Engineer

The Engineer is the firm that prepared the Drawings, Specifications, and CQA Plan for the Project. Sanborn, Head & Associates, Inc. is the Engineer for the Phase IV project.

PROJECT ROLES AND LINES OF COMMUNICATION



2.4 Contractor

The Contractor is the general contractor responsible for constructing the prescribed design in accordance with the Drawings and Specifications. The Contractor may retain the services of specialty subcontractors (e.g., material suppliers, Geosynthetics Manufacturer, Geomembrane Installer). The Contractor must have experience in successful geosynthetic installation, general earthwork, and shall have current local, state, and federal licenses as appropriate.

2.5 Geosynthetics Manufacturer

The Geosynthetics Manufacturer is the firm or firms responsible for the production of geosynthetics (i.e., geomembrane, drainage geocomposite, geotextile, etc.) to be used on this project and its delivery to the project site. The Geosynthetics Manufacturer(s) must be able to provide sufficient production capacity and qualified personnel to meet the project schedule. The Geosynthetics Manufacturer(s) must be approved by the Owner and Engineer, in accordance with the requirements of the Specifications.

2.6 Geosynthetics Installer

The Geosynthetics Installer is the company responsible for performing all aspects of the geosynthetics installation. The Geosynthetics Installer may also be responsible for specialized construction tasks (e.g., field construction of pipe boots, etc.). The Geosynthetics Installer will be trained and qualified to install the geosynthetics proposed for this project, as required by the Specifications. The Geosynthetics Installer, in particular, must be approved and/or licensed by the various Geosynthetics Manufacturer(s) for installation of the various geosynthetic components. Further, the Geosynthetics Installer must be approved by the Owner and Engineer.

2.7 Contractor's Surveyor

The Contractor's Surveyor must be a licensed professional in the state of New Hampshire with a minimum of five years of construction surveying experience and be familiar with the surveying skills required for this project and be a party independent of the Owner and the Engineer. The Contractor's Surveyor will be a subcontractor to the Contractor and is responsible for construction layout and obtaining interim and final as-built information for the project. The final as-built information will be used by the Engineer and/or the CQA Consultant to produce Record Drawings as required in the Specifications. The qualifications required of the Contractor's Surveyor and surveying requirements for the project are provided in the Specifications.

2.8 CQA Consultant

The CQA Consultant is the firm that administers the CQA Plan. The CQA Consultant must employee a Professional Engineer licensed in the State of New Hampshire who is a qualified representative of the firm, that is experienced in observing and documenting construction.

The CQA Consultant is responsible for observing and documenting the construction activities as defined in this CQA Plan. Specific duties of the CQA Consultant personnel include:

- Reviewing the Drawings and Specifications, and modifications thereto;
- Reviewing other project-specific documentation, including proposed layouts, and manufacturer and Contractor literature;
- Documenting construction operations using field reports, logs, and/or photographs;
- Attending project meetings;
- Noting activities that could result in damage and/or delays;
- Reporting unapproved construction deviations to the Engineer and the Owner;
- Verifying that the Contractor is obtaining as-built survey information as required by this CQA plan, the Drawings, and Specifications; and
- Preparing a construction documentation report.

The CQA Consultant is a party, independent from the Contractor, the manufacturer(s), and the Geosynthetics Installer.

3.0 CQA CONSULTANT TEAM

3.1 Overview

The CQA Consultant will be a team of individuals experienced in the provision of CQA services for similar projects. The CQA team must be experienced in monitoring the construction of the various components of the project. The number of CQA Consultant personnel needed on site at a given time is dictated by the Contractor's schedule as determined by the CQA Consultant.

The CQA team will include the CQA Managing Engineer, a CQA Site Manager, and the CQA Monitor(s). The CQA Managing Engineer will lead the CQA team. The CQA team may use the services of other qualified individuals to assist with the assignments. Together, the CQA team will perform several assignments during construction. These assignments include performing CQA for earthwork construction, geosynthetics installation, and other related components of the project. The CQA team is responsible for observing and performing field testing and documentation activities related to the performance of the various components of the design. Field and laboratory testing are to be performed in accordance with applicable standards and specifications.

3.2 CQA Managing Engineer

The CQA Managing Engineer will be a Professional Engineer licensed in the State of New Hampshire. He will review approved construction clarifications and changes and will serve as technical reviewer of the construction documentation report. The CQA Managing Engineer will be in direct communication with the Owner, Engineer, and CQA personnel during construction.

Other responsibilities of the CQA Managing Engineer include:

- Being familiar with the Drawings, Specifications, and CQA Plan;
- Attending the preconstruction meetings, progress meetings, and resolution meetings when requested;
- Administering the CQA program (i.e., assigns and manages the CQA personnel, reviews field reports, and provides engineering review of CQA-related issues);
- Providing quality control of the CQA personnel, including site visits;
- Reviewing changes to the Drawings, Specifications, and CQA Plan; and
- Preparing the construction documentation report with assistance from the CQA Site Manager, including a review of the as-built record drawings provided by the Contractor.

3.3 CQA Site Manager

The CQA Site Manager will interact on a frequent basis with project personnel and has authority over the field CQA personnel. The responsibilities and duties of the CQA Site Manager include the following:

- Being familiar with the concepts used to develop the Drawings and Specifications;
- Acting as the on-site (resident) representative of the CQA Consultant;
- Evaluating conformance of materials and construction with the requirements of the Drawings and Specifications;
- Familiarizing the CQA Monitors with the project site and CQA requirements for the project;

- Reporting unresolved deviations from the CQA Plan to the Engineer and/or Owner;
- Managing the daily activities of the CQA Monitors;
- Attending CQA-related meetings (e.g., resolution, preconstruction, daily, weekly);
- Assisting the CQA Managing Engineer in preparing documentation for Requests for Information (RFI) or other clarifications to the Drawings and/or Specifications;
- Administering the CQA program (i.e., assigning and managing CQA personnel, reviewing field reports, and providing review of CQA-related issues);
- Reviewing as-built survey information submitted by the Contractor;
- Verifying the calibration and condition of the CQA equipment;
- Reviewing CQA Monitors' daily reports and logs;
- Preparing daily and weekly report, noting relevant observations reported by the CQA Monitors;
- Overseeing the collection and shipping of laboratory test samples;
- Reviewing and reporting results of laboratory testing;
- Periodically checking stockpiles or borrow pit sources for variability of the soils, and verifying that conformance testing is performed;
- Reviewing the work of the Contractor's equipment operators, to ensure that care is taken to protect other portions of the work;
- Establishing additional test requirements beyond those required in the CQA Plan, when necessary;
- Reviewing Supplier, manufacturer, and Installer certifications, when necessary;
- Reviewing the Geosynthetics Installer's personnel qualifications for conformance with those pre-approved for work on-site;
- Noting on-site activities that could result in damage to the geosynthetics;
- Designating a senior CQA Monitor to act on his/her behalf whenever he/she is absent from the project site while operations are on-going; and
- Preparing the construction documentation report with the CQA Managing Engineer.

3.4 CQA Monitors

The duties of the CQA Monitor(s) are assigned by the CQA Site Manager and include monitoring, logging, and/or documenting associated earthwork construction and geosynthetics installation. The duties to be performed and activities to be monitored by the CQA Monitor(s) associated with earthwork specifically include:

- Observing and documenting soil excavation, stockpiling, and placement;
- Observing and documenting soil moisture content and moisture conditioning, if required;
- Observing and documenting collection of soil samples for laboratory testing;

- Testing the in-situ moisture and density of compacted earthen materials;
- Observing and documenting operations to protect completed areas before the covering materials are placed;
- Examining the soil surfaces for signs of excessive wetting, desiccation, or other disturbance prior to placing cover materials; and
- Observing and documenting scarification, rewetting, recompaction, or proof rolling required to repair deteriorated areas.

The duties to be performed and activities to be monitored by the CQA Monitor(s) associated with geosynthetics and pipe installation include:

- Observing and documenting the delivery of materials;
- Observing and documenting the unloading of materials and on-site transporting and storage;
- Observing and documenting geosynthetic placement operations;
- Observing and documenting joining and/or seaming operations;
- Observing and documentation of condition of materials as placed;
- Sampling for conformance testing by the Geosynthetics CQA Laboratory as required by the Specifications;
- Marking samples for conformance testing; and
- Observing and documenting repair operations.

3.5 Soils CQA Laboratory

The Soils CQA Laboratory will have experience in the physical testing of soil and concrete, and be familiar with, and properly equipped to perform the geotechnical testing required by the CQA Plan.

3.6 Geosynthetics CQA Laboratory

The Geosynthetics CQA Laboratory will have experience in testing the types of geosynthetics to be used on the Project, and be familiar with, and properly equipped to perform the testing required by the CQA Plan. The Geosynthetics CQA Laboratory must be certified by the Geosynthetic Research Institute (GRI) for the particular tests performed in support of the project.

3.7 CQA Surveyor

During the project, the CQA Consultant may verify the as-built locations and elevations of the Contractor's work by collecting independent survey data to compare with the Contractor's survey data. The CQA Surveyor will be provided access to the project site and relevant components of the project for the purpose of obtaining independent survey data. The CQA Surveyor shall be use control established at the project site and control installed by the Contractor's Surveyor. Upon request by the Owner, the Contractor will provide survey data to the CQA Consultant and Engineer in electronic format and the same horizontal and vertical datums as shown on the Drawings for comparison.

The CQA Surveyor shall be a competent professional with a minimum of five years of construction surveying experience, be familiar with the surveying practices required for this project and be a party independent of the Contractor. The CQA Surveyor will be retained by either the Owner or the CQA Consultant. Data obtained by the CQA Surveyor will not be used for preparing as-built documentation. The responsibilities of the CQA Surveyor are presented in Section 5.0.

4.0 PROJECT MEETINGS

4.1 Introduction

In order to facilitate construction, clearly define construction goals and activities, and avoid unnecessary delays, close coordination between the Owner, Engineer, CQA Consultant, and Contractor is essential. To meet this objective, meetings will be held prior to and at regular intervals throughout the project schedule.

4.2 Preconstruction Meeting

Following award of the project to the Contractor and prior to mobilization, a Preconstruction meeting shall be held at the project site with the Owner, Contractor, Engineer, CQA Consultant, and others designated by the Owner.

The preconstruction meeting should include discussion of the following activities:

- Reviewing the responsibilities of each party;
- Confirming the lines of authority and communication;
- Communicating relevant documents to project parties;
- Reviewing critical design details of the project;
- Addressing appropriate modifications to the Drawings or Specifications so that the fulfillment of design or performance standards can be achieved;
- Establishing an understanding by the parties of the CQA Plan, and CQA and CQC procedures to be followed during the project;
- Establishing work area security and safety protocol in accordance with the Owner's and the Contractor's health and safety plans;
- Describing soil borrow source locations;
- Establishing soil stockpiling locations;
- Confirming the methods for documenting and reporting, and for distributing documents and reports;
- Confirming acceptance and approval process for task completion prior to schedule sequence advancement; and
- Establishing procedures for processing applications for payment.

Items discussed during the preconstruction meeting will be documented by a person designated at the beginning of the meeting, and minutes will be transmitted within one week of the meeting to the attending parties and others designated by the Owner.

4.3 Progress Meetings

A progress meeting (via teleconference or at the project site) will be held each week during construction between select CQA personnel, the Contractor, and the Owner. The CQA Managing Engineer and Engineer will participate in the weekly meetings when appropriate. Meeting discussion topics may include: (i) current progress; (ii) planned activities for the upcoming week, and (iii) new business or revisions to the work. Minutes of the progress meetings will be recorded by a member of the CQA team and will document problems, decisions, and questions discussed. Matters requiring action raised in the meeting will be reported to the appropriate parties. Minutes of weekly progress meetings will be distributed within three days of the meeting to each party present at the meeting, and to others designated by the Owner.

Daily progress meetings will be held between the CQA Site Manager and the Contractor prior to the start of work or following the completion of work. The purpose of these meetings is to review the previous day’s activities, review the upcoming day’s activities, and identify potential construction problems. Major items discussed during these meetings will be documented in the CQA Site Manager’s daily field reports.

4.4 Problem or Work Deficiency Meetings

Special meetings will be held by the Owner when and if problems or deficiencies are present or judged likely to occur. At a minimum, these meetings will be attended by the Contractor, the Owner, select CQA personnel, and if needed, the Engineer. The purpose of these meetings is to define and resolve the problem or work deficiency as follows:

- Define and discuss the problem or deficiency;
- Review alternative solutions; and
- Implement an action plan to resolve the problem or deficiency.

Items discussed during these meetings will be documented by the Owner, and if deemed necessary, minutes will be transmitted to the appropriate parties.

5.0 CQA SURVEYING

CQA surveying of lines and grades may be performed during construction to independently verify the work, as requested by the Owner, the Engineer, and/or the CQA Consultant. The overall responsibilities of the Contractor’s Surveyor are described in the Specifications. The CQA Surveyor will use existing control monuments at the project site and the control monuments established by the Contractor’s Surveyor during construction. The CQA Consultant will coordinate the CQA Surveyor’s fieldwork for the aspects of construction, as needed.

The scope of CQA surveying will include, but not necessarily be limited to:

- Verifying the horizontal and vertical coordinates of selected construction control points;
- Verifying layer thickness, especially of soil components of the liner system; and
- Verifying information regarding the horizontal alignment and vertical profile of leachate-collection pipes, leachate transmission piping, site drainage features, etc.

The CQA personnel and the CQA Surveyor are responsible for coordinating the CQA surveying work such that areas are promptly surveyed, interim results are reviewed, and approval is granted for the Contractor to proceed with subsequent work in the areas. The CQA Site Manager will report nonconforming work or inconsistencies to the Owner and Contractor promptly to limit the potential for construction delays.

6.0 DOCUMENTATION

6.1 Introduction

CQA Plans are based on the recognition that the construction activities should be monitored, and that the work monitored should be documented. The CQA Consultant will document that the quality assurance requirements were addressed and satisfied.

The CQA Site Manager will provide the CQA Managing Engineer and Owner with signed descriptive remarks, data sheets, and logs to verify that the monitoring activities were performed. The CQA Site Manager will maintain a complete file of the Drawings, Specifications, CQA Plan, checklists, test procedures, daily logs, and other pertinent documents at the project site, or in an electronic format that can be accessed through the Internet. The CQA Site Manager will verify that the Contractor maintains a current set of red-line Drawings and Contract Documents, which will be kept up to date by the Contractor with the latest changes to the Drawings and Specifications. The red-line Drawings and Construction Documents will be transmitted to the Owner at the conclusion of the project.

6.2 Daily Recordkeeping

Standard reporting procedures will include preparation of a daily CQA report which, at a minimum, will consist of: (i) field notes, including memoranda of meetings and/or discussions with the Contractor, Geosynthetics Installer, Subcontractors, or the Owner; (ii) CQA monitoring logs and testing data sheets; and (iii) construction problem and solution summary sheets. This information will be regularly submitted to and reviewed by the CQA Managing Engineer.

The CQA Site Manager will prepare a daily field report each day, summarizing their discussions with the Contractor and/or sub-contractors, construction operations, and CQA activities. Daily field reports will also be prepared by each member of the CQA Consultant team. At a minimum, the daily field reports will include the following information:

- Arrival and departure time of CQA personnel;
- Weather conditions (temperature, sky conditions, precipitation, etc.);
- Site conditions with specific reference and personnel involved in the project;

- A detailed description of work performed;
- A record of meeting minutes and telephone conversations;
- Decisions made regarding acceptance of work, and/or corrective actions to be implemented for instances of substandard quality; and
- Results of laboratory testing as reported or received by CQA personnel on-site.

6.3 Monitoring Logs and Test Data Sheets

Monitoring logs and test data sheets will be prepared daily. At a minimum, these logs and data sheets will include the following information:

- An identifying sheet number for cross referencing and document control;
- Date, project name, location, and other identification;
- Data on weather conditions;
- A reduced-scale drawing showing the work areas and test locations;
- Descriptions and locations of on-going construction;
- Equipment and personnel in each work area, including subcontractors;
- Descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- Locations where tests and samples were taken;
- A summary of test results;
- Calibrations or recalibrations of test equipment, and actions taken as a result of recalibration;
- Delivery schedule of off-site materials received, including quality control documentation;
- Decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality; and
- Signature of the CQA Site Manager and/or the CQA Monitor(s).

Logs are to be completely filled out with no items left blank.

6.4 Construction Problem and Solution Data Sheets

Construction problem and solution data sheets describing special construction situations will be cross-referenced with specific observation logs and testing data sheets, and must include the following information, when available:

- An identifying sheet number for cross-referencing and document control;
- A detailed description of the situation or deficiency;
- The location and probable cause of the situation or deficiency;
- How and when the situation or deficiency was found or located;
- Documentation of the response to the situation or deficiency;

- Final results of responses;
- Measures taken by the Contractor to prevent a similar situation from occurring in the future; and
- The signature of the CQA Site Manager and/or CQA Monitor, and signature of the CQA Managing Engineer indicating concurrence.

The Owner and Engineer will be made aware of significant recurring non-conformance with the Drawings and Specifications. The Owner and/or Engineer will then evaluate the cause of the non-conformance and recommend appropriate changes in procedures or Specifications. These changes will be submitted to the Engineer for approval. When this type of evaluation is made, the results will be documented, and revisions to procedures or Specifications will be approved by the Owner and Engineer.

A summary of the supporting data sheets, along with final testing results and the CQA Site Manager's approval of the work, will be required upon completion of construction for which the construction situation, deficiency, and/or defect was satisfactorily repaired and completed.

6.5 Photographic Documentation

A photographic log will be developed to serve as a pictorial record of work progress and illustrate issues and mitigation activities taken. The digital color images will be presented in chronological order and with a brief description for each. The log will be presented to the Owner upon completion of the Project.

6.6 Design and/or Specifications Changes

Changes to the Drawings and/or Specifications may be identified during construction. In such cases, the CQA Site Manager will notify the Owner and Engineer. Drawing and/or Specification changes will be made only with the written agreement of the Owner and Engineer and will take the form of an addendum to the Contract Documents.

6.7 Progress Reports

The CQA Consultant will prepare a summary progress report each week, or at time intervals established at the preconstruction meeting. As a minimum, this report will include the following information:

- A unique identifying sheet number for cross-referencing and document control;
- The date, project name, location, and other information;
- A summary of work activities during the progress reporting period;
- A summary of construction situations, deficiencies, and/or defects occurring during the progress reporting period;
- A summary of test results, failures and retests; and
- The signature of the CQA Managing Engineer and the CQA Site Manager.

6.8 Construction Documentation Report

At the completion of the project, the CQA Consultant will submit to the Owner a construction documentation report signed and sealed by a Professional Engineer licensed in New Hampshire. The construction documentation report will note: (i) that the work was performed in substantial compliance with the Drawings, Specifications, and CQA Plan; and (ii) that the physical sampling and testing, except as properly authorized, was performed at the appropriate frequencies. The report will include the necessary document to support the construction activities represented.

At a minimum, the construction documentation report will include: (i) a narrative of construction activities; (ii) observation logs and testing data sheets including sample location plans; (iii) construction problems and solutions data sheets; (iv) summary of approved Drawing and Specifications changes; (v) record Drawings; and (vi) a summary statement sealed and signed by a Professional Engineer licensed in the State of New Hampshire.

The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thickness, etc.).

7.0 EROSION AND SEDIMENT CONTROLS

7.1 Preconstruction Qualifying of Material Sources

Prior to construction, the Contractor will be required to provide the CQA Site Manager and/or Engineer with the quality control information and certification from the supplier(s) of seed, mulches or matting, etc. required in the Specifications.

The CQA Site Manager and/or Engineer will examine the suppliers' certifications to verify that the property values listed on the certifications meet or exceed the requirements of the Specifications, and that proper and complete documentation was provided by the Contractor for the temporary and permanent erosion and sedimentation materials that will be used at the project site. The CQA Site Manager will report deviations from the above requirements to the Contractor prior to approving installation of the materials.

7.2 Field Evaluation/Monitoring of Construction Techniques

The CQA Site Manager will observe the Contractor's work activities and will verify that, prior to initiating work in a given area, temporary erosion and sediment controls, as required in the Drawings and Specifications was installed. The CQA Site Manager will routinely verify that the Contractor keeps the project site free from excessive sediment and in as neat a condition as possible. This includes, but is not limited to, the project area, haul roads, detention basins, borrow areas, stockpile areas, and the entrance area to the facility.

The CQA Site Manager and/or Engineer will verify that the Contractor selects the appropriate erosion and sediment controls, installs the erosion control measures appropriately, and performs the necessary inspections, including routine weekly inspections and unscheduled inspections as soon as reasonably possible during or after rainfall events that produces runoff from the project site. If excessive sediment or damage to the erosion control measures is observed, then the Contractor will be responsible for implementing appropriate corrective measures. The Contractor may accompany the CQA Site Manager during these inspections or may perform independent inspections required in the Drawings and Specifications. The CQA Site Manger will be responsible for reviewing the Contractor's erosion control inspection checklist forms within one working day of the Contractor submitting the forms.

The CQA Site Manager will verify that stockpiles are located as shown on the Drawings or as approved by the Owner, and that the Contractor installed and is maintaining the erosion and sedimentation control measures around these areas, as required in the Specifications.

7.3 Deficiencies, Problems, and Repairs

The CQA Site Manager will report deficient and noncomplying erosion and sedimentation controls to the Contractor. The extent of the deficiencies will be evaluated by observations, review of records, or other means deemed appropriate by the CQA Site Manager and/or Owner. The Contractor will promptly correct the deficiency to the satisfaction of the CQA Site Manager, or as directed by the Owner.

8.0 EARTHWORK

8.1 Preconstruction Qualifying of Material Sources

Prior to construction with a given soil or aggregate material, the Contractor will provide the CQA Consultant with the test results for each proposed material from each proposed material source. The CQA Consultant will review the test results to verify that each material meets the requirements of the Specifications. Results of the preconstruction tests will not be counted toward the conformance testing frequency requirements. The CQA Consultant may also request that the Contractor provide a sample of each material for additional testing, if further preconstruction qualification testing by the CQA Consultant is warranted.

If a preconstruction qualifying sample fails to meet the requirements of the Specifications, then the CQA Consultant will notify the Contractor. Use of the material will not be allowed until the material is pre-qualified by further tests. Additional tests, if necessary, will be performed by the CQA Consultant at the request of the Owner and/or Engineer.

8.2 Material Conformance Testing

During construction, the CQA Consultant will verify that the physical properties of the earthwork materials meet the specified material properties. The CQA Consultant will obtain soil samples for conformance testing from borrow sources, on-site stockpiles, or from trucks as they unload material in the work area. Conformance sampling and laboratory testing of soil and aggregate will be performed in accordance with the Specifications.

If a sample fails a conformance test, then the CQA Consultant will notify the Contractor and use of the material represented by that sample will not be allowed. Additional tests may be performed by the CQA Consultant if directed by the Owner, or the Contractor will use material from a different source.

8.3 Field Evaluation/Monitoring of Construction Techniques

The CQA Consultant will monitor and document the earthwork activities. Monitoring the construction work for the earthwork materials will include the following:

- Monitoring the thickness of lifts as loosely placed and after being compacted;
- Documenting the type of construction equipment and methods used to place and compact the material;
- Observing the action of the compaction and heavy hauling equipment on the construction surface (i.e., penetration, pumping, cracking, etc.) to detect inadequate compaction;
- Verifying that proper equipment and methods are used to place soil or aggregate over geosynthetic components of the liner system, and that wrinkles or excess tensile stresses to underlying geosynthetics are minimized; and
- Verifying that only low-ground pressure equipment traverse over lined areas unless an approved thickness of protective soil is first placed.

9.0 FIELD TESTING

9.1 Routine Field Testing

Conformance field testing (e.g., grain-size distribution, hydraulic conductivity, density, and moisture content testing) of placed/compacted earthwork materials will be performed by the CQA Consultant during construction to confirm that the requirements of the Specifications are met. Conformance field testing will be performed according to test methods provided in the Specifications. Testing frequencies are outlined on the Tables 1 thorough 4. The CQA Consultant will select the test locations.

The CQA Consultant is responsible for submitting the appropriate number and sized samples to the Soils CQA Laboratory to meet the minimum testing frequency and testing requirements. The CQA Consultant also is responsible for monitoring the placement and compaction of soil in the liner system anchor trench. The CQA Consultant will verify that the backfilling techniques do not damage the geosynthetics in or near the anchor trench.

9.2 Modified Testing Frequency

A modified testing frequency may be used at the discretion of the CQA Consultant when initial testing or visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- The compactor rollers slip during compaction operations;
- The lift thickness is greater than specified;
- The material is at a highly variable moisture content;
- Dirt-clogged rollers are used to compact the material;
- The material properties are highly variable;
- The degree of compaction is doubtful; or
- As directed by the CQA consultant, Engineer, or Owner.

During construction, the frequency of testing may also be increased in the following situations:

- Adverse weather conditions;
- Breakdown of equipment;
- At the start and finish of grading;
- If the material initially fails to meet compaction requirements; or
- The work area is reduced.

9.3 Deficiencies, Problems, and Repairs

If a deficiency or noncompliance is discovered, then the CQA Consultant will promptly evaluate the extent and nature of the defect. The extent of the deficient area will be evaluated by additional tests, observations, a review of records, or other means deemed appropriate (e.g., proof rolling by the Contractor).

After defining the extent and nature of a defect, the CQA Consultant will notify the Contractor, and at times, the Owner, to schedule appropriate retests after the work deficiency is corrected.

If a specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Owner or Engineer suggested alternative solutions for approval. Retests recommended by the CQA Consultant must verify that the deficiency was corrected before additional work is performed by the Contractor in the area of the deficiency.

10.0 GEOMEMBRANE

10.1 Monitoring

The CQA Consultant will monitor geomembrane installation. Specific monitoring activities include, but are not limited to:

- Reviewing the required submittals to verify that the resin used to manufacture the geomembrane and the geomembrane itself meet the material requirements of the Specifications;
- Collecting conformance samples of the geomembrane at the manufacturing facility or after delivered to the project site and forwarding the samples to an approved off-site testing laboratory for testing;
- Collecting and reviewing the Geosynthetic Manufacturers' quality control (MQC) documentation to verify that the certifications comply with the requirements of the Specifications;
- Tracking inventory of the geomembrane rolls delivered to the project site;
- Observing geomembrane rolls delivered to the project site to observe whether the materials were damaged during transportation and, if damaged, marking damaged locations for repair or replacement;

- Observing and documenting material unloading and on-site transport and storage;
- Reviewing and evaluating laboratory CQA conformance test results for the geomembrane to verify that the test results met the requirements of the Specifications;
- Monitoring deployment and installation of the geomembrane and marking locations for replacement or repair;
- Monitoring overlapping of adjacent geomembrane panels;
- Monitoring geomembrane trial seaming operations and field testing of trial seams (both fusion and extrusion);
- Monitoring geomembrane production seaming operations (both fusion and extrusion);
- Monitoring nondestructive testing (both air pressure and vacuum) of geomembrane seams and repairs;
- Selecting geomembrane seam sample locations, monitoring sample collection, distributing samples to the Geosynthetics Installer and Owner, and destructively testing the samples at an approved Geosynthetics CQA Laboratory to verify compliance with the requirements of the Specifications and CQA Plan;
- Monitoring repairs to portions of the geosynthetics that were observed to have defects or that failed the criteria for destructive or nondestructive testing;
- Observing and documenting repair operations;
- Monitoring geomembrane patching sizes. If patches exceed one quarter (25 percent) of the panel's area, then the CQA Personnel has the authority to reject the panel and it shall be removed/replaced by the Geosynthetics Installer;
- Noting on-site activities that could result in damage to the geomembrane; and
- Monitoring placement of the geosynthetics in the anchor trench.

10.2 Preconstruction Qualifying or Material Sources

Prior to construction, the Geosynthetics Installer will provide the CQA Consultant with the quality control information and certifications from the Geomembrane Manufacturer as required by the Specifications.

The CQA Consultant will review the Geomembrane Manufacturer's certifications to verify that the property values listed on the manufacturer's certifications meet or exceed the Specifications and that proper and complete documentation was provided by the Geosynthetics Installer for geomembrane to be used at the project site. The CQA Consultant will report deviations from the above requirements to the Geosynthetics Installer prior to approving installation of the geomembrane.

10.3 Material Conformance Testing

Conformance sampling of the geomembrane will be performed by the CQA Consultant either at the manufacturing facility or upon delivery of the rolls to the project site. The geomembrane samples will be forwarded to the Geosynthetics CQA laboratory for testing to evaluate whether the material meets the requirements of the Specifications and the Geomembrane Manufacturer's list of certified properties.

Sampling will be performed at the minimum frequency listed on Table 5. Conformance samples will be taken across the entire width of the roll and will not include the first three feet of material. Unless otherwise specified, samples will be three feet long by the roll width. Samples will be tested using the methods listed on Table 5.

The CQA Consultant will mark the machine direction on the samples with an arrow and affix a label, tag, or otherwise mark each sample with the following information:

- Date sampled;
- Project number;
- Lot/batch number and roll number;
- Conformance sample number; and
- CQA personnel identification.

The CQA Consultant will review the MQC and CQA conformance test results before approving deployment of the geomembrane. Material not meeting the required physical properties will be promptly reported to the Geosynthetic Installer. The following procedure will apply whenever a geomembrane sample fails a conformance test performed by the CQA Consultant:

- The Geosynthetic Installer will be required to replace all rolls of geomembrane within the lot/batch from which the nonconforming sample was obtained.
- Alternatively, if the Geosynthetic Installer, Geomembrane Manufacturer, and the Owner all agree, the CQA Consultant will obtain additional conformance samples from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the conformance test requirements. If either of these samples fails to meet the requirements, then samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the CQA Consultant. These ten samples must pass the above conformance tests. If any of these samples fail, then a sample from every roll of geomembrane from the batch/lot on-site may be conformance tested by the CQA Consultant for the failing property test.

During conformance testing, the CQA Consultant will also verify that the Geomembrane Manufacturer identified all rolls of geomembrane with the following information:

- Name of manufacturer;
- Product identification;
- Thickness;
- Lot number;
- Batch number;
- Roll number; and

- Roll dimensions.

The CQA Consultant will record the above information for each roll delivered to the project site using a Material Inventory Log form.

10.4 Field Evaluation/Monitoring of Construction Techniques

During unloading and storage, the Contractor and/or the Geosynthetics Installer is required to keep the geomembrane off the ground and protected the geomembrane from direct sunlight, precipitation or other inundation, excessive heat or cold, mud, dirt, dust, puncture, cutting, or other damaging or deleterious conditions.

The CQA Consultant will observe rolls upon delivery at the project site and deviations from the above requirements will be reported to the Geosynthetics Installer. Damaged rolls will be rejected by the CQA Consultant and required to be repaired or replaced by the Geosynthetics Installer.

The Geosynthetics Installer is required to handle and deploy the geomembrane in such a manner as to ensure the geomembrane is not damaged. The CQA Consultant will verify compliance with the following:

- In the presence of wind, the geomembrane is weighted with sandbags (or equivalent ballast weight approved by the CQA Consultant), and that sandbags remain until replaced with the overlying protective cover soil layer;
- Efforts are made to minimize the presence of wrinkles in the geomembrane, and if necessary, the geomembrane is positioned by hand after being unrolled to minimize wrinkles;
- Care is taken by the Geosynthetics Installer not to entrap stones, soil, dust, or moisture that could damage the geomembrane; and
- After installation, the surface of the geomembrane is observed to verify that no potentially harmful foreign objects, such as tools, are present.

The CQA Consultant will verify that the Contractor and/or Geosynthetics Installer places soil or geosynthetic materials on top of geomembrane such that:

- The geomembrane and underlying materials are not damaged;
- Wrinkles are minimized; and
- Excess tensile stresses are not produced in the geomembrane.

10.5 Deficiencies, Problems, and Repairs

The CQA Consultant will report to the Geosynthetics Installer unresolved deficiencies in the underlying materials prior to geomembrane placement and will not approve of geomembrane deployment until the geomembrane deficiencies are resolved to the satisfaction of the CQA Consultant and in accordance with the Specifications.

The CQA Consultant will verify that holes or tears in the geomembrane are repaired in accordance with the Specifications.

The CQA Consultant will document deficiencies or noncompliance with the specified requirements and report them to the Geosynthetics Installer. The extent of deficiencies will be evaluated by observations, a review of records, or other means deemed appropriate by the CQA Consultant. The Geosynthetics Installer will correct the deficiency to the satisfaction of the CQA Consultant. If a Specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Engineer and the Owner suggested alternative solutions for approval. Retests or subsequent re-evaluations recommended by the CQA Consultant must verify that the deficiency has been corrected before additional work is performed by the Geosynthetics Installer in the area of the deficiency.

11.0 GEOTEXTILE

The CQA Consultant will monitor geotextile installation. Specific monitoring activities include, but are not limited to:

- Reviewing the required submittals to verify that the geotextile meets the requirements of the Specifications;
- Collecting and reviewing the MQC documentation to verify that the certifications comply with the requirements of the Specifications;
- Tracking inventory of the geotextile rolls delivered to the project site;
- Observing geotextile rolls delivered to the project site to observe whether the materials were damaged during transportation and, if damaged, marking damaged locations for repair or replacement;
- Observing and documenting material unloading and on-site transport and storage;
- Immediately prior to geotextile placement, verifying that the subgrade is free of sharp protrusions or other obstructions that could potentially damage the geotextile;
- In the presence of wind, observing that the geotextile is weighted with sandbags (or equivalent ballast weight approved by the CQA Consultant), and that sandbags remain until replaced with an overlying layer;
- Observing that efforts are made to minimize the presence of wrinkles in the geotextile, and if necessary, the geotextile is positioned by hand after being unrolled to minimize wrinkles;
- After installation, observing that the geotextile surface to verify that no potentially harmful foreign objects, such as needles or tools, are present; and
- Verifying that the geotextile is not left exposed for longer that the maximum allowable period (as set forth in the Specifications) after placement unless a longer exposure period is approved by the Engineer.

The CQA Consultant will verify that the Contractor places soil and aggregate materials on top of the geotextile such that:

- The geotextile and underlying materials are not damaged;
- Wrinkles are minimized; and
- Excess tensile stresses are not produced in the geotextile.

12.0 DRAINAGE GEOCOMPOSITE

12.1 Monitoring

The CQA Consultant will monitor drainage geocomposite installation. Specific monitoring activities include, but are not limited to:

- Reviewing the required submittals to verify that the drainage geocomposite meets the requirements of the Specifications;
- Collecting conformance samples of the drainage geocomposite after delivered to the project site and forwarding the samples to the Geosynthetics CQA Laboratory;
- Collecting and reviewing the MQC documentation to verify that the certifications comply with the requirements of the Specifications;
- Tracking inventory of the drainage geocomposite rolls delivered to the project site;
- Observing drainage geocomposite rolls delivered to the project site to observe whether the materials were damaged during transportation and, if damaged, marking damaged locations for repair or replacement;
- Observing and documenting material unloading and on-site transport and storage;
- Reviewing and evaluating laboratory CQA conformance test results for the drainage geocomposite to verify that the test results met the requirements of the Specifications;
- In the presence of wind, observing that the drainage geocomposite is weighted with sandbags (or equivalent ballast weight approved by the CQA Consultant), and that sandbags remain until replaced with an overlying layer;
- Observing that efforts are made to minimize the presence of wrinkles in the drainage geocomposite;
- After installation, observing that the drainage geocomposite surface to verify that no potentially harmful foreign objects, such as needles or tools, are present; and
- Verifying that the drainage geocomposite is not left exposed for longer that the maximum allowable period (as set forth in the Specifications) after placement unless a longer exposure period is approved by the Engineer.

The CQA Consultant will verify that the Contractor places soil and aggregate materials on top of the drainage geocomposite such that:

- The drainage geocomposite and underlying materials are not damaged;
- Wrinkles are minimized; and
- Excess tensile stresses are not produced in the drainage geocomposite.

12.2 Preconstruction Qualifying of Material Sources

Prior to construction, the Geosynthetics Installer will provide the CQA Consultant with the quality control information and certifications from the Drainage Geocomposite Manufacturer as required by the Specifications.

The CQA Consultant will examine the Drainage Geocomposite Manufacturer's certifications to verify that the property values listed on the manufacturer's certifications meet or exceed the Specifications and that proper and complete documentation was provided by the Geosynthetics Installer. The CQA Consultant will also verify that the manufacturer of the nonwoven geotextile component(s) of the drainage geocomposite provides certification that the geotextile was continuously inspected for the presence of needles using a metal detector during the manufacturing process. The CQA Consultant will report deviations from the above requirements to the Geosynthetics Installer prior to approving installation of the drainage geocomposite.

12.3 Material Conformance Testing

Conformance sampling of the drainage geocomposite may be performed by the CQA Consultant either at the manufacturing plant or upon delivery of rolls to the project site. The CQA Consultant will obtain samples and forward them to the Geosynthetics CQA Laboratory for testing to evaluate whether the material meets the requirements of the Specifications and the manufacturer's list of certified properties.

Sampling will be performed at the minimum frequency listed on Table 6. Conformance samples will be taken by the CQA Consultant across the entire width of the roll and will not include the first three feet along the length of the roll. Unless otherwise specified, samples will be three feet long by the full roll width. The CQA Consultant will mark the machine direction on the samples with an arrow and affix a label, tag, or otherwise mark each sample with the following information:

- Date sampled;
- Project number;
- Lot/batch number and roll number;
- Conformance sample number; and
- CQA Consultant personnel identification.

Samples will be tested using the methods listed on Table 6. Conformance test results will be reviewed by the CQA Consultant before installation of the drainage geocomposite. Material not meeting the required physical properties will be promptly reported to the Geosynthetic Installer. The following procedure will apply whenever a drainage geocomposite sample fails a conformance test conducted by the Geosynthetics CQA Laboratory.

- The Geosynthetics Installer will be required to replace all rolls of drainage geocomposite within the batch from which the sample that is not in conformance with the Specifications was obtained.

- Alternatively, if the Geosynthetics Installer, Drainage Geocomposite Manufacturer, and the Project Manager all agree, the CQA Consultant will obtain additional conformance samples from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the conformance tests specified above. If either of these samples fails to meet the requirements, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of drainage geocomposite from the batch/lot on-site maybe conformance tested by the CQA Consultant for the failing property test.

During conformance testing, the CQA Consultant will also verify that the Drainage Geocomposite Manufacturer identified all rolls of drainage geocomposite with the following information:

- Name of manufacturer;
- Product identification;
- Lot number;
- Batch number;
- Roll number; and
- Roll dimensions.

The CQA Consultant will record the above information for each roll delivered to the project site using a Material Inventory Log form.

12.4 Field Evaluation/Monitoring of Construction Techniques

During unloading and storage, the Contractor and/or the Geosynthetics Installer is required to keep the drainage geocomposite off the ground and protected from direct sunlight, precipitation or other inundation, excessive heat or cold, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

The CQA Consultant will observe rolls upon delivery at the project site and deviations from the above requirements will be reported to the Geosynthetics Installer. Damaged rolls will be rejected by the CQA Consultant and required to be repaired or replaced by the Geosynthetics Installer.

The Geosynthetics Installer will be required to handle and deploy the drainage geocomposite in such a manner as to ensure the drainage geocomposite is not damaged. The CQA Consultant will verify compliance with the following:

- Immediately prior to drainage geocomposite placement, the underlying geomembrane surface is free of moisture or obstructions that could potentially damage the drainage geocomposite;

- In the presence of wind, the drainage geocomposite is weighted with sandbags (or equivalent ballast weight approved by the CQA consultant), and that sandbags remain until replaced with the overlying protective cover soil layer;
- Efforts are made to minimize the presence of wrinkles in the drainage geocomposite, and if necessary, the drainage geocomposite is positioned by hand after being unrolled to minimize wrinkles;
- Care is taken by the geosynthetics installer not to entrap stones, soil, dust, or moisture that could damage or cause clogging to the drainage geocomposite;
- After installation, that the drainage geocomposite surface to verify that no potentially harmful foreign objects, such as needles or tools, are present; and
- The drainage geocomposite is not left exposed for longer than the maximum allowable period (as set forth in the Specifications) after placement unless a longer exposure period is approved by the engineer.

The CQA Consultant will verify that the components of the drainage geocomposite (i.e., geotextile-geonet-geotextile) are sewn, joined, and/or overlapped to like-components in adjacent drainage geocomposite panels as required by the Specifications.

The CQA Consultant will verify that the Contractor and/or Geosynthetics Installer places soil or geosynthetic materials on top of drainage geocomposite such that:

- The drainage geocomposite and underlying materials are not damaged;
- Wrinkles are minimized; and
- Excess tensile stresses are not produced in the drainage geocomposite.

12.5 Deficiencies, Problems, and Repairs

The CQA Consultant will report to the Geosynthetics Installer unresolved deficiencies in the underlying geomembrane prior to drainage geocomposite placement and will not approve of drainage geocomposite deployment until the geomembrane deficiencies are resolved to the satisfaction of the CQA Consultant and in accordance with the Specifications.

The CQA Consultant will verify that holes or tears in the drainage geocomposite are repaired in accordance with the Specifications, and that care is taken by the Contractor to remove soil or other materials that may have penetrated the torn drainage geocomposite.

The CQA Consultant will document deficiencies or noncompliance with the specified requirements and report them to the Geosynthetics Installer. The extent of deficiencies will be evaluated by observations, a review of records, or other means deemed appropriate by the CQA Consultant. The Geosynthetics Installer will correct the deficiency to the satisfaction of the CQA Consultant. If a Specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Engineer and the Owner suggested alternative solutions for approval. Retests or subsequent re-evaluations recommended by the CQA Consultant must verify that the deficiency was corrected before additional work is performed by the Geosynthetics Installer in the area of the deficiency.

13.0 GEOSYNTHETIC CLAY LINER (GCL)

13.1 Monitoring

The CQA Consultant will monitor GCL installation. Specific monitoring activities include, but are not limited to:

- Reviewing the required submittals to verify that the GCL meets the requirements of the Specifications;
- Collecting conformance samples of the GCL after delivered to the project site and forwarding the samples to the Geosynthetics CQA Laboratory;
- Collecting and reviewing the MQC documentation to verify that the certifications comply with the requirements of the Specifications;
- Tracking inventory of the GCL rolls delivered to the project site;
- Observing GCL rolls that had been delivered to the project site to observe whether the materials had been damaged during transportation and, if damaged, marking damaged locations for repair or replacement;
- Observing and documenting material unloading and on-site transport and storage;
- Reviewing and evaluating laboratory CQA conformance test results for the GCL to verify that the test results met the requirements of the Specifications;
- Observing that the GCL is stored in accordance with the specifications and is protected from puncture, dirt, grease, water, moisture, mud, excessive heat and cold, and other damage;
- After installation, observing that the GCL surface to verify that no potentially harmful foreign objects, such as needles or tools, are present; and
- Verifying that the GCL is not left exposed for longer that the maximum allowable period (as set forth in the Specifications) after placement unless a longer exposure period is approved by the Engineer.

The CQA Consultant will verify that the Contractor places geosynthetic, soil, and aggregate materials on top of the GCL such that:

- The GCL and underlying materials are not damaged; and
- Excess tensile stresses are not produced in the GCL.

13.2 Preconstruction Qualifying of Material Sources

Prior to construction, the Geosynthetics Installer will provide the CQA Consultant with the quality control information and certifications from the GCL Manufacturer required in of the Specifications.

The CQA Consultant will examine the GCL Manufacturer's certifications to verify that the property values listed on the manufacturer's certifications meet or exceed the Specifications and that proper and complete documentation was provided by the Geosynthetics Installer for the GCL used at the project site. The CQA Consultant will report deviations from the above requirements to the Geosynthetics Installer prior to approving installation of the GCL.

13.3 Material Conformance Testing

Conformance sampling of the GCL may be performed by the CQA Consultant either at the manufacturing plant or upon delivery of rolls to the project site. The CQA Consultant will obtain samples and forward them to the Geosynthetics CQA Laboratory for testing to evaluate whether the material meets the requirements of the Specifications and the manufacturer's list of certified properties.

Sampling will be performed at the minimum frequency listed on Table 7. Conformance samples will be taken across the entire roll width. Samples may be cut for shipping purposes, but a minimum of five square feet must be sent to the testing laboratory. The CQA Consultant will mark on the samples with an arrow and affix a label, tag, or otherwise mark each sample with the following information:

- Date sampled;
- Project number;
- Lot/batch number and roll number;
- Conformance sample number; and
- CQA Consultant personnel identification.

Samples will be tested using the methods listed on Table 7. Conformance test results will be reviewed by the CQA Consultant before installation of the GCL. Material not meeting the required physical properties will be promptly reported to the Geosynthetic Installer. The following procedure will apply whenever a GCL sample fails a conformance test conducted by the Geosynthetics CQA Laboratory.

- The Geosynthetics Installer will be required to replace all rolls of GCL within the batch from which the sample that is not in conformance with the Specifications was obtained.
- Alternatively, if the Geosynthetics Installer, GCL Manufacturer, and the Project Manager all agree, the CQA Consultant will obtain additional conformance samples from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the conformance tests specified above. If either of these samples fails to meet the requirements, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of the samples fail, then a sample from every roll of GCL from the batch/lot on-site maybe conformance tested by the CQA Consultant for the failing property test.

During conformance testing, the CQA Consultant will also verify that the GCL Manufacturer identified all rolls of drainage geocomposite with the following information:

- Name of manufacturer;
- Product identification;
- Lot number;
- Batch number;
- Roll number; and
- Roll dimensions.

The CQA Consultant will record the above information for each roll delivered to the project site using a Material Inventory Log form.

13.4 Field Evaluation/Monitoring of Construction Techniques

During unloading and storage, the Contractor and/or the Geosynthetics Installer will be required to keep the GCL off the ground and protect the GCL from direct sunlight, precipitation or other inundation, excessive heat or cold, mud, dirt, dust, puncture, cutting, or other damaging or deleterious conditions.

The CQA Consultant will observe GCL rolls upon delivery at the project site and deviations from the above requirements will be reported to the Geosynthetics Installer. Damaged rolls will be rejected by the CQA Consultant and required to be repaired or replaced by the Geosynthetics Installer.

The Geosynthetics Installer is required to handle and deploy the GCL in such a manner as to ensure the GCL is not damaged. The CQA Consultant will verify compliance with the following:

- Monitor that, in the presence of wind, the GCL are sufficiently weighted with sandbags to prevent movement. Sandbags are to be installed during placement and will remain until replaced with the overlying layer;
- Monitor that cutting of the GCL is performed using a utility knife in a manner approved by the CQA Consultant. Care should be taken to prevent damage to the underlying liner system components during cutting;
- Monitor that during placement, care is taken to not to entrap stones, or moisture under the GCL. Care will be taken to not to drag equipment across the exposed GCL;
- Verify that GCL damaged by stones or other foreign objects, or installation activities is replaced;
- Monitor that the GCL is not installed on a saturated subgrade or on standing water. The GCL is to be installed in a way that prevents hydration of the material during construction;
- Monitor that the GCL is not installed during precipitation or other conditions that may cause hydration of the GCL;

- Verify that the GCL is installed with the specified side up;
- Verify that geomembrane installation immediately follows the GCL installation and that the GCL placed during the day's work is covered with geomembrane before the Geosynthetics Contractor leaves the project site at the end of the day;
- Verify that no geomembrane is installed over a hydrated GCL;
- Verify that seams in the geomembrane overlying a GCL are welded after each GCL panel is placed. Heat sealing of the seam alone is not acceptable;
- Verify that defects in the geomembrane overlying a GCL and seam sample locations are immediately repaired;
- Verify that hydrated GCL is removed and replaced by the Geosynthetics Installer; and
- Verify that GCLs are overlapped in accordance with the manufacturer's specifications.

13.5 Deficiencies, Problems, and Repairs

The CQA Consultant will report to the Geosynthetics Installer unresolved deficiencies in the GCL prior to geomembrane placement and will not approve of geomembrane deployment until the GCL deficiencies are resolved to the satisfaction of the CQA Consultant and in accordance with the Specifications.

The CQA Consultant will verify that holes or tears in the GCL be repaired by placing a GCL patch over the hole; the patch will overlap the edges of the hole or tear by 2 feet in each direction. If deemed necessary by the CQA Manager, then the patch will be secured with a water-based adhesive approved by the GCL Manufacturer. Verify that soil or other material that may have penetrated the GCL is removed. Verify that patches are not nailed or stapled.

The CQA Consultant will document deficiencies or noncompliance with the specified requirements and report them to the Geosynthetics Installer. The extent of deficiencies will be evaluated by observations, a review of records, or other means deemed appropriate by the CQA Consultant. The Geosynthetics Installer will correct the deficiency to the satisfaction of the CQA Consultant. If a Specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Engineer and the Owner suggested alternative solutions for approval. Retests or subsequent re-evaluations recommended by the CQA Consultant must verify that the deficiency was corrected before additional work is performed by the Geosynthetics Installer in the area of the deficiency.

14.0 HDPE PIPE AND FITTINGS

14.1 Preconstruction Qualifying of Material Sources

The leachate collection and transmission systems include perforated and solid-wall HDPE collection pipes and fittings. The pipes and fittings must be prequalified as described below. Prior to the shipment of the HDPE pipes and fittings to the project site the Contractor will be required to provide the CQA Site Manager and/or Engineer the quality control information and certifications from each manufacturer as required in the Specifications.

The CQA Consultant will examine the HDPE pipe and fitting manufacturer's certifications to verify that the property values listed on the certifications meet or exceed the Specifications, and that proper and complete documentation has been provided by the Contractor for HDPE pipe, fittings, and pipe-accessories to be used at the project site. The CQA Consultant will report deviations from the above requirements to the Contractor prior to approving installation of the materials.

The CQA Consultant will verify that the following information is printed at frequent intervals on, or otherwise clearly provided for the HDPE pipe used on the project:

- Name and/or trademark of the pipe manufacturer;
- Nominal pipe size, wall thickness, and SDR;
- Manufacturing standard reference (e.g., ASTM D2513); and
- Production code from which the date and place of manufacture can be determined.

If, during preconstruction qualifying, any of the HDPE piping, fittings, and/or accessories that fails to meet the requirements of the Drawings and Specifications, then the CQA Consultant will notify the Contractor. Use of the material will not be allowed until the material is prequalified by further tests or otherwise accepted by the Engineer.

14.2 Material Conformance Testing

Material conformance testing of the HDPE pipes will not be required unless aspects of the prequalifying information are deficient or suspect, or if requested by the Engineer. If deemed necessary by the Engineer, the CQA Consultant will remove a minimum three feet long section of pipe and deliver it to the Geosynthetics CQA Laboratory for testing to evaluate whether the pipe meets the required properties of the Specifications. The conformance test requirements will be determined at that time by the Owner and/or Engineer.

14.3 Field Evaluation/Monitoring of Construction Techniques

The CQA Consultant will verify that the HDPE pipe and fittings are stored on clean level ground, free of conditions which could damage the pipe; and where necessary (e.g., due to muddy or sloping ground conditions) the pipe is stored on wooden sleepers, spaced suitably and of such width as not to allow deformation of the pipe at the point of contact with the sleeper or between supports.

During construction, the CQA Consultant will verify compliance with the following:

- The perforated pipe has the proper amount, correct size, and spacing of perforations, and that the perforations are oriented properly after the pipe is installed;
- Handling of the pipe is performed in such a manner that the pipe is not damaged;
- Ropes, fabric, or rubber-protected slings and straps are used when handling pipe;
- Pipe or fittings are not dropped onto rocky or unprepared ground or into trenches or dragged over sharp objects;
- The subgrade surface is firm and free of debris;

- Crushed aggregate for the leachate collection and transmission systems are carefully placed under and around the pipe in accordance with the Drawings and Specifications;
- Pipe segments are not brought into position until preceding lengths have been bedded and secured in its final position;
- Pipe sections are properly joined using procedures recommended by the manufacturer and/or allowed for in the Specifications;
- Joints are stable and in secure condition prior to and after backfilling;
- Blocking is not used under the pipe unless pre-approved by the Engineer; and
- Backfill is placed over the pipe in lifts meeting the requirements of the Specifications, and in a manner that will not damage the pipe.

14.4 Field Testing of Work Products

The CQA Consultant will verify that the Contractor performed the applicable pre-testing procedures required in the Specifications prior to initiating hydrostatic testing of the solid HDPE pipes during installation. The CQA Consultant will monitor the Contractor's activities associate with testing activities and will document that the Contractor follows the procedures required in the Specifications. The CQA Consultant will either record the test results or will observe the Contractor recording the results and review the results upon submittal by the Contractor.

14.5 Deficiencies, Problems, and Repairs

The CQA Consultant will report deficiencies or noncompliance in the construction to the Contractor. The extent of deficiencies will be evaluated by observations, review of records, or other means deemed appropriate by the CQA Consultant and Engineer.

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant and Engineer. If a Specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Owner and Engineer suggested alternative solutions for approval. Retests or subsequent re-evaluations recommended by the CQA Consultant must verify that the deficiency has been corrected before additional work is performed by the Contractor in the area of the deficiency.

15.0 GENERAL OBSERVATION AND DOCUMENTATION

In addition to the CQA components identified above, the CQA personnel will be present to observe and document the construction of critical components of the project not specifically referenced herein. The Contractor will provide the CQA Consultant with at least 48 hours advance notice prior to performing work requiring observation to allow the CQA Consultant to schedule the appropriate personnel. Likewise, if scheduled work requiring the presence of CQA personnel is cancelled, then the Contractor will promptly notify the CQA Manager.

CONFORMANCE TESTING SUMMARY TABLES

Table 1 – Structural Fill Conformance Testing Summary

Properties	Test Method	Frequency
Grain Size Analysis	ASTM D422 (w/o hydrometer)	1 per 5,000 yd^3 (minimum of 1 per material source)
Standard Proctor	ASTM D698	1 per 5,000 yd^3 (minimum of 2 per material source)
Nuclear Density and Moisture Content	ASTM D6938	1 per 5,000 yd^3 In trenches – 1 per lift per 100 linear feet

Table 2 – Screened Till Conformance Testing Summary

Properties	Test Method	Frequency
Grain Size Analysis	ASTM D422 (w/o hydrometer)	1 per 3,000 yd^3 (minimum of 1 per material source)
Standard Proctor	ASTM D698	1 per 3,000 yd^3 (minimum of 2 per material source)
Hydraulic Conductivity	ASTM D5084	1 per 3,000 yd^3 (minimum of 1 per material source)
Nuclear Density and Moisture Content	ASTM D6938	1 per 3,000 yd^3 In trenches – 1 per lift per 200 linear feet

Table 3 – Drainage Sand Conformance Testing Summary

Properties	Test Method	Frequency
Grain Size Analysis	ASTM D422 (w/ hydrometer)	1 per 3,000 yd^3 (minimum of 1 per material source)
Hydraulic Conductivity	ASTM D2434	1 per 3,000 yd^3 (minimum of 1 per material source)
Calcium Carbonate	ASM D4373	1 per 3,000 yd^3 (minimum of 1 per material source)

Table 4 – Crushed Stone Conformance Testing Summary

Properties	**Test Method**	**Frequency**
Grain Size Analysis	ASTM D422 (w/o hydrometer)	1 per 3,000 yd^3 (minimum of 1 per material source)

Table 5 – Textured HDPE Geomembrane Conformance Testing Summary

Properties	**Test Method**	**Conformance QA Test Frequency**
Thickness (min. ave.)	ASTM D5994	1 per 100,000 ft^2
Tensile Properties (min. ave.)	ASTM D6693 Type IV, 2 ipm 1.3-inch Gauge Length	1 per 100,000 ft^2
Puncture Resistance (min. ave.)	ASTM D4833	1 per 100,000 ft^2
Carbon Black Content	ASTM D4218	1 per 100,000 ft^2
Carbon Black Dispersion	ASTM D5596	1 per 100,000 ft^2
Vacuum Box	ASTM D5641	Extrusion welds (full length)
Air Pressure Tests	ASTM D5820	Double-fusion seams (full length)
Destructive Seam Tests	ASTM D6392	1 per 500 ft of seam

Table 6 – Drainage Geocomposite Conformance Testing Summary

Properties	**Test Method**	**Conformance QA Test Frequency**
Geonet Core		
Resin Specific Gravity	ASTM D1505	1 per 100,000 ft^2
Core Net Thickness	ASTM D5199	1 per 100,000 ft^2
Geotextile		
Mass/Unit Area (min. average roll)	ASTM D5261	1 per 100,000 ft^2
Grab Strength	ASTM D4632	1 per 100,000 ft^2
Puncture Resistance	ASTM D6241	1 per 100,000 ft^2
Composite		
Ply Adhesion (both sides)	ASTM D7005	1 psi

Table 7 – Geosynthetic Clay Liner (GCL) Conformance Testing Summary

Properties	**Test Method**	**Conformance QA Test Frequency**
Bentonite Mass/Unit Area (min. average)	ASTM D5993	1 per 250,000 ft^2
Permeability (max.)	ASTM D5887	1 per 250,000 ft^2
Fluid Loss, max. (Bentonite Property)	ASTM D5891	1
Peel Strength (min. average)	ASTM D6496	1 per 250,000 ft^2
Internal Shear Strength (min.)	ASTM D6243	1

APPENDIX A

TESTING FORMS

Daily Field Report

Page No. 1 of 1

Project I.D. Phase IV Landfill Expansion
Location: Nashua, NH
Report No.:
File No.

Time On-Site: 0.0
Office Time: 0.0
Contractor:
Travel Time: 0.0
Total Time: 0.0
Date:
Equipment On-Site:
Site Visitors:
Weather:
Field Representative:
Arrived: 0000 hrs.
Departure: 0000 hrs.

Field Representative Date

Reviewed By Date

Attachments:

☐ None
☐ Field Density Test Summary
☐ Field Sketch
☐ Other

SANBORN HEAD

P:\3000s\3066.11\Source Files\Type I-A PMA\App A - Design\CQA Plan\Forms\DFR.docx

Geosynthertic Clay Liner (GCL) Roll Identification and Certification

SANBORN HEAD	**Project:**	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___

Contractor:

Geosynthetics Installation Contractor:

GCL Roll I.D. #	Certification Checked? (Y/N)	Sanborn Head Staff	Delivered to Site? (Y/N)	Date Deployed

Comments:

Date: ________________

Reviewed By: ________________

Geocomposite Roll Identification and Certification

SANBORN HEAD	**Project:**	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___

Contractor:

Geosynthetics Installation Contractor:

Geocomposite Roll I.D. #	Certification Checked? (Y/N)	Sanborn Head Staff	Delivered to Site? (Y/N)	Date Deployed

Comments:

Date: ____________________

Reviewed By: ____________________

Geomembrane Defect Log

SANBORN HEAD

Project: **Phase IV Landfill Expansion**

Date:

Location: **Four Hills Landfill**

Project #:

Client: **City of Nashua, New Hampshire**

Sheet No.: ___ of ___

Contractor:

Geosynthetics Installation Contractor:

Defect ID	Defect Location Seam or Panel	Description	Defect Type	Log Date	Comments	Repair Date	Test Date	Sanborn Head Staff

Defect Type

AD	Animal Related Damage	EE	Earthwork Equipment Damage	PT	Pressure Test Cut
B	Undispersed Resin Bead	EXT	Extension	SI	Soil Surface Irregularity
BO	Fusion Welder Burn	FM	Fishmouth	SL	Slag on Textured Sheet
BS	Boot/Skirt for Penetration	FS	Failed Seam Length	T	Three Panel Intersection
CO	Change of Overlap	FTS	Field Test Strip	VL	Vacuum Test Leak
CR	Crease	HT	Heat Tack Burn	W	Wrinkle
D	Installation Damage	IO	Insufficient Overlay (Under Spec.)	WR	Welder Restart
DS#	Destructive Test No.	MD	Manufacturer/Delivery Damage	Other	____________________

Comments:

Date: ____________________

Reviewed By: ____________________

Geomembrane Destructive Sample Log

SANBORN HEAD

Project: Phase IV Landfill Expansion **Date:**

Location: Four Hills Landfill **Project No:**

Client: City of Nashua, New Hampshire **Sheet No.:** ___ of ___

Contractor: **Geosynthetics Installation Contractor:**

Primary ______ **Secondary** ______ **Other:** ________________________

Destruct No.	Seam No.	Fusion/ Extrusion (F/E)	Machine No.	Date Removed	Field Test Results		Sanborn Head Staff	Date Shipped	Lab Test Results (Pass/Fail)	Date of Notification	Comments
					Peel (Pass/Fail)	Shear (Pass/Fail)					
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											

Comments:

Date: ________________________

Reviewed By: ________________________

Geomembrane Destructive Test Log

SANBORN HEAD	**Project:**	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___

Contractor:

Geosynthetics Installation Contractor:

Destructive Test No. ________________

Destructive Test Information

Seam No. ____________________

Repair No. ____________________

Machine No. ____________________

Machine Operator ____________________

Date Welded ____________________

Date Tested ____________________

Date Reported ____________________

Northing ____________________

Easting ____________________

Elevation ____________________

Sanborn Head Staff ____________________

Tensiometer Configuration

Test Speed 2 inches/minute

Coupon Width 1 inch

Field Peel Tests by CCI

Minimum acceptable value = _______ lbs.

Sample No.	Strength (lbs)		Break Code	
P1				
P2				
P3				
P4				
P5				

Results (P/F): ____________

Field Shear Tests by CCI

Minimum acceptable value = _______ lbs.

Sample No.	Strength (lbs)	Break Code
S1		
S2		
S3		
S4		
S5		

Results (P/F): ____________

Break codes: BRK = Break in sheeting, SE = Seam Edge, CL = Clamp, AD = Adhesion, AD-BRK = Adhesion Break

Comments:

Date: ____________

Reviewed By: ____________

Geomembrane Panel Deployment

SANBORN HEAD	**Project:**	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___

Contractor: **Sanborn Head Staff:**

Geosynthetics Installation Contractor:

Primary _______ **Secondary** _______ **Other:** ______________________________

Deployment Equipment: ______________________________

Description	**Panel Number**	**Panel Number**	**Panel Number**	**Panel Number**
Roll Number				
Deployed Length (ft)				
Deployed Width (ft)				
Deployed Area (ft^2)				
Remarks:				

Description	**Panel Number**	**Panel Number**	**Panel Number**	**Panel Number**
Roll Number				
Deployed Length (ft)				
Deployed Width (ft)				
Deployed Area (ft^2)				
Remarks:				

Description	**Panel Number**	**Panel Number**	**Panel Number**	**Panel Number**
Roll Number				
Deployed Length (ft)				
Deployed Width (ft)				
Deployed Area (ft^2)				
Remarks:				

Description	**Panel Number**	**Panel Number**	**Panel Number**	**Panel Number**
Roll Number				
Deployed Length (ft)				
Deployed Width (ft)				
Deployed Area (ft^2)				
Remarks:				

Comments:

Date: ______________________

Total Deployed Area (ft^2) = ______________

Reviewed By: ______________________

Geomembrane Roll Identification and Conformance

SANBORN HEAD	**Project:**	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___
Contractor:				
Geosynthetics Installation Contrac				

Roll ID #	**Batch #**	**Certification Checked? (Y/N)**	**Sanborn Head Staff**	**Delivered to Site? (Y/N)**	**Conformance Test ID**	**Conformance Test Results**	
						(P/F)	**Sanborn Head Staff**

Each roll = +/- _____________ sf

Comments:

Date: ____________________

Reviewed By: ____________________

Geomembrane Seam Location Log

	Project:	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___

Contractor:		**Sanborn Head Staff:**	
Geosynthetics Installation Contractor:			

Primary ________ **Secondary** ________ **Other:** ___________________________________

Seam No.	**Seam Starting Point**	**Seam Ending Point**		**Seam No.**	**Seam Starting Point**	**Seam Ending Point**
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:
	N: E: Z:	N: E: Z:			N: E: Z:	N: E: Z:

Comments:

Date: ____________________

Reviewed By: ____________________

Geomembrane Seam Log

SANBORN HEAD

Project: Phase IV Landfill Expansion

Date:

Location: Four Hills Landfill

Project No:

Client: City of Nashua, New Hampshire

Sheet No.: ___ of ___

Contractor:

Geosynthetics Installation Contractor:

Primary ________

Secondary ________

Other: ________________

Passing Trial Seams

No.	**Time**	**Machine #**	**Tech**

Destructive Length Carry Over From Previous Log	

Seam No.	Seam Location	Observed Overlap (inches)	Start Time	Machine No.	Weld Tech	Air Temp (ºF)	Preheat Temp. or Machine Speed	Barrel or Machine Temp (ºF)	Length Welded (ft)	Length from Previous Destruct	Destruct No.	Sanborn Head Staff	Air Pressure Test[1]			V-box (P/F)
													Test Date	Test Pressure/ Drop	(P/F)	
								Total								

[1] Passing Pressure Test = 30 psi for 5 minutes with less than 4 psi drop.

Comments:

Date: ________________

Reviewed By: ________________

Geomembrane Trial Seam Log

SANBORN HEAD

Project: Phase IV Landfill Expansion

Location: Four Hills Landfill

Client: City of Nashua, New Hampshire

Date:

Project No:

Sheet No.: ___ of ___

Contractor:

Geosynthetics Installation Contractor:

Primary ________ **Secondary** ________ **Other:** ____________________

F - # = Fusion Weld **E - # = Extrusion Weld**

Sample No.	Time	Welding Machine No.	Weld Tech	Air Temp (ºF)	Machine Speed/ Preheat Temp	Machine/ Barrel Temp (ºF)	Break code/strength (lbs) Peel Test Results (> ___ lbs)					Break code/strength (lbs) Shear Test Results (> ___ lbs)					Pass or Fail	Sanborn Head Staff	Comments

Break codes: BRK = Break in sheeting, SE = Seam Edge, CL = Clamp, AD = Adhesion, AD-BRK = Adhesion Break

Comments:

Date: ________________

Reviewed By: ________________

Geosynthetics Installation Field Report

Project: Phase IV Landfill Expansion	Location: Nashua, NH	Report No.:	File No.
Client: City of Nashua	Installation Contractor:		Date:
Sanborn Head Rep.:	Time On-Site:	Weather:	

Page No. 1 of 1

Geosynthetics Deployed

Trial Seaming

Seaming

Non-Destructive Testing

Destructive Sampling

General Comments

Field Representative Date

Reviewed By Date

Attachments:
☐ None
☐ Field Sketch
☐ Other (specify)

SANBORN HEAD

Geotextile Roll Identification and Certification

SANBORN HEAD	**Project:**	Phase IV Landfill Expansion	**Date:**	
	Location:	Four Hills Landfill	**Project #:**	
	Client:	City of Nashua, New Hampshire	**Sheet No.:**	___ of ___

Contractor:

Geosynthetics Installation Contractor:

Geotextile Roll I.D. #	Certification Checked? (Y/N)	Sanborn Head Staff	Delivered to Site? (Y/N)	Date Deployed

Comments:

Date: ____________________

Reviewed By: ____________________

Pipe Hydrostatic Pressure Test Log

SANBORN HEAD

Project No.:

Project Name: Phase IV Landfill Expansion

Project Location: Four Hills Landfill, Nashua, New Hampshire

Weather:

Contractor:

Sanborn Head Personnel:

Person/Company Performing Test:

Pipe Length:	Pipe Diameter:	Date of Test:	
Pipe Material:	Pipe SDR/Sch.:	Start Time:	Finish Time:
Rated Working Pressure:		Test Pressure:	

Location/designation of pipe tested:

t Time (minutes)	T_1 Pipe Temperature (ºC)	P_t Pressure Guage Reading (psig)	Amount of Make-up Water Added (gallons)
0			

Pass?	Fail?	Is this a retest?	Yes	No

Comments:

Signature:

Low Pressure Pneumatic Pressure Test Log

SANBORN HEAD

Project No.:

Project Name: Phase IV Landfill Expansion

Project Location: City of Nashua, New Hampshire

Weather:

Contractor:

Person/Company Performing Test:

Sanborn Head Personnel:

Pipe Length:

Pipe Diameter:

Date of Test:

Pipe Material:

Pipe SDR/Sch.:

Start Time:

Finish Time:

Rated Working Pressure:

Test Pressure:

Location/designation of pipe tested:

t Time (minutes)	T Pipe Temperature (ºC)	P_t Pressure Guage Reading (psig)	P_c Pressure Drop (%) (see below)
0			

Pass?	Fail?	Is this a retest?	Yes	No

P_c = Percent Pressure Drop = $\frac{P_o - P_t}{P_o} x \ 100$

P_o = Initial Pressure Gauge Reading

P_t = Pressure Gauge reading at Time t

Comments:

Signature:

SANBORN HEAD

SUBGRADE ACCEPTANCE CERTIFICATE

Project: Phase IV Landfill Expansion

Client: City of Nashua, New Hampshire

Contractor: ______________________

Geosynthetic Installation Contractor: ______________________

Date: ______________________

The *undersigned* hereby accept the area(s) defined below as being suitable to receive ______________________. This applies only to the visible surface of the subgrade and not structural stability.

Area Certified: ______________________

____

(See attached field sketch)

CERTIFICATE OF ACCEPTANCE RECEIVED FROM REPRESENTATIVE OF

SIGNATURE NAME TITLE DATE

CERTIFICATE OF ACCEPTANCE RECEIVED FROM REPRESENTATIVE OF

SIGNATURE NAME TITLE DATE

CERTIFICATE OF ACCEPTANCE RECEIVED FROM REPRESENTATIVE OF SANBORN, HEAD & ASSOCIATES, INC.

SIGNATURE NAME TITLE DATE

ATTACHMENT D

NOTIFICATIONS TO FAA AND AIRPORTS

THE CITY OF NASHUA
"The Gate City"
Division of Public Works
Solid Waste Department

Federal Aviation Administration
New England Region, ANE-600
1200 District Avenue
Burlington, MA 01803

July 17, 2020
File No. 3066.11

Re: Four Hills Landfill
Nashua, New Hampshire
Type I-A Permit Modification
DES-SW-SP-95-002

To Whom it May Concern:

The purpose of this correspondence is to notify you that The City of Nashua (City) is filing a Type I-A permit modification application with the New Hampshire Department of Environmental Services (NHDES) on or about July 17, 2020. This application is being filed to obtain permit approval for the proposed Phase IV expansion at the Four Hills Landfill located at 840 West Hollis Street in Nashua, New Hampshire.

The facility, and the land where it is located, is owned and operated by the City's Department of Public Works. This notice is being provided in accordance with 40-CFR, Section 258.10(b) of RSA 149-M and the NHDES Solid Waste Rules because our landfill is located within a five-mile radius of the end of the runaway at the Nashua Airport (Boire Field) in Nashua, New Hampshire and the Pepperell Airport in Pepperell, Massachusetts. Our landfill is not located within 10,000 feet of these airport runways.

This project is proposed to be constructed on the Four Hills Landfill property between two existing landfill units. The type of material managed, and the operation of the facility, are not proposed to change as part of this permit modification. Only waste generated within the City of Nashua is accepted at the facility including municipal solid waste, construction and demolition debris, and special non-hazardous wastes that are approved by NHDES. The project will add about 3.9 million cubic yards of capacity and extend the facility's site life by approximately 30 years.

Copies of this permit application will be available for review at the Four Hills Landfill office building, City of Nashua Town Hall, and at the NHDES office located at 29 Hazen Drive in Concord, New Hampshire. Please schedule an appointment with the City Solid Waste Department (603-589-3410), the City Clerk's Office (603-589-3010), or the NHDES Public Information & Permitting Office (603-271-2919) to review a hard copy of the permit application.

As part of this application, the City of Nashua is required to inform you of the basic steps that will be involved in the processing of this permit application. Upon receipt of this application, the NHDES will review its contents and determine whether it is complete and that it contains all the information required for their approval. If the application is complete, a technical review will then be made to determine whether the proposed activity meets all application requirements of the New Hampshire Solid Waste Rules. If it is decided that the application satisfies these requirements, then it will be approved, and the permit will be issued. A public hearing on this application is required and will be scheduled upon completion of the technical review. Please refer to the enclosed application flow chart.

Included with the Type I-A permit modification is an Application for Waiver specific to Env-Sw 805.05(j).

Information regarding this application may be obtained by calling Ms. Jaime Colby, P.E., NHDES Permit Engineer, at (603) 271-5185, Jaime.Colby@des.nh.gov, or by writing to her at the following address:

NH Department of Environmental Services
Waste Management Division
PO Box 95
Concord, NH 03301

If you have any questions or comments regarding the application, please contact me at (603) 589-3410 or LafleurJ@nashuanh.gov. You may also contact Ms. Jamie Colby, P.E. at the NHDES, 29 Hazen Drive, Concord, New Hampshire 03301.

Very truly yours,
The City of Nashua

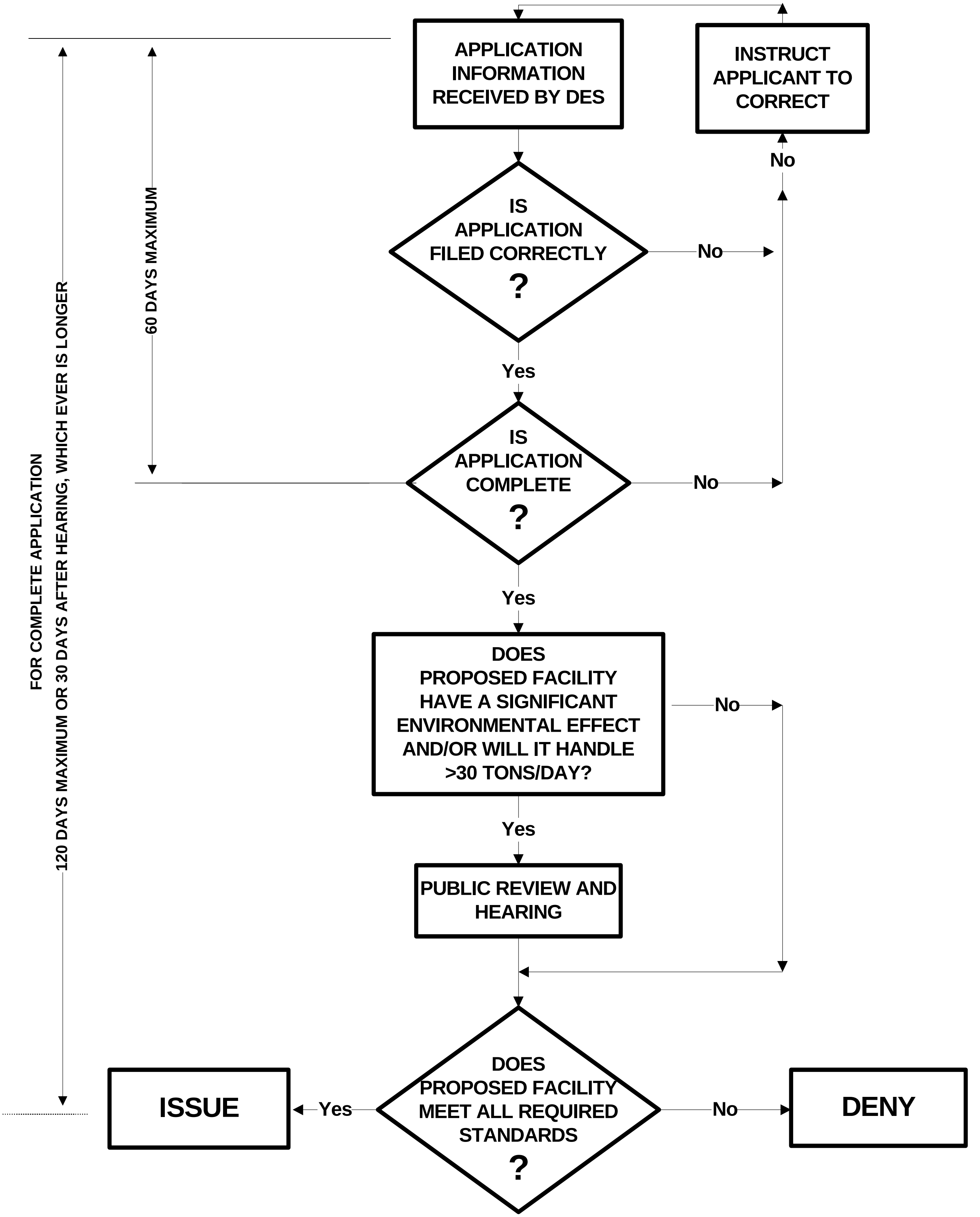
Jeffrey Lafleur
Superintendent of Solid Waste

Copies to: Nashua Airport, Nashua, New Hampshire
Pepperell Airport, Pepperell, Massachusetts

Enclosure: Permit Application Flow Chart

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

STANDARD PERMIT APPLICATION PROCESSING PROVISIONS AS PROVIDED IN PARTS Env-Sw 303 - 305 OF THE *NEW HAMPSHIRE SOLID WASTE RULES*



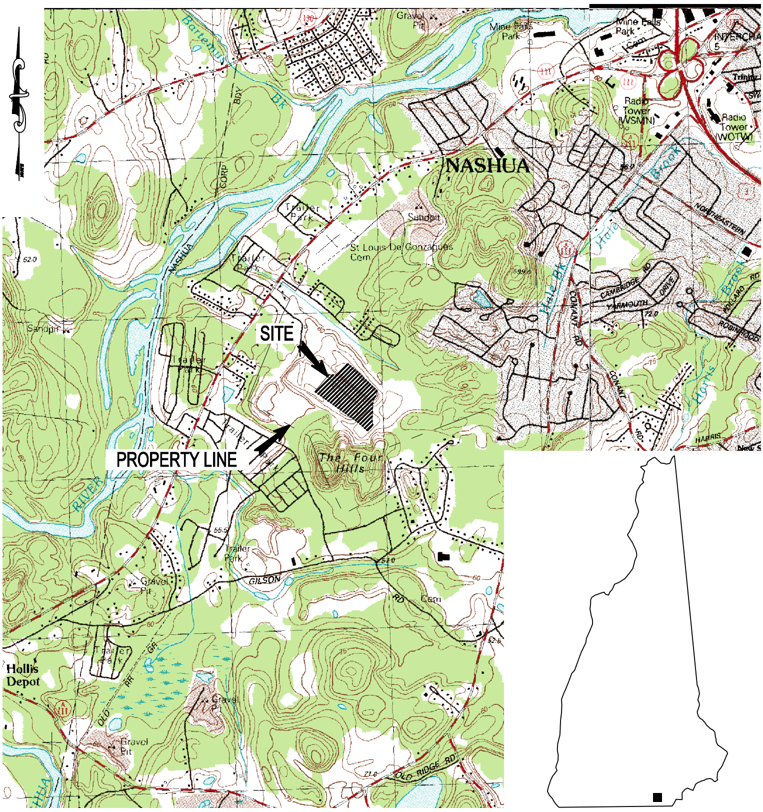
APPENDIX B

DRAWINGS

(PROVIDED UNDER SEPARATE COVER)

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA

NASHUA, NEW HAMPSHIRE
JULY 2020



FROM: USGS TOPOGRAPHIC MAP- NASHUA, NEW HAMPSHIRE (2003)

LOCUS PLAN

SCALE: 1"=1000'

SHEET INDEX

SHEET NO.	TITLE
1	NOTES, LEGEND, AND ABBREVIATIONS
2	OVERALL SITE PLAN
3	ANTICIPATED SITE CONDITIONS PRIOR TO LANDFILL CONSTRUCTION
4	DEMOLITION, FINAL COVER SYSTEM, AND GAS COLLECTION AND CONTROL SYSTEM MODIFICATIONS PLAN
5	OVERALL SECONDARY BASE GRADING PLAN
6	STAGE I SECONDARY BASE GRADING PLAN
7	STAGE II SECONDARY BASE GRADING PLAN
8	STAGE III SECONDARY BASE GRADING PLAN
9	STAGE IV SECONDARY BASE GRADING PLAN
10	FINAL GRADING AND GAS COLLECTION AND CONTROL SYSTEM PLAN
11-12	LANDFILL CROSS-SECTIONS
13-15	SUMP RISER / CLEANOUT DETAILS
16-17	LINER SYSTEM DETAILS
18	LINER SYSTEM & PERIMETER DETAILS
19	SUMP RISER BUILDING AREA PLAN AND DETAILS
20-21	SUMP RISER BUILDING ELEVATIONS AND SECTIONS
22	LEACHATE GRAVITY MAIN DETAILS
23	STORMWATER DETAILS
24	EROSION AND SEDIMENT CONTROL DETAILS
25	FINAL CAPPING DETAILS
26	GAS COLLECTION AND CONTROL SYSTEM PLAN
27-28	GAS COLLECTION AND CONTROL SYSTEM DETAILS

PREPARED FOR:

CITY OF NASHUA

FOUR HILLS LANDFILL

NASHUA, NEW HAMPSHIRE

PREPARED BY:

SANBORN | HEAD

20 FOUNDRY STREET, CONCORD, NEW HAMPSHIRE 03301
(603) 229-1900 FAX (603) 229-1919

ERIC SCOTT STEINHAUSER
No. 11494

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

PROJ.#: 3066.11 "TYPE I-A PERMIT APPLICATION, PHASE IV DESIGN, FOUR HILLS LANDFILL, NASHUA, NEW HAMPSHIRE," JULY 2020

IMAGES: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\City Seal.png
S:\CAD Library\Shared\GIS\New Hampshire\Quads\drg210.tif
S:\CAD Library\Shared\GIS\New Hampshire\Quads\drg211.tif
Q:\Program Files\Autodesk Land Desktop 2008\Template\SHA-E Color Logo.bmp
E:\Steinhauser-NH.tif

XREFS:

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\D00 - Cover.dwg
LAYOUT: Cover
CTB FILE: SHA STANDARD.CTB
PLOT DATE: 7-14-20

PURPOSE STATEMENT

1. THE PHASE IV DESIGN DRAWINGS ARE AN INTEGRAL COMPONENT OF THE APPLICATION FOR A TYPE I-A MODIFICATION TO SOLID WASTE MANAGEMENT FACILITY PERMIT (TYPE I-A PMA) SUBMITTED BY THE CITY OF NASHUA, NEW HAMPSHIRE FOR THE FOUR HILLS LANDFILL. THESE DRAWINGS WERE PREPARED IN ACCORDANCE WITH APPLICABLE AND RELEVANT NEW HAMPSHIRE SOLID WASTE AND ALTERATION OF TERRAIN RULES. INFORMATION PRESENTED ON THESE DRAWINGS MAY BE SUPPLEMENTED BY, OR COMPLEMENTED WITH, INFORMATION PRESENTED ON OTHER PORTIONS OF THE PHASE IV TYPE I-A PMA.

REFERENCE NOTES

1. THE BASE MAP, INCLUDING LOCATIONS OF SUBSURFACE UTILITIES, PROPERTY LINES, AND LANDFILL LIMIT INFORMATION, WAS OBTAINED FROM A DRAWING PREPARED BY CMA ENGINEERS INC. OF PORTSMOUTH, NH (CMA), TITLED, "CITY OF NASHUA , NH, FOUR HILLS LANDFILL, PHASE II SECURE SOLID WASTE, PHASE II OPERATING PLAN, FILLING SEQUENCE DRAWINGS, PHASE II, STAGE 1- INITIAL LIFT," DATED JUNE 2010.

   HORIZONTAL DATUM: NAD83 (2001)
   HORIZONTAL PROJECTION: NH STATE PLANE
   VERTICAL DATUM: NGVD 1929

2. RESIDENTIAL BUILDING LOCATIONS WERE SUPPLEMENTED WITH ELECTRONIC GIS DATA OBTAINED FROM THE CITY OF NASHUA, NH GIS DEPARTMENT'S OPEN DATA SITE ON MARCH 22, 2017.
3. WETLAND AREA LIMITS WERE OBTAINED FROM THE US FISH AND WILDLIFE SERVICE NATIONAL WETLAND INVENTORY WETLANDS MAPPER.
4. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.
5. THE EXISTING TOPOGRAPHY ASSOCIATED WITH PHASE III REPRESENTS ON THE GROUND SURVEY PERFORMED BY WSP USA, OF MERRIMACK, NEW HAMPSHIRE DURING DECEMBER OF 2019 AS PART OF THEIR RECORD DRAWINGS. THE TOPOGRAPHIC SURVEY WAS PROVIDED TO SANBORN HEAD BY CHARTER CONTRACTING, INC.IN AN ELECTRONIC FILE TITLED "190278A-4 AS-BUILT.DWG" ON JANUARY 7, 2020.
6. THE EXISTING TOPOGRAPHY ASSOCIATED WITH PHASES I AND II REPRESENT ON THE GROUND FIELD SURVEY PERFORMED BY WSP USA INC. (WSP) OF MERRIMACK, NEW HAMPSHIRE ON JULY 24, 2019.

GENERAL NOTES

1. FOR CLARITY, EXISTING SITE FEATURES ARE SHOWN SCREENED AND PROPOSED FEATURES ARE SHOWN BOLD.
2. TECHNICAL SPECIFICATIONS ARE PROVIDED IN APPENDIX A OF THE PHASE IV TYPE I-A PMA.

ABBREVIATIONS

°	DEGREES
Ø	DIAMETER
"	INCHES
'	FEET
B	BORING CONVERTED TO A GROUNDWATER MONITORING WELL LOCATION
CB	CATCH BASIN
CMP	CORRUGATED METAL PIPE
CMU	CONCRETE MASONRY UNIT
CPP	CORRUGATED POLYETHYLENE PIPE
DI	DROP INLET
DIV	DIVISION
DMH	DRAIN MANHOLE
E	EASTING
ELEV	ELEVATION
FM	FORCE MAIN
GCL	GEOSYNTHETIC CLAY LINER
GM	GRAVITY MAIN
HDPE	HIGH-DENSITY POLYETHYLENE
HH	HIGH, HIGH
HP	HORSEPOWER
INV	INVERT
LED	LIGHT EMITTING DIODE
LFG	LANDFILL GAS
M	MANHOLE
MAX.	MAXIMUM
MIN	MINIMUM
MW	MONITORING WELL
N	NORTHING
NHDES	NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
O.C.	ON CENTER
OD	OUTER DIAMETER
oz./yd^2	OUNCES PER SQUARE YARD
P	PRIMARY
PVC	POLYVINYL CHLORIDE
RCP	REINFORCED CONCRETE PIPE
S	SECONDARY, SHALLOW
SCH	SCHEDULE
SDR	STANDARD DIMENSION RATIO
S.S.	STAINLESS STEEL
UE	UNDERGROUND ELECTRIC
TYP	TYPICAL

LEGEND

EXISTING CONDITIONS

— — —	PROPERTY LINE
— AT — AT —	ANCHOR TRENCH
———	2-FOOT ELEVATION CONTOUR
— 220 —	10-FOOT ELEVATION CONTOUR
⌒⌒⌒	TREE LINE
—●—●—	LITTER CONTROL FENCE
— · · · —	EDGE OF WATER/STREAM
- - - -	EDGE OF GRAVEL ROAD
— W — W — W —	WATER PIPE
— SW — SW —	CULVERT
▨	WETLAND
○	UTILITY POLE
○	GUY WIRE
⊙	POST/MISC. OBJECT
○—○	SIGN
○—○—○	GUARDRAIL
FH	FIRE HYDRANT
▭	BUILDING
☁	TREE/BUSH
○	CATCH BASIN
Ⓜ	MANHOLE
— s —	SEWER PIPE
△	SURVEY CONTROL POINT
◐ MW-111 S/R	GROUNDWATER MONITORING WELL
>>>>>>>	SEEPAGE BENCH
⊕ V001	LANDFILL GAS EXTRACTION WELL
⊕ V019	REMOTE LFG EXTRACTION WELL (WELLHEAD LOCATED ELSEWHERE)
— 4" —	LFG CONVEYANCE PIPE AND PIPE DIAMETER
▓	EXISTING TYPE A CAP AREA
░	EXISTING TYPE B CAP AREA

PROPOSED CONDITIONS

———	2-FOOT ELEVATION CONTOUR
— 230 —	10-FOOT ELEVATION CONTOUR
━━ ━ ━━	LIMIT OF WASTE CONTAINMENT
━ ━ ━ ━	DISPOSAL AREA LIMITS
— — — —	TOE OF SLOPE
━━━	SOLID HDPE PIPE
— · — · —	PERFORATED HDPE PIPE
— UE — UE —	UNDERGROUND ELECTRIC
- - - -	EDGE OF ROAD
— GM — GM —	GRAVITY MAIN PIPE
— P — P —	PRIMARY LEACHATE PIPE
— S — S —	SECONDARY LEACHATE PIPE
———	GEOMEMBRANE
— — —	GCL
▒	DRAINAGE GEOCOMPOSITE
—►—►—►	SWALE
▨	RIPRAP-LINED SWALE
▨	VEGETATED STORMWATER FEATURE
▓	GEOMEMBRANE OR SMARTDITCH LINED SWALE
☁	FEATURE TO BE DECOMMISSIONED
▭	BUILDING
○	CATCH BASIN / DRAIN MANHOLE
⊔	HDPE END CAP
⊕	REMOTE LFG EXTRACTION WELL
⊕	LFG EXTRACTION WELL
———	LFG EXTRACTION PIPE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L. TRACY
DESIGNED BY: T. PETIT
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

NOTES, LEGEND, AND ABBREVIATIONS

PROJECT NUMBER: 3066.11

SHEET NUMBER: 1 OF 28

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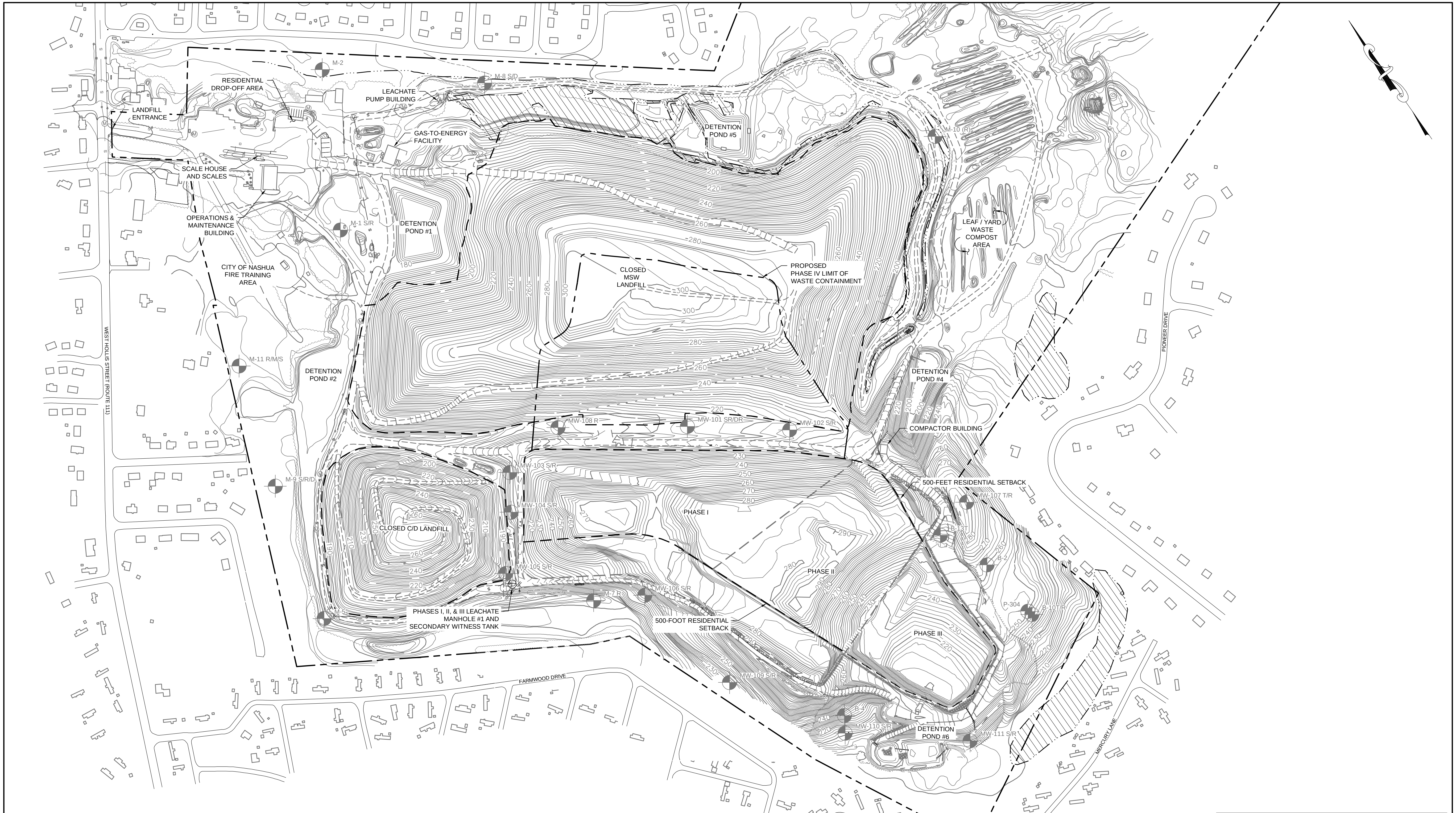


NOTE:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHIC SCALE
200' 100' 0' 200' 400'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

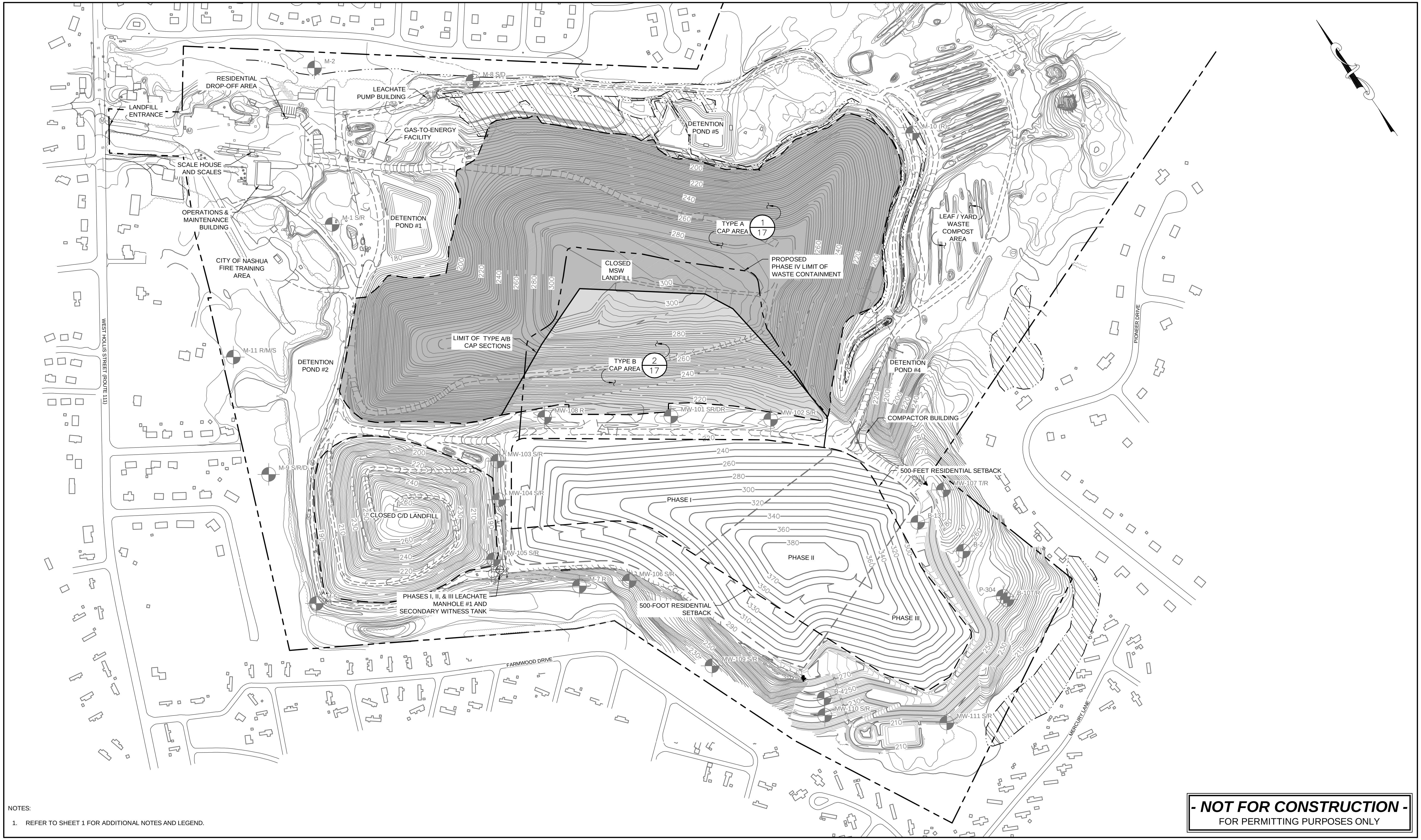
DRAWN BY: S. SANTIAGO
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

OVERALL SITE PLAN

PROJECT NUMBER: 3066.11

SHEET NUMBER: 2 OF 28



NOTES:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
200' 100' 0' 200' 400'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

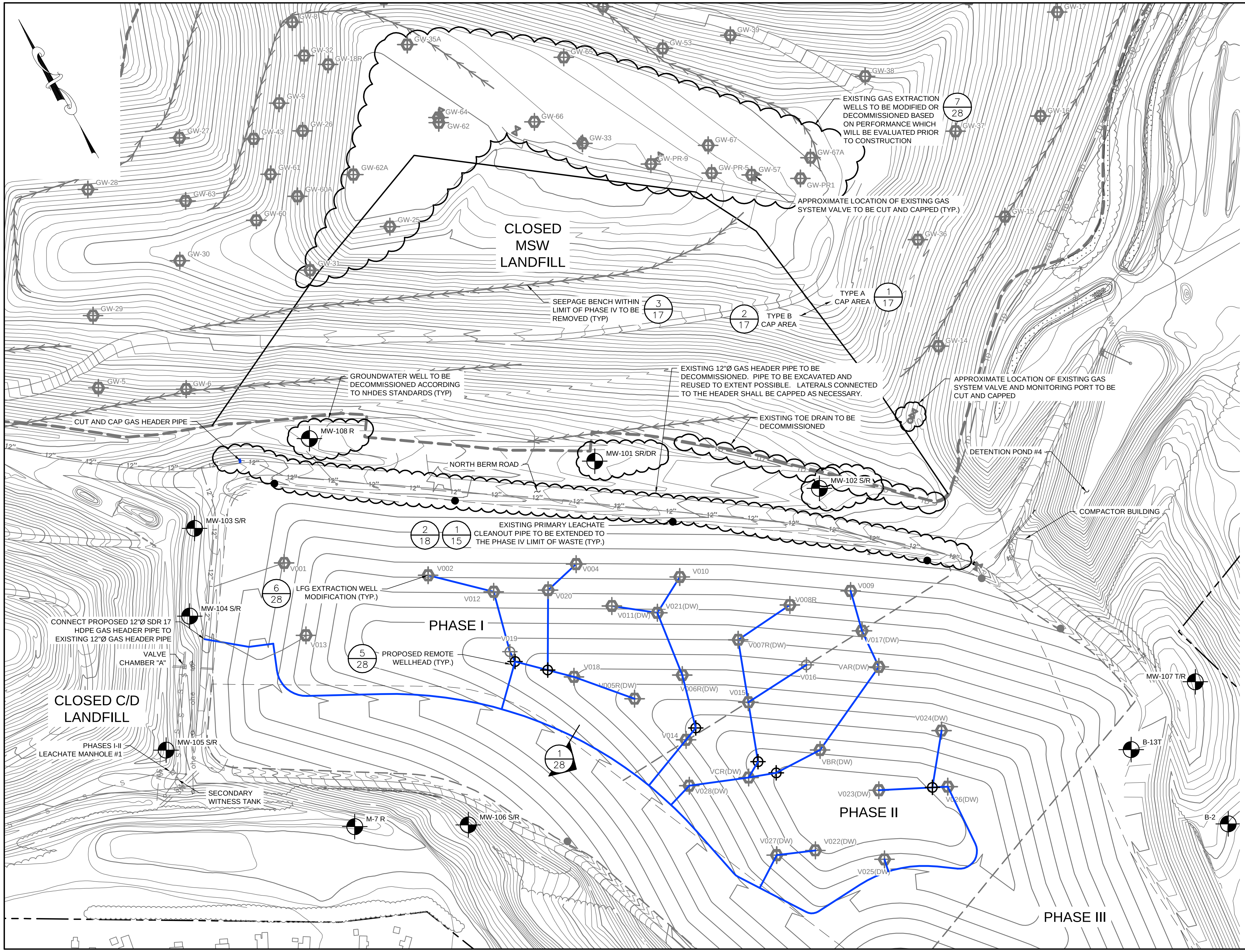
DRAWN BY: L. TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

ANTICIPATED SITE CONDITIONS PRIOR TO LANDFILL CONSTRUCTION

PROJECT NUMBER:
3066.11

SHEET NUMBER:
3 OF 28



NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. EXISTING LFG PIPES WITHIN THE LIMITS OF WASTE NOT SHOWN FOR CLARITY.

LEGEND:

●	EXISTING LEACHATE CLEANOUT PIPE TO BE EXTENDED TO THE PHASE IV LIMIT OF WASTE
▬	PROPOSED LFG PIPING

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

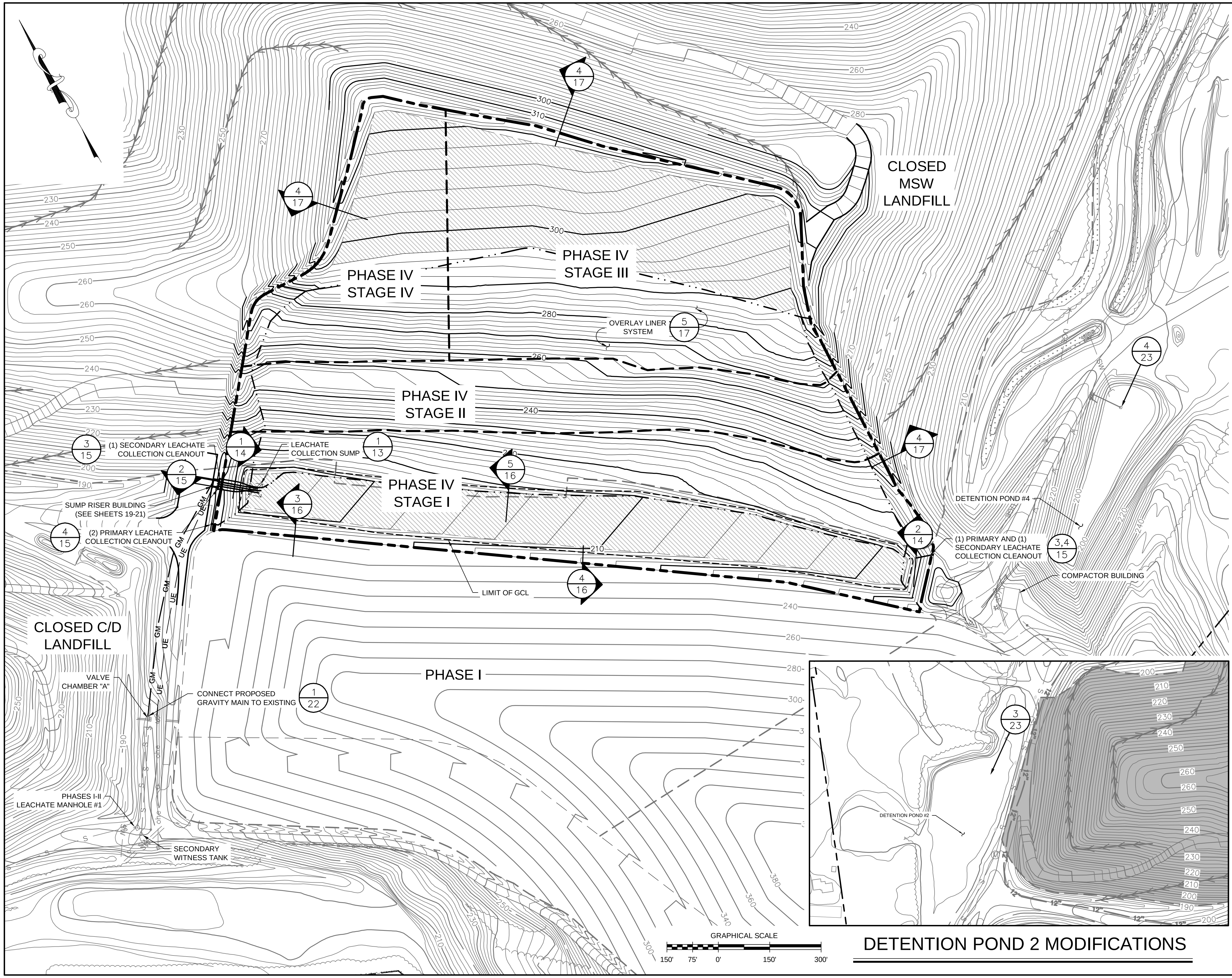
DRAWN BY: J. GRACE/L. TEAL
DESIGNED BY: J. GRACE/L. TEAL
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

DEMOLITION, FINAL COVER SYSTEM,
GAS COLLECTION AND CONTROL SYSTEM
MODIFICATIONS PLAN

PROJECT NUMBER:
3066.11

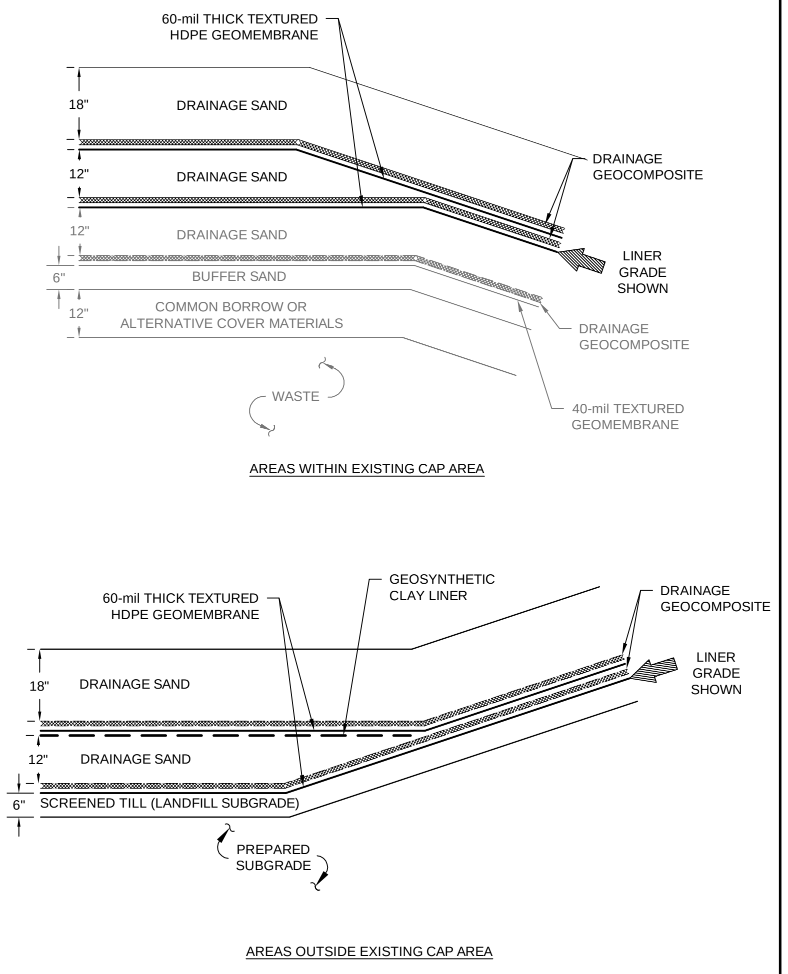
SHEET NUMBER:
4 OF 28



DETENTION POND 2 MODIFICATIONS

NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHIC DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED ACCORDING TO THE PERMITTED LIMIT OF WASTE.
3. EXISTING GAS EXTRACTION WELLS AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.



GRADING KEY

LEGEND:

▨ AREA TO RECIEVE SECONDARY SAND

- - - - LIMIT OF GEOSYNTHETIC CLAY LINER

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN ||| HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

STATE OF NEW HAMPSHIRE
ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

OVERALL SECONDARY BASE GRADING PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
5 OF 28

IMAGES: E:\Steinhauser-NH.tif

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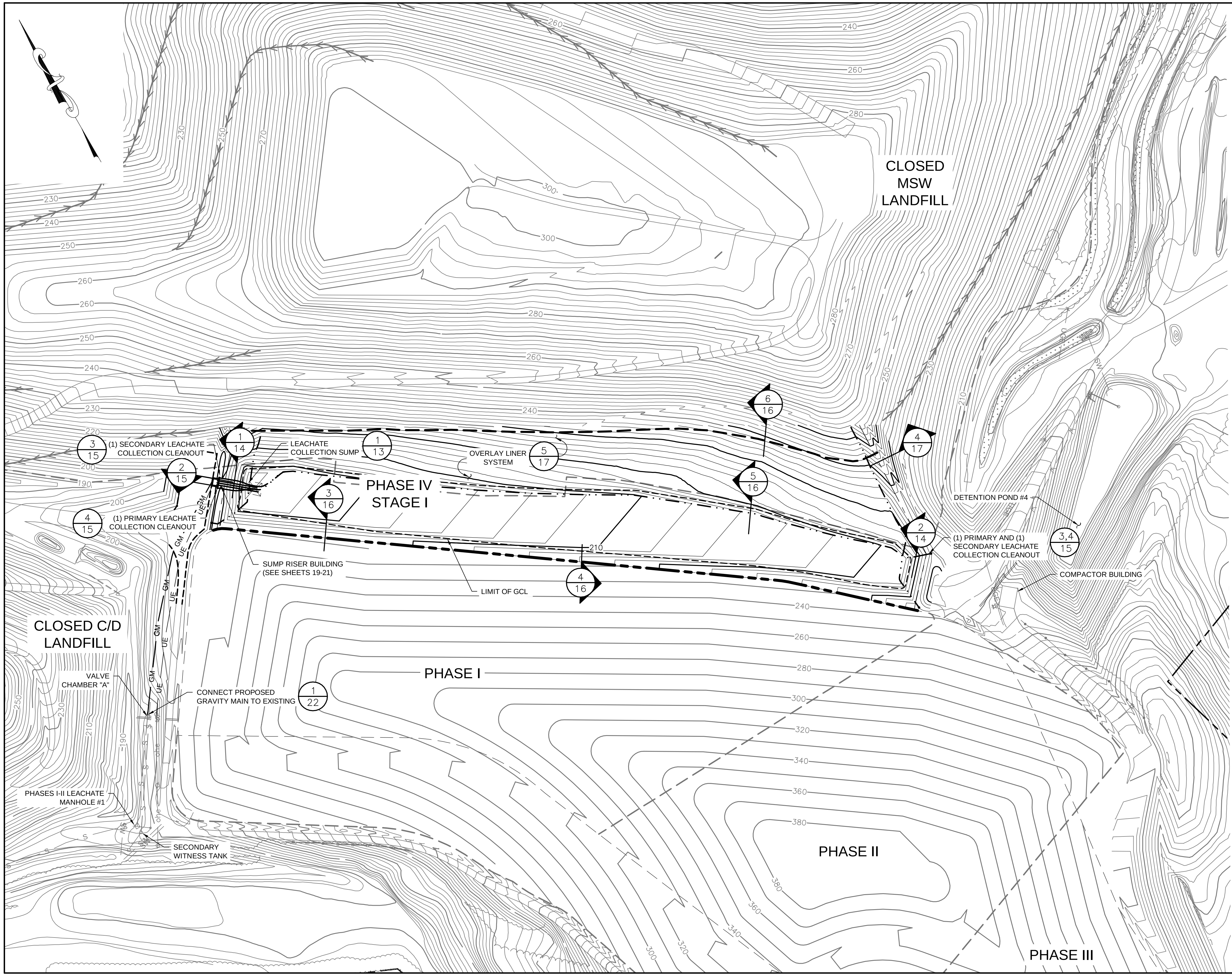
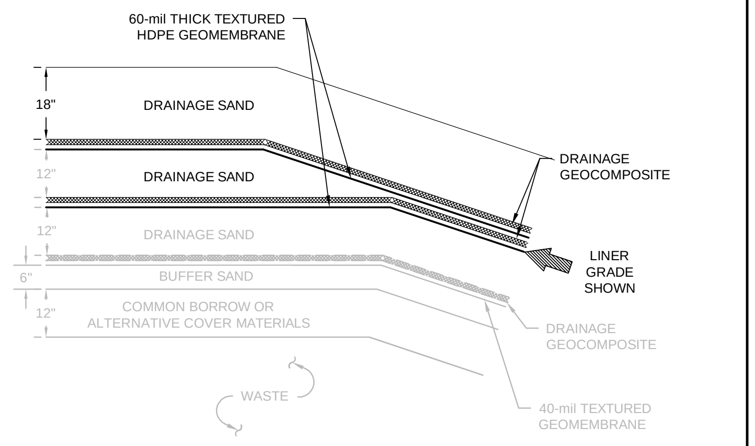
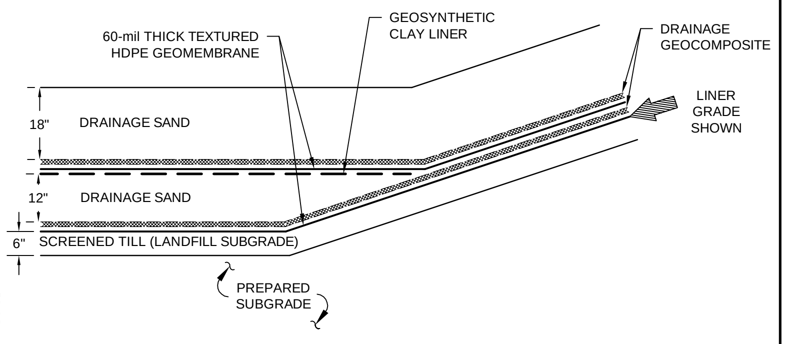


NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED AS NECESSARY ACCORDING TO THE PERMITTED LIMIT OF WASTE.
3. EXISTING GAS EXTRACTION WELLS AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.



AREAS WITHIN EXISTING CAP AREA



AREAS OUTSIDE EXISTING CAP AREA

GRADING KEY

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

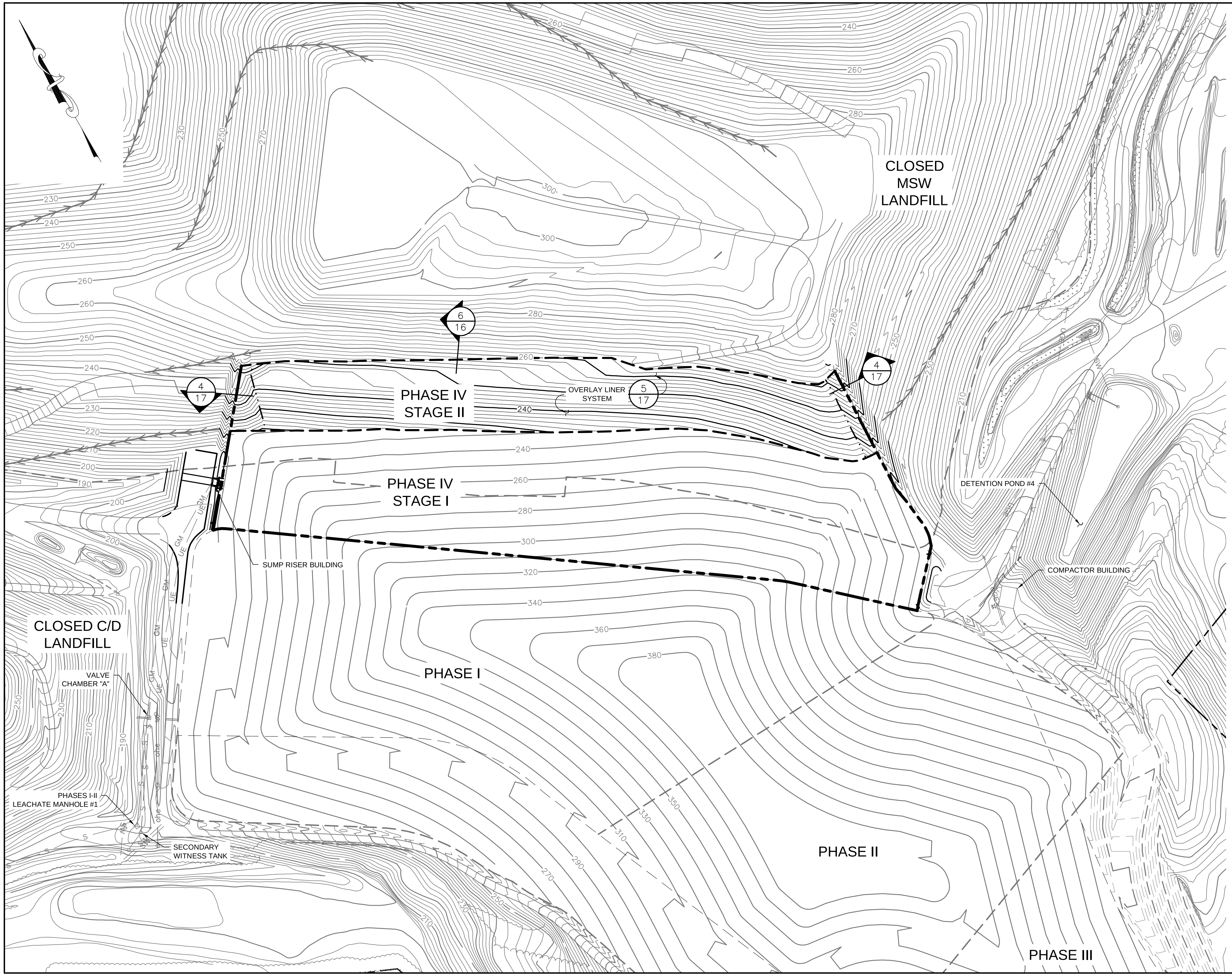
DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE I SECONDARY BASE GRADING PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
6 OF 28

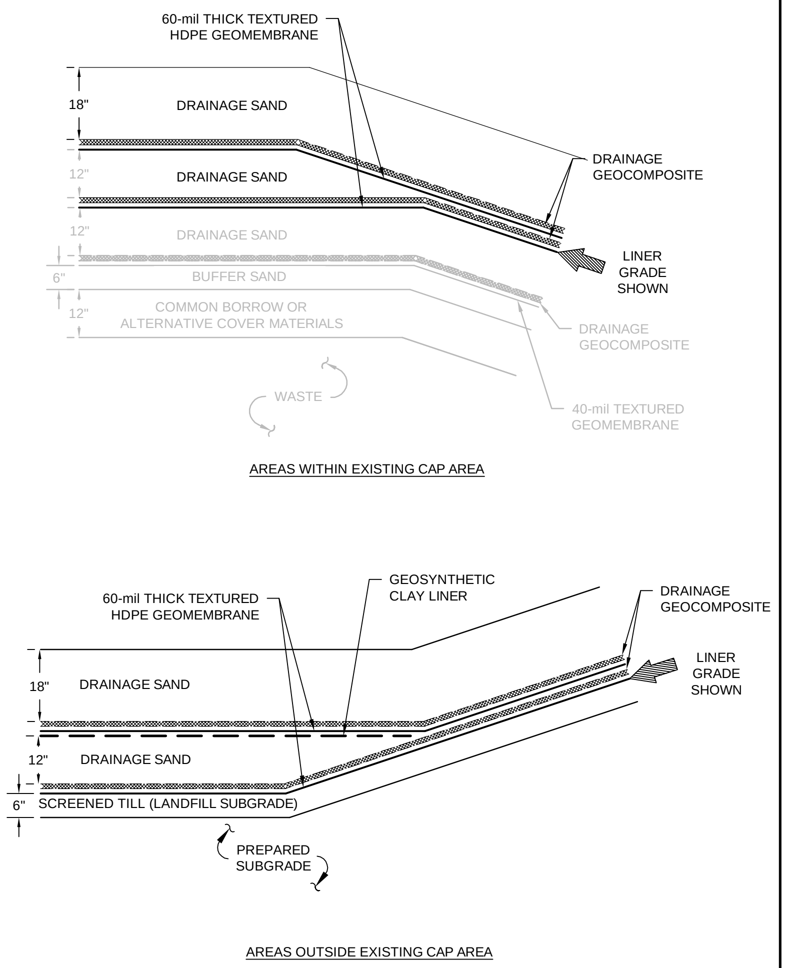


NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.

2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED AS NECESSARY ACCORDING TO THE PERMITTED LIMIT OF WASTE.

3. EXISTING GAS EXTRACTION WELL AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.



AREAS WITHIN EXISTING CAP AREA

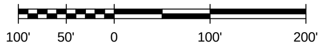
AREAS OUTSIDE EXISTING CAP AREA

GRADING KEY

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE



ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

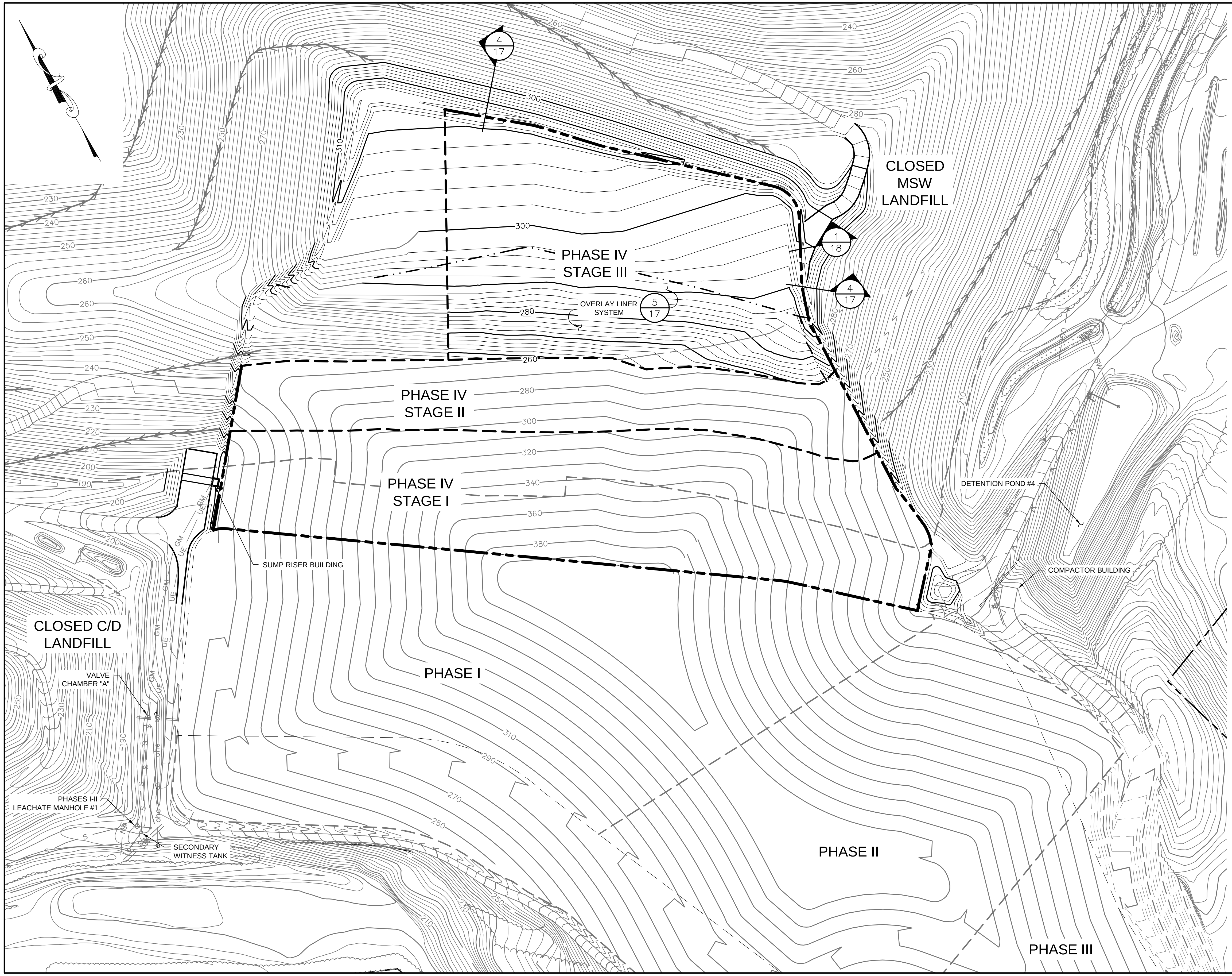
DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE II SECONDARY BASE GRADING PLAN

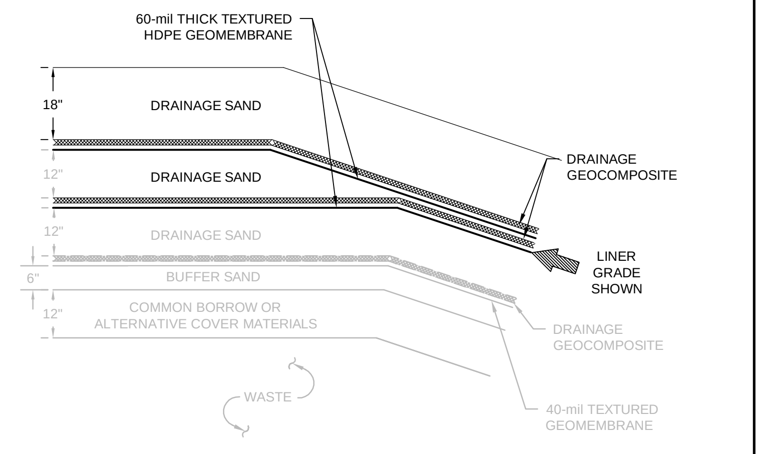
PROJECT NUMBER: 3066.11

SHEET NUMBER: 7 OF 28

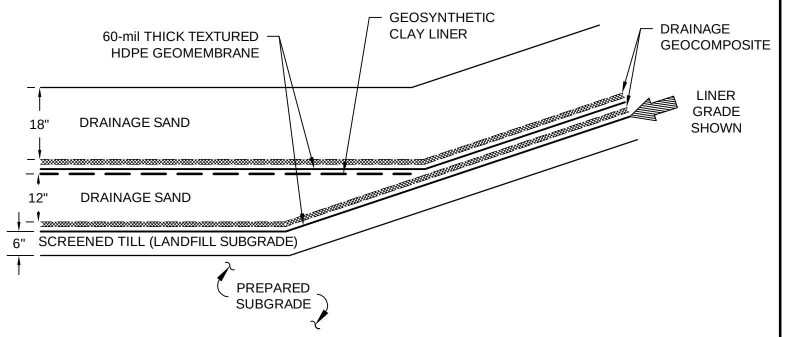


NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED AS NECESSARY ACCORDING TO THE PERMITTED LIMIT OF WASTE.
3. EXISTING GAS EXTRACTION WELLS AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.



AREAS WITHIN EXISTING CAP AREA



AREAS OUTSIDE EXISTING CAP AREA

GRADING KEY

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN | HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

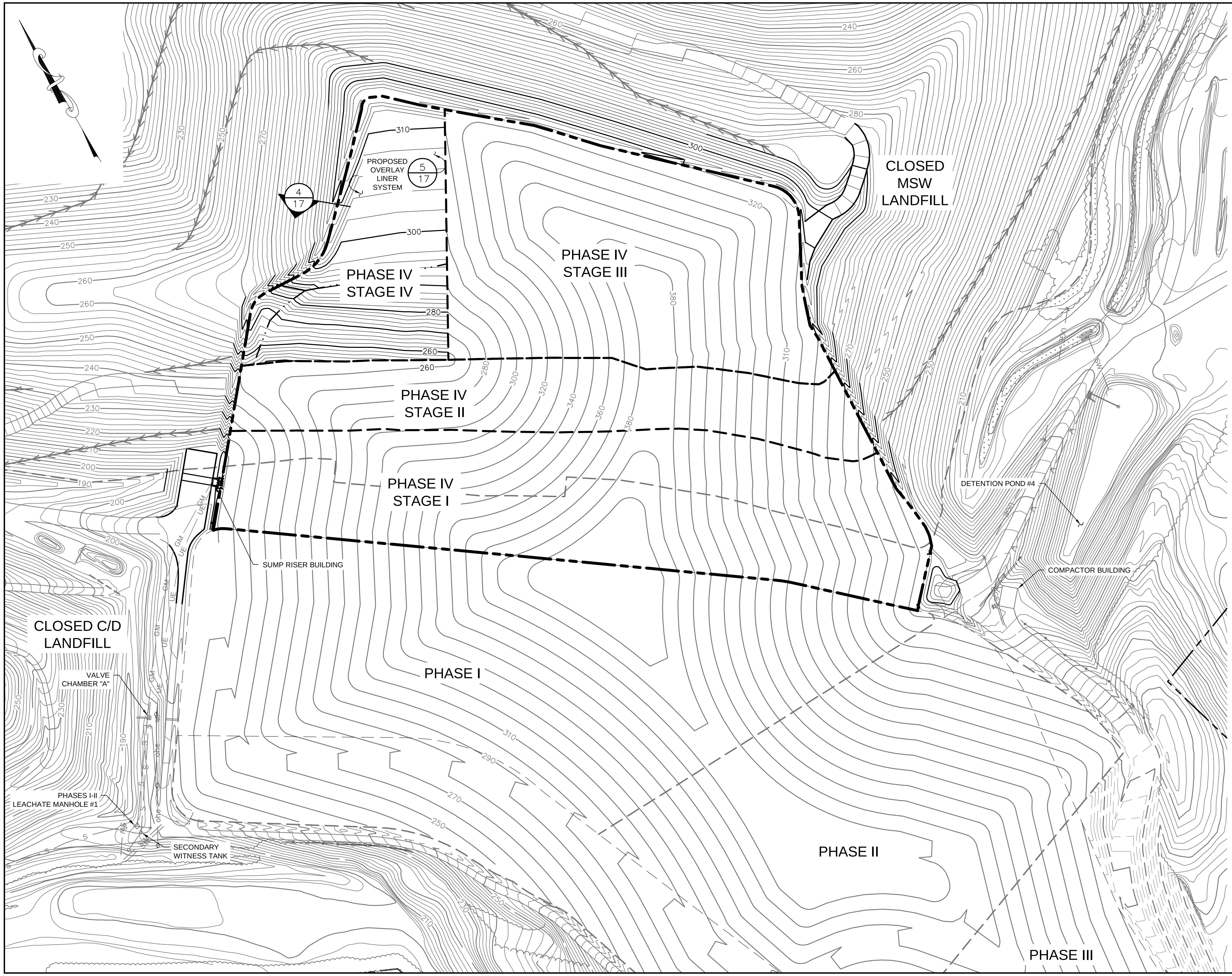
DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE III SECONDARY BASE GRADING PLAN

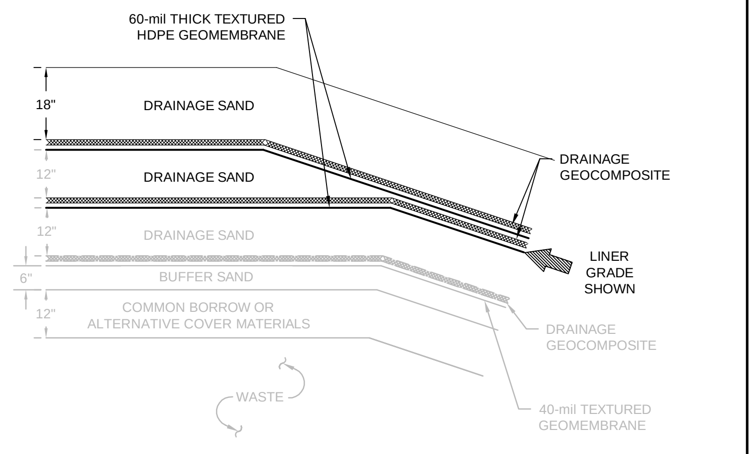
PROJECT NUMBER: 3066.11

SHEET NUMBER: 8 OF 28

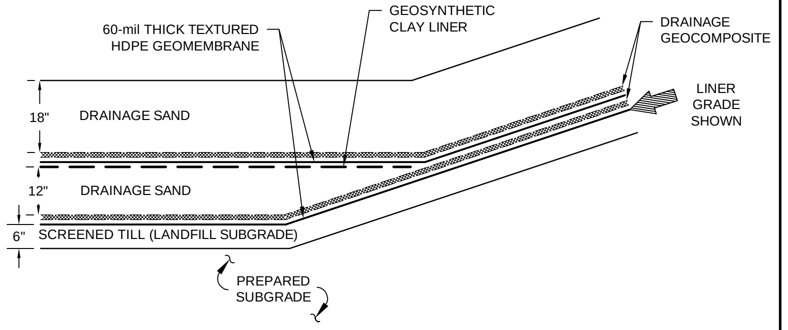


NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED ACCORDING TO THE PERMITTED LIMIT OF WASTE AS NECESSARY.
3. EXISTING GAS EXTRACTION WELLS AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.



AREAS WITHIN EXISTING CAP AREA



AREAS OUTSIDE EXISTING CAP AREA

GRADING KEY

- *NOT FOR CONSTRUCTION* -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

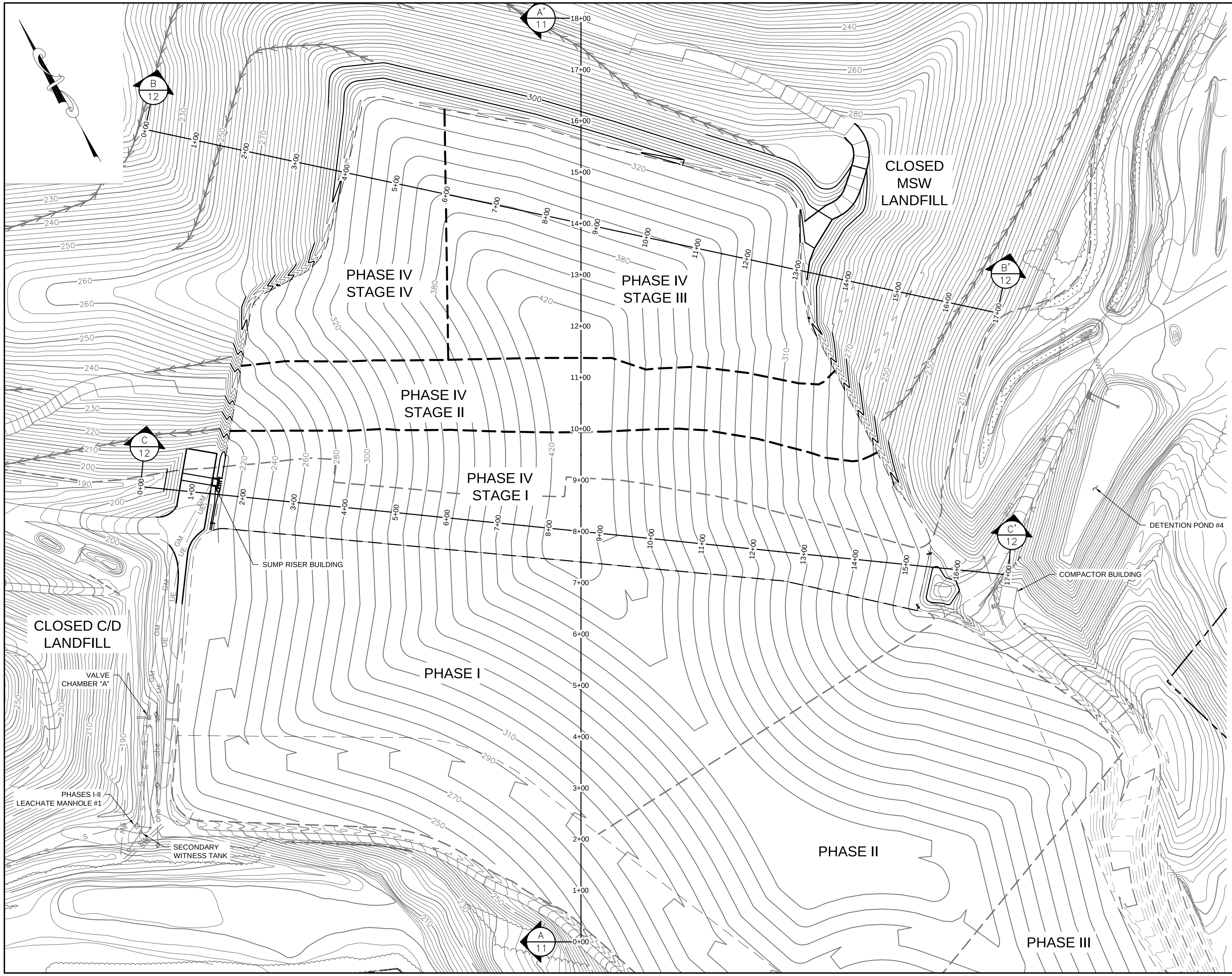
DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE IV SECONDARY BASE GRADING PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
9 OF 28



NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED ACCORDING TO THE PERMITTED LIMIT OF WASTE AS NECESSARY.
3. EXISTING GAS EXTRACTION WELL AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.

- *NOT FOR CONSTRUCTION* -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

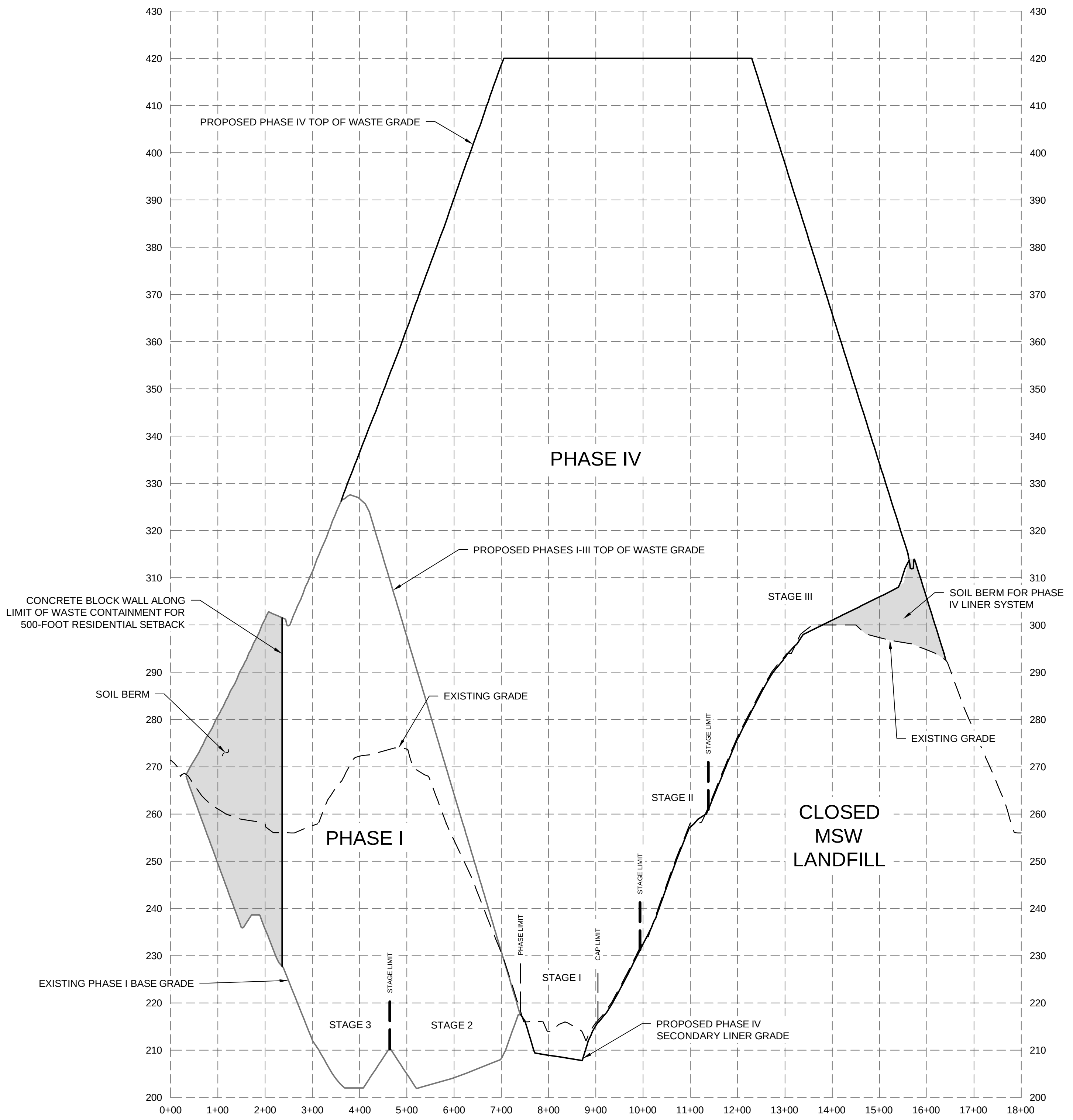
DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

FINAL GRADING AND GAS COLLECTION AND CONTROL SYSTEM PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
10 OF 28



LANDFILL CROSS-SECTION A-A'

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN | HEAD

VERTICAL SCALE
15' 7.5' 0 15' 30'
150' 75' 0 150' 300'
HORIZONTAL SCALE

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LANDFILL CROSS-SECTIONS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
11 OF 28

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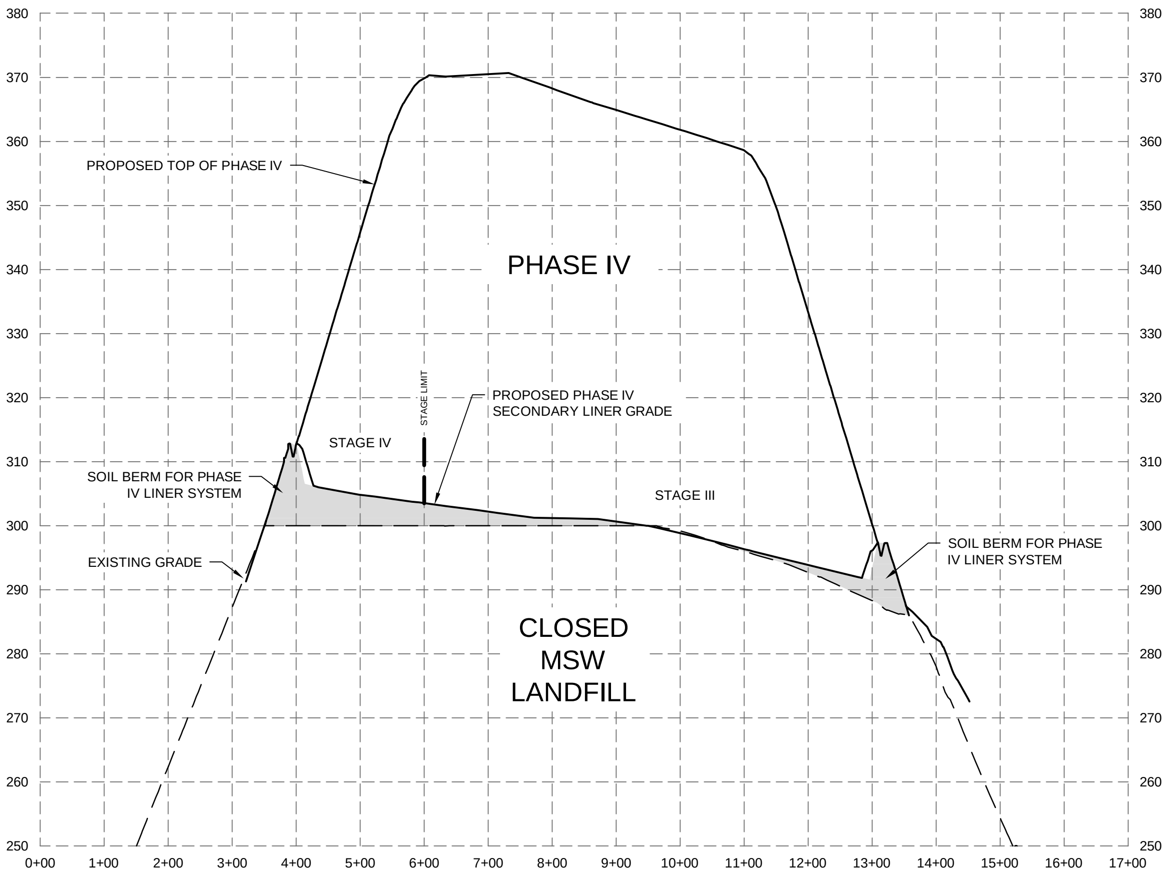
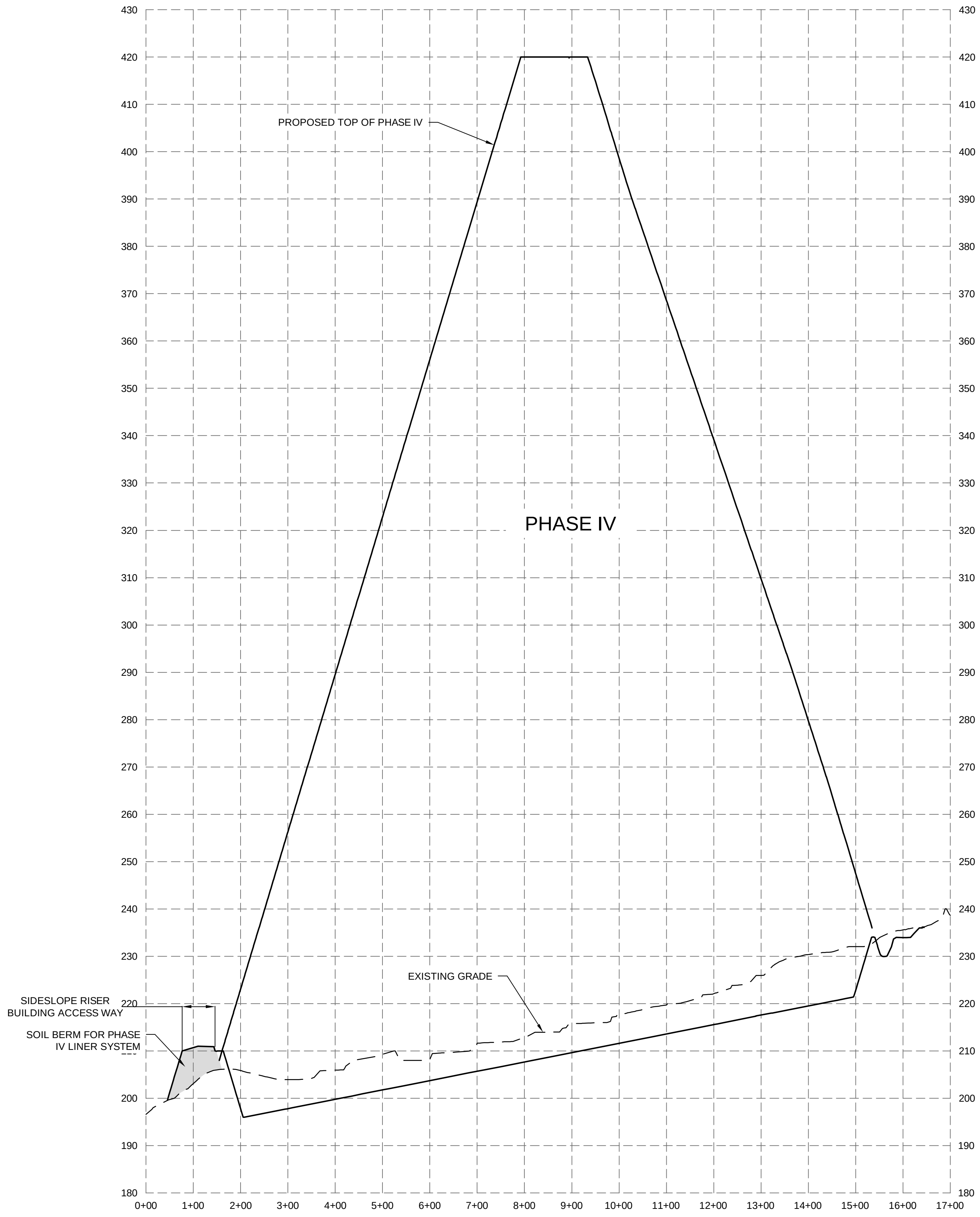


LANDFILL CROSS-SECTION B-B'



LANDFILL CROSS-SECTION C-C'

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN | HEAD

VERTICAL SCALE
15' 7.5' 0 15' 30'
150' 75' 0 150' 300'
HORIZONTAL SCALE

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LANDFILL CROSS-SECTIONS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
12 OF 28

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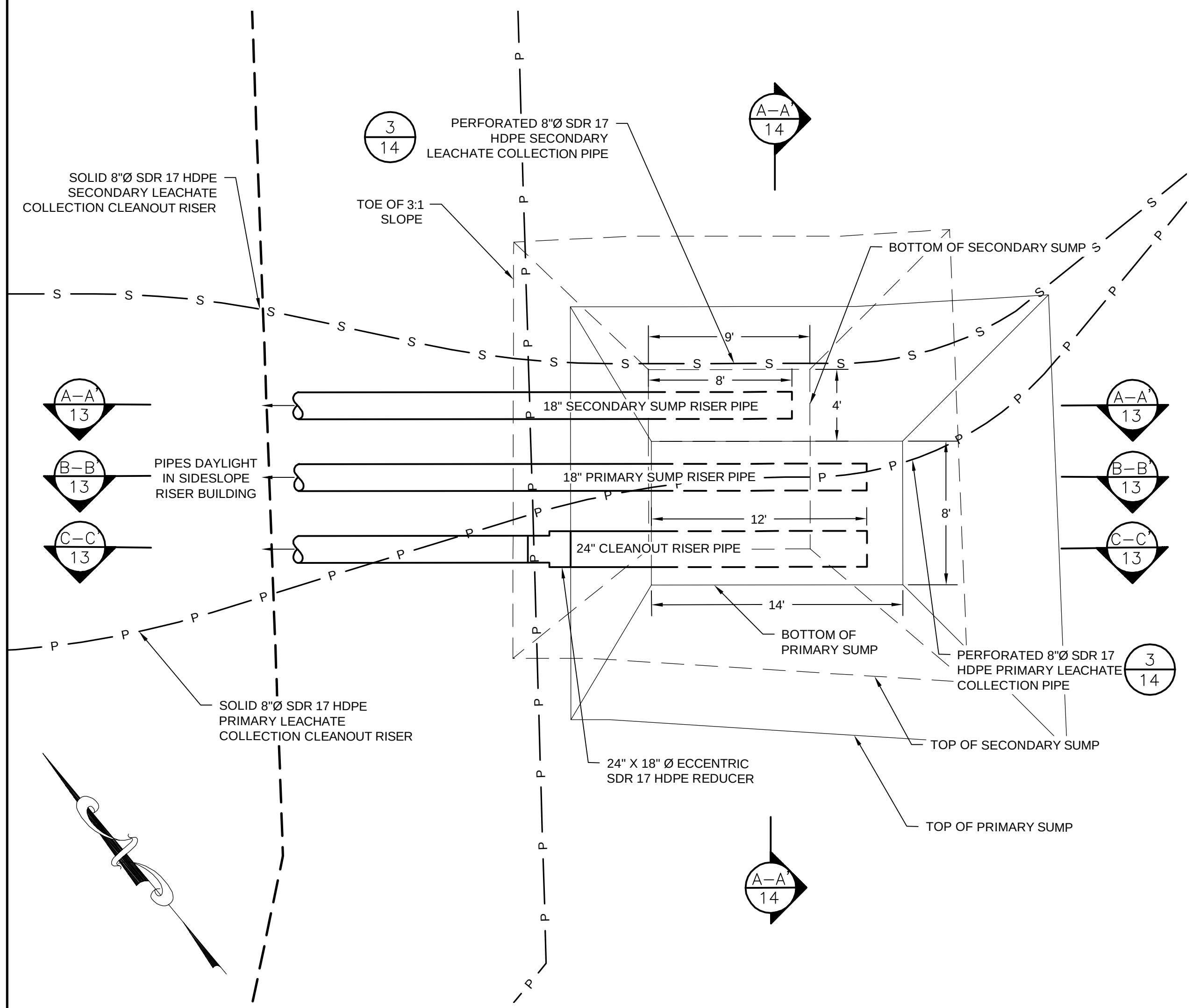
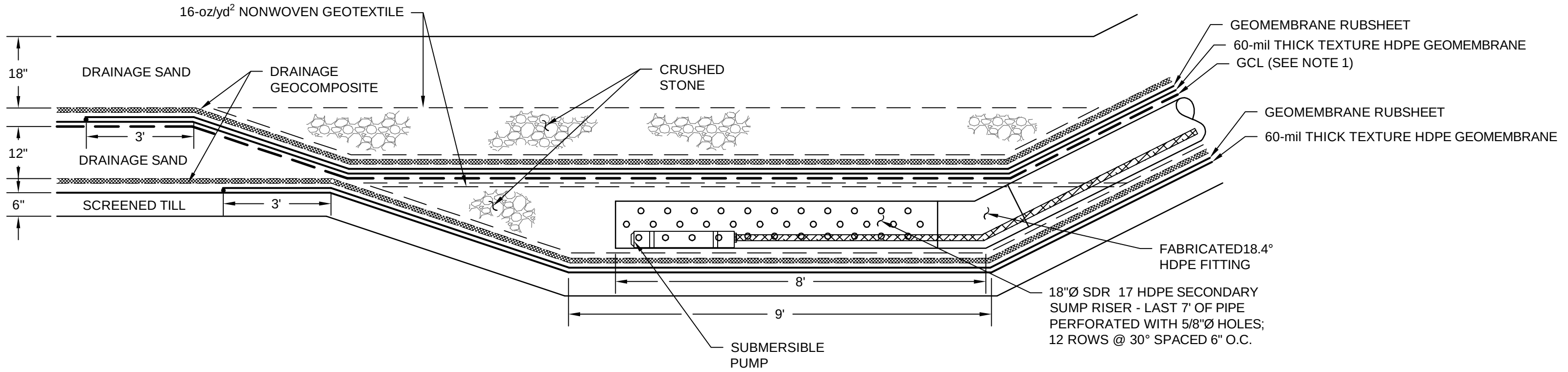


1 LEACHATE COLLECTION SUMP

NOT TO SCALE

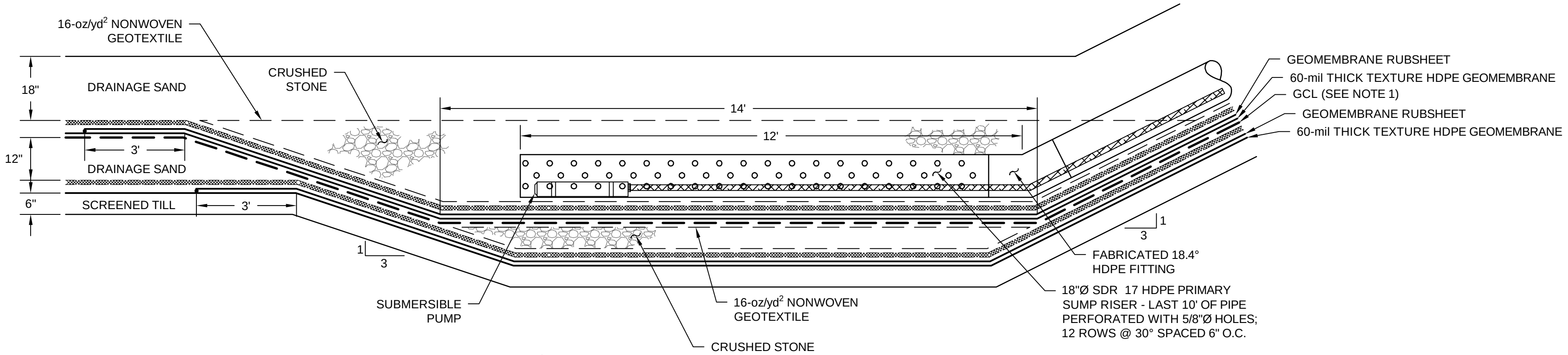


NOTE:

1. SEE SHEET 5 FOR LIMIT OF GCL.

SECTION A-A' SECONDARY SUMP RISER

NOT TO SCALE

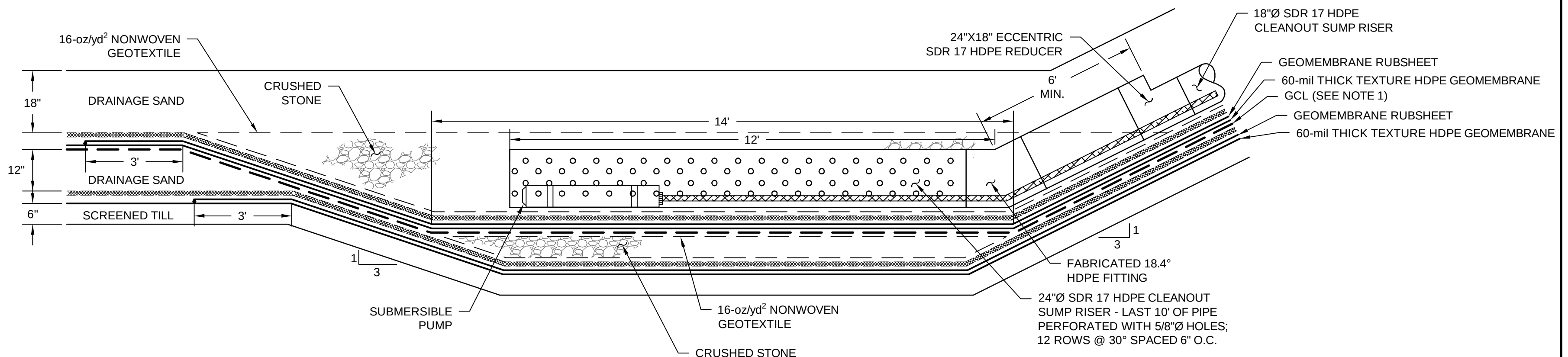


NOTE:

1. SEE SHEET 5 FOR LIMIT OF GCL.

SECTION B-B' PRIMARY SUMP RISER

NOT TO SCALE



NOTE:

1. SEE SHEET 5 FOR LIMIT OF GCL.

SECTION C-C' CLEANOUT SUMP RISER

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L. TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SUMP RISER / CLEANOUT DETAILS

PROJECT NUMBER: 3066.11

SHEET NUMBER: 13 OF 28

IMAGES: E:\Steinhauser-NH.tif

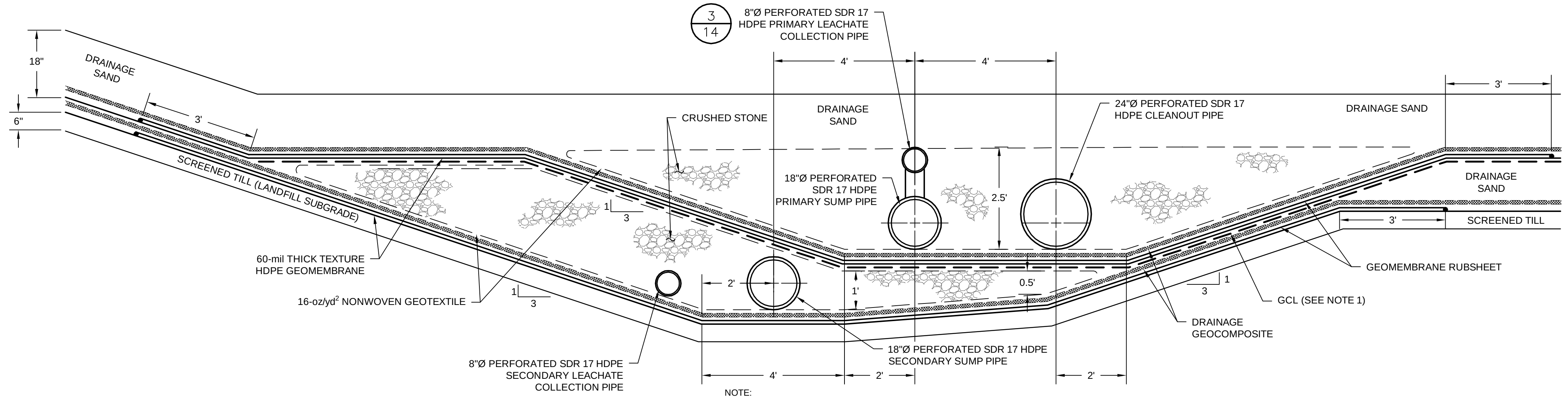
XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\BORDER.dwg
.\XREFS\Proposed Secondary Liner Grades.dwg

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\D13-15 - Cleanout and Liner Details.dwg
LAYOUT: 13
USER: ssantiago
PLOT DATE: 7-14-20 4:00 PM

IMAGES: E:\Steinhauser-NH.tif

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\BORDER.dwg
.\XREFS\Proposed Secondary Liner Grades.dwg

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\D13-15 - Cleanout and Liner Details.dwg
LAYOUT: 14
USER: ssantiago
PLOT DATE: 7-14-20 4:00 PM

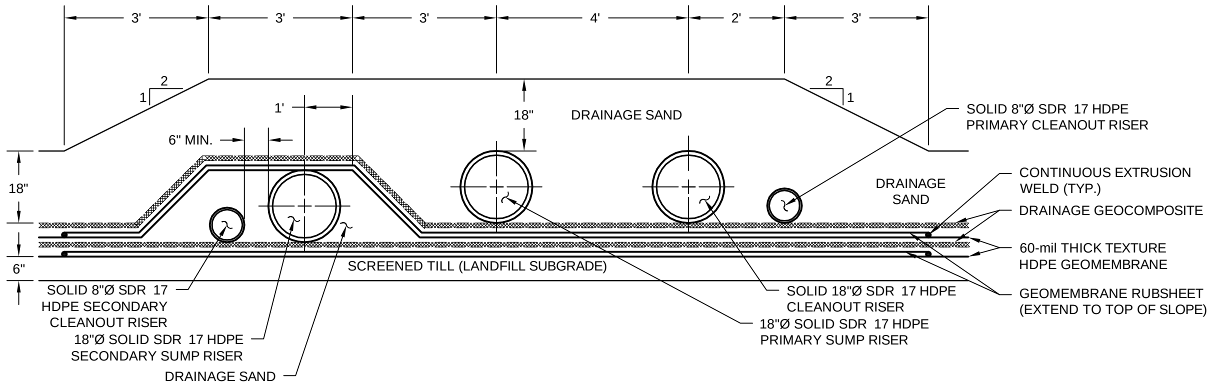


NOTE:

1. SEE SHEET 5 FOR LIMIT OF GCL.

SECTION A-A' PRIMARY AND SECONDARY LEACHATE SUMPS

NOT TO SCALE

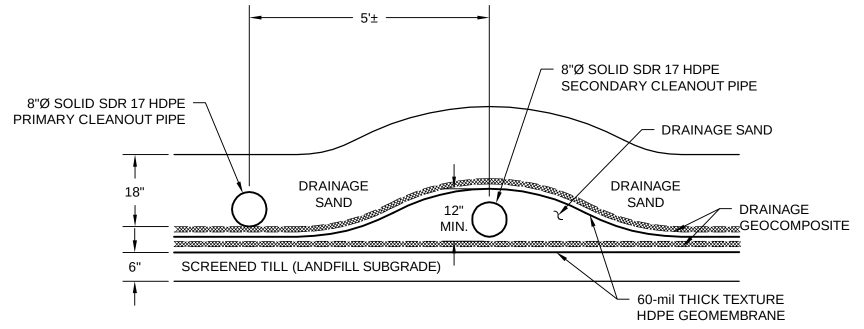


SECTION VIEW LOOKING DOWNSLOPE

SUMP RISER

1

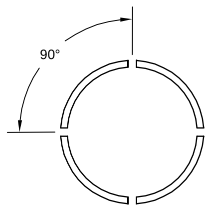
NOT TO SCALE



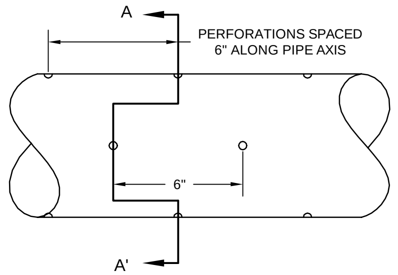
LEACHATE COLLECTION CLEANOUT RISERS

2

NOT TO SCALE



SECTION A-A'



ELEVATION

NOTE:

1. 8"Ø SDR 17 HDPE PIPE PERFORATED WITH 1/2"Ø HOLES SPACED 90° APART CIRCUMFERENTIALLY, AND 6 INCHES ON CENTER AXIALLY.

LEACHATE COLLECTION PIPE PERFORATION

3

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

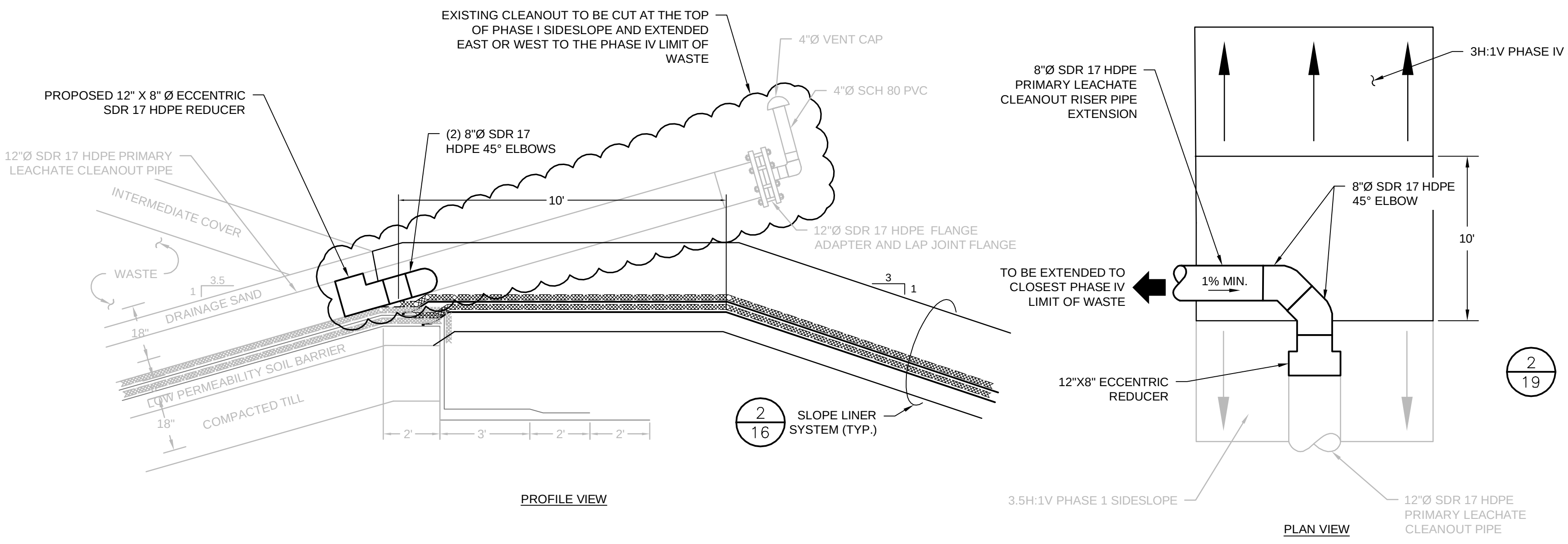
DRAWN BY: L. TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SUMP RISER / CLEANOUT DETAILS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
14 OF 28

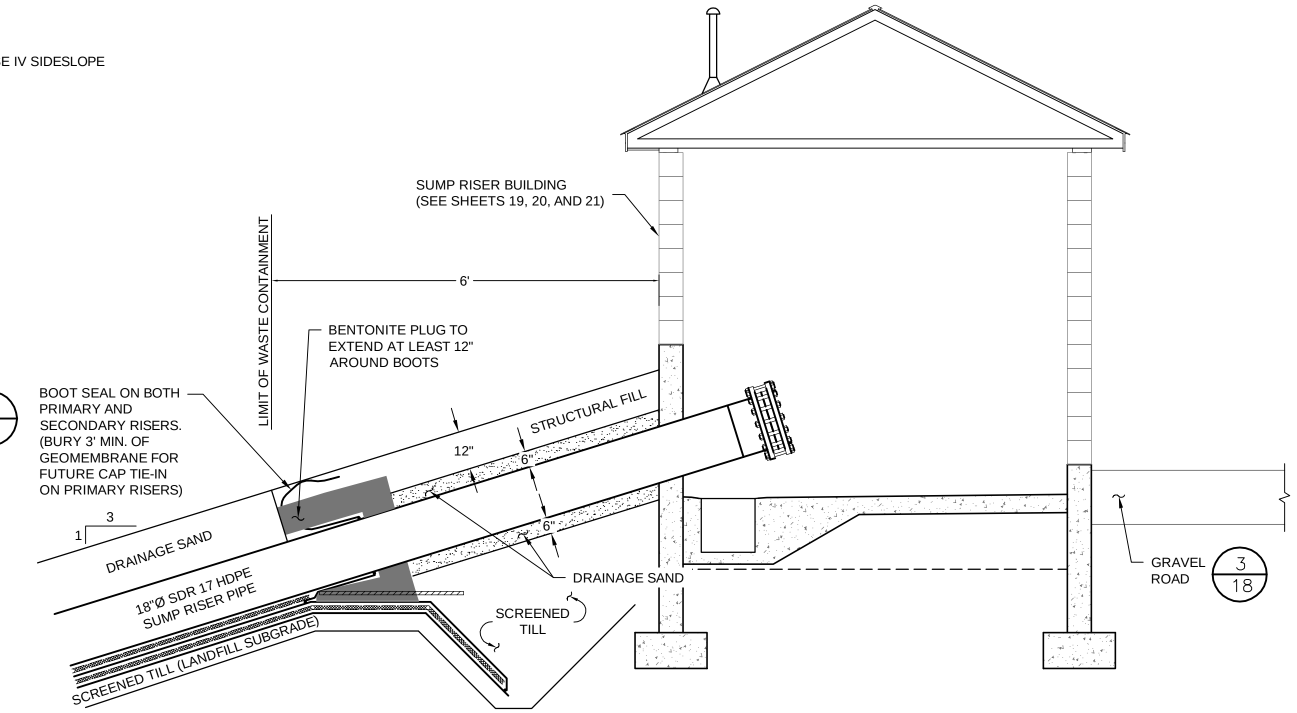


NOTE:

1. EXISTING PHASE I PRIMARY TO SECONDARY GEOMEMBRANE WELD AND ANCHOR TRENCH GEOSYNTHETICS TO BE REMOVED PRIOR TO INSTALLATION OF THE PHASE IV LINER SYSTEM.

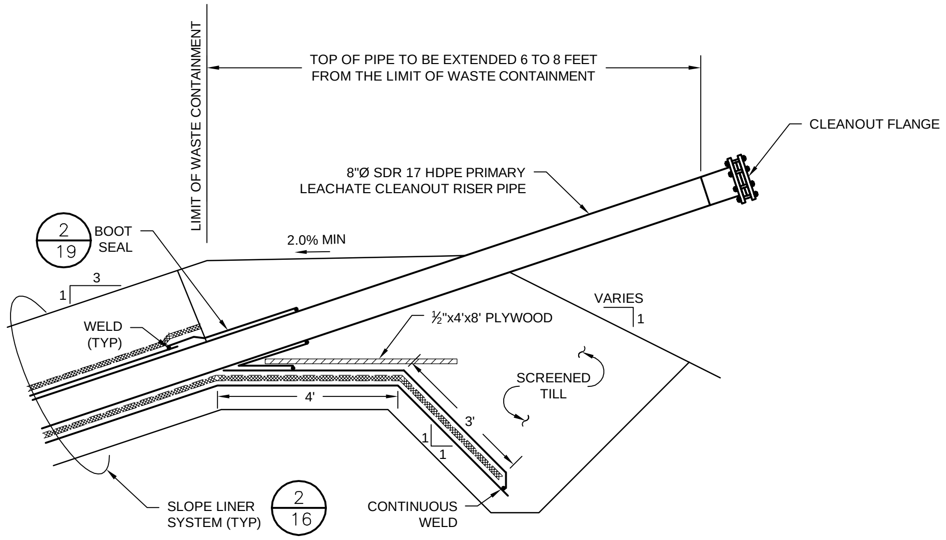
1 TYPICAL PHASE I PRIMARY LEACHATE CLEANOUT PIPE EXTENSION

NOT TO SCALE



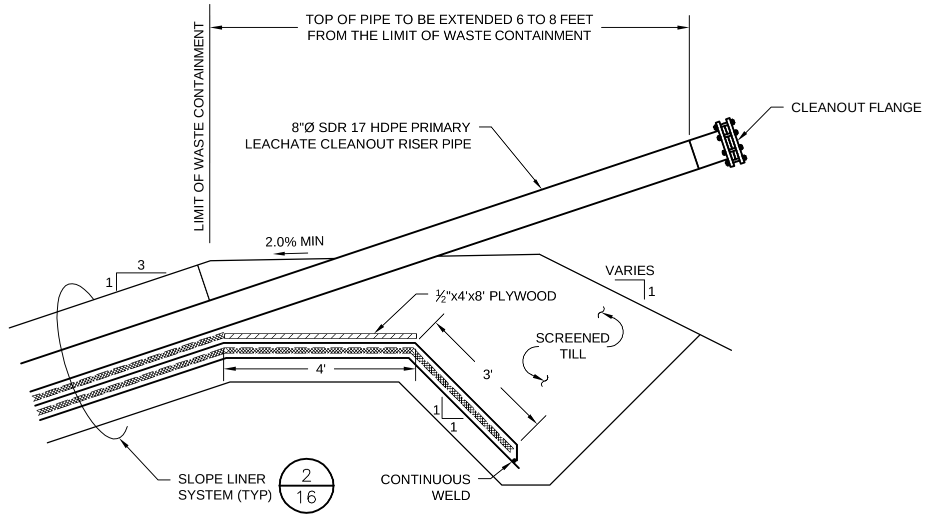
2 SUMP RISER SECTION

NOT TO SCALE



3 SECONDARY LEACHATE COLLECTION PIPE CLEANOUT

NOT TO SCALE



4 PRIMARY LEACHATE COLLECTION PIPE CLEANOUT

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L. TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SUMP RISER / CLEANOUT DETAILS

PROJECT NUMBER: 3066.11

SHEET NUMBER: 15 OF 28

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\BORDER.dwg
.\XREFS\Proposed Secondary Liner Grades.dwg

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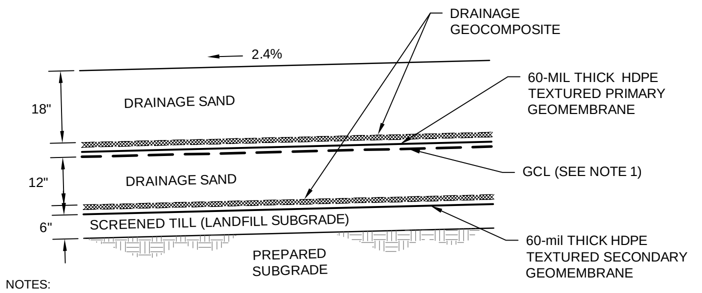
USER: ssantiago
PLOT DATE: 7-14-20 4:00 PM

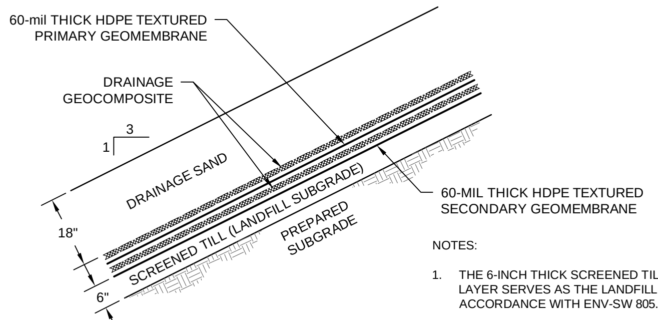


NOTES:

1. SEE SHEET 5 FOR LIMIT OF GCL. THE GCL SHALL BE PLACED BENEATH THE PRIMARY GEOMEMBRANE IN ALL BASE AREAS AND SHALL EXTEND 10 FEET UP SIDE SLOPES.
2. THE 6-INCH THICK SCREENED TILL (LANDFILL SUBGRADE) LAYER SERVES AS THE LANDFILL SUBGRADE IN ACCORDANCE WITH ENV-SW 805.03.
3. PREPARED SUBGRADE SHALL BE ESTABLISHED BY PROOF ROLLING NATURAL GROUND IN AREAS OF CUT OR BY COMPACTING STRUCTURAL FILL.

1 LINER SYSTEM (TYP)

NOT TO SCALE

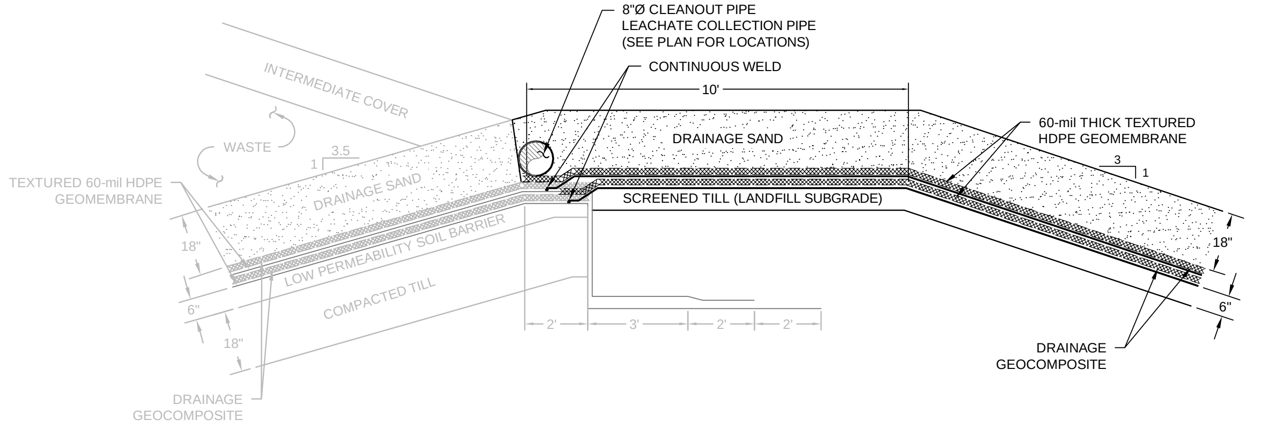


NOTES:

1. THE 6-INCH THICK SCREENED TILL (LANDFILL SUBGRADE) LAYER SERVES AS THE LANDFILL SUBGRADE IN ACCORDANCE WITH ENV-SW 805.03.
2. PREPARED SUBGRADE SHALL BE ESTABLISHED BY PROOF ROLLING NATURAL GROUND IN AREAS OF CUT OR BY COMPACTING STRUCTURAL FILL.

2 SLOPE LINER SYSTEM (TYP)

NOT TO SCALE (OUTSIDE THE EXISTING CAP AREA)

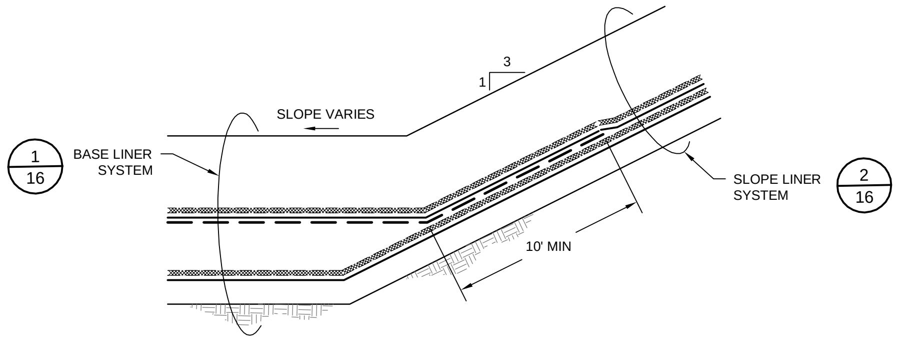


NOTE:

1. EXISTING PHASE I PRIMARY TO SECONDARY GEOMEMBRANE WELD AND ANCHOR TRENCH GEOSYNTHETICS TO BE REMOVED PRIOR TO INSTALLATION OF THE PHASE IV LINER SYSTEM.

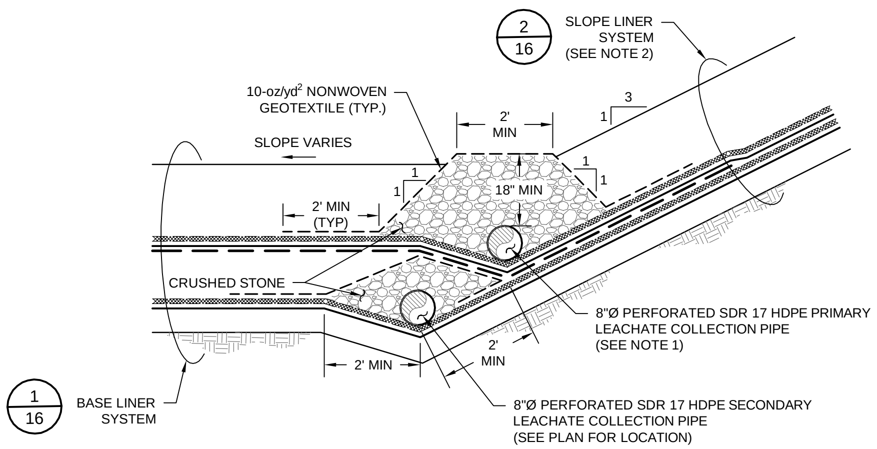
3 LINER CONNECTION ALONG PHASE I

NOT TO SCALE



4 LINER SYSTEM AT TOE OF SLOPE

NOT TO SCALE (WITHOUT LEACHATE COLLECTION PIPE)

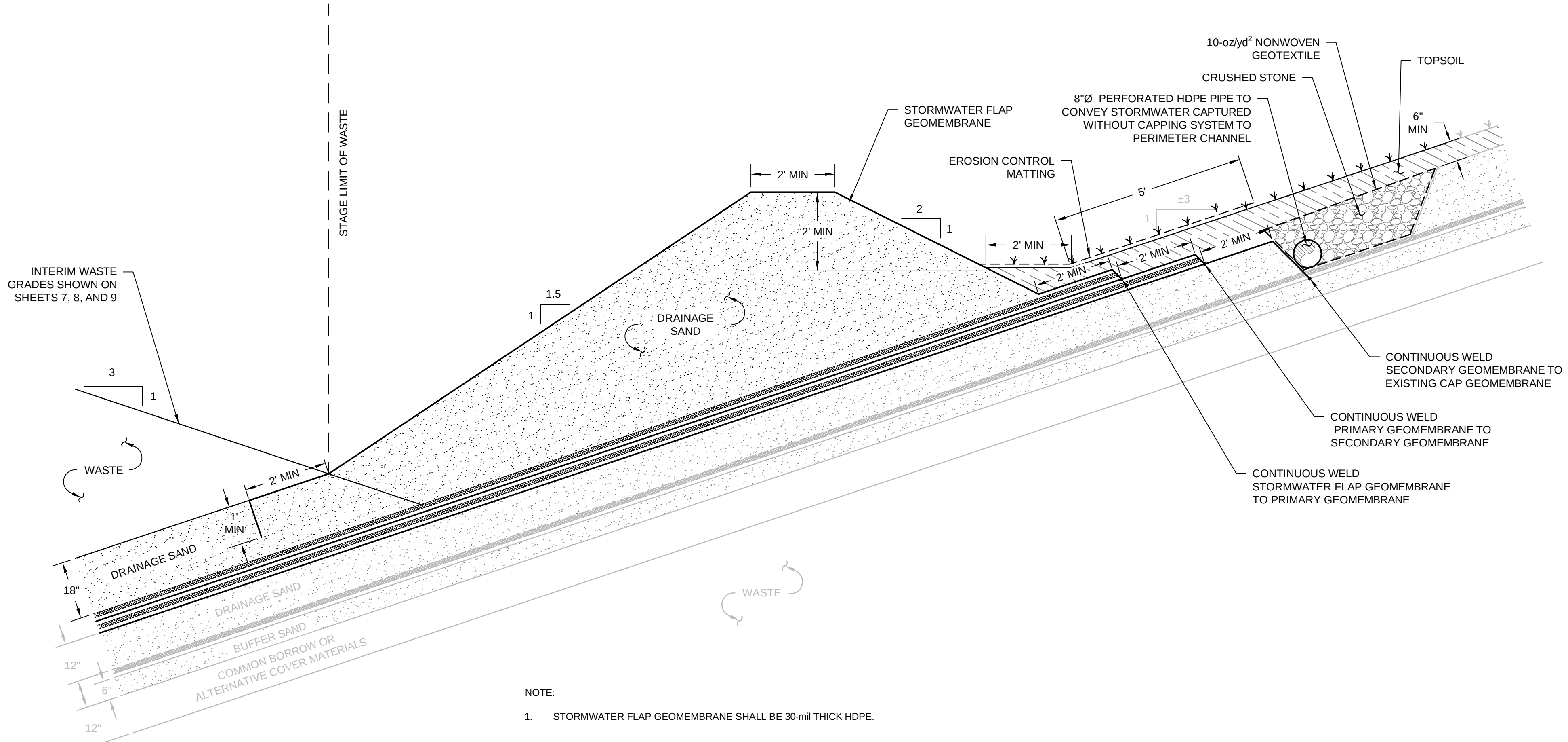


NOTES:

1. SEE DETAIL 3 ON SHEET 14 FOR PIPE PERFORATION INFORMATION.

5 LINER SYSTEM AT TOE OF SLOPE

NOT TO SCALE (WITH LEACHATE COLLECTION PIPE)



NOTE:

1. STORMWATER FLAP GEOMEMBRANE SHALL BE 30-mil THICK HDPE.

6 TEMPORARY DIVISION BERM

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

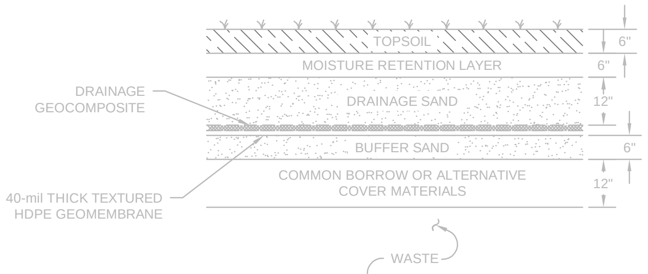
DRAWN BY: L.TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LINER SYSTEM DETAILS

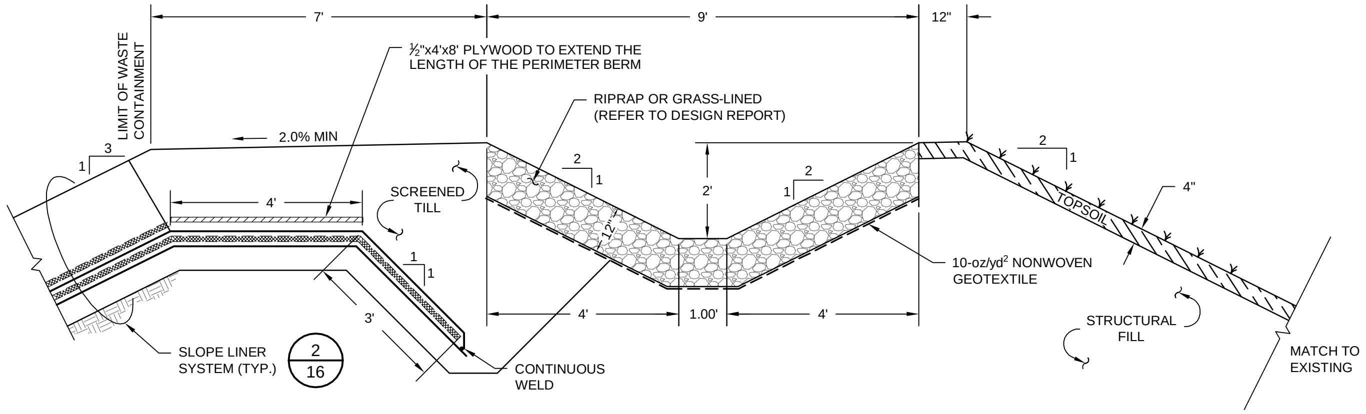
PROJECT NUMBER: 3066.11

SHEET NUMBER: 16 OF 28



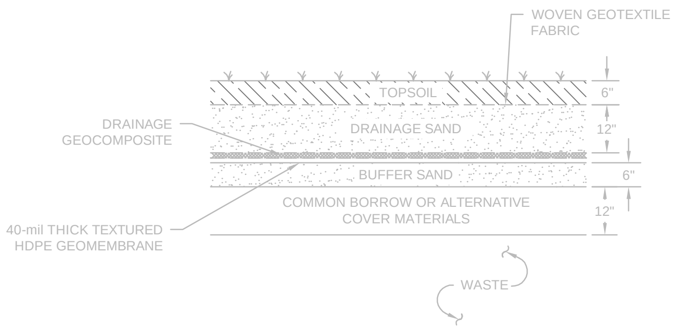
1 EXISTING TYPE A CAP AREA SECTION

NOT TO SCALE



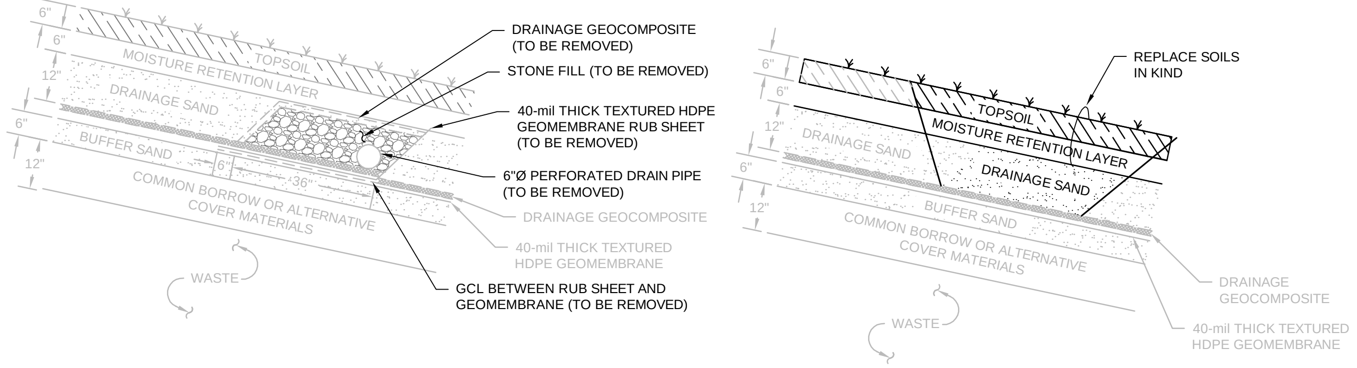
4 PERIMETER BERM (TYP.)

NOT TO SCALE



2 EXISTING TYPE B CAP AREA SECTION

NOT TO SCALE

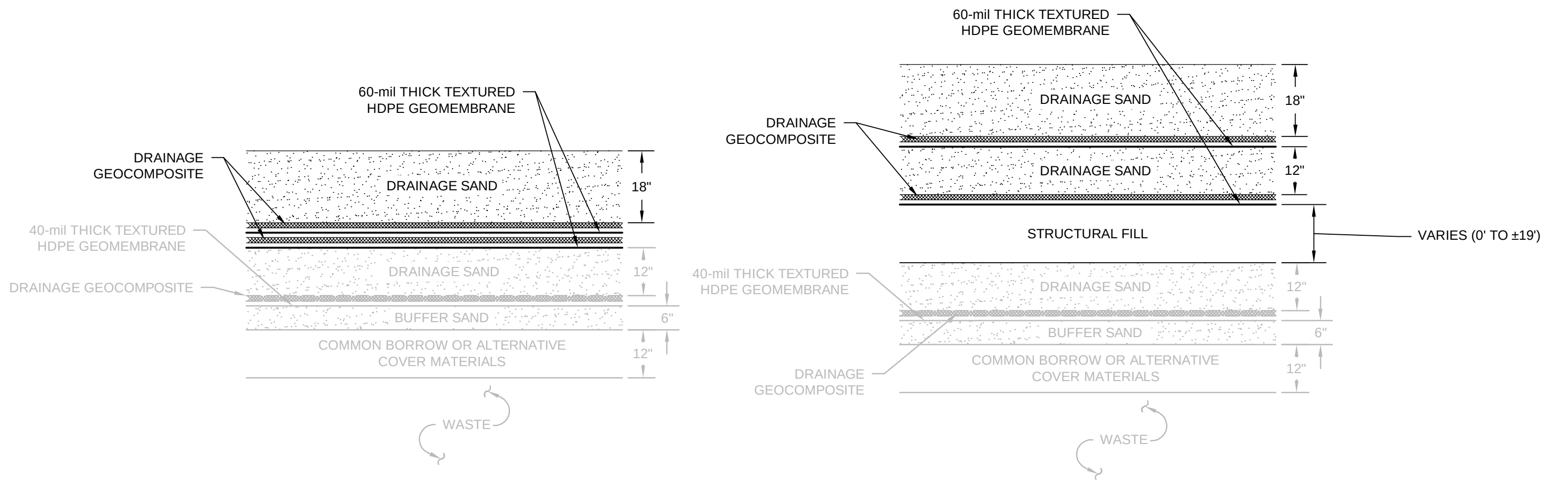


EXISTING

PROPOSED

3 SEEPAGE BENCH REMOVAL DETAIL

NOT TO SCALE



AREAS WITH SLOPES GREATER THAN 10%

AREAS WITH SLOPES LESS THAN 10%

5 OVERLAY LINER SYSTEM BASE AREA SECTION

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE AS INDICATED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L. TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LINER SYSTEM DETAILS

PROJECT NUMBER: 3066.11

SHEET NUMBER: 17 OF 28

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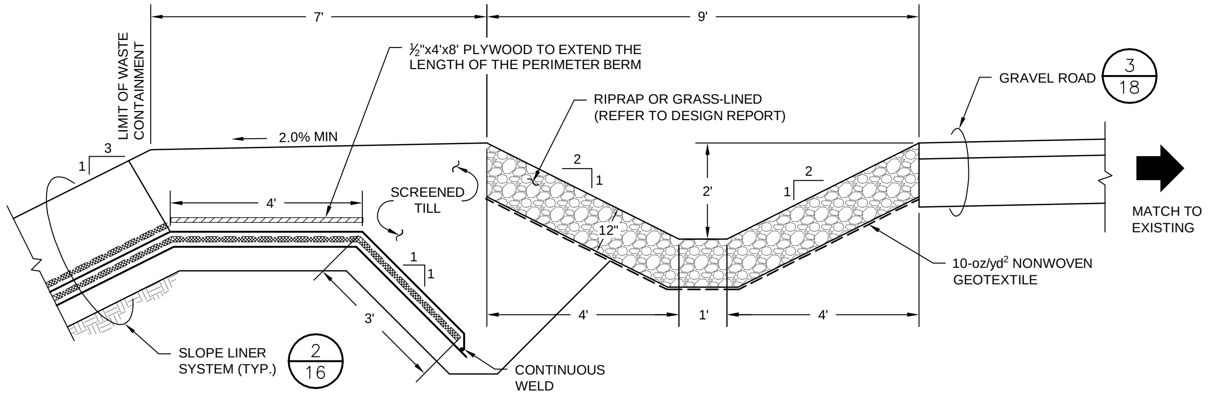
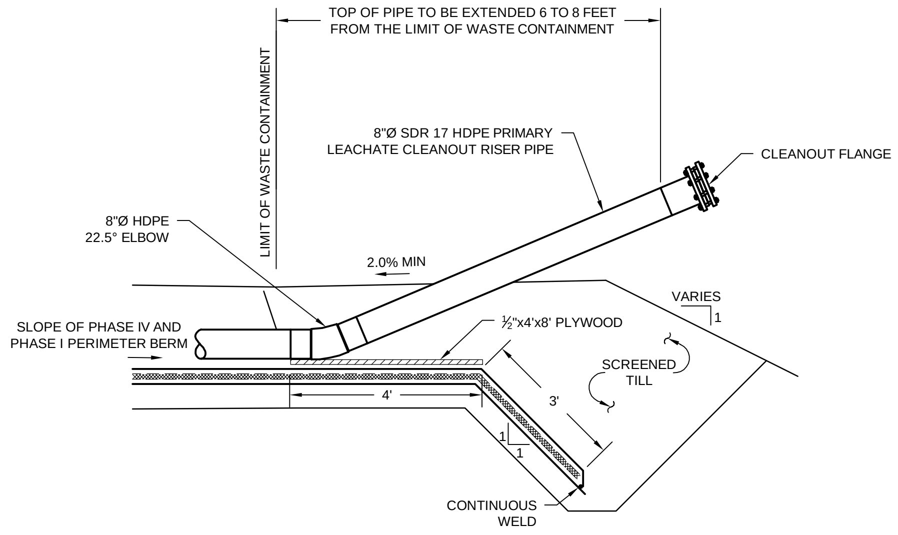
PLOT DATE: 7-14-20 4:01 PM



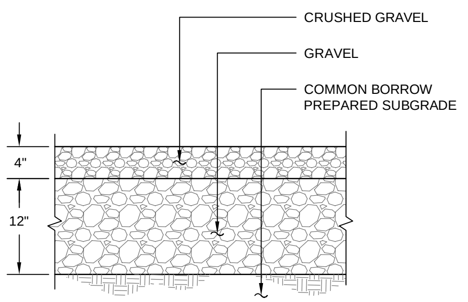
1 PERIMETER BERM ALONG ROADWAY

NOT TO SCALE



2 PHASE I PRIMARY LEACHATE COLLECTION PIPE CLEANOUT

NOT TO SCALE



3 GRAVEL ROAD

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L .TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LINER SYSTEM & PERIMETER DETAILS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
18 OF 28

IMAGES: E:\Steinhauser-NH.tif

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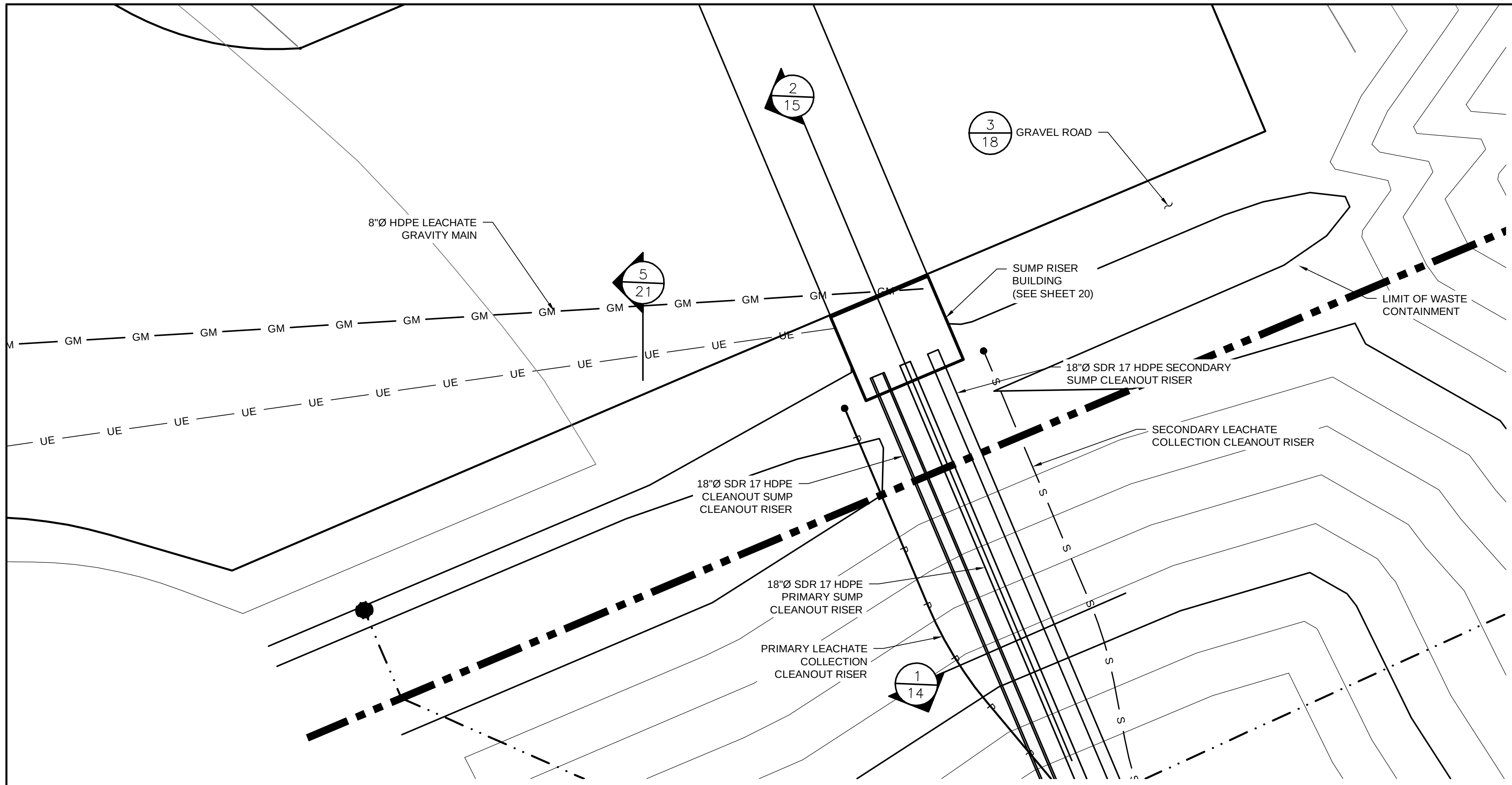
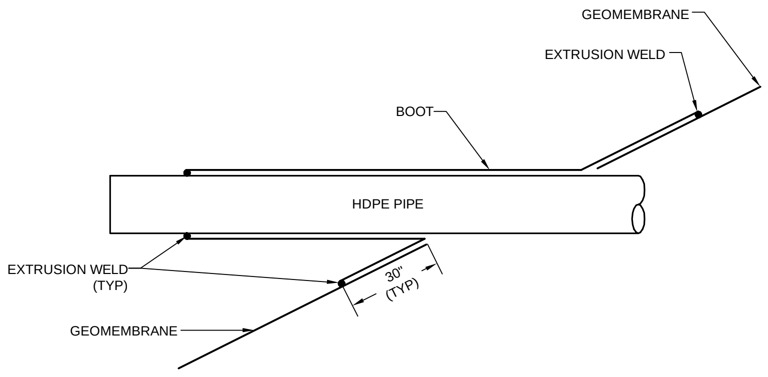


SUMP RISER BUILDING AREA PLAN

1

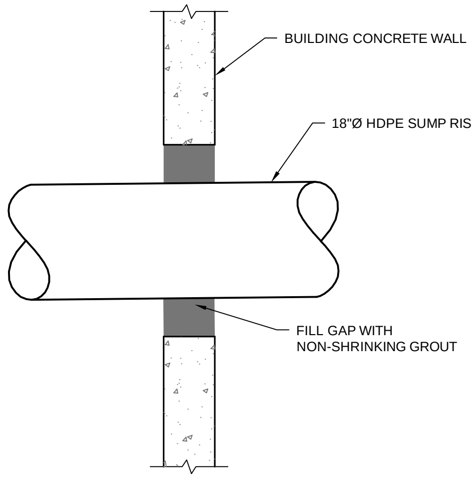
SCALE: AS NOTED



BOOT SEAL (TYPICAL)

2

NOT TO SCALE



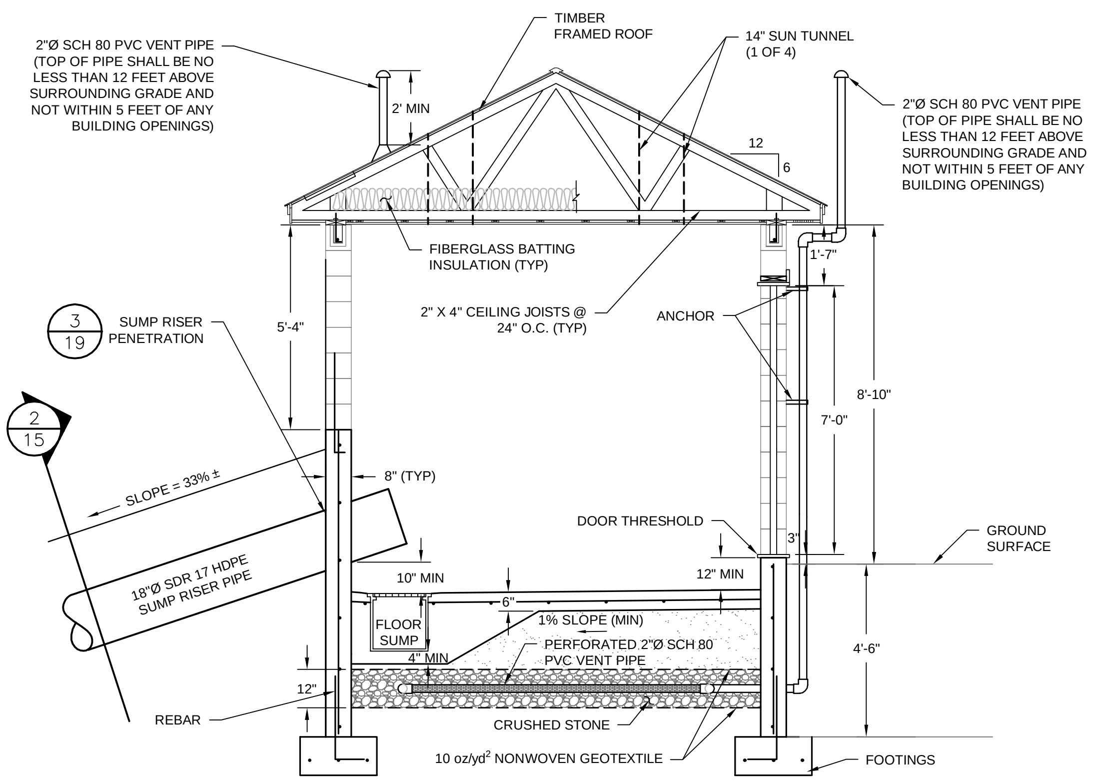
SUMP RISER PENETRATION

3

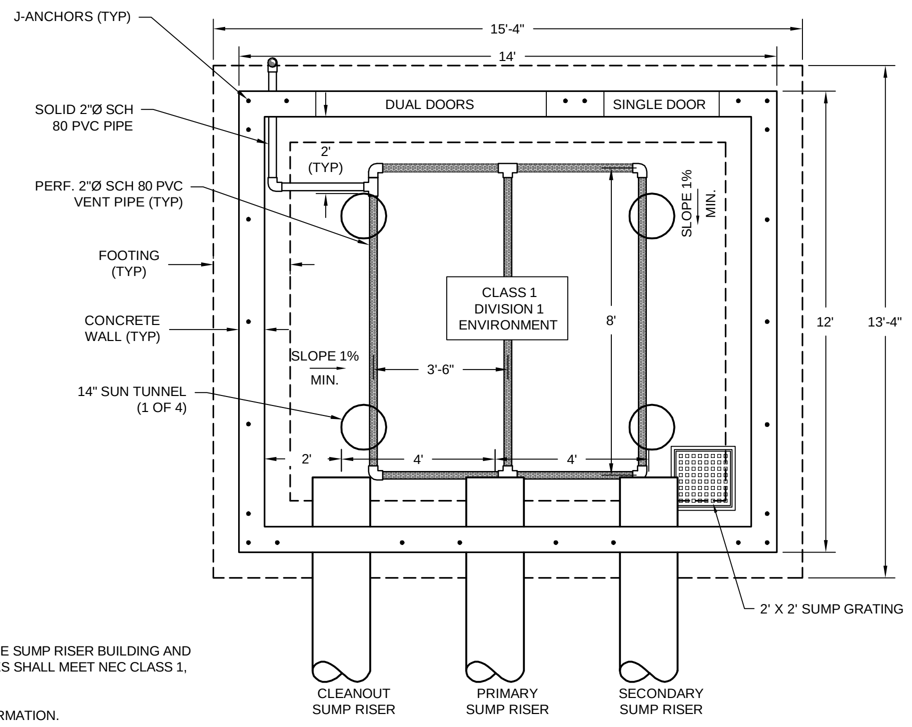
NOT TO SCALE

NOTES:

1. ALL ELECTRICAL EQUIPMENT WITHIN THE SUMP RISER BUILDING AND UNDERGROUND LEACHATE STRUCTURES SHALL MEET NEC CLASS 1, DIVISION 1, GROUP D REQUIREMENTS.
2. SEE SHEETS 20 AND 21 FOR MORE INFORMATION.



PROFILE



PLAN

SUMP RISER BUILDING

4

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

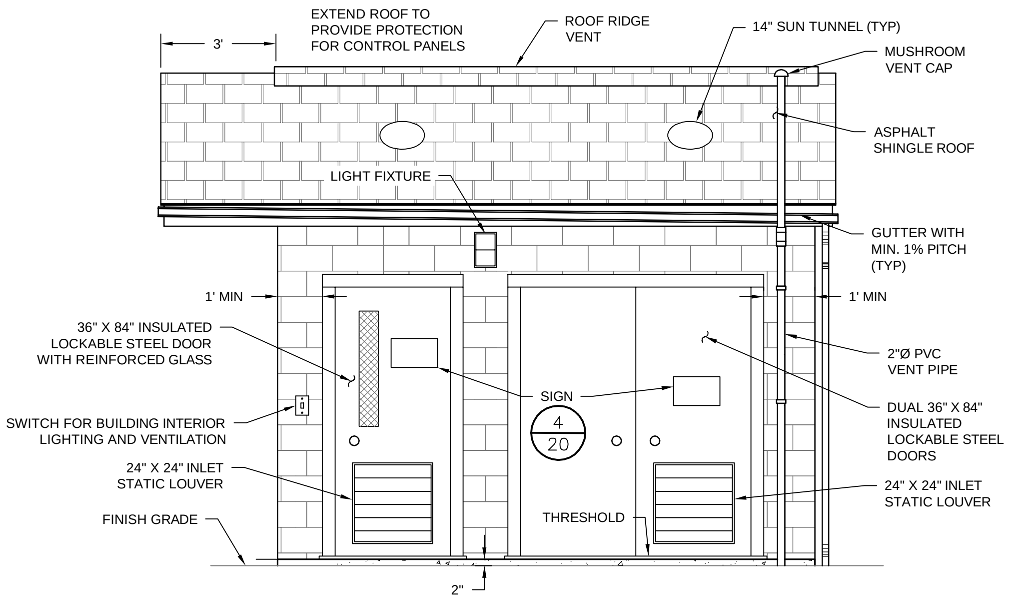
DRAWN BY: L. TRACY
DESIGNED BY: T. PETIT
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SUMP RISER BUILDING AREA
PLAN AND DETAILS

PROJECT NUMBER:
3066.11

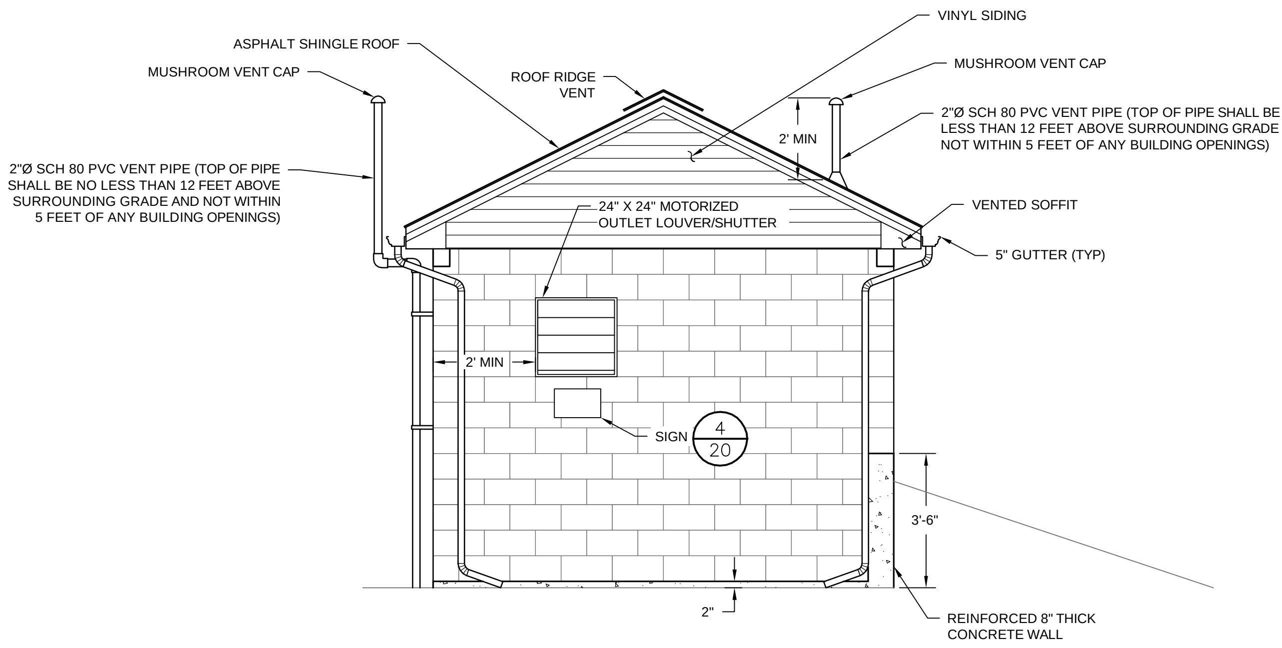
SHEET NUMBER:
19 OF 28



SUMP RISER BUILDING FRONT ELEVATION

1

NOT TO SCALE



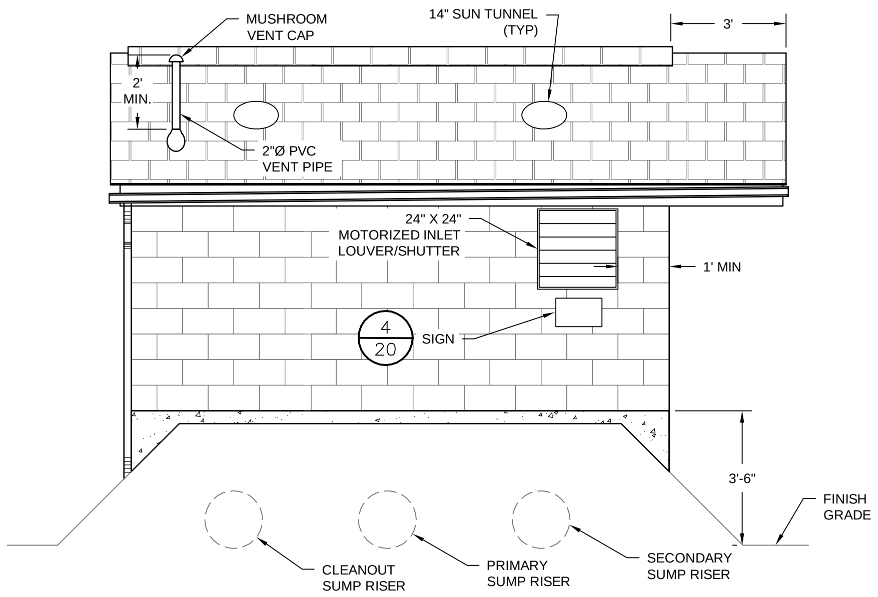
PHASE IV SUMP RISER BUILDING
CLASS 1, DIVISION 1, GROUP D ATMOSPHERE

DANGER, ALLOW BUILDING TO VENT FOR 30
SECONDS AND CHECK GAS MONITORS
BEFORE ENTERING.

SIGN DETAIL

4

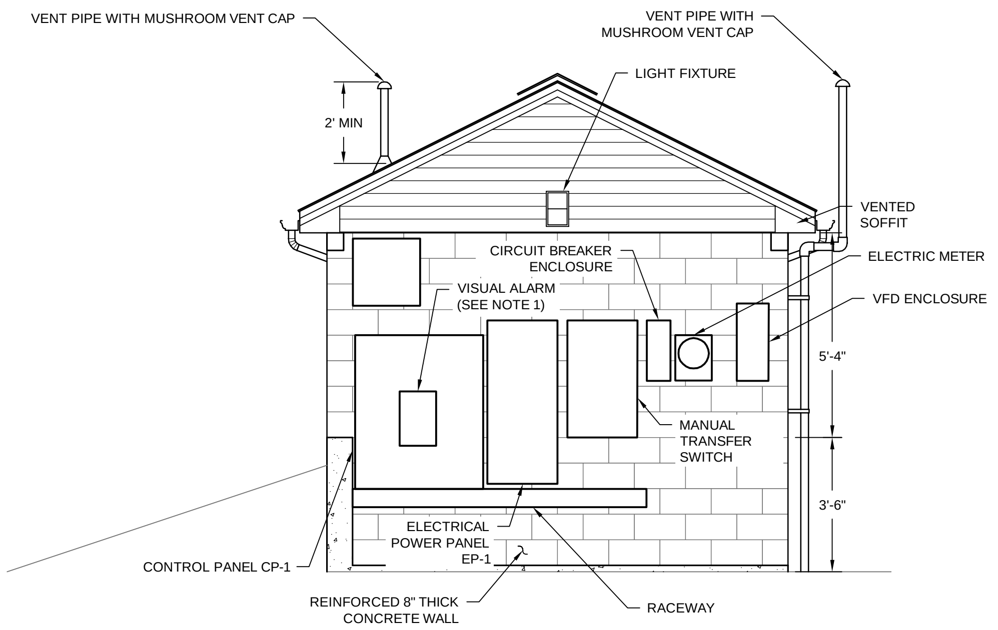
NOT TO SCALE



SUMP RISER BUILDING BACK ELEVATION

2

NOT TO SCALE



SUMP RISER BUILDING SIDE ELEVATIONS

3

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

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DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

SUMP RISER BUILDING ELEVATIONS AND SECTIONS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
20 OF 28

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\XREFS\BORDER.dwg
IMAGES: E:\Steinhauser-NH.tif
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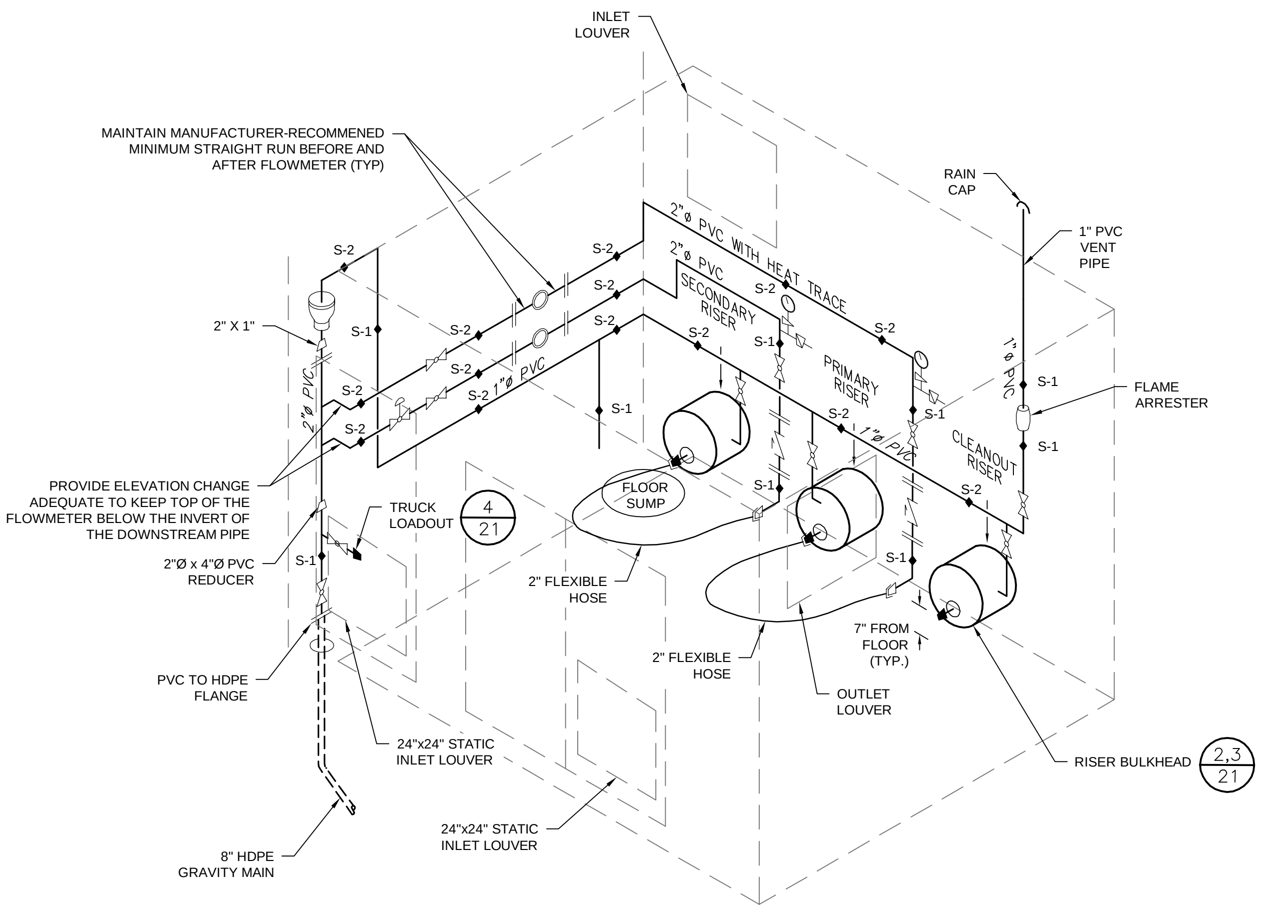


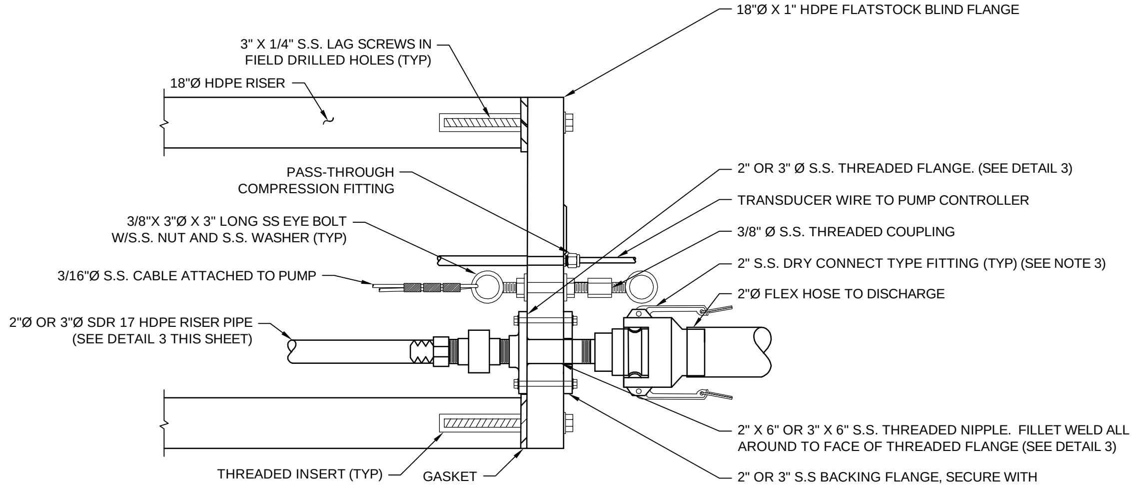
1 SUMP RISER BUILDING PIPING ISOMETRIC

NOT TO SCALE

ALL ELECTRICAL EQUIPMENT WITHIN THE SUMP RISER BUILDING AND UNDERGROUND LEACHATE STRUCTURES SHALL MEET NEC CLASS 1, DIVISION 1, GROUP D REQUIREMENTS

LEACHATE BUILDING PIPING ISOMETRIC SYMBOL LEGEND:

- RIGID PIPE
- FLEXIBLE HOSE
- ACTUATED BALL VALVE
- PLUG VALVE
- CHECK VALVE
- FLOW METER
- WYE
- BUSHING
- S-1 ◆ PIPE SUPPORT 6/21
- CAMLOCK FITTING
- QUICK DISCONNECT FITTING - STANDARD
- QUICK DISCONNECT FITTING - DRY STYLE
- VACUUM /AIR RELEASE VALVE
- FLANGE
- BALL VALVE NORMALLY OPEN
- BALL VALVE NORMALLY CLOSED
- PRESSURE GAUGE
- SAMPLE PORT
- FLAME ARRESTOR

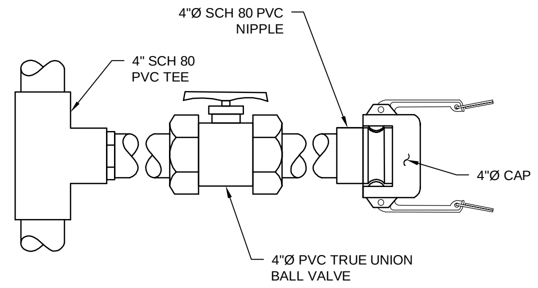


NOTES:

1. ALL ELECTRICAL EQUIPMENT WITHIN THE SUMP RISER BUILDING AND UNDERGROUND LEACHATE STRUCTURES SHALL MEET NEC CLASS 1, DIVISION 1, GROUP D REQUIREMENTS.
2. PUMP POWER CORD CONNECTOR NOT SHOWN FOR CLARITY.
3. FOR CLEANOUT RISER CONDITION, REDUCE DOWN FROM 3"Ø TO 2"Ø BEFORE THE DRY CONNECT TYPE FITTING.

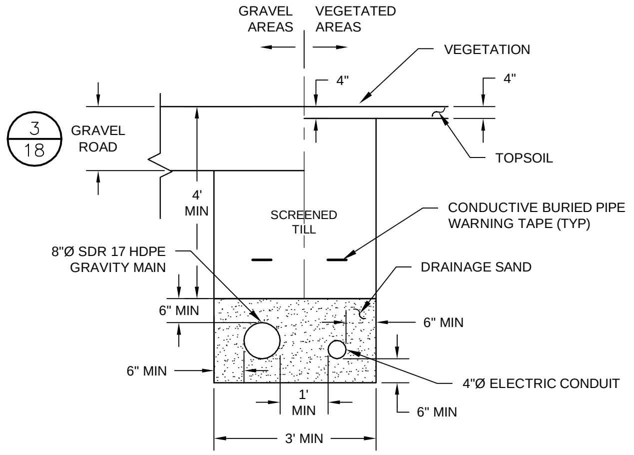
2 BULKHEAD PIPING

NOT TO SCALE



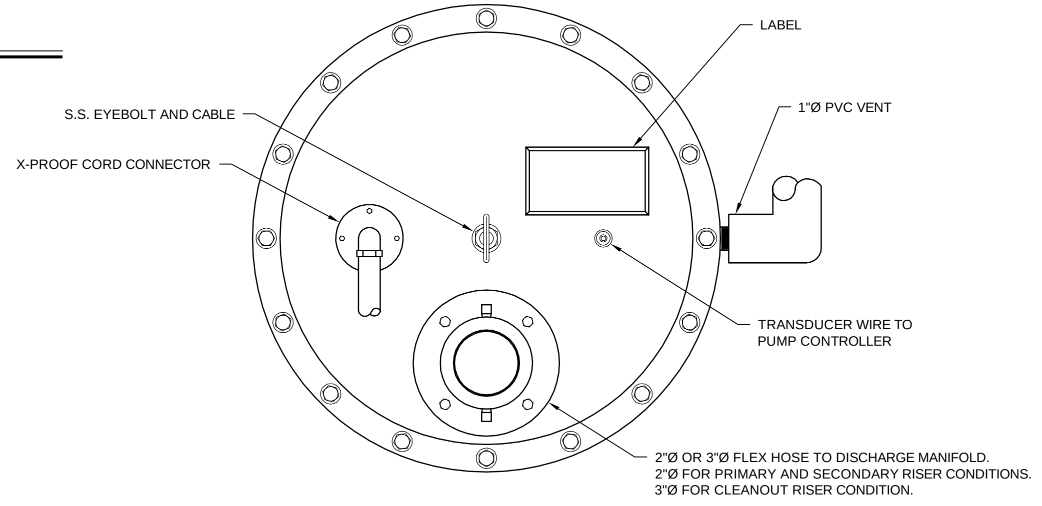
4 TRUCK LOADOUT

NOT TO SCALE



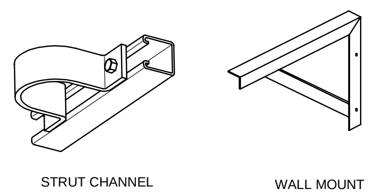
5 UTILITY TRENCH

NOT TO SCALE



3 BULKHEAD BLIND FLANGE PIPING LAYOUT

NOT TO SCALE



NOTE:

1. PIPE SUPPORTS SHALL BE CONSTRUCTED USING 2" X 1/8" S.S. ANGLE, AND 2" X 1/4" S.S. FLATSTOCK. SUPPORTS SHOWN ARE INTENDED TO ILLUSTRATE GENERAL DESIGN. MODIFY DESIGN AS REQUIRED TO MEET SPECIFIC REQUIREMENTS, AND CONFORM TO SPECIFICATIONS.

6 PIPE SUPPORT

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE: AS NOTED

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

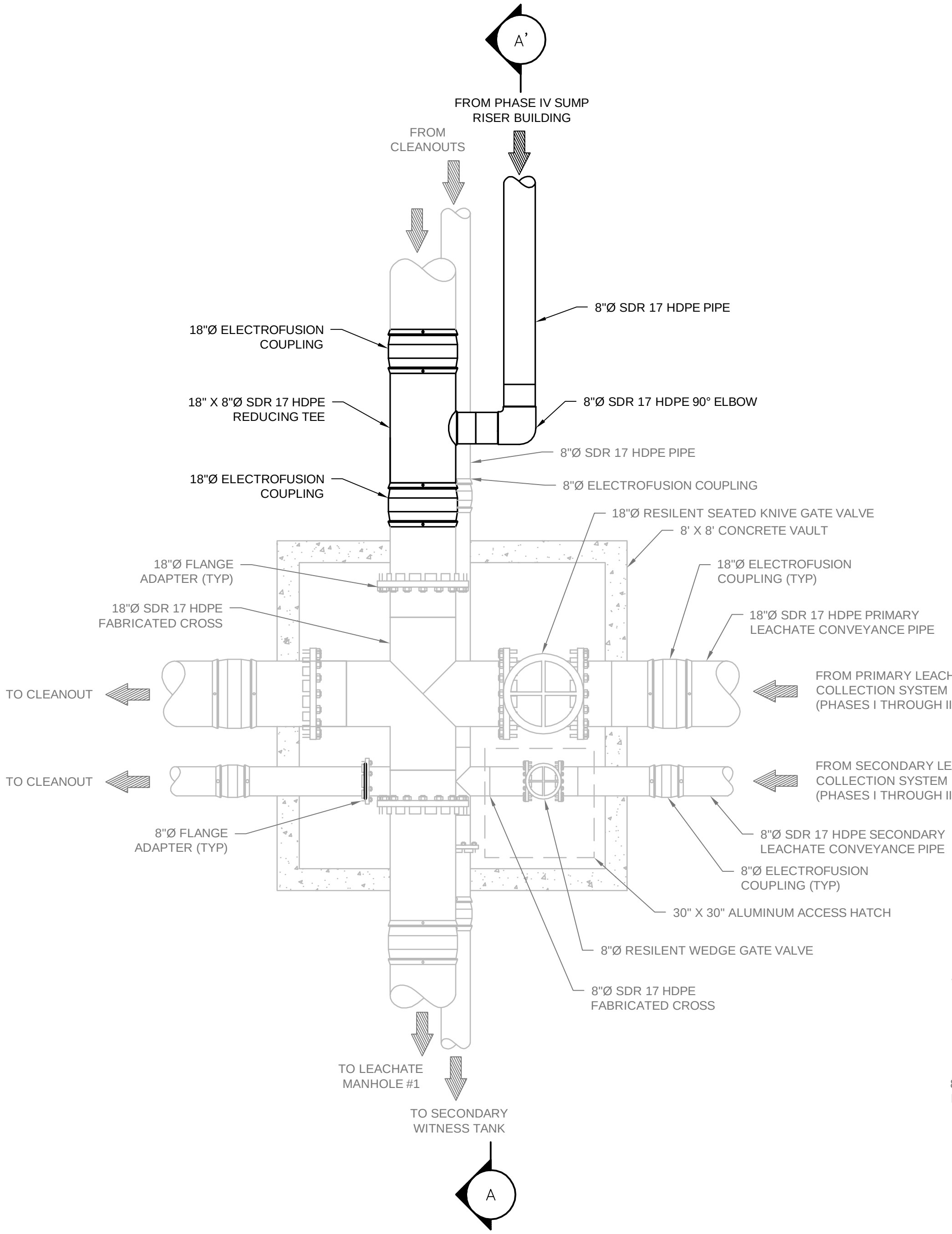
DRAWN BY: L .TRACY
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

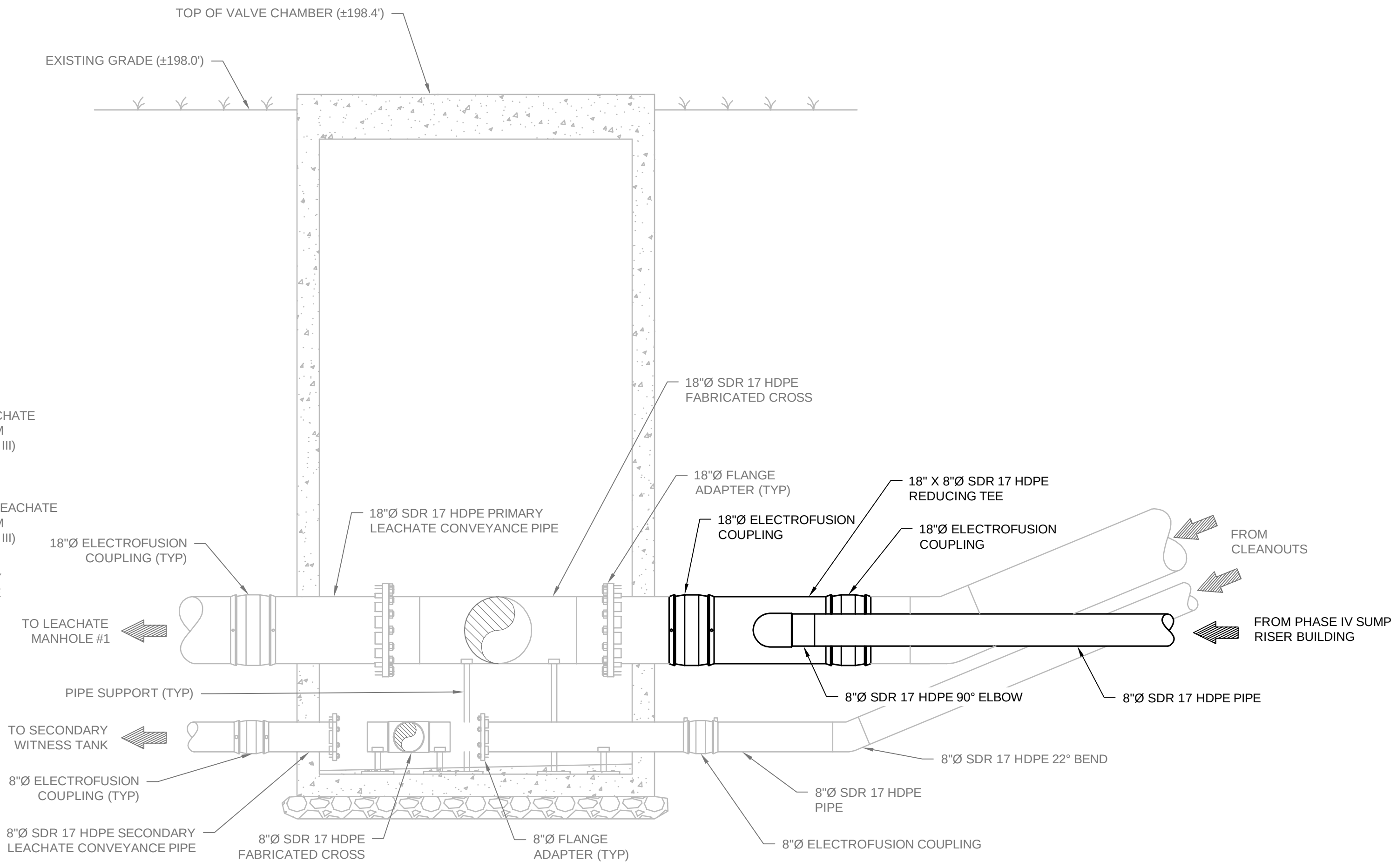
SUMP RISER BUILDING ELEVATIONS AND SECTIONS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
21 OF 28



PLAN VIEW



SECTION A-A'

1 PROPOSED GRAVITY MAIN CONNECTION TO EXISTING VALVE CHAMBER "A"

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE AS INDICATED

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

LEACHATE GRAVITY MAIN DETAILS

PROJECT NUMBER: 3066.11

SHEET NUMBER: 22 OF 28

IMAGES: E:\Steinhauser-NH.tif

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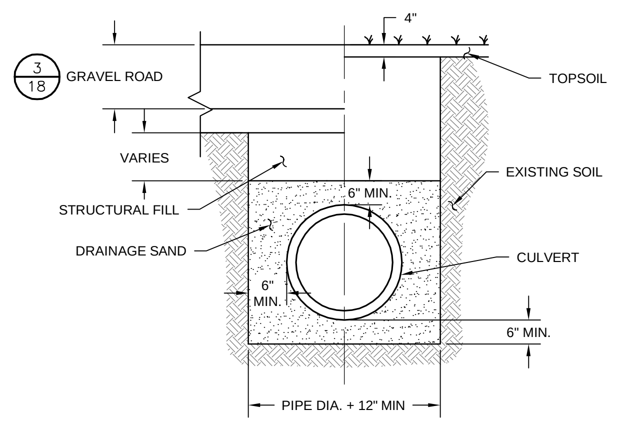
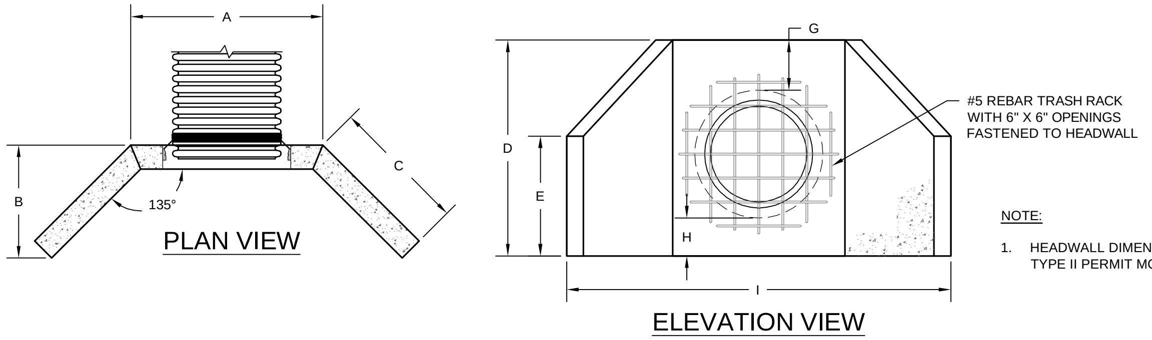
LAYOUT: D22
USER: ssantiago
PLOT DATE: 7-14-20 4:03 PM



1 CULVERT TRENCH

NOT TO SCALE



PLAN VIEW

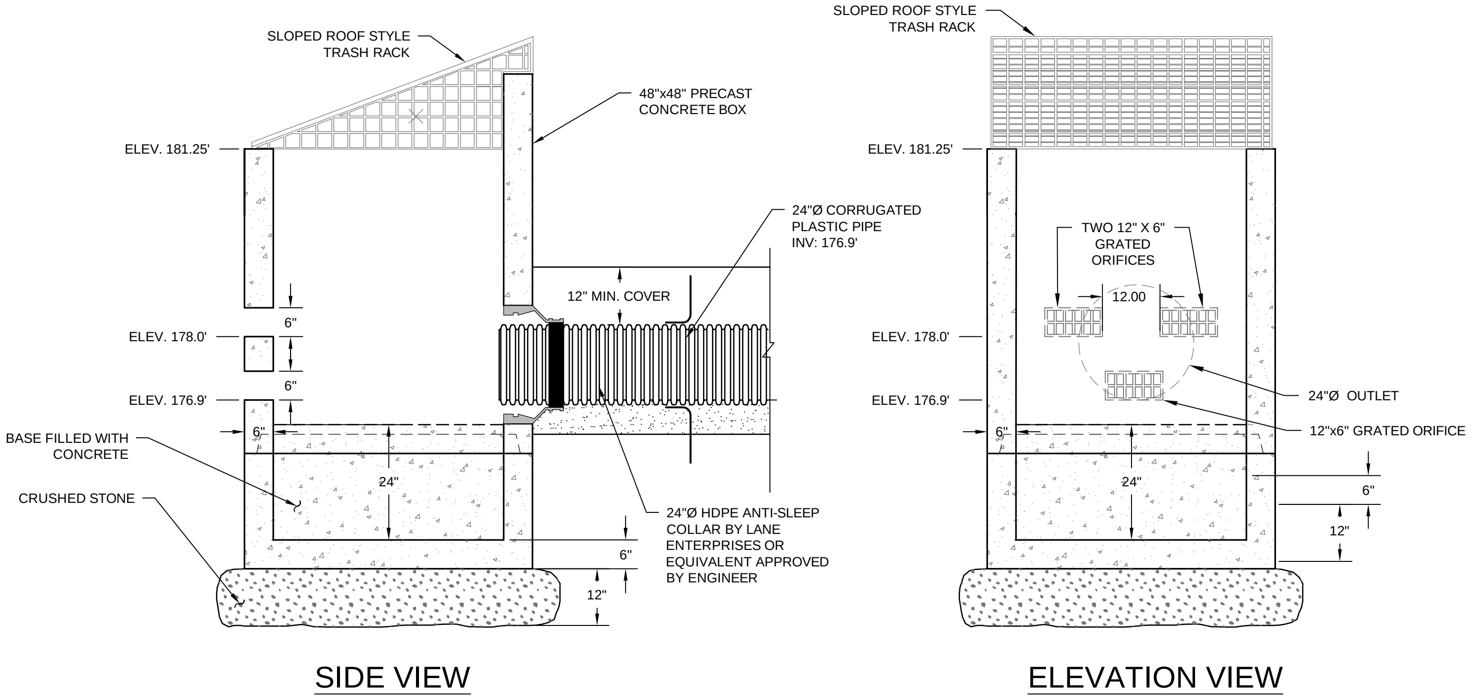
ELEVATION VIEW

NOTE:

1. HEADWALL DIMENSIONS TO BE DETERMINED DURING TYPE II PERMIT MODIFICATION APPLICATION.

2 HEADWALL DETAIL

NOT TO SCALE

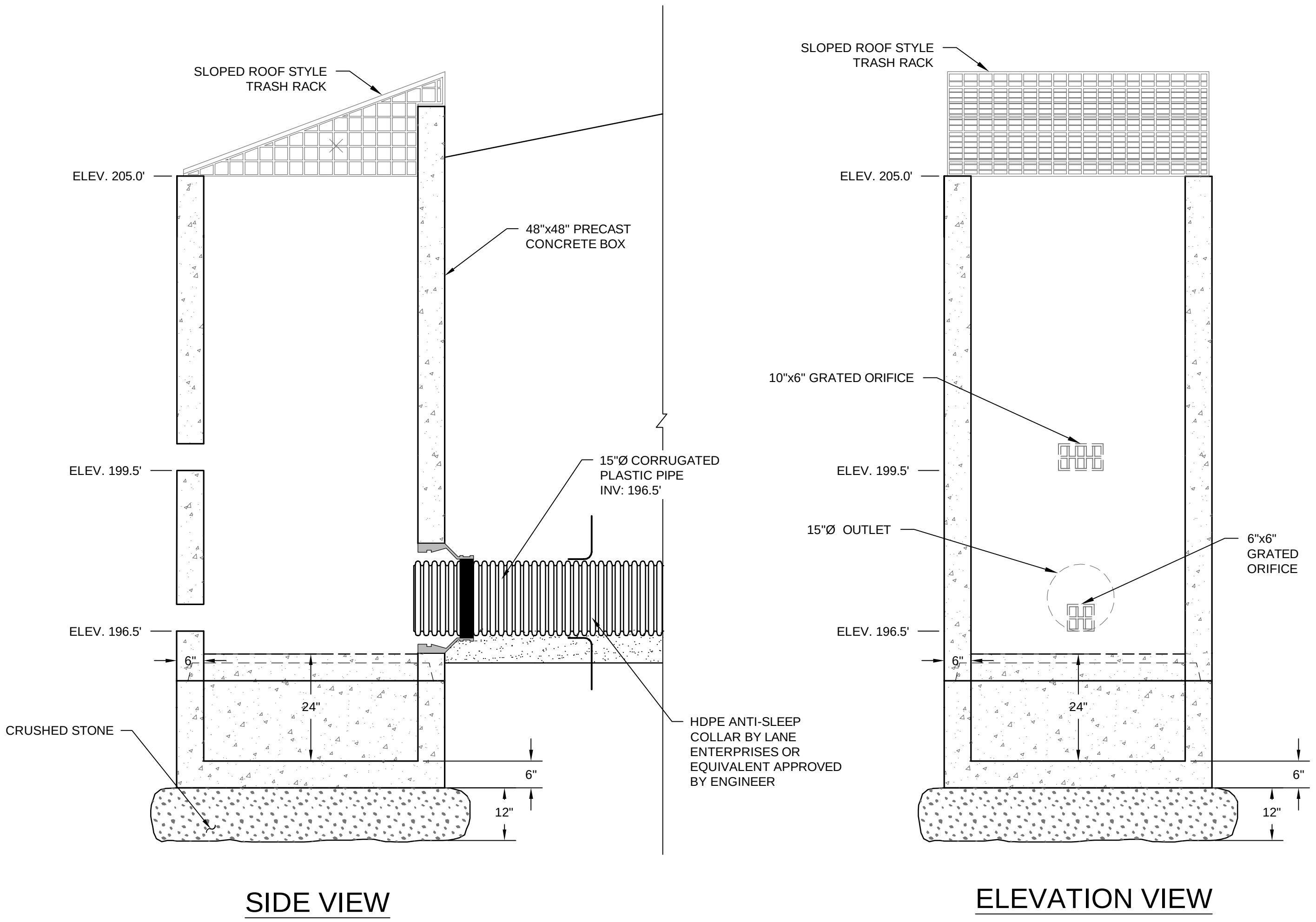


SIDE VIEW

ELEVATION VIEW

3 POND 2 OUTLET STRUCTURE

NOT TO SCALE



SIDE VIEW

ELEVATION VIEW

4 POND 4 OUTLET STRUCTURE

NOT TO SCALE

- *NOT FOR CONSTRUCTION* -
FOR PERMITTING PURPOSES ONLY

SANBORN | HEAD

SCALE AS INDICATED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: O. HERNANDEZ
DESIGNED BY: O. HERNANDEZ / R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STORMWATER DETAILS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
23 OF 28

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A App Drawings\D23 - Stormwater Details.dwg
LAYOUT: D23
USER: ssantiago
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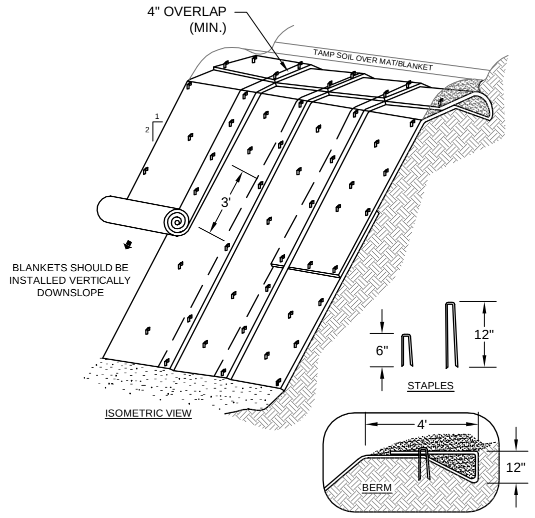
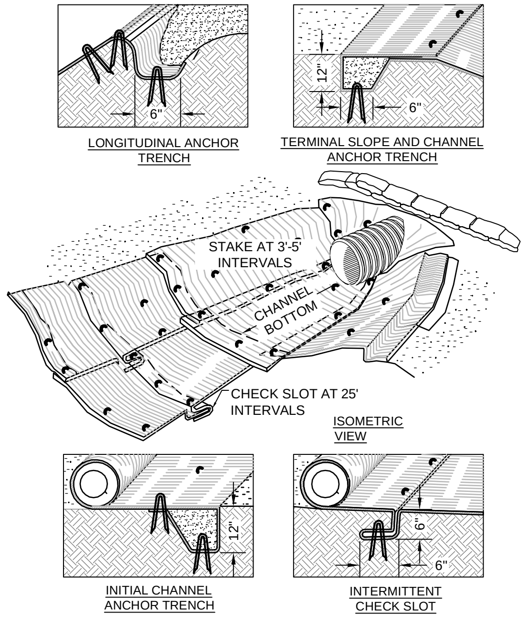


SLOPE INSTALLATION

SLOPE INSTALLATION NOTES:

1. DIMENSIONS GIVEN IN THE DRAWINGS ARE EXAMPLES; MATERIAL SHOULD BE INSTALLED PER MANUFACTURER'S SPECIFICATIONS.
2. SLOPE SURFACE SHALL BE FREE OF ROCKS, CLODS, STICKS AND GRASS. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.
3. APPLY PERMANENT SEEDING BEFORE PLACING BLANKETS.
4. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH.



CHANNEL INSTALLATION

CHANNEL INSTALLATION NOTES:

1. DIMENSIONS GIVEN IN THE DRAWINGS ARE EXAMPLES; MATERIAL SHOULD BE INSTALLED PER MANUFACTURER'S SPECIFICATIONS.
2. CHECK SLOTS TO BE CONSTRUCTED PER MANUFACTURER'S SPECIFICATIONS.
3. STAKING OR STAPLING LAYOUT PER MANUFACTURER'S SPECIFICATIONS.

SOURCE: "NEW HAMPSHIRE STORMWATER MANUAL, VOLUME 3 EROSION AND SEDIMENT CONTROLS DURING CONSTRUCTION" REVISION 1.0, DECEMBER 2008, PAGES 74 AND 75.

1 EROSION CONTROL BLANKET INSTALLATION

NOT TO SCALE

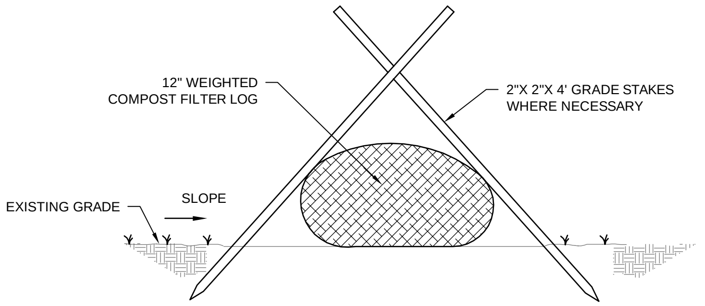
GENERAL NOTES*:

1. PERIMETER CONTROLS SHALL BE INSTALLED PRIOR TO EARTH MOVING OPERATIONS.
2. THE SMALLEST PRACTICAL AREA SHALL BE DISTURBED DURING CONSTRUCTION, BUT IN NO CASE SHALL EXCEED 5 ACRES AT ANY ONE TIME BEFORE DISTURBED AREAS ARE STABILIZED. THE TERM "STABLE" IS DEFINED AS MEETING ONE OF THE FOLLOWING CRITERIA:
    - A. BASE COURSE GRAVELS HAVE BEEN INSTALLED IN AREAS TO BE PAVED;
    - B. A MINIMUM OF 85 PERCENT VEGETATED GROWTH HAS BEEN ESTABLISHED;
    - C. A MINIMUM THICKNESS OF 3 INCHES OF NON-EROSIVE MATERIAL SUCH AS STONE HAS BEEN INSTALLED; OR
    - D. EROSION CONTROL BLANKETS HAVE BEEN PROPERLY INSTALLED.
3. All PONDS AND SWALES SHALL BE INSTALLED EARLY ON IN THE CONSTRUCTION SEQUENCE, BEFORE ROUGH GRADING THE SITE. ALL DRAINAGE SWALES SHALL BE STABILIZED PRIOR TO DIRECTING RUNOFF TO THEM.
4. APPLY SEED, LIME, FERTILIZER, AND CLEAN STRAW MULCH TO DISTURBED AREAS, NEWLY-PLACED FILL SLOPES, AND GRASS-LINED SWALES WITHIN SEVEN DAYS OF ACHIEVING FINAL GRADE. CLEAN STRAW MULCH SHALL BE APPLIED AT THE RATE OF 1.5 TO 2 TONS PER ACRE.
5. FILTER LOGS SHALL BE INSTALLED DOWNSLOPE AT THE DISCRETION OF THE ENGINEER. FILTER LOGS SHALL BE INSTALLED ALONG THE CONTOUR AND TOED UPSLOPE. FILTER LOGS ARE TO BE MAINTAINED AND CLEANED UNTIL VEGETATIVE COVER IS ESTABLISHED.
6. ALL EROSION CONTROLS, SUCH AS FILTER LOGS, SHALL BE INSPECTED WEEKLY DURING THE LIFE OF THE PROJECT AND AFTER EACH STORM EVENT THAT PRODUCES 0.25 INCHES OF RAINFALL. ALL DAMAGED FILTER LOGS SHALL BE REPAIRED PROMPTLY.
7. TRACK UP AND DOWN REGRADED SLOPES (GROUSER TRACKS PERPENDICULAR TO THE SLOPE) WITH A BULLDOZER TO LIMIT EROSION.
8. REMOVE SEDIMENT BUILD UP FROM THE STORMWATER POND AND FOREBAY AS NEEDED TO MAINTAIN STORAGE CAPACITY.
9. REMOVE SEDIMENT BUILD UP FROM BEHIND EROSION AND SEDIMENT CONTROL DEVICES. MAINTAIN TEMPORARY EROSION AND SEDIMENT CONTROL DEVICES UNTIL FULL ESTABLISHMENT OF PERMANENT GROUND COVER.
10. THE PROJECT SHALL BE MANAGED IN A MANNER THAT MEETS THE REQUIREMENTS AND INTENT OF RSA 430:53 AND CHAPTER AGR 3800 RELATIVE TO INVASIVE SPECIES.
11. THE DRAINAGE SWALES AND THE STORMWATER BASINS SHALL BE STABILIZED BEFORE RUNOFF IS DIRECTED TO THEM.
12. ALL PAVED AREAS SHALL BE STABILIZED WITHIN 72 HOURS OF ACHIEVING FINISHED GRADE.
13. ALL CUT AND FILL SLOPES SHALL RECEIVE 4-INCH THICK LAYER OF TOPSOIL AND BE SEEDED WITHIN 72 HOURS OF ACHIEVING FINISHED GRADE.
14. ALL DISTURBED AREAS SHALL BE STABILIZED WITHIN 45 DAYS OF INITIAL DISTURBANCE.
15. FUGITIVE DUST TO BE CONTROLLED IN ACCORDANCE WITH ENV-A 1000.
16. CONTRACTOR IS RESPONSIBLE FOR PREPARING A CONSTRUCTION STORMWATER POLLUTION PREVENTION PLAN IN ACCORDANCE TO Env-Wq 1504.08.
17. IF THE UN-STABILIZED DISTURBED AREA EXCEEDS 5 ACRES DURING CONSTRUCTION, AN ENVIRONMENTAL MONITOR SHALL BE EMPLOYED. THE ENVIRONMENTAL MONITOR SHALL:
    - A. INSPECT THE PROJECT SITE AT LEAST ONCE A WEEK UNTIL THE UN-STABILIZED DISTURBED AREA NO LONGER EXCEEDS 5 ACRES.
    - B. INSPECT THE PROJECT SITE DURING ANY RAIN EVENT IN WHICH 0.5 INCHES OF PRECIPITATION OR MORE FALLS WITHIN A 24 HOUR PERIODS, PROVIDED THAT IF THE ENVIRONMENTAL MONITOR IS UNABLE TO BE PRESENT DURING SUCH A STORM, THE MONITOR SHALL INSPECT THE PROJECT SITE WITHIN 24 HOURS OF THE RAIN EVENT.
    - C. SUBMIT A WRITTEN REPORT, STAMPED BY A QUALIFIED ENGINEER OR A CPESC SPECIALIST TO THE NHDES WITHIN 24 HOURS OF EACH INSPECTION. THE WRITTEN REPORT SHALL BE IN ACCORDANCE WITH THE NHDES ENV-WQ 1500.02(C)(3).
18. THE CITY SHALL SUBMIT TO THE NHDES A WRITTEN UPDATED OF THE PROJECT AND REVISED PLANS DOCUMENTING THE PROJECT STATUS EVERY FIVE YEARS FROM THE DATE OF THE AOT PERMIT.

WINTER NOTES*:

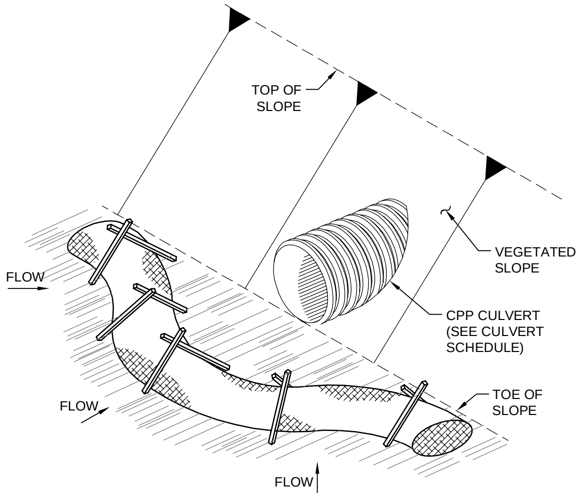
1. ALL PROPOSED VEGETATED AREAS THAT DO NOT EXHIBIT A MINIMUM OF 85% VEGETATIVE GROWTH BY OCTOBER 15TH, OR ARE DISTURBED AFTER OCTOBER 15TH, SHALL BE STABILIZED BY SEEDING AND INSTALLING EROSION CONTROL BLANKETS ON SLOPES GREATER THAN 3:1, AND SEEDING AND PLACING 3 TO 4 TONS OF MULCH PER ACRE, SECURED WITH ANCHORED NETTING, ELSEWHERE. THE INSTALLATION OF EROSION CONTROL BLANKETS OR MULCH AND NETTING SHALL NOT OCCUR OVER ACCUMULATED SNOW OR ON FROZEN GROUND AND SHALL BE COMPLETED IN ADVANCE OF THAW OR SPRING MELT EVENTS.
2. ALL DITCHES OR SWALES THAT DO NOT EXHIBIT A MINIMUM OF 85% VEGETATIVE GROWTH BY OCTOBER 15TH, OR ARE DISTURBED AFTER OCTOBER 15TH, SHALL BE STABILIZED TEMPORARILY WITH STONE OR EROSION CONTROL BLANKETS APPROPRIATE FOR THE DESIGN FLOW CONDITIONS.
3. AFTER NOVEMBER 15TH, INCOMPLETE ROAD OR PARKING SURFACES, WHERE WORK HAS STOPPED FOR THE WINTER SEASON, SHALL BE PROTECTED WITH A MINIMUM OF 3 INCHES OF CRUSHED GRAVEL PER NHDOT ITEM 304.3.

* PROVIDED AS REQUIRED IN THE NEW HAMPSHIRE CODE OF ADMINISTRATIVE RULES ENV-WQ 1500.



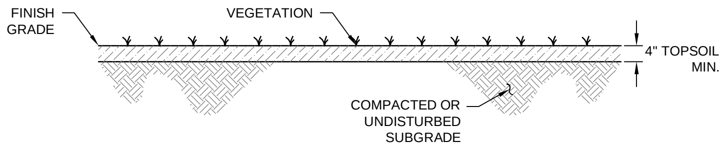
2 FILTER LOG

NOT TO SCALE



3 TEMPORARY FILTER LOG INLET PROTECTION DETAIL

NOT TO SCALE



4 TOPSOIL AND SEED

NOT TO SCALE

- NOT FOR CONSTRUCTION -

FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE AS INDICATED

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

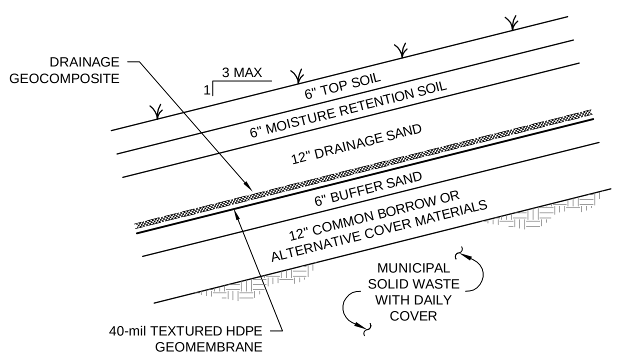
DRAWN BY: E. GALVIN
DESIGNED BY: E. GALVIN
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

EROSION & SEDIMENT CONTROL DETAILS

PROJECT NUMBER: 3066.11

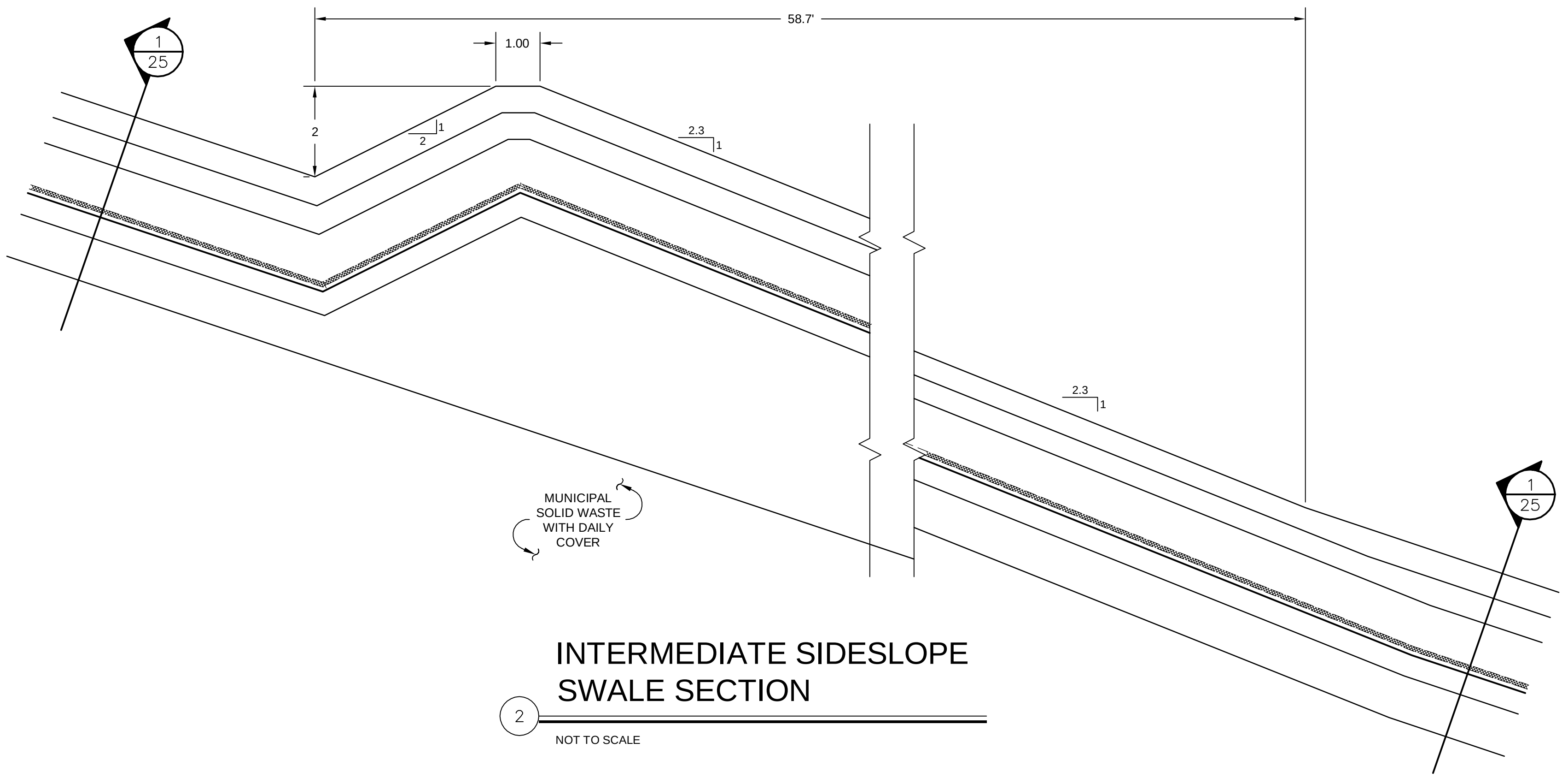
SHEET NUMBER: 24 OF 28



CAP SECTION

1

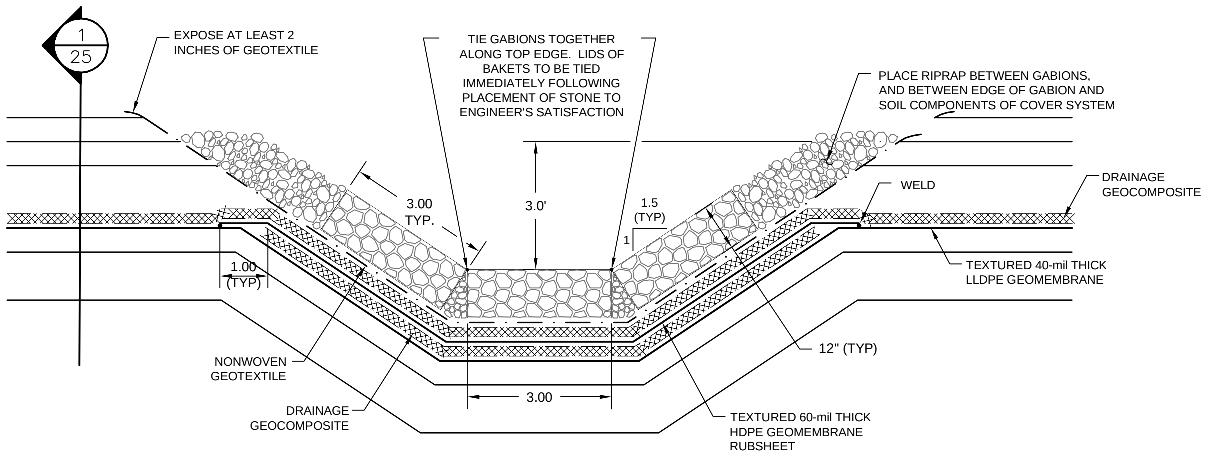
NOT TO SCALE



INTERMEDIATE SIDESLOPE SWALE SECTION

2

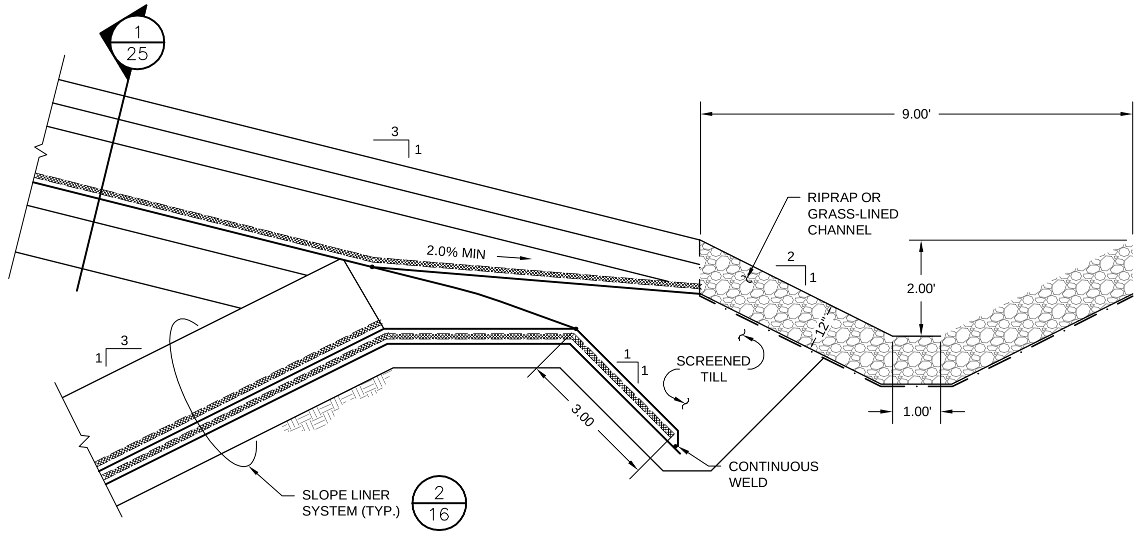
NOT TO SCALE



GABION-LINED DOWNCHUTE DETAIL (TYPICAL)

3

NOT TO SCALE



TOE OF SLOPE DETAIL

4

NOT TO SCALE

- *NOT FOR CONSTRUCTION* -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE AS INDICATED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

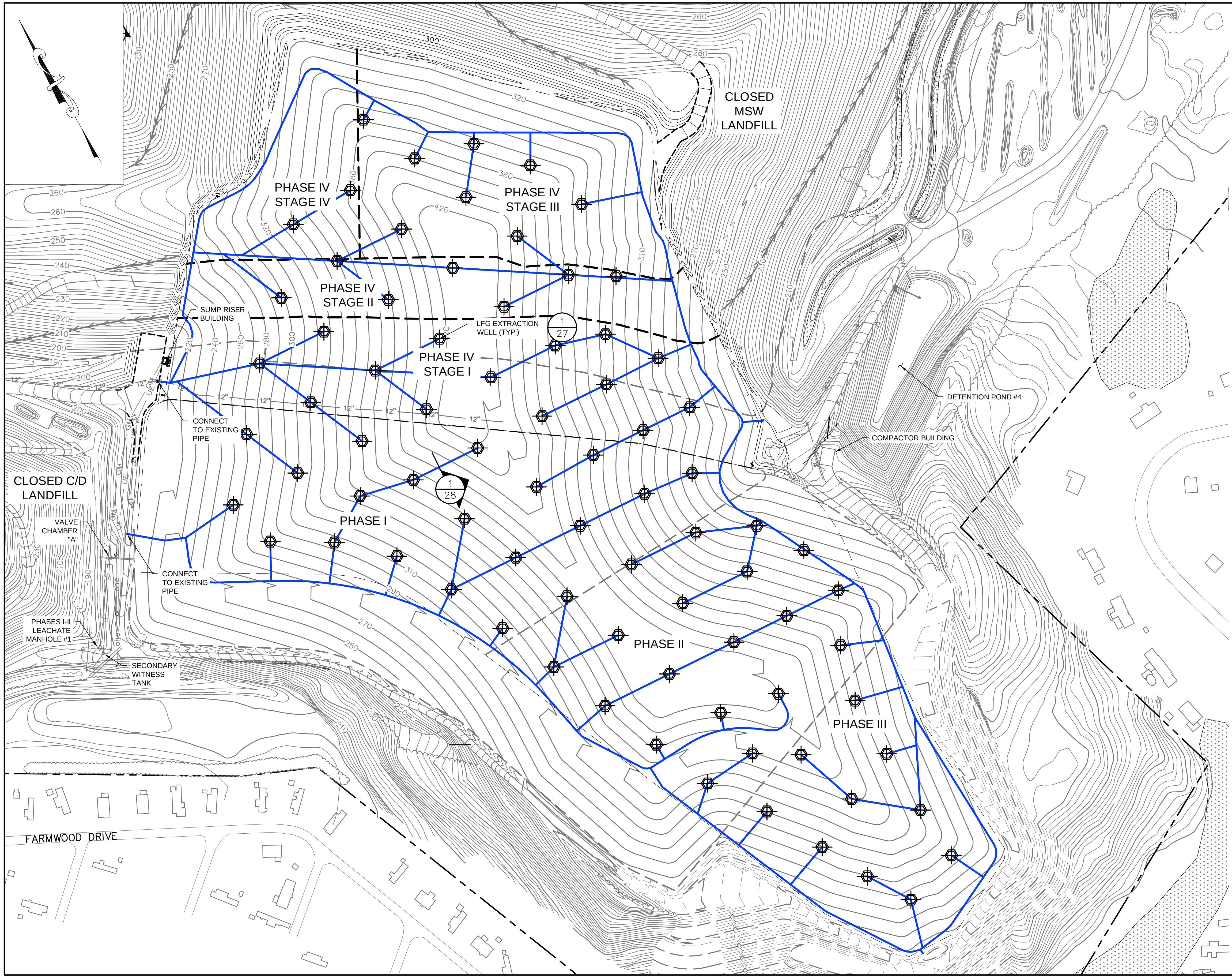
DRAWN BY: E. GALVIN
DESIGNED BY: E. GALVIN
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

FINAL CAPPING DETAILS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
25 OF 28



NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. EXISTING GAS EXTRACTION WELL AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.
3. CONDENSATE TRAPS THAT DRAIN TO LEACHATE CLEANOUTS SHALL BE INSTALLED AT HEADER LOW POINTS.

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

GRAPHICAL SCALE
120' 60' 0' 120' 240'

ERIC SCOTT STEINHAUSER No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L. TEAL
DESIGNED BY: L. TEAL
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

GAS COLLECTION AND CONTROL SYSTEM PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
26 OF 28

IMAGES: E:\SteinhauserNH.tif

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.\XREFS\Proposed Waste Grades.dwg
.\XREFS\Phases I Through III Waste Grades.dwg
.\XREFS\LIMITS.dwg

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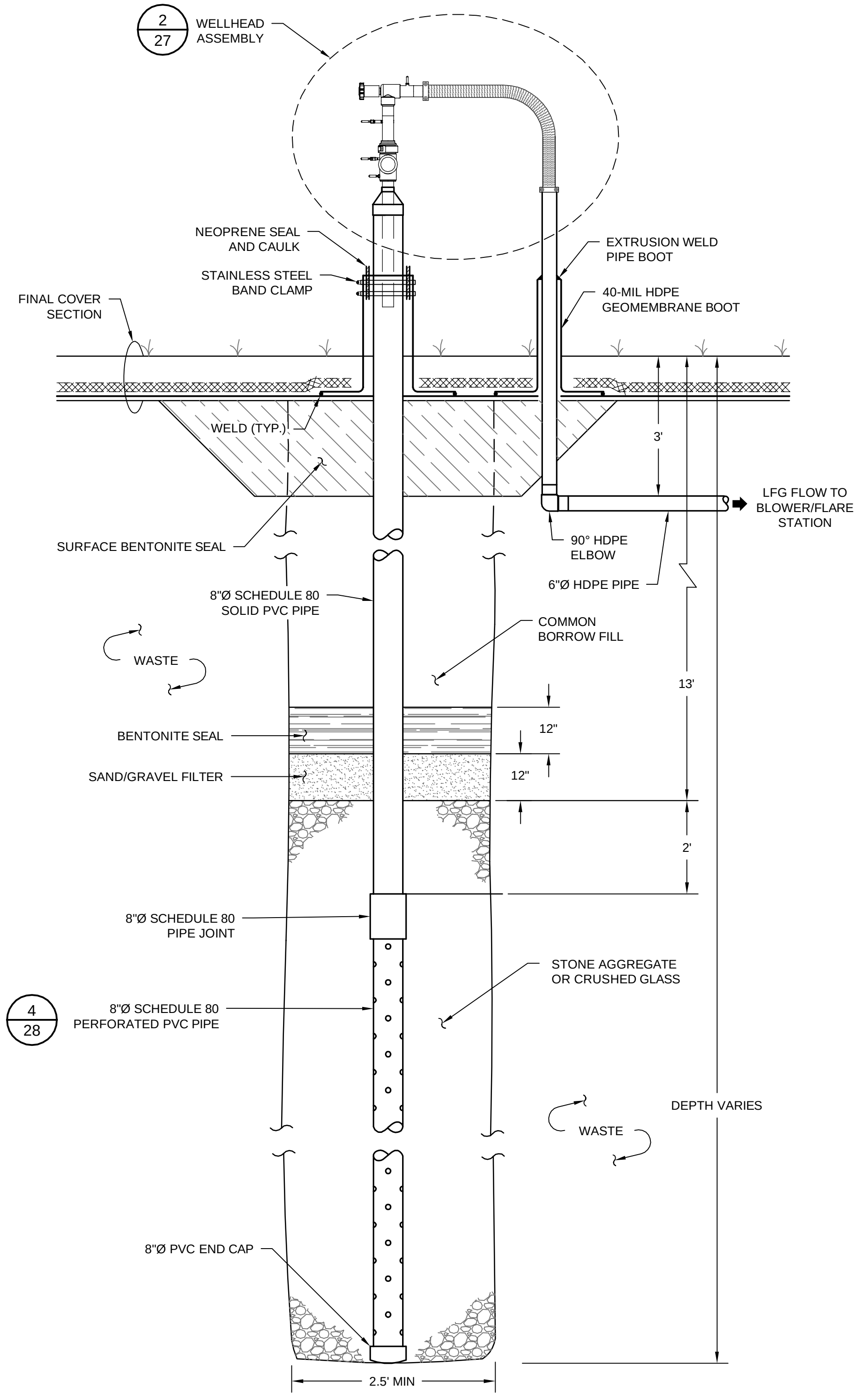
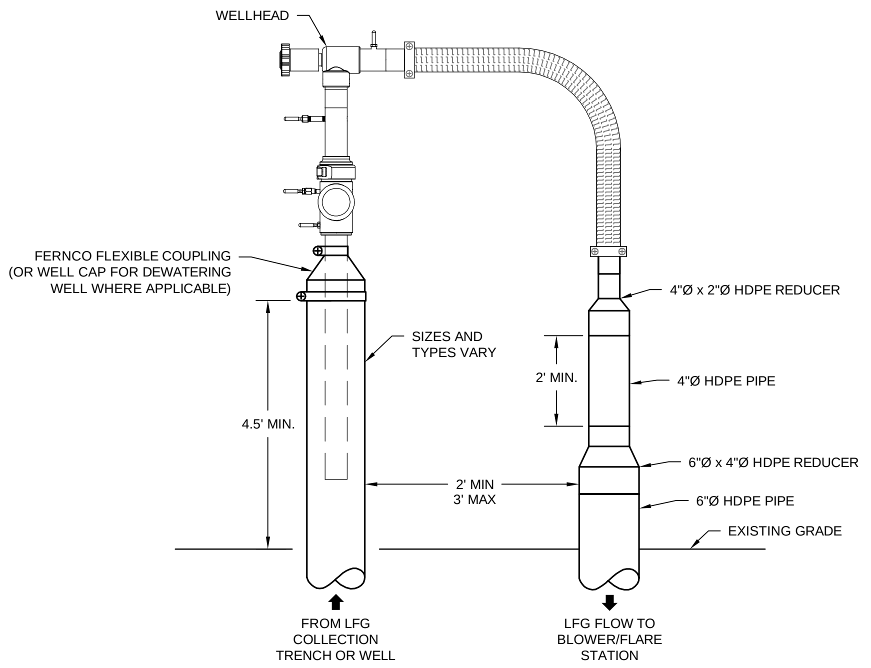


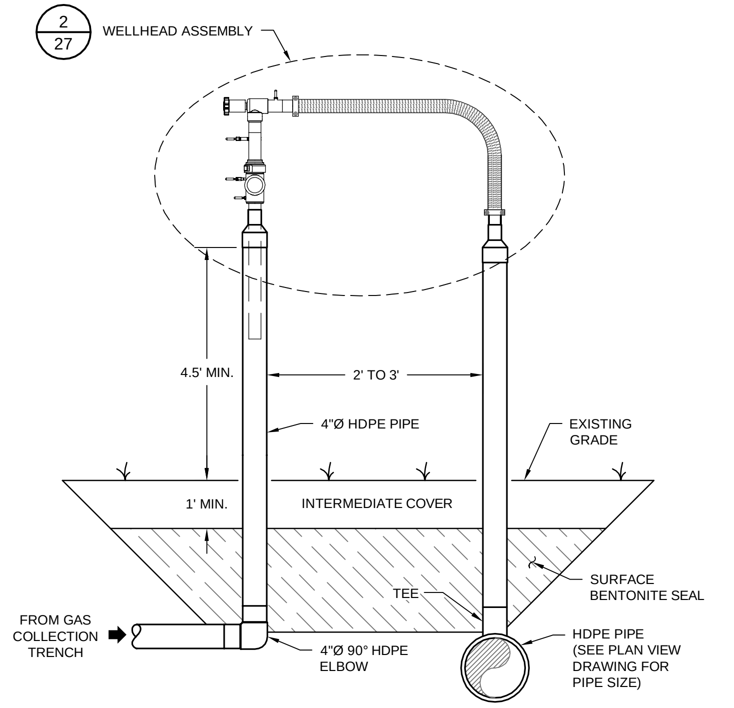
1 LFG EXTRACTION WELL

NOT TO SCALE



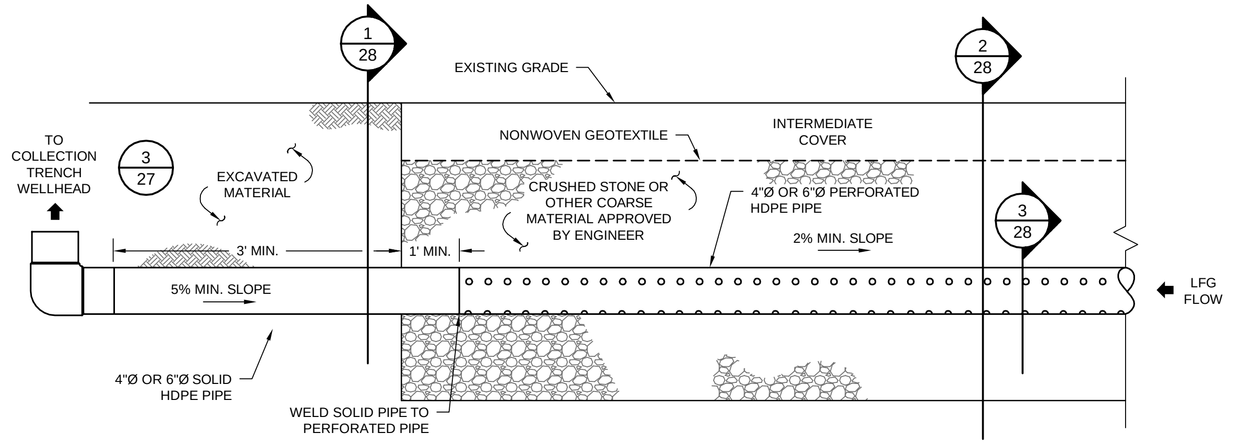
2 WELLHEAD ASSEMBLY

NOT TO SCALE



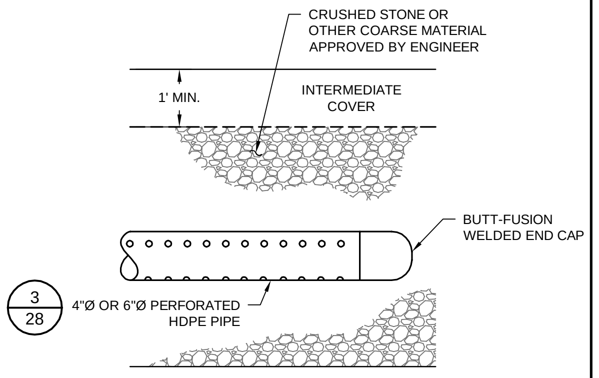
3 COLLECTION TRENCH WELLHEAD

NOT TO SCALE



4 GAS COLLECTION TRENCH TRANSITION

NOT TO SCALE



5 PERFORATED PIPE TRENCH TERMINATION

NOT TO SCALE

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE AS NOTED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

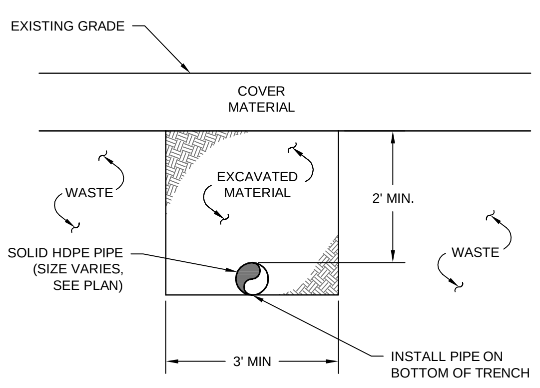
DRAWN BY: L. TEAL
DESIGNED BY: L. TEAL
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

GAS COLLECTION AND CONTROL SYSTEM DETAILS

PROJECT NUMBER:
3066.11

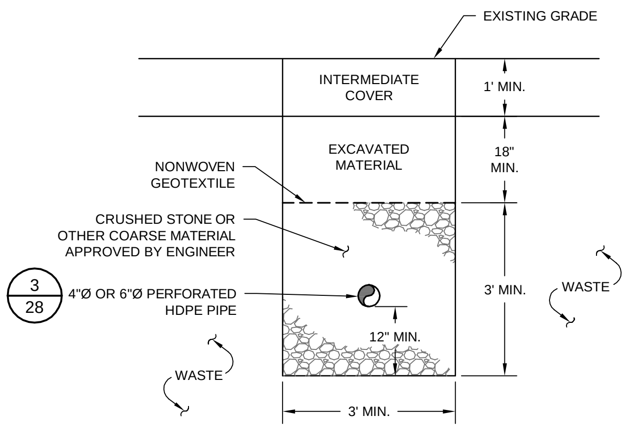
SHEET NUMBER:
27 OF 28



SOLID LFG PIPE TRENCH

1

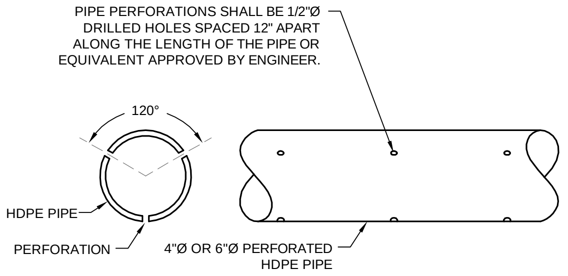
NOT TO SCALE



PERFORATED PIPE TRENCH

2

NOT TO SCALE

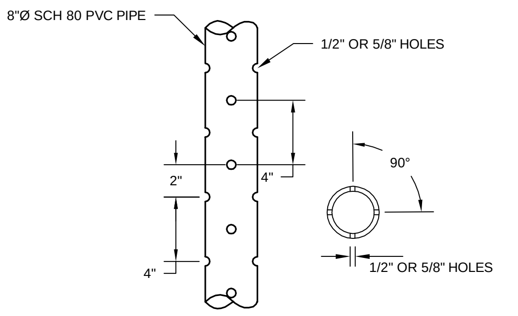


PERFORATED HDPE PIPE

3

NOT TO SCALE

(GAS COLLECTION TRENCH)



NOTES:

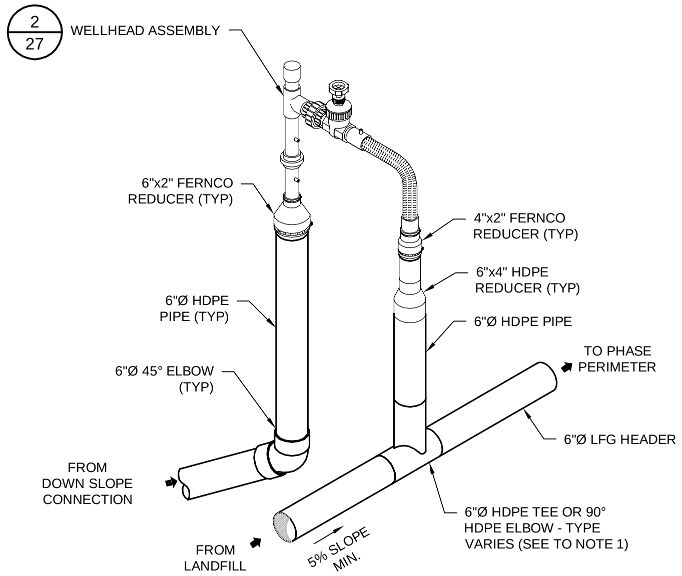
1. PERFORATIONS SPACED 90° APART HORIZONTALLY.
2. PERFORATIONS SPACED 4" APART VERTICALLY.
3. 90° AND 270° ROWS STAGGERED 2" BELOW 0° AND 180° ROWS.

PERFORATED PVC PIPE

4

NOT TO SCALE

(LFG EXTRACTION WELL)



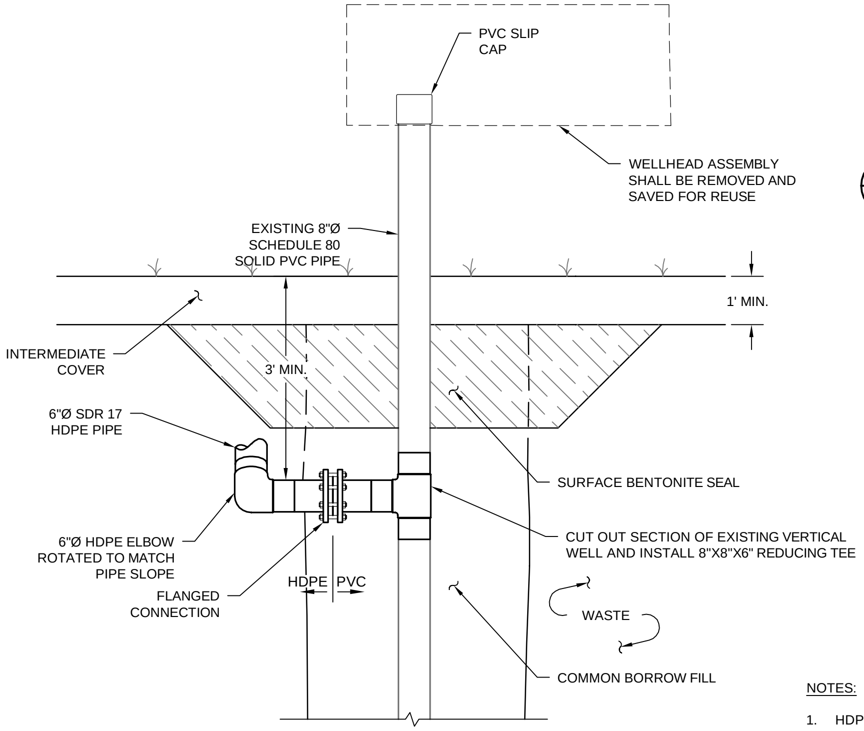
NOTE:

1. INSTALL A 6"Ø HDPE TEE WHEN LFG HEADER PASSES BY WELLHEAD. INSTALL A 6"Ø HDPE 90° ELBOW WHEN LFG HEADER ENDS AT WELLHEAD.

REMOTE WELLHEAD

5

NOT TO SCALE



NOTES:

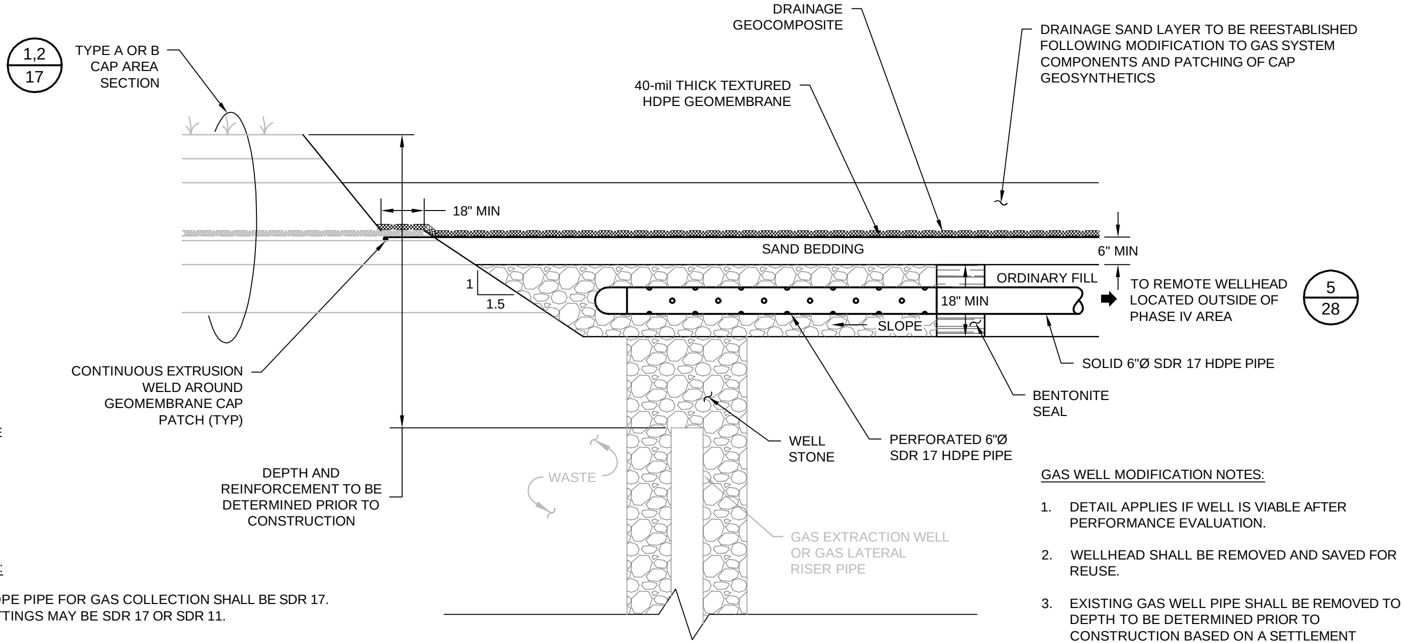
1. REPAIR OR REPLACE IN KIND DISTURBED INTERMEDIATE COVER AND BENTONITE SEAL

LFG EXTRACTION WELL MODIFICATION

6

NOT TO SCALE

PHASE I AND PHASE II AREAS



NOTES:

1. HDPE PIPE FOR GAS COLLECTION SHALL BE SDR 17. FITTINGS MAY BE SDR 17 OR SDR 11.
2. SOLID HDPE PIPE SHALL BE BUTT-FUSION WELDED UNLESS OTHERWISE INDICATED.
3. ON LANDFILL SIDESLOPES, PROVIDE MINIMUM 2 FEET OF COVER OVER SOLID HDPE PIPE AND STABILIZE AGAINST EROSION.
4. SOLID PIPE OUTSIDE LIMIT OF WASTE SHALL BE BACKFILLED WITH CLEAN MATERIAL.

GAS WELL MODIFICATION NOTES:

1. DETAIL APPLIES IF WELL IS VIABLE AFTER PERFORMANCE EVALUATION.
2. WELLHEAD SHALL BE REMOVED AND SAVED FOR REUSE.
3. EXISTING GAS WELL PIPE SHALL BE REMOVED TO A DEPTH TO BE DETERMINED PRIOR TO CONSTRUCTION BASED ON A SETTLEMENT EVALUATION.
4. REINFORCEMENT (SUCH AS A GEOGRID) SHALL BE INSTALLED ABOVE THE GAS EXTRACTION WELL AND BENEATH THE PHASE IV AS NECESSARY IN ACCORDANCE WITH A SETTLEMENT EVALUATION PERFORMED PRIOR TO CONSTRUCTION.

LFG EXTRACTION WELL MODIFICATION DETAIL

7

NOT TO SCALE

CLOSED MSW LANDFILL AREA

- NOT FOR CONSTRUCTION -

FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

SCALE AS NOTED

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: L. TEAL
DESIGNED BY: L. TEAL
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

GAS COLLECTION AND CONTROL SYSTEM DETAILS

PROJECT NUMBER:
3066.11

SHEET NUMBER:
28 OF 28

IMAGES: E:\Steinhauser-NH.tif

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APPENDIX C

HYDROGEOLOGICAL INFORMATION

SANBORN HEAD
Building Trust. Engineering Success.

HYDROGEOLOGIC REPORT
Phase IV Expansion Area
NASHUA FOUR HILLS LANDFILL
Nashua, New Hampshire
NHDES Site No. 198403099

Prepared for City of Nashua
File No. 3066.12
July 2020

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1.0 INTRODUCTION

Sanborn, Head & Associates, Inc. (Sanborn Head) prepared this hydrogeologic report as part of the application for a Type I-A Modification to Solid Waste Management Facility Permit (Type I-A PMA) for the Phase IV Secure Landfill Expansion, a proposed lined disposal area at the Four Hills Landfill Facility (Facility) in Nashua, New Hampshire. This report was prepared to satisfy the siting and groundwater and surface water monitoring requirements of the New Hampshire Solid Waste Rules (specifically Env-Sw 800) and is subject to the limitations in Appendix A of this report.

1.1 Purpose

This hydrogeologic report characterizes the geologic and hydrologic conditions in the vicinity of the proposed Phase IV expansion area for the purposes of:

- Demonstrating the suitability of the Phase IV expansion area for development as a municipal solid waste (MSW) landfill according to: Env-Sw 804.02 Groundwater Protection Standards; Env-Sw 804.03 Surface Water Protection Standards; and Env-Sw 804.05 Geologic Siting Limitations;
- Presenting data for the design of the Phase IV expansion; and
- Proposing locations for groundwater monitoring wells and surface water monitoring locations as required in Env-Sw 805.08 Groundwater and Surface Water Monitoring System Design Standards.

The Phase IV expansion area is located between the closed, unlined landfill and the lined Phase I disposal area. These areas of the Facility that have been the subject of historic hydrogeologic and surface water reporting to the New Hampshire Department of Environmental Services (NHDES). Therefore, this report summarizes the hydrologic and geologic data that has been transmitted to the NHDES in the form of annual groundwater monitoring reports and reports or applications that supported the permitting and construction of the lined disposal areas (i.e., Phases I, II, and III). A list of these reports and submittals are provided in Section 1.4.

1.2 Location and Background

The 294-acre[1] Facility is located at 840 West Hollis Street (Parcel 0000D-00054-CI) within the Nashua River watershed (see Locus Plan, Figure 1). The Facility is owned and operated by the City and serves as its primary waste disposal and recycling location.

The Facility was developed from agricultural and forested land. According to the City Zoning Map, the Facility property is zoned as “R-30 A Suburban Residence,” and the surrounding area includes suburban residential zoned land[2]. Trestle Brook is located along the northern property boundary and flows from the eastern side of the property in a northwest direction towards the Nashua River.

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[1] http://assessing.gonashua.com/Summary.asp?AccountNumber=39412

[2] City of Nashua – Zoning Map, prepared by the City of Nashua, revised January 2017; accessed via https://www.nashuanh.gov/DocumentCenter/View/3832

As shown on Figure 2, the Facility includes: (i) two unlined landfills; (ii) the lined Secure Landfill (disposal areas known as Phases I, II, and III); (iii) a landfill gas to energy facility. (iv) a residential drop-off area; (v)a municipal operations and maintenance building; (vi) a leaf/yard waste compost area; and (vii) wooded areas. Since 1971, the City has operated the Facility as a disposal facility for MSW and construction and demolition debris (C&D). The unlined 11-acre C&D landfill was active until 1994 and closed with a synthetic capping system between 1997 and 1998. The approximately 60-acre unlined MSW landfill was operated until August 2003 and closed with a synthetic cap in fall of 2003. MSW disposal operations began in the lined Phase I area in 2000. MSW disposal operations began in the lined Phase II area in 2009. MSW disposal operations are anticipated to begin in the lined Phase III area in 2020.

1.3 Project Description

The Phase IV expansion will cover approximately 32.4 acres. This area includes 11.3 acres of vertical expansion on top of the northeastern side of the lined Phases I and II. The Phase IV liner will be tied to the liner of Phases I and II at the existing perimeter berm and will overlay about 16.9 acres on the southwestern side of the closed, unlined MSW landfill, and approximately 4.2 acres in between the two disposal areas. This central area currently consists of an existing access road between the landfills, and miscellaneous infrastructure (e.g., monitoring wells, gas wells, drainage features). Details of the Phase IV expansion are included Design Report and Drawings (Appendices A and B, respectively) of the Type I-A PMA.

1.4 Previous Studies

Many hydrogeologic and geotechnical studies were performed in association with the Facility and its vicinity to support the more than 40-years of Facility operations and permitted construction projects. Public references (geologic maps, hydrologic data) are referenced in-line in subsequent sections. Key studies reviewed as part of this report are listed below. Unless otherwise noted, all reports were prepared on behalf of the City.

- ***Sanitary Land Fill, Four Hills Site, Nashua, New Hampshire***, (Haley & Aldrich, Inc.; 1969) presents the results of the subsurface soil exploration for the Facility prior to its development. Exploration activities documented include seismic traverses, test pits, test borings, and soil sampling. Additional items of interest include geologic cross sections, test pit logs, and boring logs for locations B-2 through B-19.

- ***Hydrogeological Report for a Secure Expansion of the Four Hills Landfill, Nashua, New Hampshire***, (Caswell, Eichler & Hill, Inc.; 1992) presents the hydrogeologic assessment of characteristics relevant to a secure landfill expansion and regulatory requirements at the time. Exploration activities documented include electromagnetic terrain anomaly mapping, fracture trace analysis, test boring and soil sampling, monitoring well installation, water level measurements, permeability/hydraulic conductivity testing, and water quality sampling. Additional items of interest include hydrogeologic cross sections, bedrock surface topography and groundwater elevation contours.

- ***Secure Expansion – Phase I Groundwater Separation Demonstration, Nashua Four Hills Landfill, NHDES Permit #DES-SW-SP-95-002,*** (CMA Engineers, Inc.; January 19, 1999) documented topographic modifications and resultant groundwater elevation changes performed as part of the 1996 Phase I Site Work Contract and demonstrated the six-foot groundwater separation distance for the Phase I expansion. This letter also includes logs for piezometers PZ-05 through -14, water level time series plots, and a groundwater contour plan.

- ***Phase I Type II Permit Modification Application (with Amendments), Nashua Four Hills Landfill Expansion,*** (CMA Engineers, Inc., March 16, 1999) provides information supporting the Type II permit modification in accordance with the Solid Waste Facility and Groundwater Permits for the Facility. This application includes an operation plan, design documentation report, closure plan, and groundwater monitoring plan.

- ***Site Specific Permit Application, Four Hills Landfill, Phase I Secure Solid Waste Landfill Expansion, City of Nashua, NH,*** (CMA Engineers, Inc.; March 19, 1999) provided the information required for the Phase I expansion permit application to NHDES, including a project narrative and pre- and post-development conditions.

- ***June/July 2011 Groundwater Monitoring Data Review, Nashua Four Hills Landfill, DES Site # 198403099***, (City of Nashua, New Hampshire; September 14, 2011) provided a summary of monitoring well installation data, groundwater quality data, and groundwater quality technical review comments to NHDES in response to a May 12, 2011 letter from NHDES to the City.

- ***Application for NHDES Type II Modification to Solid Waste Management Facility Permit, Phase II Four Hills Secure Lined Landfill Expansion, City of Nashua, New Hampshire,*** (CMA Engineers, Inc.; August 2007, revised December 2007) provided the information required for the Phase II expansion permit application to NHDES. Components of the application of interest include Section 4.0 Groundwater Separation Demonstration and related water level contour figures and cross-sections, and the project narrative, which provided historical development information.

- ***Application for NHDES Type II Permit Modification – Groundwater Separation Demonstration (Supplemental Submittal) NHDES Permit # DES-SW-SP-95-002, CMA #653, City of Nashua, New Hampshire, Four Hills Landfill – Phase II Expansion,*** (CMA Engineers, Inc., January 30, 2008) provides additional information to NHDES to support the groundwater separation demonstration for the Phase II landfill. Items of interest include boring logs for P-201 and P-202 in the Phase II area, water elevation data, cross-sections, and water level contour plans.

- ***Groundwater Management and Release Detection Permit No. GWP-198403099-N-05***, (NHDES; June 15, 2016, revised 2019) was reviewed for groundwater monitoring requirements for the current permit.

- ***2019 Annual Report, Nashua Four Hills Landfill, Nashua, New Hampshire,*** (Sanborn Head; February 1, 2020), presents the results of annual water quality testing completed pursuant to the Groundwater Management and Release Detection Permit (GWP-198403099-N-005). This report includes recent and historical groundwater and surface water elevation measurements, water quality results, and a summary of the data.

- ***Phase III Groundwater Separation Demonstration, Nashua Four Hills Landfill, Nashua, New Hampshire,*** (Sanborn Head; June 2019), presents the results of monthly groundwater elevation monitoring at monitoring wells around the Phase III Landfill Expansion Area.

The data from these previous studies, particularly bedrock elevations, overburden thicknesses, and groundwater elevations, inform the basis for the hydrogeologic conceptual model. Logs for groundwater monitoring wells that are currently present within the Phase IV expansion area are provided in Appendix B to this report.

2.0 SUMMARY OF HYDROGEOLOGIC CONDITIONS

This section presents a general summary of the physiographic setting, bedrock geology, surficial geology, surface water hydrology, and groundwater flow conditions at the Facility. As previously mentioned, the Phase IV expansion area is located within the same area as Phases I, II, and III, and the closed, unlined MSW landfill, and as such, the hydrogeologic information obtained for those areas is directly relevant and pertinent to the proposed Phase IV expansion. Pursuant to the current permit requirements (GWP-198403099-N-005), groundwater quality is monitored and reported as part of annual reports[3].

2.1 General Setting

The Facility is in the Nashua River valley with topography and surficial geology strongly influenced by Pleistocene glaciations. Topography in the Facility area ranges from approximately 300 feet above mean sea level (ft amsl) in the eastern portion of the Facility to around 170 ft amsl along the northeastern boundary in the vicinity of Trestle Brook, and along the western boundary of the Facility. The regional topographic setting is shown on Figure 1, and Facility topography is shown on Figure 2.

2.2 Surface Water

Regional hydrology in the vicinity of the Facility has been the subject of past U.S. Geological Survey (USGS) studies by Toppin[4]. According to the USGS watershed boundary dataset, the western portion of the Facility is located within the Unkety Brook-Nashua River drainage, while the eastern edge of the Facility is located within the Salmon Brook drainage. The western property boundary is approximately 0.2 to 0.5 miles from the Nashua River.

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[3] Sanborn Head (January 2020), 2019 Annual Groundwater Report.

[4] Toppin, K.W. (1987), Hydrogeology of stratified drift aquifers and water quality in the Nashua Regional Planning Commission Area, South-central New Hampshire, Water-Resources Investigations Report 86-4358, prepared in cooperation with the Nashua Regional Planning Commission and the New Hampshire Water Resources Board.

Surface water conditions at the Facility are summarized on Figure 3. As indicated on Figure 3 there are wetland areas to the southeast and northwest of the existing landfills. Trestle Brook, located to the north of the closed, unlined MSW landfill, flows generally from east to west towards the Nashua River. Pursuant to the current permit requirements (GWP-198403099-N-005), surface water quality is monitored at two locations on Trestle Brook, and results are reported as part of annual reports[5].

The Federal Emergency Management Agency (FEMA) database was reviewed to assess if the Facility is located within any 100-year flood plain areas. Review of the FEMA data shows that the Facility is not located in a 100-year floodplain zone, and as shown on Figure 4 the nearest flood zone is greater than 1,000 feet from Phase IV. In addition, based on review of information obtained from the NHDES OneStop Program, there are no surface water reservoirs or intakes used for community drinking water supply located downgradient of the Facility on the Nashua River. On the Nashua River, the Mine Falls Dam is located approximately 1.6 miles (downriver) for the Facility. On Trestle Brook, the Holden Dam is located approximately 0.4 miles (2,112 feet) up gradient (upriver) from the Facility. Also, there are no surface water intakes indicated for these dams.

2.3 Surficial Geology

The surficial or overburden geology at the Facility is characterized by glacial till, glaciofluvial and glaciolacustrine deposits. A portion of the regional surficial geologic map that includes the Facility is portrayed in Figure 5 and a brief summary of the surficial geology present in the vicinity of the Facility, as described by Koteff and Volckmann[6], CEH[7] and CMA[8], is summarized below in general order from oldest to youngest deposits:

- Till – Four north-south trending drumlins exist or previously existed at the Facility. Quaternary-aged till present at the Facility consists of unsorted clay, silt and fine to medium sand with some gravel. The till can be divided into two layers: (1) relatively less-weathered gray basal till, and (2) relatively more weathered brown till. According to the CEH 1992 hydrogeologic assessment[9], the gray basal till ranges in hydraulic conductivity from $3.5\text{x}10^{-5}$ cm/s to $9.4\text{x}10^{-8}$ cm/s, and the brown till ranges in permeability from $2\text{x}10^{-4}$ cm/s to $2.6\text{x}10^{-6}$ cm/s.

- Glacial lake deposits – Quaternary-aged glacial lake deposits, consisting of coarse sand and gravel associated with kame deltas, fluvial sediments, and lake-bottom sediments are exposed in the western and southern portions of the Facility. These sediments reportedly on-lap the till deposits. According to the CEH 1992 hydrogeologic

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[5] Sanborn Head (January 2020), https://www4.des.state.nh.us/IISProxy/IISProxy.dll?ContentId=4696667.

[6] Koteff, C. and Volckmann, R.P. (1973), Surficial Geologic Map of the Pepperell Quadrangle, Middlesex County, Massachusetts, and Hillsborough County, New Hampshire, scale 1:24,000 (https://pubs.er.usgs.gov/publication/gq1118).

[7] CEH (1992), Hydrogeologic Report for a Secure Expansion of the Four Hills Landfill, Nashua, New Hampshire.

[8] Type II Permit Modification for Phase II Secure Landfill Expansion, prepared by CMA Engineers, Inc., dated August 2007, and supplemental submittal dated January 2007.

[9] CEH (1992), Hydrogeologic Report for a Secure Expansion of the Four Hills Landfill, Nashua, New Hampshire.

assessment[10], the lake deposits range in hydraulic conductivity from 1x10^{-3} cm/s to 5.87x10^{-3} cm/s, with an average value of 2.8x10^{-3} cm/s.

Overburden descriptions from historical boring logs in the proposed Phase IV expansion footprint[11] are generally consistent with the regional geology. Within the immediate proposed Phase IV expansion area, the overburden materials have been modified from landfill activities. The eastern portion of the Facility includes the closed, unlined MSW landfill, while the western portion of the Facility includes the closed, unlined C/D landfill and the lined Phase I disposal area. An access road for the Phase II and Phase III disposal areas extends northwest-southeast through the Facility. The proposed Phase IV expansion area, when not coinciding with existing landfill materials, overlies a combination of till and glacial lake deposits based on the surficial geologic plan portrayed in Figure 5.

2.4 Bedrock Geology

The regional bedrock geologic map[12] is provided as Figure 6. According to the regional geologic map, bedrock in the area primarily consists of Late to Early Devonian two-mica granite. The western portion of the Facility is underlain by rocks from the Ordovician- to Silurian-aged Berwick Formation (Merrimack Group), which includes purple biotite-feldspar-quartz granofels or schist with interbeds of calcsilicate granofels and minor pelites.[13] The eastern portion of the Facility is underlain by Devonian-aged Exeter Diorite, which consists of diorite, gabbro, and two-mica granite.[14] The eastern portion of the Facility has also been mapped as the Chelsmford Granite, a Devonian-aged two-mica granite[15]. As interpreted on Figure 7, bedrock elevations in the vicinity of Phase IV range from approximately 140 to 190 feet above mean sea level (ft amsl)[16].

Rock cores collected by CEH as part of their 1992 hydrogeologic assessment[17] are consistent with the bedrock geologic mapping: metasedimentary rocks (primarily schist) were observed in most of the Facility, and granitic bedrock, likely the Chelmsford Granite, was observed in borings B-11T and B-3R located in the southeastern portion of the Facility. According to the rock quality designations for B-10R, B-12TR, B-14R, B-17R, B-18DR, B-18SR, B-19DR, and B-19SR as summarized in the 1992 Hydrogeologic Investigation (Table II), the upper 10 feet of bedrock is more fractured compared to deeper intervals. Hydraulic

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[10] CEH (1992), Hydrogeologic Report for a Secure Expansion of the Four Hills Landfill, Nashua, New Hampshire.

[11] Boring logs are available from B-5S/R, B-6, and B-18S/R.

[12] Digital representation of Lyons, J.B., Bothner, W.A., Moench, R.H., and Thompson, J.B., Jr. (1997), Bedrock geologic map of New Hampshire: U.S. Geological Survey, scale 1:250000; accessed via nhdesonestop.sr.unh.edu; Also described in Walsh, G. J., Jahns, R. H., and Aleinikoff, J. N. (2013), Bedrock Geologic Map of the Nashua South Quadrangle, Hillsborough County, New Hampshire and Middlesex County, Massachusetts, U. S. Geological Survey Scientific Investigations Map 3200.

[13] Ibid.

[14] Ibid.

[15] Robinson, G.R. (1978), Bedrock geologic map of the Pepperell, Shirley, Townsend quadrangles, and part of the Ayer quadrangle, Massachusetts and New Hampshire, U.S. Geological Survey Miscellaneous Field Studies Map MF-957.

[16] Depth to bedrock are interpreted based on historical boring logs.

[17] CEH (1992), Hydrogeologic Report for a Secure Expansion of the Four Hills Landfill, Nashua, New Hampshire.

conductivity values in the bedrock reported in the CEH 1992 hydrogeologic assessment ranged from 6.9x10^{-7} centimeters per second (cm/s) to 1.6x10^{-4} cm/s; discounting the high and low outliers, the average permeability in bedrock was reported to be 1.5x10^{-5} cm/s[18].

The nearest fault lines, as identified from state geologic mapping and shown on Figure 6, are summarized below:

- Flint Hill Fault Zone –an approximately northeast-southwest orientation and is located approximately 2-miles west of the Facility[19] (refer to Figure 6). According to CEH's 1992 hydrogeologic assessment and references therein, displacement occurred along this fault in the Jurassic or more recently, based on cross-cutting of Mesozoic-aged dikes. As described in Bothner and Hussey[20] and references therein, the Flint Hill Fault extends from Maine to Massachusetts, where it continues as the Brook-Wekepeke fault system, and based on fracture pattern analysis of the fault in Raymond, NH, there was late Paleozoic through middle Mesozoic movement with up to 2 kilometers of down-to-the-east dip-slip motion based on petrologic data. Apatate and fission-track age dating indicates the Wekepeke fault was also active in the Mesozoic with displacement in the Middle Cretaceous[21]. A published literature search did not produce records suggesting more recent displacement than the Miocene. The Flint Hill Fault does not appear in the U.S. Geological Survey Quaternary Faults and Folds Database[22].

- Unnamed Fault 1 – an approximately northeast-southwest orientation and is located approximately 1 mile east of the Facility. A published literature search did not produce records suggesting more recent displacement than the Miocene. The fault is not included in the U.S. Geological Survey Quaternary Faults and Folds Database[23].

Based on Clark et al.[24], northeast and northwest trending lineaments, shown on Figure 6, are observed in the vicinity of the Facility. In addition, a 1992 stereographic assessment by CEH summarized in their 1992 hydrogeologic assessment identified several lineaments within the Facility property boundary with azimuths primarily trending east-west, and additional features trending northwest and northeast, although the CEH study acknowledged the difficulty in identifying bedrock lineaments due to the thickness of the

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[18] CEH (1992), Hydrogeologic Report for a Secure Expansion of the Four Hills Landfill, Nashua, New Hampshire.

[19] CEH describes this fault zone as "immediately to the west of the study area."

[20] Bothner, W.A. and Hussey, A.M. II (1999), Norumbega Connections: Casco Bay, Maine to Massachusetts? In Ludman A., and West, D.P., Jr. eds, Norumbega Fault System of the Northern Appalachians: Boulder Colorado, Geological Society of America Special Paper 331.

[21] Potter, J.K., Winch, J.L., Roden-Tice, M.K., Reiners, P.W., West, D.P. Jr., Wintsch, R.P. (2005), Mid-Cretaceous Fault Reactivation in Central New England: Evidence from (U-Th)/He and Apaatite Fission-Track Thermochronology, Geological Society of America Abstracts with Programs, vol. 37, no. 1, p. 77.

[22] U.S. Geological Survey (2006), Quaternary fault and fold database for the United States, accessed December 17, 2018, from USGS web site: http//earthquake.usgs.gov/hazards/qfaults/.

[23] U.S. Geological Survey (2006), Quaternary fault and fold database for the United States, accessed December 17, 2018, from USGS web site: http//earthquake.usgs.gov/hazards/qfaults/.

[24] Clark, S.F., Jr., Ferguson, E. W., Picard, M. Z., and Moore, R. B. (1997), Lineament map of Area 2 of the New Hampshire bedrock aquifer assessment, south-central New Hampshire. U.S. Geological Survey Open File Report 96-490.

overburden material in the vicinity of the Facility. As indicated on Figure 6, the distance between the identified faults and the proposed Phase IV area exceeds the minimum setback distance of 200 feet. Published references reviewed as part of this report[25,26] indicate lack of evidence for faults near the Facility that have had displacement in Holocene time (i.e., within the last 11,000 years). Based on our review of the available geologic literature summarized below, there are no known areas of karstified dolomite, karstified limestone, or areas susceptible to mass movements of earth material such as landslides, rockfalls, mudslides, slumps, earth flows, or subsidence. In addition, the Facility has been operational for over 40 years, and no such issues of unstable ground or geologic formations are known at the Facility. The following literature resources and LIDAR data was reviewed to support this interpretation:

- Bennett, D.S., Lyons, J.B., Wittkop, C.A., and Dicken, C.L. (2006), Bedrock geologic map of New Hampshire, a digital representation of Lyons and others 1997 map and ancillary files: U.S. Geological Survey Data Series 215, 1 CD-ROM; accessed via NHDES OneStop27.
- Lyons, J.B., Bothner, W.A., Moench, R.H., and Thompson, J.B., Jr. (1997), Bedrock geologic map of New Hampshire: U.S. Geological Survey Special Map, 2 map sheets, scale 1:250,000.
- U.S. Geological Survey (2006), Quaternary fault and fold database for the United States, accessed December 17, 2018, from USGS web site: http//earthquake.usgs.gov/hazards/qfaults/.
- U.S. Geological Survey (2018), New Hampshire Earthquake Information Website. https://earthquake.usgs.gov/earthquakes/byregion/newhampshire.php. Accessed May 17, 2018.
- Wheeler, Russell L. (2006). Quaternary tectonic faulting in the Eastern United States. Engineering Geology 82, 165-186.
- Weary, D.J. and Doctor, D.H. (2014), Karst in the United States: A Digital Map Compilation and Database, U.S. Geological Survey Open-File Report 2014-1156.
- Tobin., B.D., and Weary, D.J. (2004), Digital Engineering Aspects of Karst Map : A GIS version of Davies, W.E., Simpson, J.H., Ohlmacher, G.C., Kirk, W.S., and Newton, E.G. (1984), Engineering aspects of karst: U.S. Geological Survey, National Atlas of the United States of America, scale 1:7,500,000, U.S. Geological Survey Open-File Report 2004-1352.
- LIDAR data accessed via NHDES Onestop on December 28, 2018.

2.5 Groundwater Flow Conditions

Groundwater elevation data within the proposed Phase IV area and vicinity are collected as part of on-going monitoring and reporting activities[28]. A summary of the water level measurement data is compiled on Table 1. Figures 8 and 9 depict in plan-view the

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[25] Crone, A.J., Wheeler, R.L. (2000), Data for Quaternary faults, liquefaction features, and possible tectonic features in the central and eastern United States, east of the Rocky Mountain front. U.S. Geological Survey Open-File Report 00-0260. 341 pp.

[26] U.S. Geological Survey (2006), Quaternary fault and fold database for the United States, accessed December 17, 2018, from USGS web site: http//earthquake.usgs.gov/hazards/qfaults/.

[27] http://nhdesonestop.sr.unh.edu/html5viewer/#.

[28] Ibid

equipotential water table surface based on November 2019 measurements from monitoring wells screened in overburden and bedrock, respectively.

Based on the contours as depicted in Figures 8 and 9, groundwater in both the overburden and underlying bedrock flows in an overall southeast to northwest direction across the Facility, which is consistent with ground surface topography. Local variations to this overall southeast-to-northwest flow pattern include a small area of more southerly flow, as indicated by the groundwater level data to the south/southwest of Phase II. Local groundwater "highs" coincide with local topographic highs and lower permeability till, while groundwater elevations are generally lower, and gradients are less steep, in lower areas with sandy soils (e.g. beneath the closed, unlined MSW landfill). Consistent with overall gradients, overburden and bedrock groundwater in the proposed Phase IV expansion area is inferred to flow generally from south/southeast to north/northwest based on measurements from MW-101SR, MW-102S, and other Facility monitoring wells.

Based on November 2019 groundwater elevation monitoring results and as shown in Figures 8 and 9, horizontal hydraulic gradients in overburden and bedrock in the center of the Phase IV expansion area (along the current access road) range from approximately 0.01 to 0.02 feet/feet (ft/ft). Upgradient (southeast) of the Phase IV expansion area, hydraulic gradients range from 0.02 to 0.015 ft/ft in overburden to 0.05 ft/ft in bedrock near the groundwater "high" indicated by B-13T and MW-107R. Downgradient (west) of the Phase IV expansion area, hydraulic gradients are nearly flat in bedrock and overburden based on groundwater elevation differences of ±0.4 feet and 2 feet in overburden and bedrock, respectively based on measurements from MW-103S/R, MW-104S/R, MW-105S/R, M-5, M-9/9R, M-11/11R, and M-1/1R. Groundwater elevations observed in MW-101 and MW-102 couplets indicate generally downward vertical hydraulic gradients between the intervals sampled by the monitoring well couplets. Based on calculations summarized in Table 2 and groundwater water level measurements from 2014 to 2019, vertical gradient potential[29] range from -0.14 ft/ft to -0.08 ft/ft between MW-101SR and MW-101DR, and from +0.01 to -0.07 ft/ft between MW-102S and MW-102R, excluding anomalous measurements in April 2016 indicating 0.38 and 0.23 ft/ft at the couplets, respectively.

In addition to reviewing groundwater conditions at the Facility, we have also made a review of information obtained from the NHDES OneStop Program to assess groundwater use within the vicinity. As shown on Figure 4, based on our review of this information, there are no public water supplies located within a 1-mile radius of the center of the Facility and the Facility is not sited within a well head protection area of a public water system. The nearest identified well head protection area for a public water system (System ID: 1625020) is located over 5,000 feet south of the Facility.

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[29] The vertical hydraulic gradient for each monitoring well couplet is defined as the vertical head difference divided by the vertical separation distance of the screen midpoint, expressed in units of feet per feet (ft/ft). The presence of a vertical gradient does not necessarily indicate hydraulic connection.

3.0 SEASONAL HIGH GROUNDWATER DEMONSTRATION

This section provides an assessment of site groundwater conditions to address Env-Sw 804.02 – Groundwater Protection Standards part (d), which states that the base of the bottom liner system should be a minimum of 6 feet above the seasonal high groundwater table. Groundwater level measurements within the Phase IV expansion area begin in 1999. As previously discussed in the Phase III Groundwater Separation Demonstration, groundwater elevation data measured at the site since May 2008 is representative for assessment of seasonal high groundwater elevations. Groundwater elevations measured prior to this date are not considered representative because construction of Phase I, Phase II and most recently Phase III have modified groundwater conditions due to excavation of overburden soils and reduced recharge due to construction of liner systems across the landfill footprint. Following installation of liners/caps in the Phase IV area, groundwater levels are anticipated to lower in the southern portion of the Facility due to a further reduction in recharge.

Groundwater monitoring wells within the footprint of the Phase IV area that are representative of water table conditions include MW-101SR and MW-102S. Based on measurements recorded since May 2008, groundwater elevations have ranged from approximately 181.38 to 182.51 ft amsl at MW-101SR and 183.68 to 187.30 ft amsl at MW-102S. These two groundwater monitoring locations are in the central roadway area between the lined and unlined landfills. This central roadway area corresponds approximately with the area of Phase IV that will have the lowest base grades. Therefore, these two monitoring wells are considered most representative for assessment of Env-Sw 804.02 (d). However, we have also reviewed other water table monitoring wells around the periphery of the Phase IV area to develop groundwater contours to assess seasonal high groundwater levels across the entire Phase IV footprint. Groundwater elevation data for these wells in provided in Table 1.

To assess seasonal high groundwater elevations at the site, each monitoring well data set was reviewed, and the maximum groundwater elevation value measured since April 2008 was chosen as representative of seasonal high groundwater elevations. The Charts provided in Appendix C show the groundwater elevation time series data for the period since May 2008 at the above described wells, and other representative wells adjacent to the Phase IV footprint (MW-103S, MW-104S, MW-105S, and MW-106S). The identified seasonal high value at each of these wells is indicated on the charts by a horizontal line (light-blue dash line) and show that the value is representative of the seasonal high during the last decade. The same approach was also used for other wells shown in Figure 10, which presents the seasonal high groundwater levels and the groundwater contours developed using this data. The only deviation from this approach is for monitoring wells that were monitored in support of the Phase III Groundwater Separation Demonstration. Monthly monitoring of groundwater monitoring points was performed for a subset of site wells as part of the Phase III Groundwater Separation Demonstration for the period from July 2018 to June 2019. During this monthly monitoring, the seasonal groundwater high occurred in the month of May 2019. Approximately weekly monitoring was performed in May 2019 to better identify the period during which the seasonal high elevations occurred. The May 7, 2019 groundwater elevations measured as part of the Phase III Groundwater

Separation Demonstration are considered representative of the seasonal high during the last decade in the Phase III area of the site.

The data and groundwater contours presented in Figure 10 will be used for the Phase IV design to demonstrate that there will be a minimum of 6 feet of separation distance between seasonal high groundwater elevation and the base of the bottom liner system of the Phase IV Landfill Expansion. Cross-sections A-A’ and B-B’ (Figure 11 and 12 respectively) depict the relationship between the proposed Phase IV base grades, the seasonal-high water table, and the bedrock surface.

4.0 SUMMARY OF COMPLIANCE WITH LANDFILL SITING REQUIREMENTS

This hydrogeologic report was prepared to address the requirements of the New Hampshire Solid Waste Rules, specifically the relevant parts of Env-Sw 804 – Siting Requirements for Landfills. This report is based on hydrogeologic information available for the Facility that encompasses the Phase IV expansion area. The findings of this hydrogeologic report are intended to support the design and permitting of the Type I-A PMA for the proposed Phase IV expansion. The following summarizes the individual rules pertinent to the finding of this report:

<u>Env-Sw 804.02 Groundwater Protection Standards.</u>
(a) A landfill shall not be sited within the well head protection area of a community or noncommunity, non-transient water supply well system as delineated in the department's source water protection area inventory.
As summarized in Section 2.5 of this report and shown on Figure 4, the Phase IV expansion will not be sited in areas listed in 804.02(a). Based on review of information obtained from the NHDES OneStop Program, there are no public water supplies located within a 1-mile radius of the center of the Facility and the Facility is not sited within a well head protection area of a public water system. The nearest well head protection area for a public water system (System ID: 1625020) is located over 5,000 feet south of the Facility.

(b) A landfill and all associated leachate storage units shall be located only in areas where groundwater monitoring for release detection, characterization and remediation can be conducted prior to a release having an adverse effect on a water supply.

This report presents information obtained as part of previous studies identified in Sections 1 and 2. These previous studies provide the information necessary to define the pre-construction and post-construction groundwater and surface water regimens. The findings of this report were used, in conjunction with the Phase IV expansion design, to develop recommendations for post-construction groundwater monitoring per Env-Sw 805. Further information relating to the design grades, specific recommendations for groundwater monitoring, and other aspects of Phase IV expansion design are presented in the Design Report included as part of the Type I-A PMA. Proposed replacement release detection monitoring wells for locations proposed for decommissioning as part of Phase IV expansion are summarized in Section 5.0.

(c) Identification of the areas cited in (b) above shall be based upon a hydrogeologic investigation which provides all site-specific information required to model the pre-construction and post-construction groundwater and surface water regimen.
This report presents information obtained as part of previous studies identified in Section 2. These previous studies provide the information necessary to define the pre-construction groundwater and surface water regimen as summarized in Section 2 and shown on Figures 3 and 10 of this report. Further information is provided in the text and figures of the Design Report included as part of the Type I-A PMA.

(d) The base of the bottom liner system, or the base of the facility if unlined, shall be a minimum of 6 feet above the seasonal high groundwater table and the confirmed bedrock surface.
As summarized in this report, the combined information from numerous previous studies provides a detailed understanding of the seasonal high groundwater table and the bedrock surface in the Phase IV expansion area. The information in this report was used to design a liner system that will be 6 feet or more above these surfaces. Further information is provided in the text and figures of the Design Report included as part of the Type I-A PMA.

<u>Env-Sw 804.03 Surface Water Protection Standards.</u>
(b) A landfill and all associated leachate storage units shall be located only in areas where potential adverse effects to surface water quality, due to erosion, sedimentation, siltation, flood, or discharge of contaminants, can be prevented or minimized and mitigated by facility design.
Information required to comply with 804.03(b) was obtained as part numerous previous studies. This information was used to design the Phase IV expansion to comply with 804.03(b) and further discussion of the design is provided in the Design Report included as part of the Type I-A PMA.

(c) Identification of the areas cited in (b) above shall be based on a thorough Hydrogeological investigation to demonstrate the following:

(1) Compliance with Env-Sw 804.02;
(2) That engineering design measures can be incorporated to control erosion, sedimentation and siltation; and
(3) The potential release of contaminants to surface waters can be prevented, attenuated or otherwise remediated.

This report presents information obtained as part of previous studies identified in Section 2. This report provides the information necessary to define the pre-construction groundwater and surface water regimen as summarized in Section 2 and Figures 3 and 10 of this report.

(d) The footprint of a landfill shall not be located within 200 feet of any perennial surface water body, measured from the closest bank of a stream and closest shore of a lake, as applicable.
As summarized in Section 2.2 and shown in Figure 3 of this report, the Phase IV expansion will not be sited within 200 feet of the features listed in 804.03(d).

(e) The footprint of a landfill shall not be located within 200 feet upgradient and 100 feet downgradient of a wetland within the jurisdiction of RSA 482-A, excluding any drainage appurtenances related to the site, that is not allowed to be filled under the authority of RSA 482-A.
As summarized in Section 2.2 and shown in Figure 3 of this report, there are no jurisdictional wetlands within 200 feet of the Phase IV expansion.

(f) The footprint of a landfill shall not be located within 1,000 feet upgradient of a surface water reservoir or intake used for a community drinking water supply.
As summarized in Section 2.2 of this report, the Phase IV expansion is not sited within 1,000ft of the features listed in 804.03(f).

(g) The footprint of a landfill shall not be located within the 100-year flood hazard zone.
As summarized in Section 2.2 and shown in Figure 4 of this report, the Phase IV expansion will not be sited within 200 feet of the features listed in 804.03(g).

Env-Sw 804.05 Geologic Siting Limitations.
(a) The footprint of a landfill and associated leachate storage units shall be a minimum of 200 feet from faults that have had displacement in Holocene time, meaning from Pleistocene to present or within the last 11,000 years.
As summarized in Section 2.4 and shown in Figure 6 of this report, the footprint of the Phase IV expansion and associated leachate storage units will be a minimum of 200 feet from the features listed in 804.05(a).

(b) No landfill footprint or associated leachate storage units shall overlie an area underlain by karstified dolomite or limestone or an area susceptible to mass movements of earth material such as landslides, rockfalls, mudslides, slumps, earth flows, or subsidence.
As summarized in Section 2.4 and shown in Figure 6 of this report, the footprint of the Phase IV expansion and associated leachate storage units will not be underlain by, or susceptible to, the features listed in 804.05(b).

5.0 GROUNDWATER MONITORING RECOMMENDATIONS

Env-Sw 805.02(a)(4) – Groundwater Monitoring System Requirements and Env-Sw 805.08 – Groundwater Monitoring System Design Requirements requires a groundwater monitoring system to consist of at least one hydraulically upgradient monitoring well and at least three monitoring wells in each hydraulically downgradient direction. The Phase IV expansion area is located within the Four Hills Landfill Groundwater Management Zone (GMZ) and a monitoring well network already exists at the Facility.

The proposed design of the Phase IV expansion area is anticipated to have an influence on groundwater table elevation as a result of construction activities and changing recharge conditions in the area between the closed, unlined MSW landfill and Phase I. As shown on Figure 13, five current groundwater release detection wells would be decommissioned, and four replaced wells installed prior to construction of the proposed Phase IV. A summary of the monitoring wells to be decommissioned is presented in Table 3 below.

Table 3 - Release Detection Wells Proposed for Decommissioning and Replacement

Location	Ground Elevation (ft amsl)	Well Depth (ft bgs)	Bottom Elevation (ft amsl)	Screen Length (ft)	Inferred Screen Elevation (ft amsl)	Screened Formation
MW-101SR	215.75	45.4	170.4	10	170.4 to 180.4	Bedrock
MW-101DR	215.83	59.8	156.0	10	156.0 to 166.0	Bedrock
MW-102S	225.08	45	180.1	10	180.1 to 190.1	Medium to fine sand
MW-102R	225.23	74.5	150.8	10	150.8 to 160.8	Bedrock
MW-108R	205.66	32	173.7	10	173.7 to 183.7	Bedrock

Notes:

1. Information referenced from Table I of the June/July 2011 Groundwater Monitoring Data Review Four Hills Landfill DES Site #198403099, prepared by City of Nashua, dated September 14, 2011.
2. Table I assumed that the bottom 10 ft of the well is screen, and ground elevation is 3 feet less than the measuring point elevation for the above monitoring wells. Boring logs unavailable.
3. Historically, MW-101SR has been considered an overburden monitoring well. MW-101SR was indicated as screened in bedrock in Table I of the June/July 2011 Groundwater Monitoring Data Review Four Hills Landfill DES Site #198403099, prepared by City of Nashua, dated September 14, 2011.

Proposed replacement groundwater release detection wells are summarized in Table 4 below. The proposed replacement wells are intended to sample a similar geologic setting as MW-101SR/DR, MW-102S/R, and MW-108R, with the following exceptions: (i) the wells are located to sample upgradient and downgradient of the proposed Phase IV area; and (ii) MW-101SR will be replaced with a monitoring well that samples overburden.

Table 4 - Summary of Proposed Replacement Release Detection Wells

Proposed Location	Approximate Ground Elevation	Anticipated Bedrock Elevation	Anticipated Overburden Water Elevation	Anticipated Screened Interval		Target Screened Formation	Position Relative to Proposed Phase IV
	(ft amsl)	(ft amsl)	(ft amsl)	(ft amsl)	(ft bgs)		
A	250	170	190	182 to 192	58 to 68	Overburden	Upgradient
B				165 to 175	75 to 85	Bedrock	Upgradient
C	210	160	170	162 to 172	38 to 48	Overburden	Downgradient
D				145 to 155	55 to 65	Bedrock	Downgradient

Notes:

1. Anticipated bedrock and overburden water table elevations are referenced from Figures 8 and 9, respectively.
2. Overburden monitoring wells will be screened to intercept the shallow water table. Bedrock wells will be screened within the upper 15 of bedrock. Actual depths will be determined during time of well installation based on field observations.

TABLES

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)[2]	Reference Elevation (ft. MSL)[3]	Water Level Elevation (ft. MSL)[3]
M-1(R)[1]	12/19/90	21.82	189.45	167.63
M-1R	09/02/09	12.11	179.19	167.08
M-1R	11/16/09	13.85	179.19	165.34
M-1R	04/14/10	8.98	179.19	170.21
M-1R	08/02/10	13.49	179.19	165.70
M-1R	11/17/10	13.62	179.19	165.57
M-1R	07/01/11	11.55	179.19	167.64
M-1R	11/30/11	10.12	179.19	169.07
M-1R	04/09/12	11.82	179.19	167.37
M-1R	11/01/12	12.70	179.19	166.49
M-1R	04/08/13	10.99	179.19	168.20
M-1R	11/01/13	14.65	179.19	164.54
M-1R	04/14/14	10.71	179.19	168.48
M-1R	11/03/14	13.17	179.19	166.02
M-1R	04/22/15	10.34	179.19	168.85
M-1R	11/02/15	14.30	179.19	164.89
M-1R	04/12/16	11.66	179.19	167.53
M-1R	11/01/16	14.18	179.19	165.01
M-1R	04/05/17	11.48	179.19	167.71
M-1R	11/01/17	12.24	179.19	166.95
M-1R	04/23/18	10.53	179.19	168.66
M-1R	11/06/18	10.71	179.19	168.48
M-1R	04/01/19	10.52	179.19	168.67
M-1R	11/22/19	13.03	179.19	166.16
M-1S	01/15/92	23.91	191.82	167.91
M-1S	02/11/92	24.15	191.82	167.67
M-1S	11/16/09	12.96	179.45	166.49
M-1S	04/14/10	9.15	179.45	170.30
M-1S	08/02/10	13.63	179.45	165.82
M-1S	11/17/10	13.81	179.45	165.64
M-1S	06/30/11	11.71	179.45	167.74
M-1S	11/30/11	10.21	179.45	169.24
M-1S	04/09/12	11.91	179.45	167.54
M-1S	11/01/12	12.74	179.45	166.71
M-1S	04/08/13	11.12	179.45	168.33
M-1S	11/01/13	14.12	179.45	165.33
M-1S	04/14/14	10.87	179.45	168.58
M-1S	11/03/14	13.15	179.45	166.30
M-1S	04/22/15	10.53	179.45	168.92
M-1S	11/02/15	14.50	179.45	164.95
M-1S	04/12/16	11.76	179.45	167.69
M-1S	11/01/16	14.33	179.45	165.12
M-1S	04/05/17	10.98	179.45	168.47
M-1S	11/01/17	12.31	179.45	167.14
M-1S	04/23/18	10.71	179.45	168.74
M-1S	11/06/18	10.80	179.45	168.65
M-1S	04/01/19	10.67	179.45	168.78
M-1S	11/22/19	13.19	179.45	166.26
M-1M	05/27/94	22.49	191.26	168.77
M-1M	06/23/94	23.54	191.26	167.72
M-2	12/19/90	7.63	176.93	169.30
M-2	01/09/91	8.05	176.93	168.88
M-2	11/16/09	6.50	176.93	170.43
M-2	04/14/10	5.52	176.93	171.41
M-2	08/02/10	11.69	176.93	165.24
M-2	11/17/10	5.41	176.93	171.52
M-2	06/21/11	9.32	176.93	167.61
M-2	11/30/11	NA	176.93	Area Flooded
M-2	04/09/12	7.00	176.93	169.93
M-2[1]	11/02/12	4.19	175.93	171.74
M-2[1]	04/08/13	3.57	175.93	172.36
M-2[1]	11/01/13	12.15	175.93	163.78
M-2[1]	04/14/14	3.85	175.93	172.08
M-2[1]	11/04/14	4.30	175.93	171.63
M-2[1]	04/22/15	4.00	175.93	171.93
M-2[1]	11/03/15	12.15	175.93	163.78
M-2[1]	04/12/16	4.20	175.93	171.73
M-2[1]	11/01/16	7.62	175.93	168.31
M-2[1]	04/06/17	3.37	175.93	172.56
M-2[1]	11/02/17	4.33	175.93	171.60
M-2[1]	04/23/18	5.03	175.93	170.90
M-2[1]	11/06/18	3.35	175.93	172.58
M-2[1]	04/03/19	6.39	175.93	169.54
M-2[1]	11/22/19	8.94	175.93	166.99
M-3	12/19/90	19.48	186.54	167.06
M-3	01/09/91	19.37	186.54	167.17
M-4	12/19/90	13.11	180.71	167.60
M-4	01/09/91	12.99	180.71	167.72
M-5	12/19/90	12.12	179.85	167.73
M-5	01/09/91	12.03	179.85	167.82
M-5	11/16/09	12.98	179.85	166.87
M-5	04/14/10	10.46	179.85	169.39
M-5	08/02/10	15.99	179.85	163.86
M-5	11/17/10	13.44	179.85	166.41
M-5	06/21/11	11.98	179.85	167.87

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^{2}	Reference Elevation (ft. MSL)^{3}	Water Level Elevation (ft. MSL)^{3}
M-5	11/28/11	12.85	179.85	167.00
M-5	11/28/11	12.85	179.85	167.00
M-5	04/09/12	12.12	179.85	167.73
M-5	11/01/12	12.83	179.85	167.02
M-5	04/08/13	11.65	179.85	168.20
M-5	11/01/13	13.36	179.85	166.49
M-5	04/14/14	11.55	179.85	168.30
M-5	11/03/14	13.00	179.85	166.85
M-5	04/22/15	11.22	179.85	168.63
M-5	11/02/15	13.60	179.85	166.25
M-5	04/12/16	11.88	179.85	167.97
M-5	11/01/16	13.54	179.85	166.31
M-5	04/05/17	11.74	179.85	168.11
M-5	11/01/17	12.74	179.85	167.11
M-5	04/23/18	11.53	179.85	168.32
M-5	11/06/18	11.59	179.85	168.26
M-5	04/01/19	11.28	179.85	168.57
M-5	11/22/19	12.92	179.85	166.93
M-6	12/19/90	10.00	209.88	199.88
M-6	07/30/97	13.74	209.88	196.14
M-7R	12/19/90	NA	187.90	NA
M-7R	01/09/91	12.07	187.90	175.83
M-7R	11/16/09	28.09	186.84	158.75
M-7R	04/14/10	21.59	186.84	165.25
M-7R	08/02/10	27.61	186.84	159.23
M-7R	11/17/10	28.96	186.84	157.88
M-7R	06/21/11	25.94	186.84	160.90
M-7R	11/28/11	24.21	186.84	162.63
M-7R	04/09/12	25.69	186.84	161.15
M-7R	11/01/12	27.98	186.84	158.86
M-7R	04/08/13	24.85	186.84	161.99
M-7R	11/01/13	27.70	186.84	159.14
M-7R	04/14/14	24.70	186.84	162.14
M-7R	11/03/14	27.92	186.84	158.92
M-7R	04/22/15	24.10	186.84	162.74
M-7R	11/02/15	28.30	186.84	158.54
M-7R	04/12/16	25.85	186.84	160.99
M-7R	11/01/16	28.90	186.84	157.94
M-7R	04/07/17	25.42	195.94	170.52
M-7R	11/01/17	27.97	195.94	167.97
M-7R	04/23/18	24.81	195.94	171.13
M-7R	11/06/18	26.76	195.94	169.18
M-7R	04/01/19	24.49	195.94	171.45
M-7R	11/21/19	27.66	195.94	168.28
M-8(D)	02/11/92	4.14	180.38	176.24
M-8(D)	02/20/92	4.29	180.38	176.09
M-8D	11/16/09	5.99	180.38	174.39
M-8D	04/14/10	4.68	180.38	175.70
M-8D	08/02/10	7.83	180.38	172.55
M-8D	11/17/10	6.44	180.38	173.94
M-8D	06/30/11	5.75	180.38	174.63
M-8D	12/01/11	4.82	180.38	175.56
M-8D	04/09/12	5.60	180.38	174.78
M-8D	11/01/12	5.60	180.38	174.78
M-8D	04/09/13	5.16	180.38	175.22
M-8D	11/01/13	7.18	180.38	173.20
M-8D	04/14/14	4.84	180.38	175.54
M-8D	11/04/14	6.00	180.38	174.38
M-8D	04/22/15	4.35	180.38	176.03
M-8D	11/02/15	7.62	180.38	172.76
M-8D	04/12/16	5.28	180.38	175.10
M-8D	11/01/16	7.24	180.38	173.14
M-8D	04/05/17	4.53	180.38	175.85
M-8D	11/01/17	5.36	180.38	175.02
M-8D	04/23/18	4.95	180.38	175.43
M-8D	11/06/18	4.54	180.38	175.84
M-8D	04/02/19	4.84	180.38	175.54
M-8D	11/22/19	5.67	180.38	174.71
M-8S	05/27/94	4.52	180.61	176.09
M-8S	06/23/94	5.25	180.61	175.36
M-8S	11/16/09	5.29	180.61	175.32
M-8S	04/14/10	4.68	180.61	175.93
M-8S	08/02/10	7.63	180.61	172.98
M-8S	11/17/10	5.04	180.61	175.57
M-8S	06/21/11	5.18	180.61	175.43
M-8S	12/01/11	4.48	180.61	176.13
M-8S	04/05/12	5.02	180.61	175.59
M-8S	11/01/12	4.50	180.61	176.11
M-8S	04/09/13	4.56	180.61	176.05
M-8S	11/01/13	6.16	180.61	174.45
M-8S	04/14/14	4.24	180.61	176.37
M-8S	11/04/14	4.76	180.61	175.85
M-8S	04/22/15	3.98	180.61	176.63
M-8S	11/02/15	6.42	180.61	174.19
M-8S	04/12/16	4.50	180.61	176.11
M-8S	11/01/16	5.51	180.61	175.10
M-8S	04/05/17	3.94	180.61	176.67
M-8S	11/01/17	4.46	180.61	176.15

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)[2]	Reference Elevation (ft. MSL)[3]	Water Level Elevation (ft. MSL)[3]
M-8S	04/23/18	4.56	180.61	176.05
M-8S	11/06/18	4.13	180.61	176.48
M-8S	04/02/19	4.36	180.61	176.25
M-8S	11/22/19	4.86	180.61	175.75
M-9S	05/27/94	15.05	183.55	168.50
M-9S	06/23/94	15.88	183.55	167.67
M-9S	11/16/09	17.16	183.55	166.39
M-9S	04/14/10	14.31	183.55	169.24
M-9S	08/02/10	17.41	183.55	166.14
M-9S	11/17/10	17.61	183.55	165.94
M-9S	07/01/11	16.00	183.55	167.55
M-9S	11/29/11	15.13	183.55	168.42
M-9S	04/05/12	16.06	183.55	167.49
M-9S	11/02/12	16.96	183.55	166.59
M-9S	04/09/13	15.57	183.55	167.98
M-9S	11/05/13	17.69	183.55	165.86
M-9S	04/11/14	15.46	183.55	168.09
M-9S	11/04/14	17.18	183.55	166.37
M-9S	04/23/15	15.06	183.55	168.49
M-9S	11/02/15	17.88	183.55	165.67
M-9S	04/13/16	15.88	183.55	167.67
M-9S	11/02/16	17.75	183.55	165.80
M-9S	04/07/17	15.30	183.55	168.25
M-9S	11/02/17	16.78	183.55	166.77
M-9S	04/24/18	15.25	183.55	168.30
M-9S	11/07/18	15.08	183.55	168.47
M-9S	04/03/19	15.01	183.55	168.54
M-9S	11/21/19	16.98	183.55	166.57
M-9D	05/27/94	14.98	183.81	168.83
M-9D	06/23/94	15.72	183.81	168.09
M-9D	11/16/09	37.82	183.81	145.99
M-9D	04/14/10	14.23	183.81	169.58
M-9D	08/02/10	17.35	183.81	166.46
M-9D	11/17/10	17.64	183.81	166.17
M-9D	07/01/11	15.95	183.81	167.86
M-9D	11/29/11	15.11	183.81	168.70
M-9D	11/29/11	15.11	183.81	168.70
M-9D	04/05/12	16.02	183.81	167.79
M-9D	11/02/12	16.92	183.81	166.89
M-9D	04/09/13	15.53	183.81	168.28
M-9D	04/11/14	15.44	183.81	168.37
M-9D	11/03/14	17.10	183.81	166.71
M-9D	11/05/14	17.60	183.81	166.21
M-9D	04/23/15	15.00	183.81	168.81
M-9D	11/02/15	17.83	183.81	165.98
M-9D	04/13/16	15.84	183.81	167.97
M-9D	11/01/16	17.70	183.81	166.11
M-9D	04/07/17	15.27	183.81	168.54
M-9D	11/02/17	16.75	183.81	167.06
M-9D	04/24/18	15.24	183.81	168.57
M-9D	11/06/18	15.02	183.81	168.79
M-9D	04/03/19	14.94	183.81	168.87
M-9D	11/21/19	16.90	183.81	166.91
M-9R	05/27/94	14.45	183.33	168.88
M-9R	06/23/94	15.22	183.33	168.11
M-9R	11/16/09	16.84	183.33	166.49
M-9R	04/14/10	13.94	183.33	169.39
M-9R	08/02/10	16.96	183.33	166.37
M-9R	11/17/10	17.29	183.33	166.04
M-9R	07/01/11	15.63	183.33	167.70
M-9R	11/29/11	14.63	183.33	168.70
M-9R	04/05/12	15.54	183.33	167.79
M-9R	11/02/12	16.45	183.33	166.88
M-9R	04/09/13	14.98	183.33	168.35
M-9R	11/05/13	17.10	183.33	166.23
M-9R	04/11/14	14.94	183.81	168.87
M-9R	11/03/14	16.60	183.81	167.21
M-9R	04/23/15	14.52	183.81	169.29
M-9R	11/02/15	17.32	183.81	166.49
M-9R	04/13/16	15.34	183.81	168.47
M-9R	11/02/16	17.04	183.81	166.77
M-9R	04/07/17	14.75	183.81	169.06
M-9R	11/02/17	16.27	183.81	167.54
M-9R	04/24/18	14.75	183.81	169.06
M-9R	11/07/18	14.48	183.81	169.33
M-9R	04/03/19	14.43	183.81	169.38
M-9R	11/21/19	16.41	183.81	167.40
M-10	05/27/94	5.65	194.57	188.92
M-10	06/23/94	7.23	194.57	187.34
M-10(R)	11/16/09	4.51	194.57	190.06
M-10(R)	04/14/10	3.35	194.57	191.22
M-10(R)	08/02/10	7.41	194.57	187.16
M-10(R)	11/17/10	4.41	194.57	190.16
M-10(R)	06/21/11	3.60	194.57	190.97
M-10(R)	12/01/11	3.56	194.57	191.01
M-10(R)	04/05/12	4.41	194.57	190.16
M-10(R)	11/01/12	4.36	194.57	190.21
M-10(R)	04/09/13	3.53	194.57	191.04

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^2	Reference Elevation (ft. MSL)^3	Water Level Elevation (ft. MSL)^3
M-10(R)	11/01/13	7.44	194.57	187.13
M-10(R)	04/14/14	3.40	194.57	191.17
M-10(R)	11/04/14	6.00	194.57	188.57
M-10(R)	04/22/15	2.96	194.57	191.61
M-10(R)	11/03/15	7.14	194.57	187.43
M-10(R)	04/16/16	3.15	194.57	191.42
M-10(R)	11/01/16	5.23	194.57	189.34
M-10(R)	04/06/17	2.55	194.57	192.02
M-10(R)	11/01/17	3.71	194.57	190.86
M-10(R)	04/23/18	3.13	194.57	191.44
M-10(R)	11/07/18	4.00	194.57	190.57
M-10(R)	04/02/19	3.48	194.57	191.09
M-10(R)	11/21/19	5.90	194.57	188.67
M-11S	05/27/94	21.95	190.32	168.37
M-11S	06/23/94	22.78	190.32	167.54
M-11S	11/16/09	24.73	190.32	165.59
M-11S	04/14/10	21.33	190.32	168.99
M-11S	08/02/10	24.91	190.32	165.41
M-11S	11/17/10	25.26	190.32	165.06
M-11S	07/01/11	23.40	190.32	166.92
M-11S	11/29/11	21.89	190.32	168.43
M-11S	04/05/12	22.95	190.32	167.37
M-11S	11/02/12	24.28	190.32	166.04
M-11S	04/09/13	22.42	190.32	167.90
M-11S	11/05/13	24.83	190.32	165.49
M-11S	04/14/14	22.30	190.32	168.02
M-11S	11/03/14	24.31	190.32	166.01
M-11S	04/23/15	21.90	190.32	168.42
M-11S	11/02/15	25.10	190.32	165.22
M-11S	04/13/16	22.90	190.32	167.42
M-11S	11/02/16	25.05	190.32	165.27
M-11S	04/07/17	22.39	190.32	167.93
M-11S	11/02/17	23.97	190.32	166.35
M-11S	04/24/18	22.10	190.32	168.22
M-11S	11/07/18	22.14	190.32	168.18
M-11S	04/03/19	21.85	190.32	168.47
M-11S	11/11/19	24.09	190.32	166.23
M-11M	05/27/94	21.62	190.04	168.42
M-11M	06/23/94	22.46	190.04	167.58
M-11M	11/16/09	23.91	190.04	166.13
M-11M	04/14/10	20.51	190.04	169.53
M-11M	08/02/10	24.12	190.04	165.92
M-11M	11/17/10	24.44	190.04	165.60
M-11M	06/30/11	22.56	190.04	167.48
M-11M	11/29/11	21.59	190.04	168.45
M-11M	04/05/12	22.63	190.04	167.41
M-11M	11/02/12	23.95	190.04	166.09
M-11M	04/09/13	22.10	190.04	167.94
M-11M	11/05/13	24.50	190.04	165.54
M-11M	04/14/14	21.99	190.04	168.05
M-11M	11/03/14	23.99	190.04	166.05
M-11M	04/23/15	21.61	190.04	168.43
M-11M	11/02/15	24.80	190.04	165.24
M-11M	04/13/16	22.60	190.04	167.44
M-11M	11/02/16	24.77	190.04	165.27
M-11M	04/07/17	22.06	190.04	167.98
M-11M	11/02/17	23.66	190.04	166.38
M-11M	04/24/18	21.78	190.04	168.26
M-11M	11/07/18	21.73	190.04	168.31
M-11M	04/03/19	21.57	190.04	168.47
M-11M	11/21/19	23.86	190.04	166.18
M-11R	05/27/94	22.16	190.21	168.05
M-11R	06/23/94	23.10	190.21	167.11
M-11R	11/16/09	24.52	190.21	165.69
M-11R	04/14/10	20.88	190.21	169.33
M-11R	08/02/10	24.74	190.21	165.47
M-11R	11/17/10	25.12	190.21	165.09
M-11R	07/01/11	23.12	190.21	167.09
M-11R	11/29/11	22.11	190.21	168.10
M-11R	04/05/12	23.24	190.21	166.97
M-11R	11/02/12	24.68	190.21	165.53
M-11R	04/09/13	22.63	190.21	167.58
M-11R	11/05/13	25.20	190.21	165.01
M-11R	04/14/14	22.58	190.21	167.63
M-11R	11/03/14	24.68	190.21	165.53
M-11R	04/23/15	22.17	190.21	168.04
M-11R	11/02/15	25.50	190.21	164.71
M-11R	04/13/16	23.30	190.21	166.91
M-11R	11/02/16	25.57	190.21	164.64
M-11R	04/07/17	22.80	190.21	167.41
M-11R	11/02/17	24.36	190.21	165.85
M-11R	04/24/18	22.36	190.21	167.85
M-11R	11/07/18	22.63	190.21	167.58
M-11R	04/03/19	22.13	190.21	168.08
M-11R	11/21/19	24.49	190.21	165.72
M-12	11/07/18	15.18	220.77	205.59
M-12	11/22/19	21.38	220.77	199.39
B-2	12/19/90	32.08	262.79	230.71

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^2	Reference Elevation (ft. MSL)^3	Water Level Elevation (ft. MSL)^3
B-2	01/09/91	27.07	262.79	235.72
B-2	11/16/09	43.94	262.79	218.85
B-2	04/14/10	28.32	262.79	234.47
B-2	08/02/10	41.50	262.79	221.29
B-2	11/17/10	48.09	262.79	214.70
B-2	06/21/11	34.72	262.79	228.07
B-2	11/29/11	NA	262.79	Not Found
B-2	04/04/12	37.70	262.79	225.09
B-2	11/06/12	45.70	262.79	217.09
B-2	04/12/13	33.47	262.79	229.32
B-2	11/06/13	44.68	262.79	218.11
B-2	04/14/14	37.97	262.79	224.82
B-2	11/05/14	47.08	262.79	215.71
B-2	04/24/15	29.52	262.79	233.27
B-2	11/03/15	47.17	262.79	215.62
B-2	04/14/16	41.58	262.79	221.21
B-2	11/01/16	48.80	262.79	213.99
B-2	04/06/17	42.39	262.79	220.40
B-2	11/02/17	45.54	262.79	217.25
B-2	04/24/18	31.02	262.79	231.77
B-2	11/06/18	44.85	262.79	217.94
B-2	04/02/19	31.10	262.79	231.69
B-2	11/22/19	45.59	262.79	217.20
B-4	12/19/90	16.79	239.20	222.41
B-4	01/09/91	15.11	239.20	224.09
B-4	11/16/09	36.49	239.20	202.71
B-4	04/14/10	15.08	239.20	224.12
B-4	08/02/10	32.69	239.20	206.51
B-4	11/17/10	42.45	239.20	196.75
B-4	06/21/11	18.08	239.20	221.12
B-4	11/30/11	15.23	239.20	223.97
B-4	04/04/12	16.89	239.20	222.31
B-4	11/09/12	39.69	239.20	199.51
B-4	04/12/13	21.04	239.20	218.16
B-4	11/06/13	38.93	239.20	200.27
B-4	04/14/14	15.90	239.20	223.30
B-4	11/05/14	41.54	239.20	197.66
B-4	04/24/15	14.50	239.20	224.70
B-4	11/03/15	41.34	239.20	197.86
B-4	04/14/16	15.77	239.20	223.43
B-4	11/01/16	43.65	239.20	195.55
B-4	11/01/16	38.59	239.20	200.61
B-4	04/06/17	13.30	239.20	225.90
B-4	11/02/17	38.59	239.20	200.61
B-4	04/24/18	14.10	239.20	225.10
B-4	11/07/18	36.60	239.20	202.60
B-4	04/02/19	15.40	239.20	223.80
B-4	11/22/19	19.96	239.20	219.24
B-5S	12/19/90	17.12	204.97	187.85
B-5S	01/09/91	17.03	204.97	187.94
B-5R	12/19/90	17.17	205.07	187.90
B-5R	01/09/91	17.05	205.07	188.02
B-6	12/19/90	17.83	188.05	170.22
B-6	01/09/91	17.67	188.05	170.38
B-9	12/19/90	14.15	260.14	245.99
B-9	01/09/91	12.27	260.14	247.87
B-10T	01/15/92	29.02	251.14	222.12
B-10T	02/11/92	29.54	251.14	221.60
B-10R	01/15/92	31.21	250.65	219.44
B-10R	02/11/92	31.86	250.65	218.79
B-10R	11/16/09	41.14	250.65	209.51
B-10R	04/14/10	29.01	250.65	221.64
B-10R	08/02/10	39.79	250.65	210.86
B-10R	11/17/10	44.61	250.65	206.04
B-10R	06/21/11	34.03	250.65	216.62
B-10R	11/30/11	NA	250.65	Not Found
B-10R	04/04/12	33.09	250.65	217.56
B-10R	11/09/12	43.05	250.65	207.60
B-10R	04/12/13	32.17	250.65	218.48
B-10R	11/06/13	41.98	250.65	208.67
B-10R	04/14/14	32.61	250.65	218.04
B-10R	11/05/14	43.78	250.65	206.87
B-10R	04/24/15	29.96	250.65	220.69
B-10R	11/03/15	43.66	250.65	206.99
B-10R	04/14/16	37.76	250.65	212.89
B-10R	11/01/16	45.22	250.65	205.43
B-10R	04/06/17	38.13	250.65	212.52
B-10R	11/02/17	42.23	250.65	208.42
B-10R	04/24/18	30.66	250.65	219.99
B-10R	11/06/18	41.49	250.65	209.16
B-10R	04/02/19	30.87	250.65	219.78
B-10R	11/22/19	41.65	250.65	209.00
B-11T	01/15/92	47.57	247.42	199.85
B-11T	02/11/92	48.31	247.42	199.11
B-12S	01/15/92	12.82	264.82	252.00
B-12S	02/11/92	13.56	264.82	251.26
B-12T	02/11/92	40.45	263.40	222.95
B-12T	02/20/92	52.18	263.40	211.22

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^2	Reference Elevation (ft. MSL)^3	Water Level Elevation (ft. MSL)^3
B-13T	01/15/92	19.81	270.23	250.42
B-13T	02/11/92	21.65	270.23	248.58
B-13T	04/14/10	24.91	270.23	245.32
B-13T	08/02/10	34.31	270.23	235.92
B-13T	11/17/10	38.21	270.23	232.02
B-13T	06/21/11	29.52	270.23	240.71
B-13T	11/30/11	25.98	270.23	244.25
B-13T	04/04/12	28.33	270.23	241.90
B-13T	11/09/12	36.06	270.23	234.17
B-13T	04/12/13	28.14	270.23	242.09
B-13T	11/06/13	35.40	270.23	234.83
B-13T	04/14/14	29.85	270.23	240.38
B-13T	11/05/14	37.75	270.23	232.48
B-13T	04/24/15	25.83	270.23	244.40
B-13T	11/03/15	37.28	270.23	232.95
B-13T	04/14/16	33.08	270.23	237.15
B-13T	11/01/16	38.93	270.23	231.30
B-13T	04/06/17	13.58	270.23	256.65
B-13T	11/02/17	35.99	270.23	234.24
B-13T	04/24/18	24.95	270.23	245.28
B-13T	11/06/18	33.74	270.23	236.49
B-13T	04/02/19	27.04	270.23	243.19
B-13T	11/22/19	36.50	270.23	233.73
B-14S	01/15/92	11.98	202.56	190.58
B-14S	02/11/92	12.85	202.56	189.71
B-14R	01/15/92	13.89	202.66	188.77
B-14R	02/11/92	14.20	202.66	188.46
B-15T	01/15/92	92.28	297.76	205.48
B-15T	02/11/92	84.84	297.76	212.92
B-16T	01/15/92	52.69	244.01	191.32
B-16T	02/11/92	54.52	244.01	189.49
B-17T	02/11/92	10.72	196.92	186.20
B-17T	02/20/92	10.85	196.92	186.07
B-17R	01/15/92	10.48	196.88	186.40
B-17R	02/11/92	12.54	196.88	184.34
B-18SR	02/11/92	16.82	199.57	182.75
B-18SR	02/20/92	16.57	199.57	183.00
B-18DR	02/11/92	18.25	200.77	182.52
B-18DR	02/20/92	18.17	200.77	182.60
B-19SR	02/11/92	14.52	185.81	171.29
B-19SR	02/20/92	14.52	185.81	171.29
B-19DR	02/11/92	14.95	186.20	171.25
B-19DR	02/20/92	15.01	186.20	171.19
B-20S	02/11/92	10.65	193.46	182.81
B-20S	02/20/92	10.67	193.46	182.79
MW-101SR	11/23/99	35.70	218.42	182.72
MW-101SR	04/12/00	35.30	218.42	NA
MW-101SR	04/14/10	36.29	218.42	182.13
MW-101SR	11/17/10	36.96	218.42	181.46
MW-101SR	06/21/11	36.30	218.42	182.12
MW-101SR	12/01/11	36.25	218.42	182.17
MW-101SR	04/05/12	36.00	218.42	182.42
MW-101SR	11/09/12	36.56	218.42	181.86
MW-101SR	04/17/13	36.45	218.42	181.97
MW-101SR	11/04/13	36.70	218.42	181.72
MW-101SR	04/14/14	36.53	218.42	181.89
MW-101SR	11/04/14	37.04	218.42	181.38
MW-101SR	04/23/15	36.52	218.42	181.90
MW-101SR	11/03/15	36.89	218.42	181.53
MW-101SR	04/14/16	36.65	218.42	181.77
MW-101SR	11/02/16	37.00	218.41	181.41
MW-101SR	04/05/17	36.60	218.41	181.81
MW-101SR	11/01/17	36.61	218.41	181.80
MW-101SR	04/23/18	36.25	218.41	182.16
MW-101SR	11/05/18	36.19	218.41	182.22
MW-101SR	04/01/19	36.22	218.41	182.19
MW-101SR	11/20/19	36.34	218.41	182.07
MW-101DR	11/02/16	31.46	218.37	186.91
MW-101DR	11/23/99	35.83	218.50	182.67
MW-101DR	04/12/00	35.60	218.50	NA
MW-101DR	04/14/10	37.10	218.50	181.40
MW-101DR	11/17/10	37.94	218.50	180.56
MW-101DR	06/21/11	37.22	218.50	181.28
MW-101DR	12/01/11	37.21	218.50	181.29
MW-101DR	04/04/12	36.98	218.50	181.52
MW-101DR	11/09/12	37.63	218.50	180.87
MW-101DR	04/17/13	37.61	218.50	180.89
MW-101DR	11/04/13	37.82	218.50	180.68
MW-101DR	04/14/14	37.78	218.50	180.72
MW-101DR	11/04/14	38.25	218.50	180.25
MW-101DR	04/23/15	38.10	218.50	180.40
MW-101DR	11/03/15	38.10	218.50	180.40
MW-101DR	04/14/16	38.80	218.50	179.70
MW-101DR	11/02/16	31.46	218.37	186.91
MW-101DR	04/05/17	38.08	218.37	180.29
MW-101DR	11/01/17	37.93	218.37	180.44
MW-101DR	04/23/18	37.60	218.37	180.77
MW-101DR	11/05/18	37.51	218.37	180.86

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)[2]	Reference Elevation (ft. MSL)[3]	Water Level Elevation (ft. MSL)[3]
MW-101DR	04/01/19	37.44	218.37	180.93
MW-101DR	11/20/19	37.55	218.37	180.82
MW-102S	11/23/99	41.80	228.08	186.28
MW-102S	04/12/00	40.85	228.08	NA
MW-102S	04/14/10	41.55	228.08	186.53
MW-102S	11/17/10	42.91	228.08	185.17
MW-102S	06/21/11	41.54	228.08	186.54
MW-102S	11/30/11	41.10	228.08	186.98
MW-102S	04/02/12	41.27	228.08	186.81
MW-102S	11/09/12	42.20	228.08	185.88
MW-102S	04/17/13	42.19	228.08	185.89
MW-102S	11/04/13	44.40	228.08	183.68
MW-102S	04/14/14	42.06	228.08	186.02
MW-102S	11/04/14	42.85	228.08	185.23
MW-102S	04/23/15	41.71	228.08	186.37
MW-102S	11/03/15	42.70	228.08	185.38
MW-102S	04/14/16	41.72	228.08	186.36
MW-102S	11/02/16	42.98	227.82	184.84
MW-102S	04/05/17	41.61	227.82	186.21
MW-102S	11/01/17	41.91	227.82	185.91
MW-102S	04/23/18	41.16	227.82	186.66
MW-102S	11/06/18	41.46	227.82	186.36
MW-102S	04/02/19	40.95	227.82	186.87
MW-102S	11/20/19	41.72	227.82	186.10
MW-102R	11/23/99	42.00	227.90	185.90
MW-102R	04/12/00	41.00	227.90	NA
MW-102R	04/14/10	41.52	227.90	186.38
MW-102R	11/17/10	43.02	227.90	184.88
MW-102R	06/21/11	41.62	227.90	186.28
MW-102R	11/30/11	41.70	227.90	186.20
MW-102R	04/05/12	41.58	227.90	186.32
MW-102R	11/09/12	43.44	227.90	184.46
MW-102R	04/17/13	42.09	227.90	185.81
MW-102R	11/04/13	44.93	227.90	182.97
MW-102R	04/14/14	42.39	227.90	185.51
MW-102R	11/04/14	43.79	227.90	184.11
MW-102R	04/23/15	41.54	227.90	186.36
MW-102R	11/03/15	43.20	227.90	184.70
MW-102R	04/14/16	43.50	227.90	184.40
MW-102R	11/02/16	36.36	228.00	191.64
MW-102R	04/05/17	41.60	228.00	186.40
MW-102R	11/01/17	42.35	228.00	185.65
MW-102R	04/23/18	43.53	228.00	184.47
MW-102R	11/05/18	41.65	228.00	186.35
MW-102R	04/02/19	41.30	228.00	186.70
MW-102R	11/20/19	41.49	228.00	186.51
MW-103S	11/23/99	48.85	215.73	166.88
MW-103S	04/12/00	47.27	215.73	NA
MW-103S	04/14/10	46.02	215.73	169.71
MW-103S	11/17/10	49.21	215.73	166.52
MW-103S	06/21/11	47.25	215.73	168.48
MW-103S	11/29/11	46.75	215.73	168.98
MW-103S	04/03/12	47.57	215.73	168.16
MW-103S	11/07/12	48.87	215.73	166.86
MW-103S	04/08/13	47.33	215.73	168.40
MW-103S	11/05/13	49.03	215.73	166.70
MW-103S	04/14/14	47.47	215.73	168.26
MW-103S	11/04/14	48.95	215.73	166.78
MW-103S	04/22/15	46.82	215.73	168.91
MW-103S	11/03/15	49.41	215.73	166.32
MW-103S	04/14/16	47.77	215.73	167.96
MW-103S	11/02/16	49.47	215.59	166.12
MW-103S	04/05/17	47.80	215.59	167.79
MW-103S	11/01/17	48.90	215.59	166.69
MW-103S	04/23/18	47.02	215.59	168.57
MW-103S	11/05/18	47.38	215.59	168.21
MW-103S	04/01/19	46.62	215.59	168.97
MW-103S	11/20/19	48.50	215.59	167.09
MW-103R	11/23/99	48.80	215.79	166.99
MW-103R	04/12/00	47.15	215.79	NA
MW-103R	04/14/10	45.92	215.79	169.87
MW-103R	11/17/10	49.19	215.79	166.60
MW-103R	06/21/11	47.38	215.79	168.41
MW-103R	11/29/11	46.68	215.79	169.11
MW-103R	04/05/12	47.47	215.79	168.32
MW-103R	11/07/12	48.45	215.79	167.34
MW-103R	04/08/13	47.30	215.79	168.49
MW-103R	11/05/13	49.08	215.79	166.71
MW-103R	04/14/14	47.34	215.79	168.45
MW-103R	11/04/14	49.01	215.79	166.78
MW-103R	04/22/15	46.75	215.79	169.04
MW-103R	11/03/15	49.47	215.79	166.32
MW-103R	04/14/16	47.98	215.79	167.81
MW-103R	11/02/16	48.56	215.65	167.09
MW-103R	04/05/17	47.67	215.65	167.98
MW-103R	11/01/17	48.80	215.65	166.85
MW-103R	04/23/18	46.93	215.65	168.72
MW-103R	11/05/18	47.21	215.65	168.44

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^2	Reference Elevation (ft. MSL)^3	Water Level Elevation (ft. MSL)^3
MW-103R	04/01/19	46.54	215.65	169.11
MW-103R	11/20/19	48.50	215.65	167.15
MW-104S	11/23/99	45.95	212.84	166.89
MW-104S	04/12/00	44.50	212.84	NA
MW-104S	04/14/10	43.25	212.84	169.59
MW-104S	11/17/10	46.54	212.84	166.30
MW-104S	06/21/11	44.63	212.84	168.21
MW-104S	11/29/11	44.04	212.84	168.80
MW-104S	04/03/12	44.66	212.84	168.18
MW-104S	11/07/12	45.95	212.84	166.89
MW-104S	04/08/13	44.24	212.84	168.60
MW-104S	11/05/13	26.50	212.84	186.34
MW-104S	04/14/14	44.52	212.84	168.32
MW-104S	11/05/14	46.05	212.84	166.79
MW-104S	04/22/15	43.92	212.84	168.92
MW-104S	11/04/15	46.54	212.84	166.30
MW-104S	04/14/16	44.82	212.84	168.02
MW-104S	11/02/16	46.56	212.54	165.98
MW-104S	04/05/17	44.37	212.54	168.17
MW-104S	11/01/17	45.97	212.54	166.57
MW-104S	04/23/18	44.12	212.54	168.42
MW-104S	11/05/18	44.49	212.54	168.05
MW-104S	04/01/19	43.80	212.54	168.74
MW-104S	11/20/19	45.63	212.54	166.91
MW-104R	11/23/99	45.75	212.70	166.95
MW-104R	04/12/00	44.23	212.70	NA
MW-104R	04/14/10	42.87	212.70	169.83
MW-104R	11/17/10	46.21	212.70	166.49
MW-104R	06/21/11	44.39	212.70	168.31
MW-104R	11/29/11	43.79	212.70	168.91
MW-104R	04/03/12	44.42	212.70	168.28
MW-104R	11/07/12	45.75	212.70	166.95
MW-104R	04/08/13	44.40	212.70	168.30
MW-104R	11/05/13	46.00	212.70	166.70
MW-104R	04/14/14	44.31	212.70	168.39
MW-104R	11/05/14	45.87	212.70	166.83
MW-104R	04/22/15	43.80	212.70	168.90
MW-104R	11/04/15	46.37	212.70	166.33
MW-104R	04/12/16	44.63	212.70	168.07
MW-104R	11/02/16	dry*	212.67	NA
MW-104R	04/05/17	44.26	212.67	168.41
MW-104R	11/01/17	45.28	212.67	167.39
MW-104R	04/23/18	43.57	212.67	169.10
MW-104R	11/05/18	43.96	212.67	168.71
MW-104R	04/01/19	43.17	212.67	169.50
MW-104R	11/20/19	45.10	212.67	167.57
MW-105S	11/23/99	24.70	191.59	166.89
MW-105S	04/12/00	23.45	191.59	NA
MW-105S	04/14/10	22.13	191.59	169.46
MW-105S	11/17/10	25.23	191.59	166.36
MW-105S	06/21/11	23.65	191.59	167.94
MW-105S	11/28/11	22.98	191.59	168.61
MW-105S	04/03/12	23.61	191.59	167.98
MW-105S	11/07/12	24.61	191.59	166.98
MW-105S	04/08/13	23.32	191.59	168.27
MW-105S	11/05/13	24.96	191.59	166.63
MW-105S	04/14/14	23.29	191.59	168.30
MW-105S	11/05/14	24.71	191.59	166.88
MW-105S	04/23/15	22.92	191.59	168.67
MW-105S	11/04/15	25.21	191.59	166.38
MW-105S	04/12/16	23.58	191.59	168.01
MW-105S	09/16/16	25.47	191.52	166.05
MW-105S	11/02/16	25.13	191.52	166.39
MW-105S	04/05/17	23.63	191.52	167.89
MW-105S	11/01/17	24.60	191.52	166.92
MW-105S	04/23/18	23.16	191.52	168.36
MW-105S	11/05/18	23.48	191.52	168.04
MW-105S	04/01/19	22.78	191.52	168.74
MW-105S	11/20/19	24.43	191.52	167.09
MW-105R	11/23/99	24.85	191.74	166.89
MW-105R	04/12/00	23.55	191.74	168.19
MW-105R	04/14/10	22.12	191.74	169.62
MW-105R	11/17/10	25.23	191.74	166.51
MW-105R	06/21/11	23.58	191.74	168.16
MW-105R	11/28/11	23.15	191.74	168.59
MW-105R	04/03/12	23.75	191.74	167.99
MW-105R	11/07/12	24.74	191.74	167.00
MW-105R	04/08/13	23.45	191.74	168.29
MW-105R	11/05/13	25.11	191.74	166.63
MW-105R	04/14/14	23.44	191.74	168.30
MW-105R	11/05/14	24.87	191.74	166.87
MW-105R	04/23/15	23.04	191.74	168.70
MW-105R	11/04/15	25.34	191.74	166.40
MW-105R	04/12/16	23.69	191.74	168.05
MW-105R	11/02/16	25.30	191.66	166.36
MW-105R	04/05/17	23.77	191.66	167.89
MW-105R	11/01/17	24.76	191.66	166.90
MW-105R	04/23/18	23.29	191.66	168.37

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^2	Reference Elevation (ft. MSL)^3	Water Level Elevation (ft. MSL)^3
MW-105R	11/05/18	23.60	191.66	168.06
MW-105R	04/01/19	22.92	191.66	168.74
MW-105R	11/20/19	24.58	191.66	167.08
MW-106S	04/08/09	45.85	261.43	215.58
MW-106S	11/16/09	26.22	261.43	235.21
MW-106S	04/14/10	44.33	261.43	217.10
MW-106S	11/17/10	52.19	261.43	209.24
MW-106S	06/30/11	63.90	261.43	197.53
MW-106S	11/30/11	47.54	261.43	213.89
MW-106S	11/08/12	Well Obstructed	261.43	
MW-106SR	04/16/13	27.97	261.43	233.46
MW-106SR	11/06/13	34.80	261.43	226.63
MW-106SR	04/15/14	26.20	261.43	235.23
MW-106SR	11/05/14	35.48	262.88	227.40
MW-106SR	04/24/15	25.18	263.54	238.36
MW-106SR	11/18/15	35.50	263.54	228.04
MW-106SR	04/12/16	31.72	263.54	231.82
MW-106SR	09/16/16	35.00	263.54	228.54
MW-106SR	11/02/16	36.59	263.54	226.95
MW-106SR	04/06/17	29.60	263.54	233.94
MW-106SR	11/02/17	33.85	263.54	229.69
MW-106SR	04/24/18	26.14	263.54	237.40
MW-106SR	08/24/18	32.68	263.54	230.86
MW-106SR	11/07/18	34.28	263.54	229.26
MW-106SR	04/02/19	26.63	263.54	236.91
MW-106SR	11/21/19	34.59	263.54	228.95
MW-106R	04/08/09	25.99	262.05	236.06
MW-106R	11/16/09	33.69	262.05	228.36
MW-106R	04/14/10	23.03	262.05	239.02
MW-106R	11/17/10	23.52	262.05	238.53
MW-106R	06/30/11	29.38	262.05	232.67
MW-106R	11/30/11	24.17	262.05	237.88
MW-106R	04/02/12	27.79	262.05	234.26
MW-106R	11/08/12	33.46	262.05	228.59
MW-106R	04/16/13	27.97	262.05	234.08
MW-106R	11/06/13	33.67	262.05	228.38
MW-106R	04/15/14	25.84	262.05	236.21
MW-106R	11/05/14	39.95	262.05	222.10
MW-106R	04/24/15	24.30	262.62	238.32
MW-106R	11/18/15	36.05	262.62	226.57
MW-106R	04/14/16	32.18	262.62	230.44
MW-106R	11/03/16	39.00	262.62	223.62
MW-106R	04/06/17	29.33	262.62	233.29
MW-106R	11/02/17	33.05	262.62	229.57
MW-106R	04/24/18	25.82	262.62	236.80
MW-106R	11/06/18	31.14	262.62	231.48
MW-106R	04/02/19	25.82	262.62	236.80
MW-106R	11/20/19	33.83	262.62	228.79
MW-107T	01/03/00	NA*	286.30	NA
MW-107T	11/05/01	NA*	286.30	NA
MW-107T	05/08/02	NA* Obstructed @ 16.5'	286.30	NA
MW-107R	04/08/09	64.73	286.61	221.88
MW-107R	11/16/09	71.20	286.61	215.41
MW-107R	04/14/10	63.43	286.61	223.18
MW-107R	11/17/10	74.11	286.61	212.50
MW-107R	06/21/11	71.90	286.61	214.71
MW-107R	11/30/11	64.75	286.61	221.86
MW-107R	04/04/12	65.74	286.61	220.87
MW-107R	11/09/12	72.60	286.61	214.01
MW-107R	04/09/13	65.61	286.61	221.00
MW-107R	11/04/13	72.58	286.61	214.03
MW-107R	04/14/14	66.15	286.61	220.46
MW-107R	11/04/14	73.72	286.61	212.89
MW-107R	04/24/15	64.40	286.61	222.21
MW-107R	11/18/15	74.20	286.61	212.41
MW-107R	04/16/16	68.03	286.61	218.58
MW-107R	11/02/16	NA	286.61	NA
MW-107R	04/06/17	71.96	286.61	214.65
MW-107R	11/02/17	73.62	286.61	212.99
MW-107R	04/24/18	64.11	286.61	222.50
MW-107R	11/06/18	73.73	286.61	212.88
MW-107R	04/02/19	64.37	286.61	222.24
MW-107R	11/21/19	72.58	286.61	214.03
MW-108R	04/08/09	28.88	207.66	178.78
MW-108R	11/16/09	29.45	207.66	178.21
MW-108R	04/14/10	29.25	207.66	178.41
MW-108R	11/17/10	30.40	207.66	177.26
MW-108R	06/21/11	29.15	207.66	178.51
MW-108R	12/01/11	29.20	207.66	178.46
MW-108R	04/04/12	29.23	207.66	178.43
MW-108R	11/09/12	29.50	207.66	178.16
MW-108R	04/17/13	28.98	207.66	178.68
MW-108R	11/05/13	29.60	207.66	178.06
MW-108R	04/14/14	29.08	207.66	178.58
MW-108R	11/04/14	29.28	207.66	178.38
MW-108R	04/23/15	29.11	207.66	178.55
MW-108R	11/03/15	30.02	207.66	177.64
MW-108R	04/14/16	28.54	207.66	179.12

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^{2}	Reference Elevation (ft. MSL)^{3}	Water Level Elevation (ft. MSL)^{3}
MW-108R	11/02/16	dry @ 32	207.54	<176
MW-108R	04/07/17	dry @ 27.55	207.54	<179.99
MW-108R	11/01/17	dry @ 27.36	207.54	<180.18
MW-108R	04/24/18	Dry		
MW-108R	11/05/18	28.61	208.05	179.44
MW-108R	04/01/19	29.45	208.05	178.60
MW-108R	11/20/19	30.10	208.05	177.95
MW-109S	04/08/09	18.23	234.40	216.17
MW-109S	11/16/09	24.58	234.40	209.82
MW-109S	04/14/10	16.55	234.40	217.85
MW-109S	11/17/10	28.90	234.40	205.50
MW-109S	06/21/11	19.81	234.40	214.59
MW-109S	11/28/11	17.07	234.40	217.33
MW-109S	04/04/12	19.14	234.40	215.26
MW-109S	11/08/12	26.49	234.40	207.91
MW-109S	04/10/13	17.50	234.40	216.90
MW-109S	11/04/13	25.17	234.40	209.23
MW-109S	04/15/14	15.39	234.40	219.01
MW-109S	11/05/14	27.32	234.40	207.08
MW-109S	04/24/15	16.79	234.40	217.61
MW-109S	11/04/15	27.07	234.40	207.33
MW-109S	04/14/16	18.01	234.40	216.39
MW-109S	09/16/16	25.87	234.40	208.53
MW-109S	11/02/16	dry @ 30	234.40	<204
MW-109S	04/07/17	12.79	234.40	221.61
MW-109S	11/02/17	25.68	234.40	208.72
MW-109S	04/24/18	15.87	234.40	218.53
MW-109S	11/07/18	26.21	234.40	208.19
MW-109S	04/02/19	17.21	234.40	217.19
MW-109S	11/21/19	26.31	234.40	208.09
MW-109R	11/10/08	30.62	232.10	201.48
MW-109R	04/08/09	28.78	232.10	203.32
MW-109R	11/16/09	33.66	232.10	198.44
MW-109R	04/14/10	25.29	232.10	206.81
MW-109R	11/17/10	35.38	232.10	196.72
MW-109R	06/21/11	26.05	232.10	206.05
MW-109R	11/28/11	25.05	232.10	207.05
MW-109R	04/04/12	24.38	232.10	207.72
MW-109R	11/08/12	33.37	232.10	198.73
MW-109R	04/10/13	24.78	232.10	207.32
MW-109R	11/04/13	31.97	232.10	200.13
MW-109R	04/15/14	28.32	232.10	203.78
MW-109R	11/05/14	36.72	232.10	195.38
MW-109R	04/24/15	23.64	232.10	208.46
MW-109R	11/04/15	33.97	232.10	198.13
MW-109R	04/14/16	28.57	232.10	203.53
MW-109R	11/03/16	35.88	232.10	196.22
MW-109R	04/07/17	20.27	232.10	211.83
MW-109R	11/02/17	32.56	232.10	199.54
MW-109R	04/24/18	22.54	232.10	209.56
MW-109R	11/07/18	32.24	232.10	199.86
MW-109R	04/02/19	21.83	232.10	210.27
MW-109R	11/21/19	32.66	232.10	199.44
MW-110S	04/08/09	Dry	213.40	Dry
MW-110S	11/16/09	Dry	213.40	Dry
MW-110S	04/14/10	23.46	213.40	189.94
MW-110S	11/17/10	Dry	213.40	Dry
MW-110S	06/21/11	28.76	213.40	184.64
MW-110S	11/30/11	29.56	213.40	183.84
MW-110S	11/09/12	31.14	213.40	182.26
MW-110S	04/12/13	31.93	213.40	181.47
MW-110S	11/06/13	30.63	213.40	182.77
MW-110S	04/14/14	32.20	213.40	181.20
MW-110S	11/05/14	31.53	213.40	181.87
MW-110S	04/24/15	30.49	213.40	182.91
MW-110S	11/03/15	31.13	213.40	182.27
MW-110S	04/14/16	32.34	213.40	181.06
MW-110S	11/01/16	32.36	213.40	181.04
MW-110S	04/06/17	32.72	213.40	180.68
MW-110S	11/02/17	30.80	213.40	182.60
MW-110S	04/24/18	30.29	213.40	183.11
MW-110S	11/07/18	30.88	213.40	182.52
MW-110S	04/02/19	27.38	213.40	186.02
MW-110S	11/22/19	29.60	213.40	183.80
MW-110R	04/08/09	23.81	212.10	188.29
MW-110R	11/16/09	27.85	212.10	184.25
MW-110R	04/14/10	22.41	212.10	189.69
MW-110R	11/17/10	29.19	212.10	182.91
MW-110R	06/21/11	26.63	212.10	185.47
MW-110R	11/30/11	26.65	212.10	185.45
MW-110R	11/09/12	30.60	212.10	181.50
MW-110R	04/12/13	28.95	212.10	183.15
MW-110R	11/06/13	31.14	212.10	180.96
MW-110R	04/14/14	29.09	212.10	183.01
MW-110R	11/05/14	31.96	212.10	180.14
MW-110R	04/24/15	27.67	212.10	184.43
MW-110R	11/03/15	31.78	212.10	180.32
MW-110R	04/14/16	30.75	212.10	181.35

Table 1
Summary of Groundwater Elevations
Four Hills Landfill, Nashua, NH

Location	Sample Date	Depth to Water (ft.TOPVC)^2	Reference Elevation (ft. MSL)^3	Water Level Elevation (ft. MSL)^3
MW-110R	11/01/16	33.33	212.10	178.77
MW-110R	04/06/17	Dry	212.10	Dry
MW-110R	11/02/17	30.72	212.10	181.38
MW-110R	04/24/18	27.84	212.10	184.26
MW-110R	11/07/18	29.43	212.10	182.67
MW-110R	04/02/19	25.47	212.10	186.63
MW-110R	11/22/19	29.04	212.10	183.06
B-3S (MW-111S)	12/19/90	15.48	202.34	186.86
B-3S (MW-111S)	01/09/91	14.67	202.34	187.67
B-3S (MW-111S)	11/16/09	13.40	202.34	188.94
B-3S (MW-111S)	04/14/10	7.09	202.34	195.25
B-3S (MW-111S)	08/02/10	15.61	202.34	186.73
B-3S (MW-111S)	11/17/10	21.17	202.34	181.17
B-3S (MW-111S)	06/21/11	13.88	202.34	188.46
B-3S (MW-111S)	11/28/11	18.91	202.34	183.43
B-3S (MW-111S)	04/02/12	14.37	202.34	187.97
B-3S (MW-111S)	11/08/12	22.69	202.34	179.65
B-3S (MW-111S)	04/10/13	16.99	202.34	185.35
B-3S (MW-111S)	11/04/13	22.50	202.34	179.84
B-3S (MW-111S)	04/15/14	14.90	202.34	187.44
B-3S (MW-111S)	11/05/14	22.97	202.34	179.37
B-3S (MW-111S)	04/23/15	13.25	202.34	189.09
B-3S (MW-111S)	11/04/15	22.77	202.34	179.57
B-3S (MW-111S)	04/14/16	21.14	202.34	181.20
B-3S (MW-111S)	11/03/16	24.63	202.34	177.71
B-3S (MW-111S)	04/07/17	18.89	202.34	183.45
B-3S (MW-111S)	11/02/17	18.02	202.34	184.32
B-3S (MW-111S)	04/24/18	12.94	202.34	189.40
B-3S (MW-111S)	08/24/18	16.44	202.34	185.90
B-3S (MW-111S)	11/07/18	12.40	202.34	189.94
B-3S (MW-111S)	04/02/19	13.22	202.34	189.12
B-3S (MW-111S)	08/01/19	21.25	212.48	191.23
B-3S (MW-111S)	09/03/19	23.17	212.48	189.31
B-3S (MW-111S)	10/31/19	24.31	212.48	188.17
B-3S (MW-111S)	12/20/19	22.16	212.48	190.32
B-3R (MW-111R)	12/19/90	20.34	202.17	181.83
B-3R (MW-111R)	01/09/91	19.96	202.17	182.21
B-3R (MW-111R)	11/16/09	20.30	202.17	181.87
B-3R (MW-111R)	04/14/10	14.39	202.17	187.78
B-3R (MW-111R)	08/02/10	20.03	202.17	182.14
B-3R (MW-111R)	11/17/10	24.45	202.17	177.72
B-3R (MW-111R)	06/21/11	19.17	202.17	183.00
B-3R (MW-111R)	11/28/11	13.72	202.17	188.45
B-3R (MW-111R)	04/04/12	14.53	202.17	187.64
B-3R (MW-111R)	11/08/12	22.73	202.17	179.44
B-3R (MW-111R)	04/12/13	15.81	202.17	186.36
B-3R (MW-111R)	11/04/13	22.62	202.17	179.55
B-3R (MW-111R)	04/15/14	20.88	202.17	181.29
B-3R (MW-111R)	11/05/14	23.08	202.17	179.09
B-3R (MW-111R)	04/23/15	19.58	202.17	182.59
B-3R (MW-111R)	11/04/15	22.93	202.17	179.24
B-3R (MW-111R)	04/14/16	21.98	202.17	180.19
B-3R (MW-111R)	11/03/16	24.62	202.17	177.55
B-3R (MW-111R)	04/07/17	22.22	202.17	179.95
B-3R (MW-111R)	11/02/17	21.68	202.17	180.49
B-3R (MW-111R)	04/24/18	20.21	202.17	181.96
B-3R (MW-111R)	11/07/18	19.93	202.17	182.24
B-3R (MW-111R)	04/02/19	17.20	202.17	184.97
B-3R (MW-111R)	08/01/19	25.40	212.63	187.23
B-3R (MW-111R)	09/03/19	23.70	212.63	188.93
B-3R (MW-111R)	11/21/19	30.83	212.63	181.80
B-3R (MW-111R)	12/20/19	30.00	212.63	182.63

The table was provided by the City to Sanborn Head in 2010; Sanborn Head entered subsequent data from analytical laboratory reports and/or EDDs provided by the City.

Notes:
1. Measured from top of protective steel casing.
2. Measured from Top of PVC riser pipe.
3. Mean Sea Level.
4. Reference elevations for MW-106SR and MW-106R were re-surveyed by the City in August 2015, as requested by NHDES because of suspected incorrect historical elevations.
5. Reference elevations for MW-101SR/DR, MW-102S/R, MW-103S/R, MW-104S/R, MW-105S/R, and MW-108R were re-surveyed by the City in August 2016, following repair of protective casings.
6. Reference elevations for B-11T, MW-111S, and MW-111R were re-surveyed by the City in July 2019, due to Phase III construction work.
7. NA = Not Available
   * = Possible obstruction.

TABLE 2
Summary of Vertical Hydraulic Gradients - Proposed Phase IV Area
Four Hills Landfill
Nashua, New Hampshire

Location		**MW-101SR**	**MW-101DR**	**MW-101SR**	**MW-101DR**	**MW-102S**	**MW-102R**	**MW-102S**	**MW-102R**
Top of PVC Elev. (ft. MSL)		218.42	218.50	218.42	218.50	228.08	227.90	228.08	227.90
Ground Elevation (ft. MSL)		215.75	215.83	215.75	215.83	225.08	225.23	225.08	225.23
Top of Screen (ft. BGS)		35.4	49.8	35.4	49.8	35	64.5	35	64.5
Bottom of Screen (ft. BGS)		45.4	59.8	45.4	59.8	45	74.5	45	74.5
Screen Midpoint (ft. MSL)		175.35	161.03	175.35	161.03	185.08	155.73	185.08	155.73
Screened Interval		Bedrock	Bedrock	Bedrock	Bedrock	Overburden	Bedrock	Overburden	Bedrock
Month / Year		April		November		April		November	
Depth to Water (ft.TPVC)	2015	36.52	38.10	36.89	38.10	41.71	41.54	42.70	43.20
Water Level Elevation (ft. MSL)		181.90	180.40	181.53	180.40	186.37	186.36	185.38	184.70
Gradient (ft/ft)		-0.10		-0.08		0.00		-0.02	
Depth to Water (ft.TPVC)	2016	36.65	38.80	37.00	31.46	41.72	43.50	42.98	36.36
Reference Elevation (ft. MSL)		218.42	218.50	218.41	218.37	228.08	227.90	227.82	228.00
Water Level Elevation (ft. MSL)		181.77	179.70	181.41	186.91	186.36	184.40	184.84	191.64
Gradient (ft/ft)		-0.14		0.38		-0.07		0.23	
Depth to Water (ft.TPVC)	2017	36.60	38.08	36.61	37.93	41.61	41.60	41.91	42.35
Water Level Elevation (ft. MSL)		181.81	180.29	181.80	180.44	186.21	186.40	185.91	185.65
Gradient (ft/ft)		-0.11		-0.09		0.01		-0.01	
Depth to Water (ft.TPVC)	2018	36.25	37.60	36.19	37.51	41.16	43.53	41.46	41.65
Water Level Elevation (ft. MSL)		182.16	180.77	182.22	180.86	186.66	184.47	186.36	186.35
Gradient (ft/ft)		-0.10		-0.09		-0.07		0.00	
Depth to Water (ft.TPVC)	2019	36.22	37.44	36.34	37.55	40.95	41.30	41.72	41.49
Water Level Elevation (ft. MSL)		182.19	180.82	182.07	180.93	186.87	186.70	186.10	186.51
Gradient (ft/ft)		-0.10		-0.08		-0.01		0.01	

Notes:

1. **Negative** values (green shading) indicate a downward vertical hydraulic gradient.
2. **Positive** values (blue shading) indicate an upward vertical hydraulic gradient.
3. A **neutral** vertical gradient is not shaded.
4. Water levels were provided by the City of Nashua to Sanborn Head. Only results from the most recent five years (2014 through 2019) are shown. Well construction and survey elevations were compiled from Table I of the June/July 2011 Groundwaetr Monitoring Data Review Letter prepared by the City and sent to New Hampshire Department of Environmental Services, dated September 14, 2011.
5. The vertical hydraulic gradient for each monitoring well couplet is defined as the vertical head difference divided by the vertical separation distance of the screen midpoint, expressed in units of feet per feet (ft/ft).
6. The presence of a vertical gradient does not necessarily indicate hydraulic connection.
7. Abbreviations: ft. BGS = feet below ground surface; ft. MSL = feet above mean sea level; ft. TPVC = feet below top of PVC riser

FIGURES

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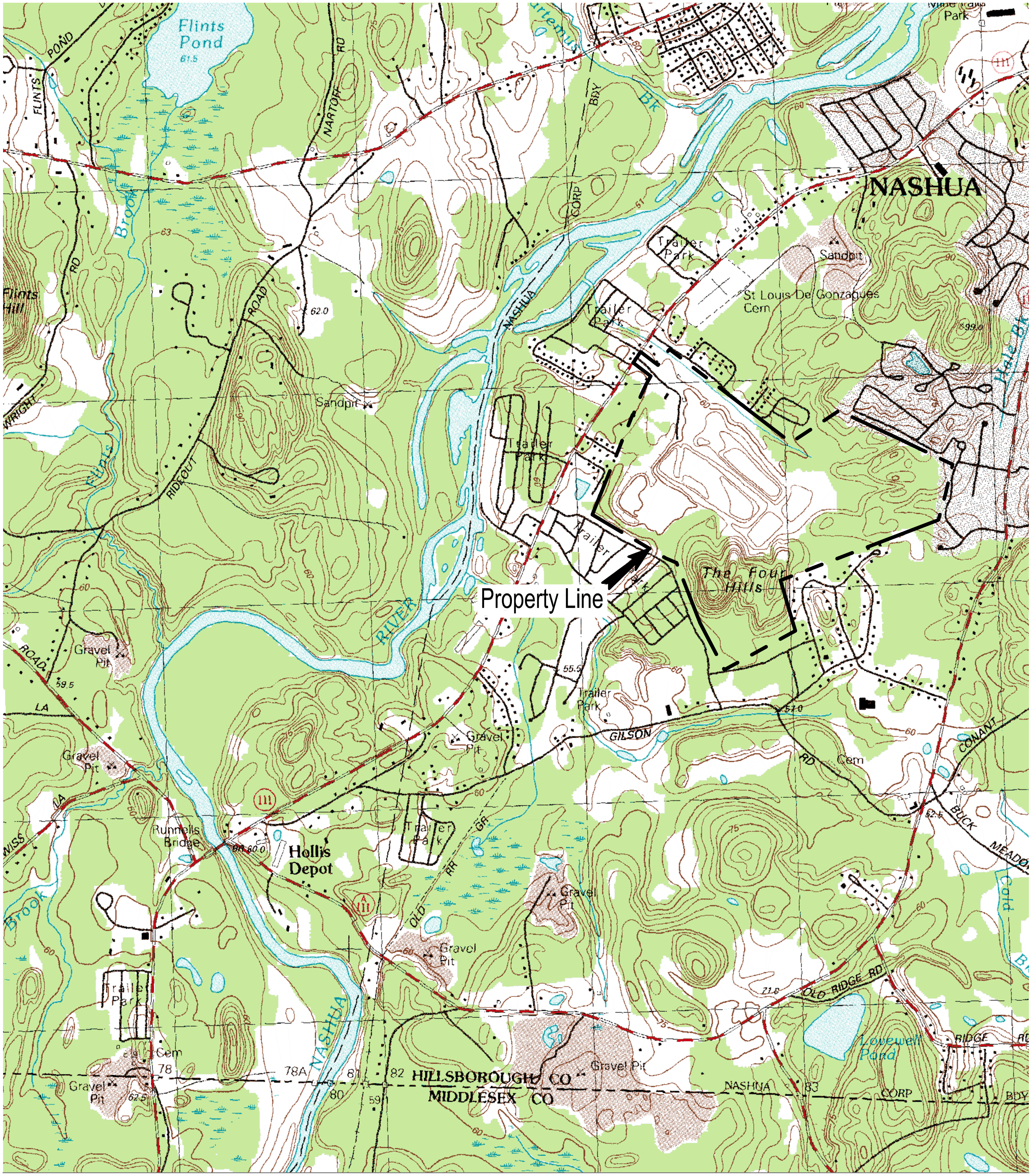


N
W E
S

Note:
Base map was taken from the "University of New Hampshire Earth Systems Research Center (NH GRANIT)"
7.5 minute USGS Quadrangle Maps: Pepperell, MA-NH,
REV:(Photorevised 2004)

Drawn By:	S. Santiago
Designed By:	A. Ashton
Reviewed By:	E. Steinhauser
Project No:	3066.12
Date:	May 2020

Feet
1000' 0 2000'

SANBORN HEAD

Figure 1

Four Hills Landfill
Locus Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire
Nashua, New Hampshire

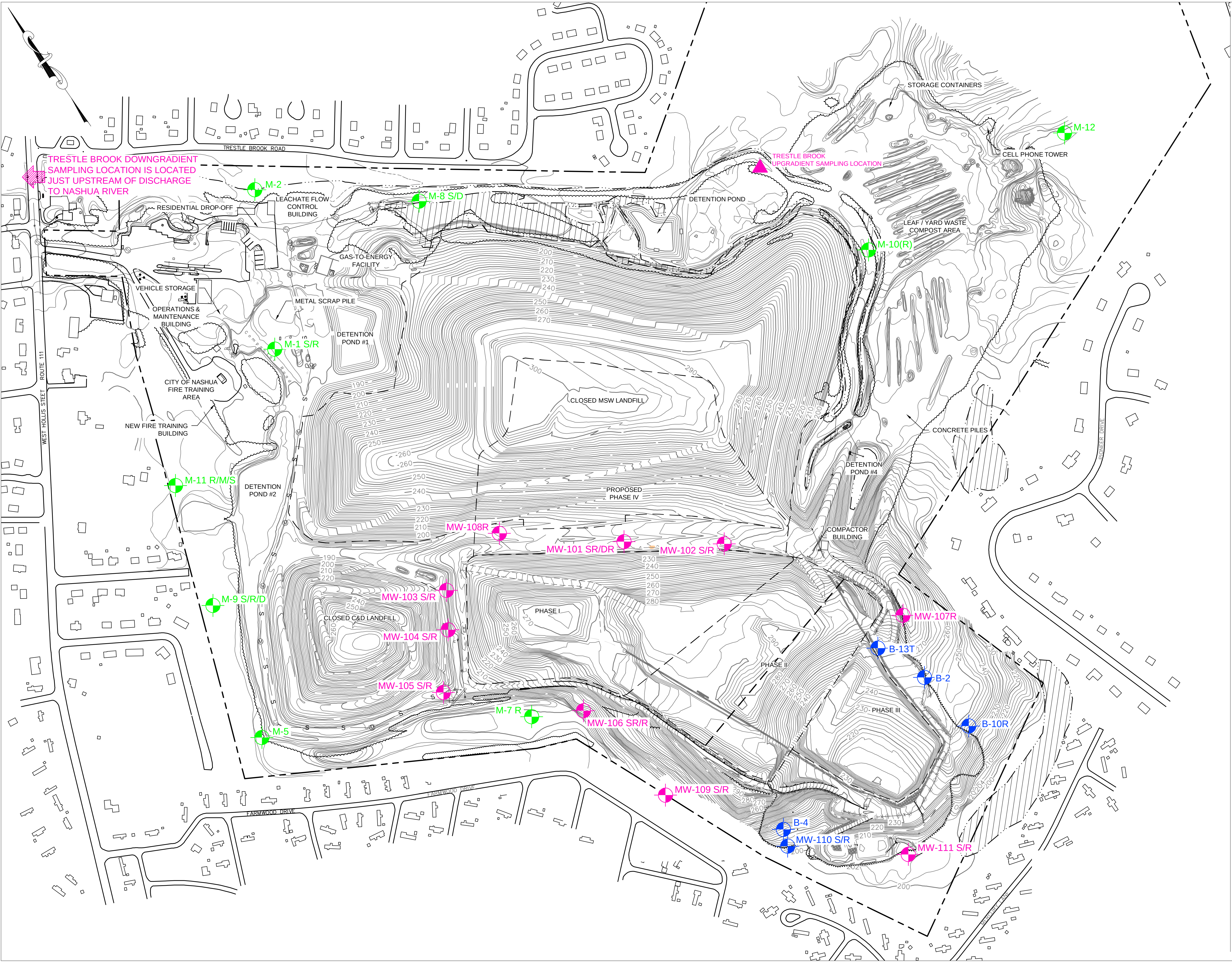


Figure 2

Four Hills Landfill Existing Conditions Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire
Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate locations of major site features and the site monitoring wells based on information provided by the City of Nashua.

Notes

1. The existing topography and site features are based on ground field survey performed by WSP USA, Inc. of Nashua, New Hampshire on July 20, 2017 and July 21, 2017. Horizontal Datum: NAD83 (2001). Horizontal Projection: NH State Plane. Vertical Datum: NGVD 29.

2. Refer to text for additional details.

Legend

⊕ MW-102S	Groundwater release detection wells
⊕ M-1S	Groundwater management wells
⊕ B-2	Groundwater elevation measurement location
▲	Surface Water Sampling Location
▨	Wetland
— — —	Phase Limit

200' 100' 0 200' 400' Feet

SANBORN HEAD

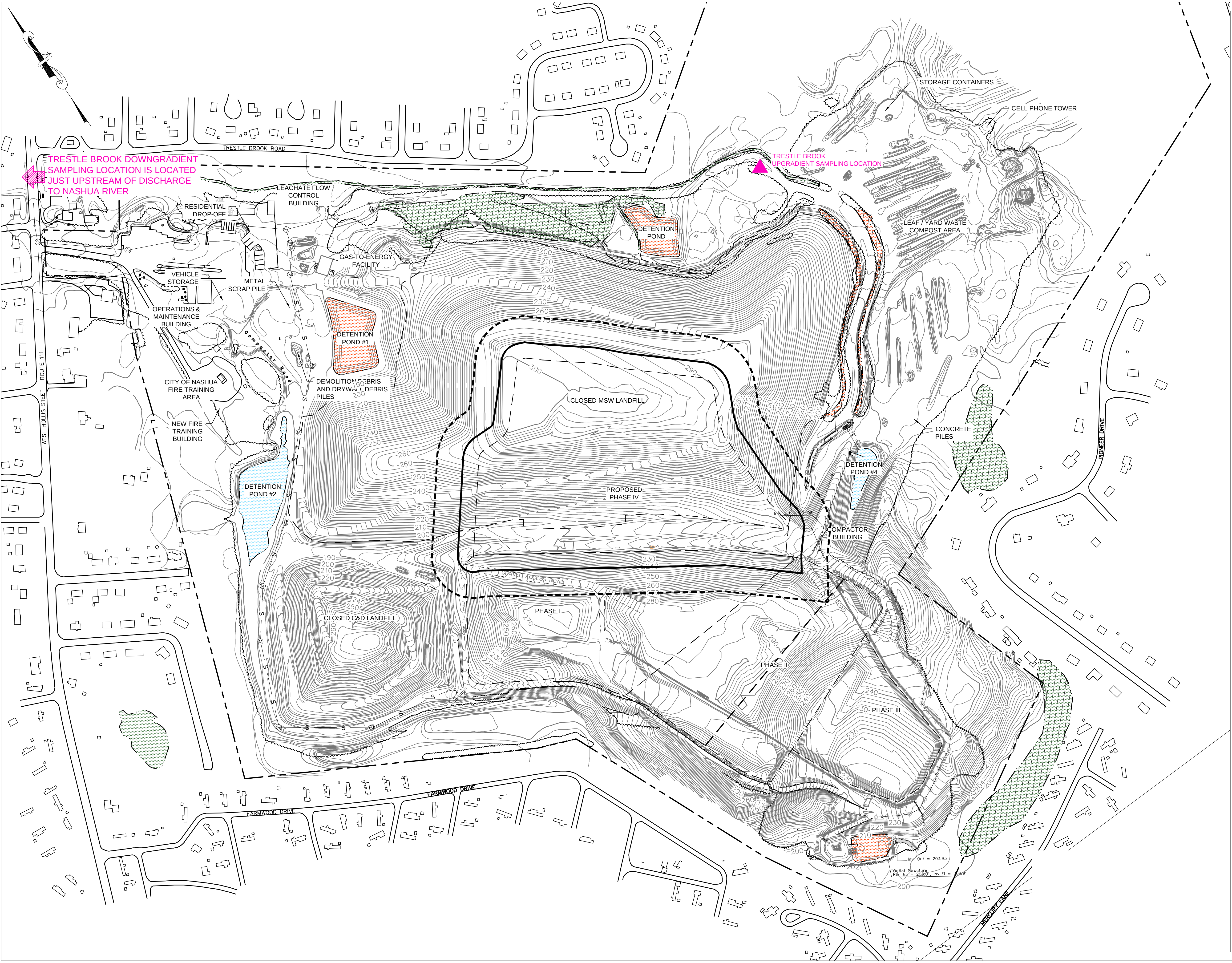


Figure 3

Four Hills Landfill Surface Water Features Plan (Site)

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire

Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate locations of major site features and surface water features at the Site including natural and man-made features.

Notes

1. The existing topography and site features are based on ground field survey performed by WSP USA, Inc. of Nashua, New Hampshire on July 20, 2017 and July 21, 2017. Horizontal Datum: NAD83 (2001). Horizontal Projection: NH State Plane. Vertical Datum: NGVD 29.

2. The retention pond locations are based on information provided by the client and knowledge of the site. Wetland area limits were obtained from the US Fish and Wildlife Service National Wetland Inventory Wetlands Mapper.

Legend

▲ Surface Water Sampling Location
– – – Phase Limit
— 100-Foot Offset From Phase Limit
- - - 200-Foot Offset From Phase Limit
🟥 Stormwater Retention Ponds
🟩 Existing Natural Wetland
🟦 Stormwater Retention Ponds With Standing Water

200' 100' 0 200' 400' Feet

SANBORN HEAD

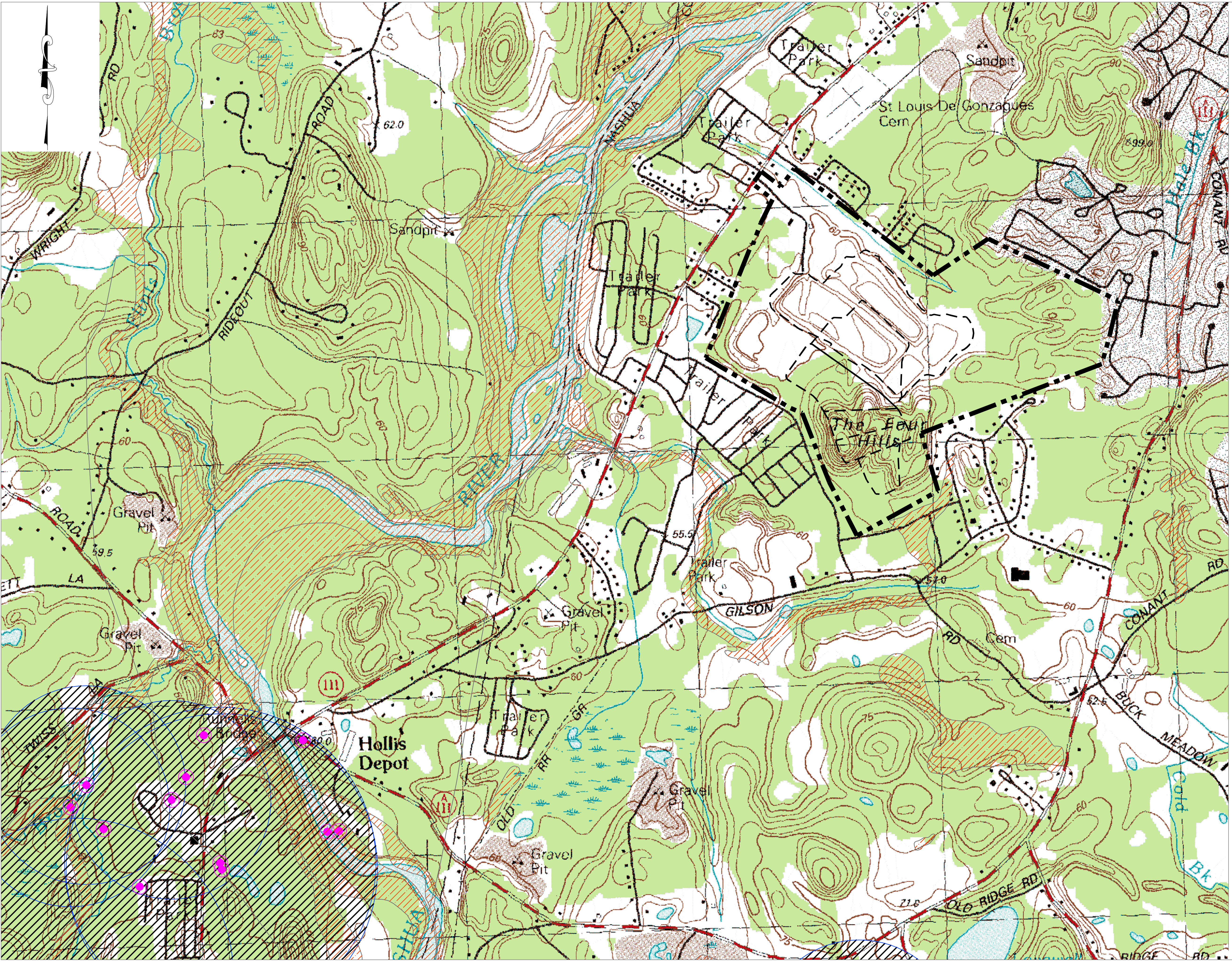


Figure 4

Four Hills Landfill Flood Zones and Well Head Protection Zones

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire

Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the locations of public water supply wells, wellhead protection areas, and 100-year Floodplains within the vicinity of the Site.

Notes

1. The existing topography and site features are based on ground field survey performed by WSP USA, Inc. of Nashua, New Hampshire on July 20, 2017 and July 21, 2017. Horizontal Datum: NAD83 (2001). Horizontal Projection: NH State Plane. Vertical Datum: NGVD 29.
2. Public water supply well and wellhead protection area information obtained from NHDES OneStop website in May 2020.
3. 100-year Floodplain locations obtained from FEMA website in May 2020.

Legend

▨	100-Year Floodplain
— · · —	Property line
— — —	Phase limits
◉	Public water supply wells
▨	Wellhead protection areas

GRAPHICAL SCALE
600' 300' 0' 600' 1200'

SANBORN HEAD

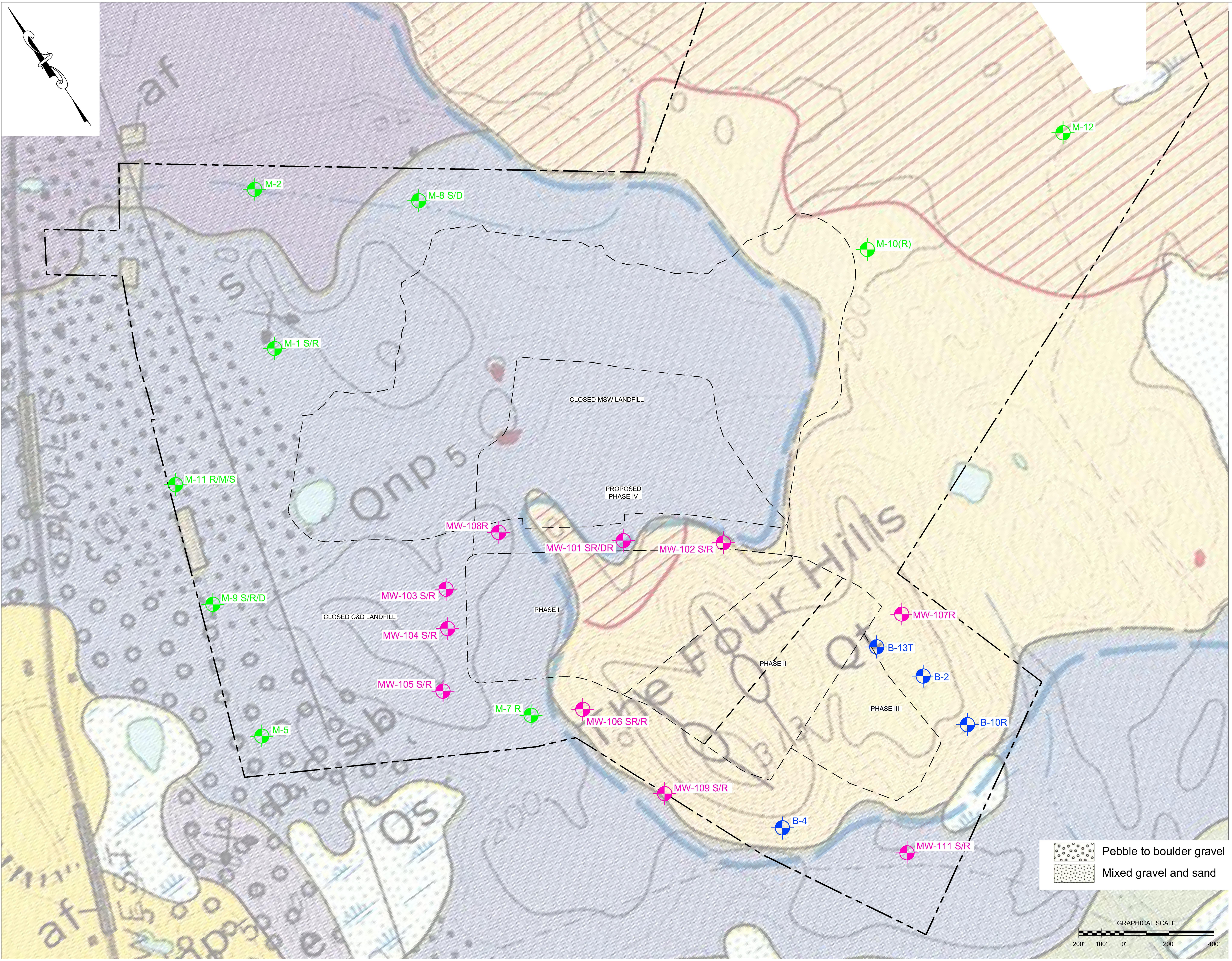


Figure 5

Four Hills Landfill Surficial Geologic Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire
Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate locations of major site features and the site monitoring wells based on information provided by the City of Nashua overlain on a surficial geological map.

Notes

1. Base plan was created using a plan titled "Overall Site Plan" prepared by CMA Engineers, of Portsmouth, New Hampshire, original scale 1"=200', provided to Sanborn Head by Nashua Division of Public Works, Solid Waste Division Four Hills Landfill, Nashua, New Hampshire.

2. Surficial geologic map from: Koteff, C. and Volckmann, R.P., 1973, Surficial Geologic Map of the Pepperell Quadrangle, Middlesex County, Massachusetts, and Hillsborough County, New Hampshire, scale 1:24,000 (https://pubs.er.usgs.gov/publication/gq118)

Legend

🟥	Groundwater release detection well
🟩	Groundwater management wells
🟦	Groundwater elevation measurement location
Qs	Swamp Deposits
Qst	Stream-Terrace Deposits
Qnp₄	Glacial Lake Nashua Deposits
Qnp₅	
Qnb	Lake Bottom Deposits
Qt	Till
af	Artificial Fill
▨	Bedrock Exposures
—	Contact
—○—	Long axis of drumlin
→	Melt-water Channel

SANBORN HEAD

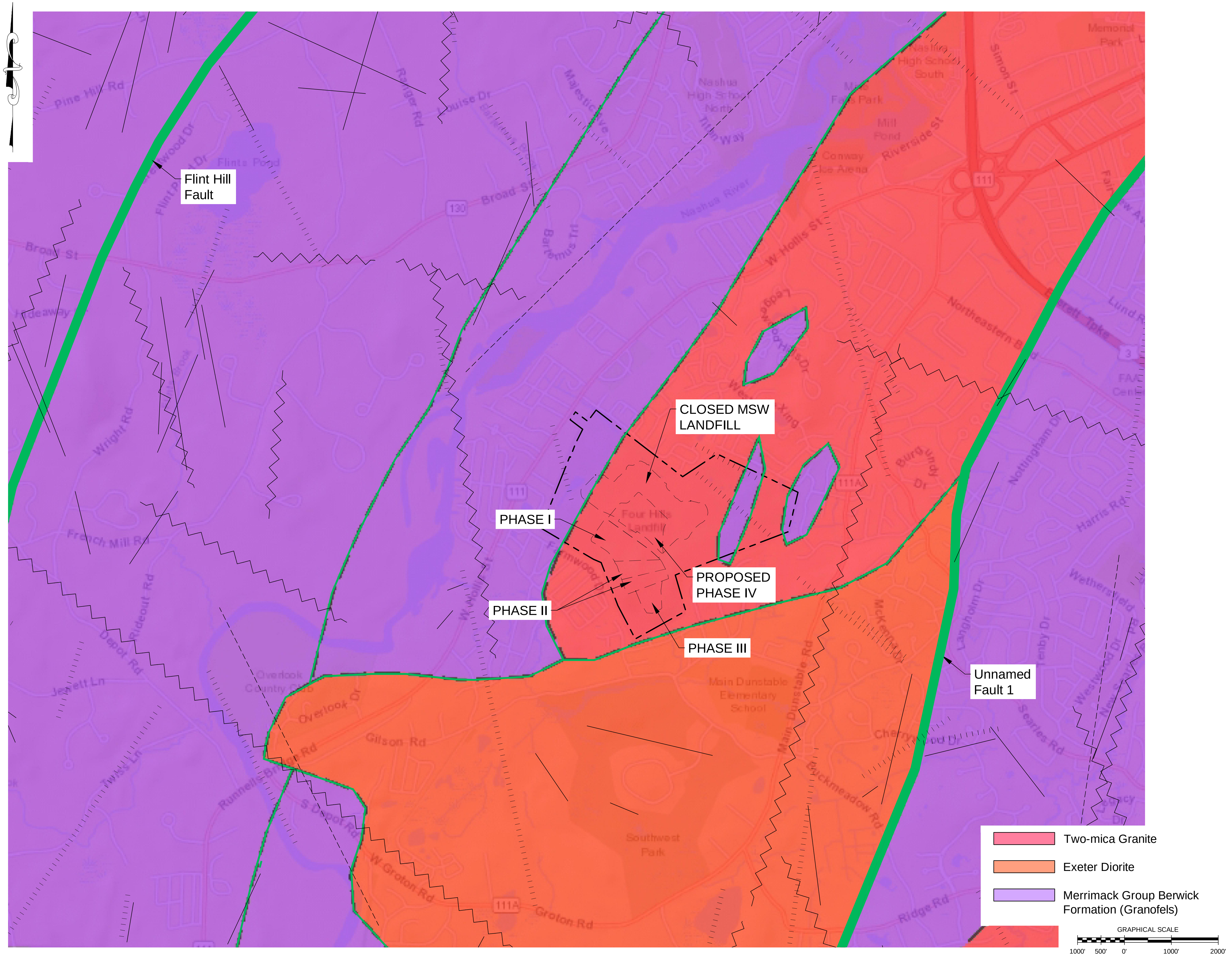


Figure 6

Four Hills Landfill Bedrock Geologic Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire
Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate extents of the various types of bedrock, inferred bedrock lineaments, and location of mapped fault lines.

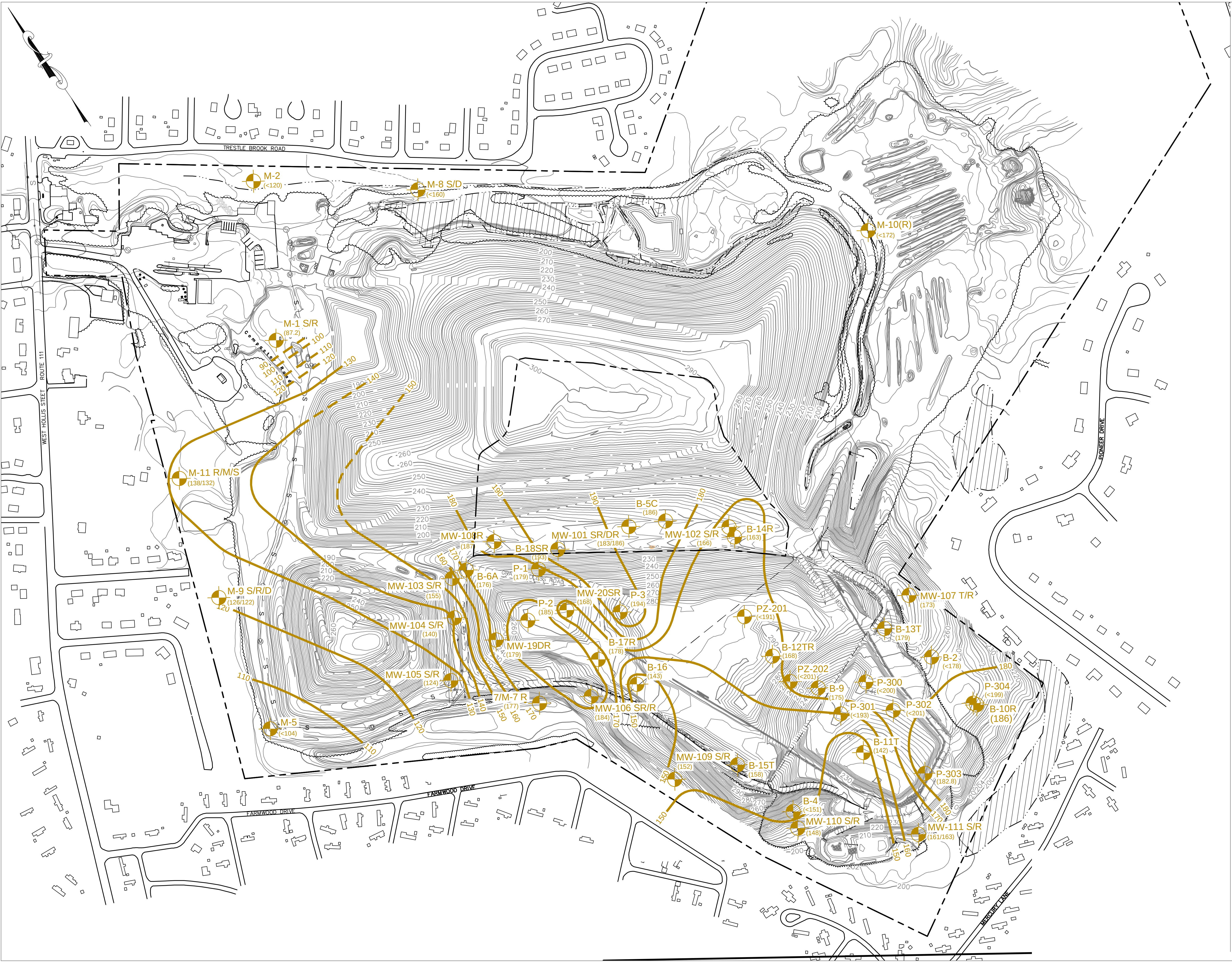
Notes

1. Bedrock geologic map: Lyons, J.B., Bothner, W.A., Moench, R.H. and Thompson, J.B., Jr., 1997, Bedrock Geologic Map of New Hampshire: U.S. Geological Survey, scale 1:250,000; downloaded through NHDES OneStop Data Mapper.
2. Lineaments are digitized from: Clark Jr., S.F, Ferguson, E.W., Picard, M.Z., Moore, R.B., 1997, Lineament Map of Area 2 of the New Hampshire Bedrock Aquifer Assessment, South-Central New Hampshire, Open File Report 96-490, scale 1:48,000.

Legend

—·—·—	Property Boundary
— — —	Phase Line
—	Lithologic Contact
▬	Fault Line
—	Lineament observed by the use of low-altitude aerial photography (Scale = 1:20,000)
ǀǀǀǀǀǀǀǀ	Lineament observed by the used of high-altitude aerial photography (Scale = 1:80,000)
/\/\/\	Lineament observed by the use of 1:250,000-scale side-looking airborne radar imagery
- - - - -	Lineament observed by the use of 1:1,000,000-scale Landsat imagery

SANBORN HEAD



File:P:\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\07-Bedrock Elevation Contour Plan.dwg Plot Date: 5-22-20

Figure 7

Four Hills Landfill Bedrock Elevation Contour Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire

Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows bedrock elevation contours. The contours have been developed based on limited information and widely spaced observation points. Actual conditions may vary from those shown.

Notes

1. Base plan was created using a plan titled "Overall Site Plan" prepared by CMA Engineers, of Portsmouth, New Hampshire, original scale 1"=200', provided to Sanborn Head by Nashua Division of Public Works, Solid Waste Division Four Hills Landfill, Nashua, New Hampshire.

2. Bedrock elevations are referenced from: "Hydrogeologic Report for a Secure Expansion of the Four Hills Landfill Nashua, New Hampshire," prepared by C.E.H., dated 1992, and "June/July 2011 Groundwater Monitoring Data Review Nashua Four Hills Landfill DES Site #198403099," prepared by the City of Nashua, New Hampshire, dated September 14, 2011.

Legend

⊕ M-7R	Monitoring Well
⊕ B-10R	Boring Location
━	Bedrock Elevation Contour
170	Bedrock Elevation Contour Label

GRAPHICAL SCALE
200' 100' 0' 200' 400'

SANBORN HEAD

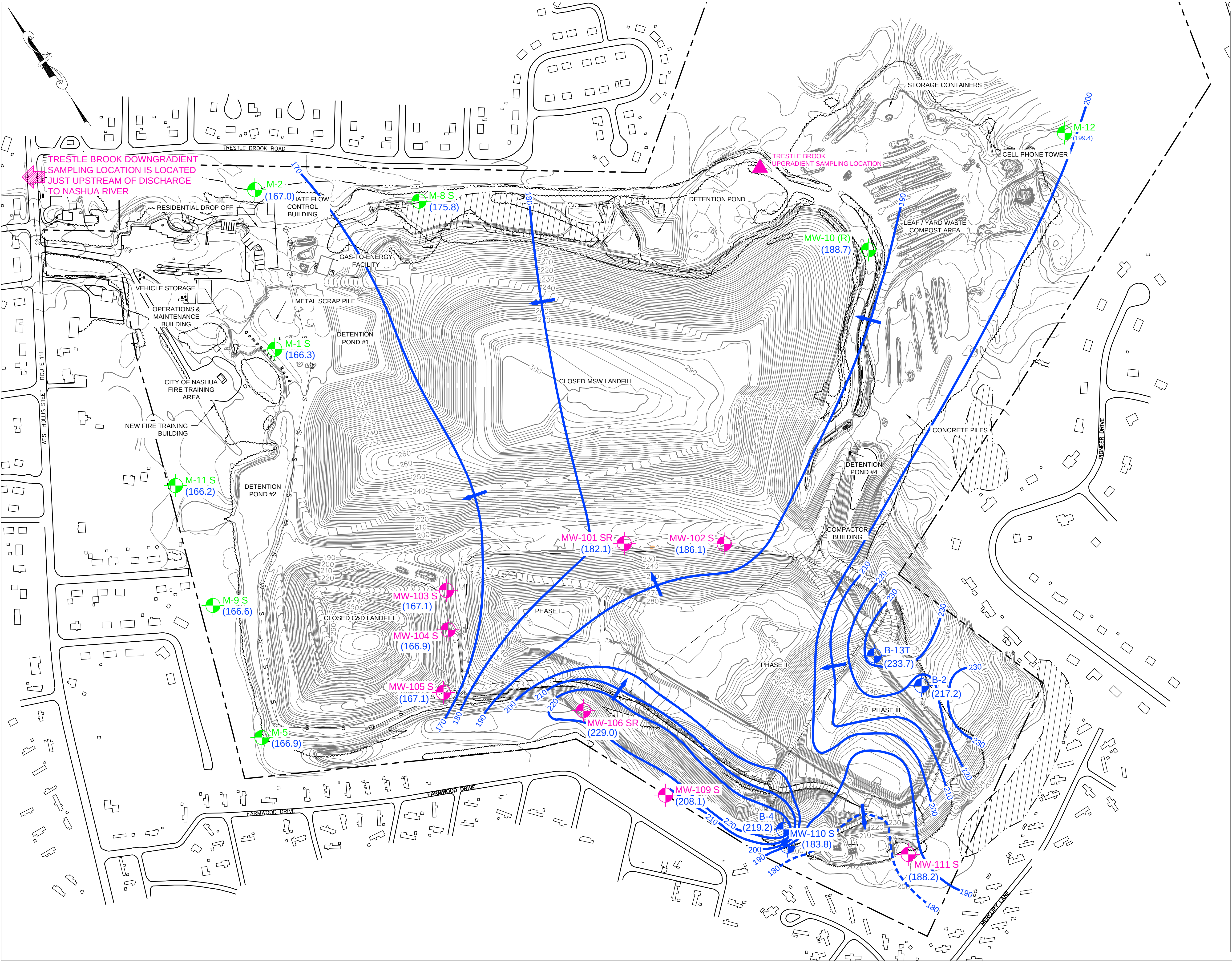


Figure 8

Four Hills Landfill Overburden Groundwater Elevation Contour Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire
Nashua, New Hampshire

Drawn By:	D. Dombrowsky
Designed By:	S. Pope
Reviewed By:	E. Steinhauser
Project No:	3066.12
Date:	May 2020

Figure Narrative

This figure shows the approximate locations of major site features, site monitoring wells and groundwater elevation data provided by the City of Nashua.

Notes

1. The groundwater level measurements were recorded at the time and under the conditions stated in the text of the report. Fluctuations in the water levels in the study area may occur due to variations in season, precipitation, temperature, runoff, and other factors. Units are in feet above mean sea level.

2. The groundwater elevation contours shown have been developed using generally accepted hydrogeologic practices based on limited information and widely spaced monitoring points. The contours shown are intended to depict inferred trends in groundwater flow conditions. Actual conditions may vary from those shown. Other interpretations are possible.

3. Refer to text for additional details.

4. M-12 is screened across both bedrock and overburden.

5. MW-111S was inaccessible during the November sampling event; the water level measurement made on October 31, 2019 is used as a proxy for this figure.

Legend

MW-102S ⊕	Groundwater release detection wells
M-1S ⊕	Groundwater management wells
B-2 ⊕	Groundwater elevation measurement location
(217.2)	Groundwater elevation during November 2019 sampling.
—190—	Groundwater elevation contour (dashed where less constrained)

200' 100' 0 200' 400' Feet

SANBORN HEAD

File:P:\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\08-09-Overburden GW and Bedrock GW Plan.dwg Plot Date: 5-19-20

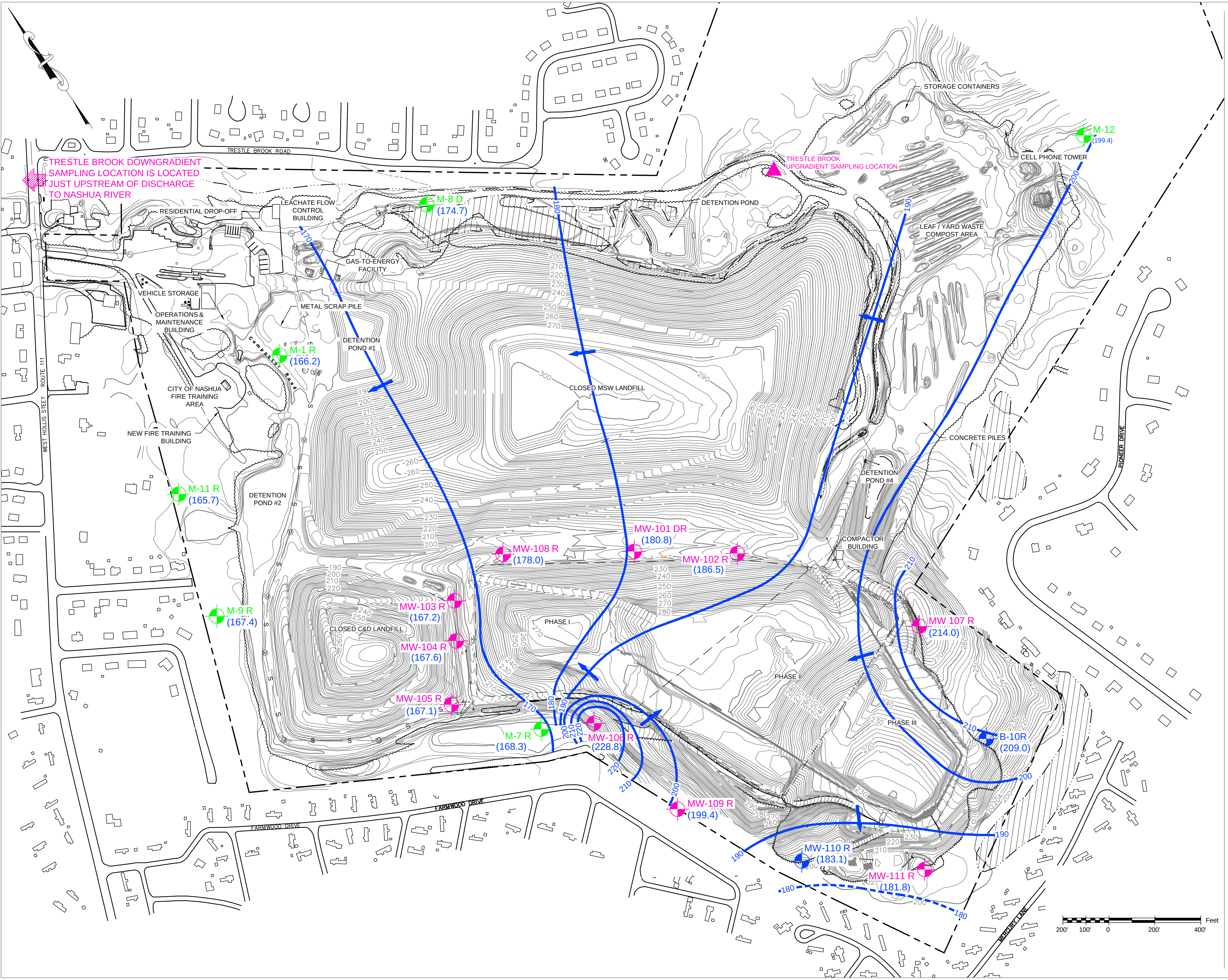


Figure 9

Four Hills Landfill Bedrock Groundwater Elevation Contour Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire

Nashua, New Hampshire

Drawn By: D. Dombrowsky
Designed By: S. Pope
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate locations of major site features, site monitoring wells and groundwater elevation data provided by the City of Nashua.

Notes

1. The groundwater level measurements were recorded at the time and under the conditions stated in the text of the report. Fluctuations in the water levels in the study area may occur due to variations in season, precipitation, temperature, runoff, and other factors. Units are in feet above mean sea level.

2. The groundwater elevation contours shown have been developed using generally accepted hydrogeologic practices based on limited information and widely spaced monitoring points. The contours shown are intended to depict inferred trends in groundwater flow conditions. Actual conditions may vary from those shown. Other interpretations are possible.

3. Refer to text for additional details.

4. M-12 is screened across both bedrock and overburden.

Legend

MW-107 R ⊕	Groundwater release detection wells
M-7 R ⊕	Groundwater management wells
B-10R ⊕	Groundwater elevation measurement location
(209.0)	Groundwater elevation during November 2019 sampling.
—190—	Groundwater elevation contour (dashed where less constrained)
<	Indicates the well was dry at the time of measurement. Elevation refers to the bottom of the well.

SANBORN HEAD

File:P:\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\08-09-Overburden GW and Bedrock GW Plan.dwg Plot Date: 5-19-20

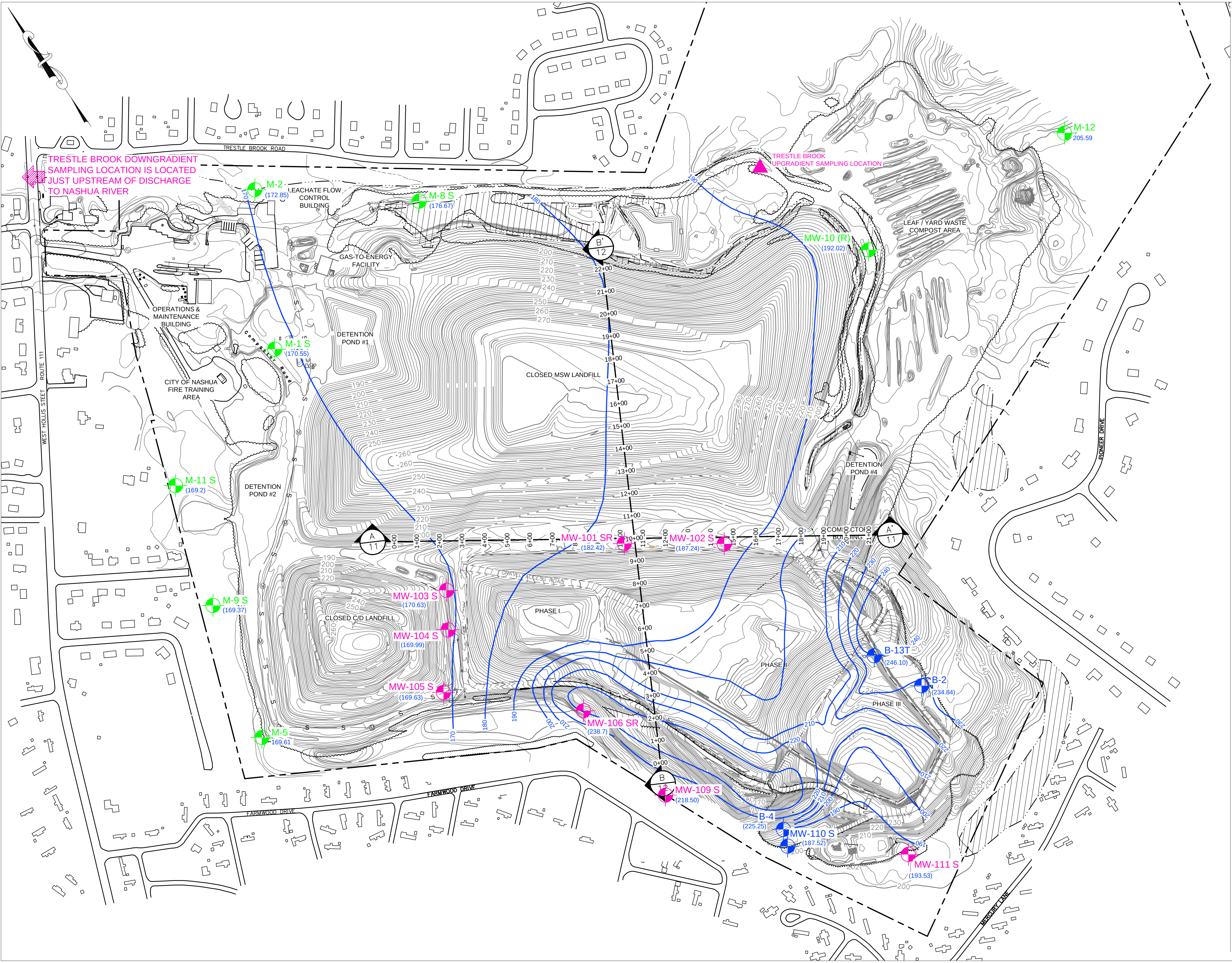


Figure 10

Seasonal High Groundwater Elevation Contour Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire

Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate locations of major site features, site monitoring wells and seasonal high groundwater elevation contours.

Notes

1. The groundwater level measurements were recorded at the time and under the conditions stated in the text of the report. Fluctuations in the water levels in the study area may occur due to variations in season, precipitation, temperature, runoff, and other factors. Units are in feet above mean sea level.

2. The groundwater elevation contours shown have been developed using generally accepted hydrogeologic practices based on limited information and widely spaced monitoring points. The contours shown are intended to depict inferred trends in groundwater flow conditions. Actual conditions may vary from those shown. Other interpretations are possible.

3. Refer to text for additional details.

Legend

⊕ ⊕ ⊕	Groundwater elevation measurement location
(208.4)	Seasonal high groundwater elevation
—190—	Groundwater elevation contour
A 11 —— A' 11	Cross Section A-A' shown on Figure 11
B 12 —— B' 12	Cross Section B-B' shown on Figure 12

200' 100' 0 200' 400' Feet

SANBORN HEAD

IMAGES

XREFS: \\conserv1\shdata\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\Xrefs\COMPILED BASE.dwg
\\conserv1\shdata\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\Xrefs\Proposed Secondary Liner Grades.dwg
\\conserv1\shdata\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\Xrefs\Proposed Waste Grades.dwg
\\conserv1\shdata\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\Xrefs\Phases I Through III Waste Grades.dwg
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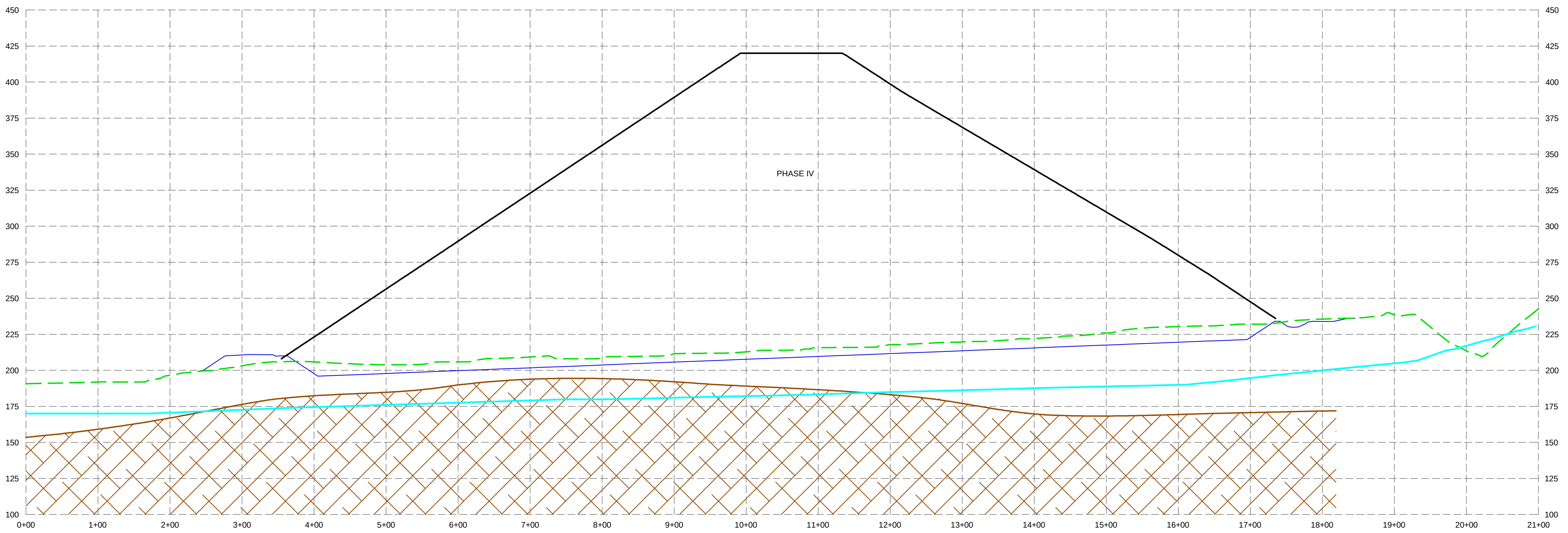
P:\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\Xrefs\190287A-4 As-Built (SHA edited).dwg

NOTE:

1. PROPOSED WASTE GRADES ARE SHOWN FOR ILLUSTRATIVE PURPOSES. REFER TO SHEET 10 OF THE PHASE IV DESIGN DRAWINGS FROM THE TYPE I-A PERMIT MODIFICATION APPLICATION.

2. BEDROCK ELEVATIONS ARE REFERENCED FROM: "HYDROGEOLOGIC REPORT FOR A SECURE EXPANSION OF THE FOUR HILLS LANDFILL NASHUA, NEW HAMPSHIRE," PREPARED BY C.E.H., DATED 1992, AND "JUNE/JULY 2011 GROUNDWATER MONITORING DATA REVIEW NASHUA FOUR HILLS LANDFILL DES SITE #198403099," PREPARED BY THE CITY OF NASHUA, NEW HAMPSHIRE, DATED SEPTEMBER 14, 2011.

3. SEASONAL HIGH GROUNDWATER ELEVATIONS ARE BASED ON GROUNDWATER ELEVATION DATA MEASURED AT THE SITE SINCE MAY 2008.



CROSS SECTION A - A'

NOT TO SCALE

LEGEND:

━ PROPOSED WASTE GRADES

─ SECONDARY BASE GRADES

– – EXISTING GRADE

▨ BEDROCK

─ SEASONAL HIGH GROUNDWATER ELEVATION

- *NOT FOR CONSTRUCTION* -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

VERTICAL SCALE
40' 20' 0' 40' 80'
80' 40' 0' 80' 160'
HORIZONTAL SCALE

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: MAY 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

CROSS SECTIONS

PROJECT NUMBER:
3066.12

FIGURE NUMBER:
11

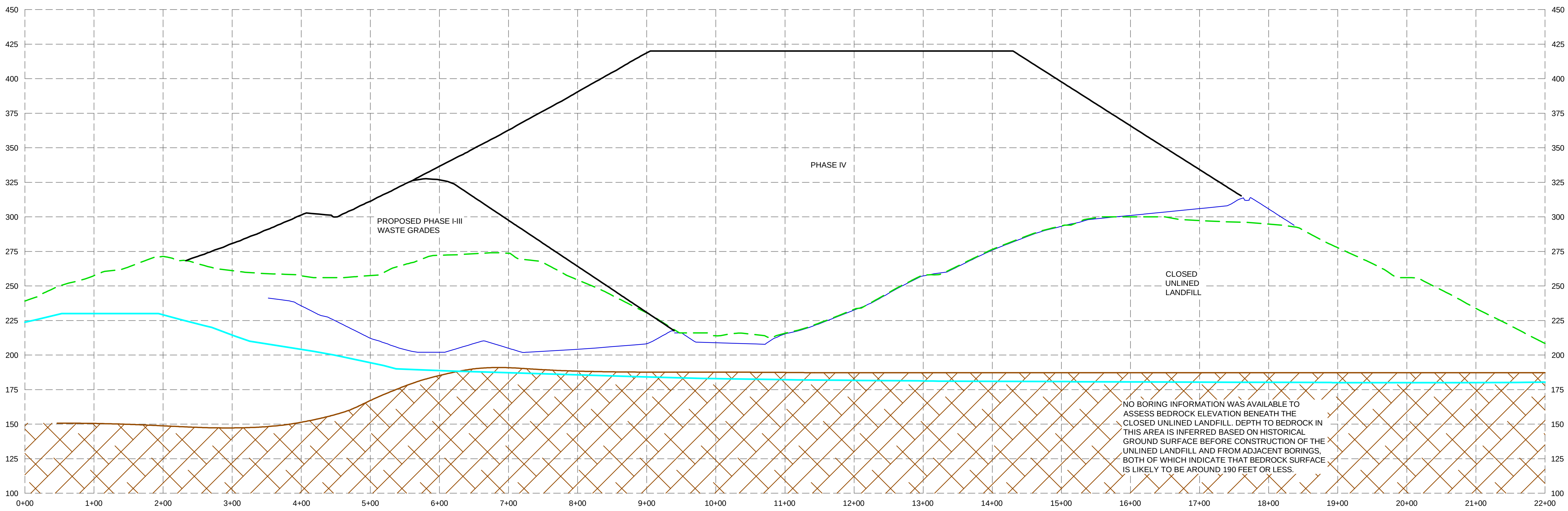
FILE: P:\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\11-12 Cross Sections.dwg
LAYOUT: A-A'
USER: ssantiago
PLOT DATE: 7-16-20 8:30 AM

NOTE:

1. PROPOSED WASTE GRADES ARE SHOWN FOR ILLUSTRATIVE PURPOSES. REFER TO SHEET 10 OF THE PHASE IV DESIGN DRAWINGS FROM THE TYPE I-A PERMIT MODIFICATION APPLICATION.

2. BEDROCK ELEVATIONS ARE REFERENCED FROM: "HYDROGEOLOGIC REPORT FOR A SECURE EXPANSION OF THE FOUR HILLS LANDFILL NASHUA, NEW HAMPSHIRE," PREPARED BY C.E.H., DATED 1992, AND "JUNE/JULY 2011 GROUNDWATER MONITORING DATA REVIEW NASHUA FOUR HILLS LANDFILL DES SITE #198403099," PREPARED BY THE CITY OF NASHUA, NEW HAMPSHIRE, DATED SEPTEMBER 14, 2011.

3. SEASONAL HIGH GROUNDWATER ELEVATIONS ARE BASED ON GROUNDWATER ELEVATION DATA MEASURED AT THE SITE SINCE MAY 2008.



NO BORING INFORMATION WAS AVAILABLE TO ASSESS BEDROCK ELEVATION BENEATH THE CLOSED UNLINED LANDFILL. DEPTH TO BEDROCK IN THIS AREA IS INFERRED BASED ON HISTORICAL GROUND SURFACE BEFORE CONSTRUCTION OF THE UNLINED LANDFILL AND FROM ADJACENT BORINGS, BOTH OF WHICH INDICATE THAT BEDROCK SURFACE IS LIKELY TO BE AROUND 190 FEET OR LESS.

CROSS SECTION B - B'

NOT TO SCALE

LEGEND:

— PROPOSED WASTE GRADES

— SECONDARY BASE GRADES

– – EXISTING GRADE

▨ BEDROCK

— SEASONAL HIGH GROUNDWATER ELEVATION

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

VERTICAL SCALE
40' 20' 0' 40' 80'
80' 40' 0' 80' 160'
HORIZONTAL SCALE

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: MAY 2020

PHASE IV AREA DESIGN
FOUR HILLS LANDFILL
NASHUA, NEW HAMPSHIRE

CROSS SECTIONS

PROJECT NUMBER:
3066.12

FIGURE NUMBER:
12

Figure 13

Four Hills Landfill Proposed Monitoring Well Location Plan

Hydrogeologic Report
Phase IV Secure Landfill Expansion
Four Hills Landfill
City of Nashua, New Hampshire

Nashua, New Hampshire

Drawn By: S. Santiago
Designed By: A. Ashton
Reviewed By: E. Steinhauser
Project No: 3066.12
Date: May 2020

Figure Narrative

This figure shows the approximate locations of major site features, site monitoring wells based on information provided by the City of Nashua, and locations of proposed replacement groundwater release detection wells.

Notes

1. The existing topography and site features are based on ground field survey performed by WSP USA, Inc. of Nashua, New Hampshire on July 20, 2017 and July 21, 2017. Horizontal Datum: NAD83 (2001). Horizontal Projection: NH State Plane. Vertical Datum: NGVD 29.

2. Refer to text for additional details.

Legend

MW-102S	Groundwater release detection wells
M-1S	Groundwater management wells
B-2	Groundwater elevation measurement location
▲	Surface Water Sampling Location
▨	Wetland
— — —	Proposed Phase IV Limit of Waste
○	Well proposed for decommissioning as part of proposed Phase IV construction
A	Proposed Replacement Groundwater Release Detection Well

200' 100' 0 200' 400' Feet

SANBORN HEAD

File:\\conserv1\shdata\3000s\3066.12\Graphics Files\CAD\Hydrogeo Rpt\13-Proposed Monitoring Well Location Plan.dwg Plot Date: 7-15-20

APPENDIX A

LIMITATIONS

APPENDIX A
LIMITATIONS

1. The conclusions and recommendations described in this report are based in part on the data obtained from a limited number of soil samples from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further investigation is initiated. If variations or other latent conditions then appear evident, it will be necessary to re-evaluate the recommendations of this report.

2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more gradual. For specific information, refer to the exploration logs.

3. Water level measurements have been made in the observation wells at times and under conditions stated within the text of the report and indicated on the exploration logs and in the report. Note that fluctuations in the level of the groundwater may occur due to variations in rainfall and other factors not evident at the time measurements were made.

4. The conclusions and recommendations contained in this report are based in part upon historical and hydrogeologic information developed by previous investigators. While Sanborn Head has reviewed that data and information as stated in this report, any of Sanborn Head's interpretations, conclusions, and recommendations that have relied on that information will be contingent on its validity. Should additional chemical data, historical information, or hydrogeologic information become available in the future, such information should be reviewed by Sanborn Head and the interpretations, conclusions and recommendations presented herein should be modified accordingly.

5. This report has been prepared for the exclusive use of the City of Nashua, New Hampshire for specific application for the Four Hills Landfill, Nashua, New Hampshire, in accordance with generally accepted hydrogeologic practices. No other warranty, express or implied, is made.

6. The analyses and recommendations contained in this report are based on the data obtained from the referenced subsurface explorations. The explorations indicate subsurface conditions only at the specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between such locations. The validity of the recommendations is based in part on assumptions Sanborn Head has made about conditions at the site. If subsurface conditions different from those described become evident, the recommendations in this report must be re-evaluated.

7. In the event that any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by Sanborn Head. Sanborn Head is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or re-use of the subsurface data or engineering analyses without the express written authorization of Sanborn Head.

P:\3000s\3066.12\Source Files\Ph IV HG Rpt\App A - Limitations\202005 Limitations.docx

APPENDIX B

PHASE IV AREA SOIL/BEDROCK BORING LOGS

E TEST BORINGS, INC.
REWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY

SHEET 1 OF 2

HOLE NO. DR-101

RILLER
ERVIN GIGUERE

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NH

OFFSET

ROUND WATER OBSERVATIONS

T FT. AFTER HOURS

T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW		HQ
SIZE I.D.	4"		2 1/2"
HAMMER WT.	300		
HAMMER FALL	16"		

DATE START 05/26/99

DATE FINISH 05/27/99

SURFACE ELEVATION

ASING LOWS PER OOT	SAMPLE NO.	SAMPLE O.D.	SAMPLE PEN.	SAMPLE REC.	SAMPLE DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	BLOWS PER 6" ON SAMPLER 6-12	BLOWS PER 6" ON SAMPLER 12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
GER										0.5	TOPSOIL
"											
"											
"											
"											
"											
"											
"											
"											
"											
17											GRAY FINE GRAVELLY FINE SANDY SILT WITH COBBLES
27											(TILL) (FILL)
43											
69											
105											
196											
178											
47											
49											
53											
										22.0	
										23.2	BROWN M-C SAND WITH COBBLES
199											
306										25.7	BOULDER
416											
246	1R	*	1.9'	1.0'	27.6	53%					BROWN M-C SAND WITH COBBLES
328											
187										29.0	
293										29.8	BOULDER
327											
398										32.6	BROWN M-C SAND WITH COBBLES
											ROCK
	2R	*	2.7'	2.7'	37.7	100%					
	3R	*	2.3'	1.7'	40.0	74%					

SAMPLES
D = SPLIT SPOON
D = 2" SHELBY TUBE
S = 3" SHELBY TUBE
P = 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:
WASHED AHEAD 12.0'-23.2'
* 3 25/32"

HOLE NO. DR-101

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY, INC.

SHEET 2 OF 2

HOLE NO. DR-101

RILLER
ERVIN GIGUERE

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

.T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NE

OFFSET

ROUND WATER OBSERVATIONS

T FT. AFTER HOURS

T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW		HQ
SIZE I.D.	4"		2 1/2"
HAMMER WT.	300		
HAMMER FALL	16"		

DATE START	DATE FINISI
05/26/99	05/27/99

SURFACE ELEVATION

ASING LOWS PER OOT	SAMPLE NO.	SAMPLE O.D.	SAMPLE PEN.	SAMPLE REC.	SAMPLE DEPTH @ BOT	BLOWS PER 6" ON SAMPLER 0-6	BLOWS PER 6" ON SAMPLER 6-12	BLOWS PER 6" ON SAMPLER 12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
	4R	3"	2.7'	2.7'	42.7	100%					
	5R	3"	2.8'	2.8'	45.5	100%					
	6R	3"	3.4'	3.4'	49.9	100%					
	7R	3"	2.1'	2.1'	51.0	100%					ROCK
	8R	3"	3.0'	3.0'	54.0	100%					
	9R	3"	3.0'	3.0'	57.0	100%					
	10R	3"	2.8'	2.8'	59.8	100%				59.8	
											BOTTOM OF BORING @ 59.8'

SAMPLES
= SPLIT SPOON
= 2" SHELBY TUBE
= 3" SHELBY TUBE
= 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
XX DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:
INSTALLED WELL @ 59.5'
" 3 25/32"

HOLE NO. DR-101

/AINE TEST BORINGS, INC. BREWER, MAINE 04412	CLIENT JACQUES WHITFORD COMPANY	SHEET 1 OF 2 HOLE NO. SR-101
RILLER ERVIN GIGUERE	PROJECT NAME NASHUA LANDFILL	LINE & STATION
T.B. JOB NUMBER 99-103	LOCATION NASHUA, NH	OFFSET

ROUND WATER OBSERVATIONS

T FT. AFTER HOURS

T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	NQ2
SIZE I.D.	4"	1 3/8"	2"
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START	DATE FINISH
05/24/99	05/25/99

SURFACE ELEVATION

ASING LOWS PER OOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
GER										0.5	TOPSOIL
"											
"											
"											
"											
"	1D	2"	18"		6.5	17	53	79			
"											
"											
"											
"											GRAY FINE GRAVELLY FINE SANDY SILT WITH COBBLES
33	2D	2"	12"		11.0	27	100				(FILL)
42											
53											
37											
33											
32	3D	2"	18"		16.5	11	9	15			
36											
43											
62											
08											
39	4D	2"	18"		21.5	21	24	22		21.0	
43										21.5	PEAT, ORGANICS
52											
63										24.0	BROWN M-F SAND
37											
76											BROWN M-C SAND WITH COBBLES, SMALL BOULDERS
72											
97											
03	1R	3"	5.0'	1.5'	29.0	30%				29.7	
	2R	3"	4.7'	2.7'	34.4	58%					ROCK
	3R	3"	4.0'	3.6'	38.4	90%					

SAMPLES

= SPLIT SPOON

= 2" SHELBY TUBE

= 3" SHELBY TUBE

= 3½" SHELBY TUBE

SOIL CLASSIFIED BY:

☒ DRILLER-VISUALLY

☐ SOIL TECHNICIAN-VISUALLY

☐ LABORATORY TESTS

REMARKS:

HOLE NO. SR-101

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY

SHEET 2 OF 2

HOLE NO. SR-101

RILLER
ERVIN GIGUERE

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

.T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NH

OFFSET

ROUND WATER OBSERVATIONS

T FT. AFTER HOURS

T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	NQ2
SIZE I.D.	4"	1 3/8"	2"
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START	DATE FINISH
05/24/99	05/25/99

SURFACE ELEVATION

ASING LOWS PER OOT	SAMPLE NO.	SAMPLE O.D.	SAMPLE PEN.	SAMPLE REC.	SAMPLE DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
	4R	3"	3.6'	3.6'	42.0	100%					
	5D	2"	1.6'	1.6'	43.6	100%					ROCK
	6R	3"	1.8'								
										45.4	
											BOTTOM OF BORING @ 45.4'

SAMPLES
= SPLIT SPOON
= 2" SHELBY TUBE
= 3" SHELBY TUBE
= 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:
INSTALLED WELL @ 43.7'

HOLE NO. SR-101

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT: JACQUES WHITFORD COMPANY, INC.

SHEET 1 OF 1

HOLE NO. B102R

RILLER: MIKE PORTER

PROJECT NAME: NASHUA LANDFILL

LINE & STATION:

.T.B. JOB NUMBER: 99-103

LOCATION: NASHUA, NH

OFFSET:

ROUND WATER OBSERVATIONS

T FT. AFTER HOURS

T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	NQ2
SIZE I.D.	4"	1 3/8"	2"
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START	DATE FINIS
07/02/99	07/03/99

SURFACE ELEVATION

ASING LOWS PER OOT	SAMPLE NO.	SAMPLE O.D.	SAMPLE PEN	SAMPLE REC	SAMPLE DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	BLOWS PER 6" ON SAMPLER 6-12	BLOWS PER 6" ON SAMPLER 12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
											AUGER 0.0'-10.0' WASH & DRIVE CASING TO 50.0'

SAMPLES
SPLIT SPOON
2" SHELBY TUBE
3" SHELBY TUBE
3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:

HOLE NO.

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY, INC.

SHEET 2 OF 2

HOLE NO. B102R

DRILLER
MIKE PORTER

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

M.T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NH

OFFSET

GROUND WATER OBSERVATIONS

AT FT. AFTER HOURS

AT FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	NQ2
SIZE I.D.	4"	1 3/8"	2"
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START	DATE FINIS
07/02/99	07/03/99

SURFACE ELEVATION

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
											GRAY SILTY SANDY GRAVEL
56											
70											
64	1D	2"	10"		56.3	52	50				
86											
66											
69											
79											
60											
63											
00										59.5	
	1R	3"	4.5'	4.5'	64.4	100%					
	2R	3"	3.1'	3.1'	67.5	100%					ROCK
	3R	3"	4.0'	4.0'	71.5	100%					
	4R	3"	3.0'	3.0'	74.5	100%				74.5	
											BOTTOM OF BORING @ 74.5'

SAMPLES
= SPLIT SPOON
= 2" SHELBY TUBE
= 3" SHELBY TUBE
= 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ XX DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:
INSTALLED WELL @ 74.5'

HOLE NO.

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY

SHEET 1 OF 2

HOLE NO. MW-102S

DRILLER
ERVIN GIGUERE

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

M.T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NH

OFFSET

GROUND WATER OBSERVATIONS

AT FT. AFTER HOURS

AT FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	
SIZE I.D.	4"	1 3/8"	
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START	DATE FINIS
05/24/99	05/25/99

SURFACE ELEVATION

CASING BLOWS PER FOOT	SAMPLE					BLOWS PER 6" ON SAMPLER			VANE READING	DEPTH	STRATUM DESCRIPTION
	NO.	O.D.	PEN	REC.	DEPTH @ BOT.	0-6	6-12	12-18			
UGER										0.5	TOPSOIL
"										2.0	BROWN GRAVELLY FINE SAND WITH COBBLES
"											
"											
"											
"											
"	1D	2"	24"		7.0	7	17	32	43		
"											
"											
"											
27	2D	2"	12"		11.0	76	99				GRAY FINE GRAVELLY FINE SANDY SILT WITH COBBLES
43											(FILL)
30											
31											
57											
24	3D	2"	18"		16.5	47	63	76			
24											
27											
32											
67	4D	2"	8"		20.7	67	100			20.5	
26										21.0	BROWN FINE SAND
43											
69											BROWN FINE GRAVELLY FINE SANDY SILT WITH COBBLES
117											
86										25.8	
62	5D	2"	18"		26.5	103	82	56			
42											
53											
51											
47											GRAY FINE GRAVELLY FINE SANDY SILT WITH COBBLES
67	6D	2"	15"		31.2	45	72	100			(TILL)
78											
59										33.5	
58											
63											
63	7D	2"	18"		36.5	45	85	73			BROWN M-F SAND WITH TRACE OF FINE GRAVEL
67											
49											
53											
62											

SAMPLES
D = SPLIT SPOON
C = 2" SHELBY TUBE
S = 3" SHELBY TUBE
P = 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:
WASHED AHEAD 10.0'-50.0'

HOLE NO. MW-102S

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY

SHEET 2 OF 2

HOLE NO. MW-102S

RILLER
ERVIN GIGUERE

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

.T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NH

OFFSET

ROUND WATER OBSERVATIONS

T FT. AFTER HOURS

T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	
SIZE I.D.	4"	1 3/8"	
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START
05/24/99

DATE FINIS
05/25/99

SURFACE ELEVATION

ASING LOWS PER FOOT	SAMPLE NO.	O.D.	PEN	REC	DEPTH @ BOT	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
52	8D	2"	18"		41.5	53	60	59			
79											BROWN M-F SAND WITH TRACE OF FINE GRAVEL
72										43.0	
68											
79											
	9D	2"	18"		46.5	45	110	157			GRAY FINE GRAVELLY FINE SANDY SILT WITH COBBLES
	10D	2"	11"		50.9	93	117			50.9	
											BOTTOM OF BORING @ 50.9'

SAMPLES
) = SPLIT SPOON
; = 2" SHELBY TUBE
; = 3" SHELBY TUBE
' = 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

REMARKS:
INSTALLED WELL @ 45.0'

HOLE NO. MW-102S

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT
JACQUES WHITFORD COMPANY, INC.

SHEET 1 OF 1

HOLE NO. B-108SR

RILLER
ERVIN GIGUERE

PROJECT NAME
NASHUA LANDFILL

LINE & STATION

.T.B. JOB NUMBER
99-103

LOCATION
NASHUA, NE

OFFSET

ROUND WATER OBSERVATIONS

.T FT. AFTER HOURS

.T FT. AFTER HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	HW	SS	HQ
SIZE I.D.	4"	1 3/8"	2 1/2"
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START	DATE FINISI
05/26/99	05/27/99

SURFACE ELEVATION

ASING LOWS PER FOOT	SAMPLE NO.	SAMPLE O.D.	SAMPLE PEN.	SAMPLE REC.	SAMPLE DEPTH @ BOT	BLOWS PER 6" ON SAMPLER 0-6	BLOWS PER 6" ON SAMPLER 6-12	BLOWS PER 6" ON SAMPLER 12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
IGER										0.5	TOPSOIL
"											
"											GRAY FINE GRAVELLY FINE SANDY SILT W/COBBLES
"											
"											
"	1D	2"	18"		6.5	100					
"										7.2	
"											
"										9.5	BROWN M-F SAND
"	2D	2"	6"		10.5	120					
47											
83											BROWN FINE GRAVELLY FINE SANDY SILT WITH COBBLES
237											
83											
	3D	2"	1"		15.1	120				15.1	
										17.3	BOULDER
										19.1	BROWN FINE GRAVELLY FINE SANDY SILT WITH COBBLES
	1R	*	1.0'	1.0'	21.0	100%					
	2R	*	1.0'	1.0'	22.0	100%					
	3R	*	3.4'	3.4'	25.3	100%					
											ROCK
	4R	*	3.0'	3.0'	28.3	100%					
	5R	*	1.7'	1.0'	30.0	59%					
	6R	*	2.3'	2.3'	32.3	100%				32.3	
											BOTTOM OF BORING @ 32.3'

SAMPLES
= SPLIT SPOON
= 2" SHELBY TUBE
= 3" SHELBY TUBE
= 3½" SHELBY TUBE

SOIL CLASSIFIED BY:
☒ XX DRILLER-VISUALLY
☐ SOIL TECHNICIAN-VISUALLY
☐ LABORATORY TESTS

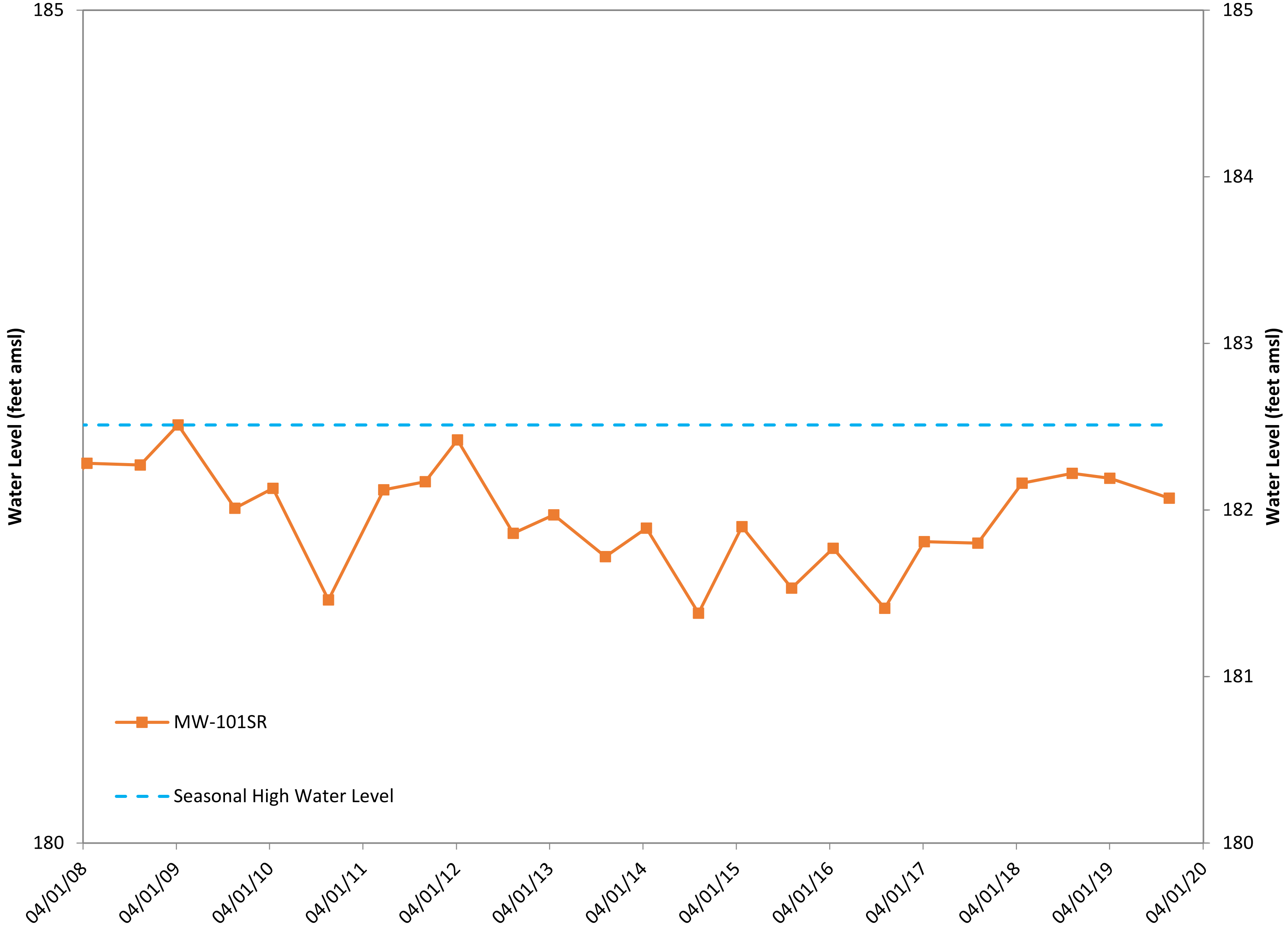
REMARKS:
* 3 25/32"
INSTALLED WELL @

HOLE NO. B-108SR

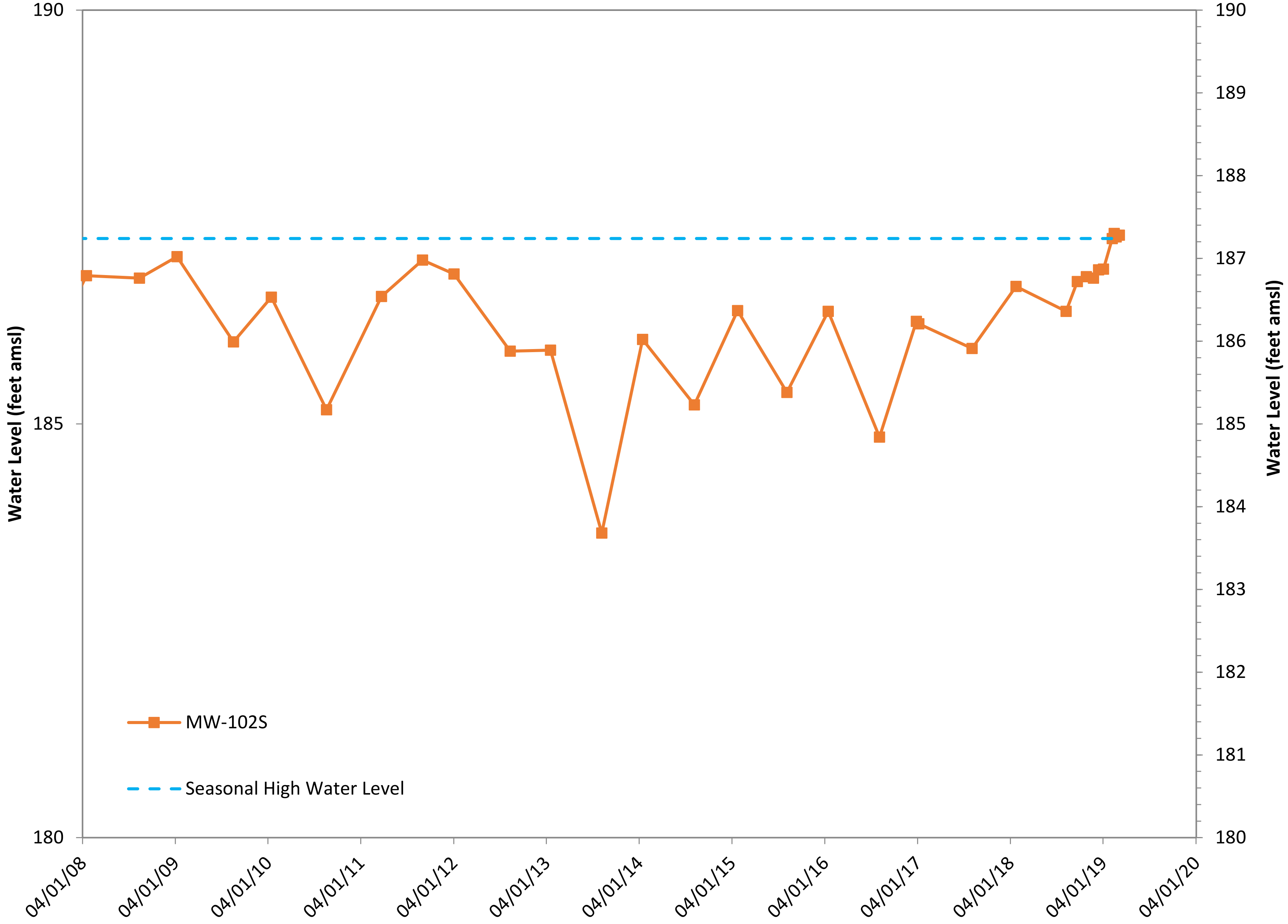
APPENDIX C

GROUNDWATER ELEVATION CHARTS

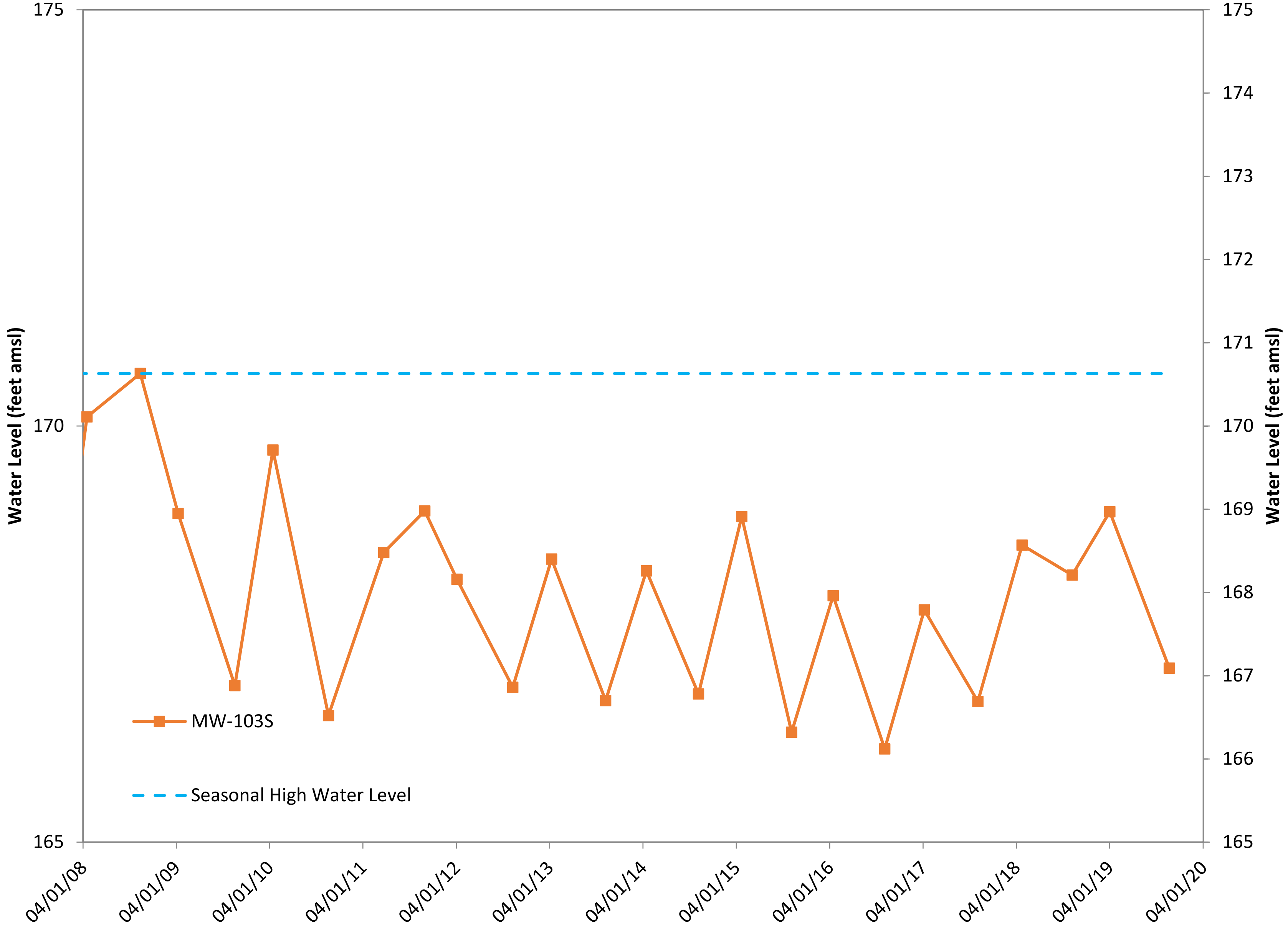
MW-101SR Water Level Summary Chart

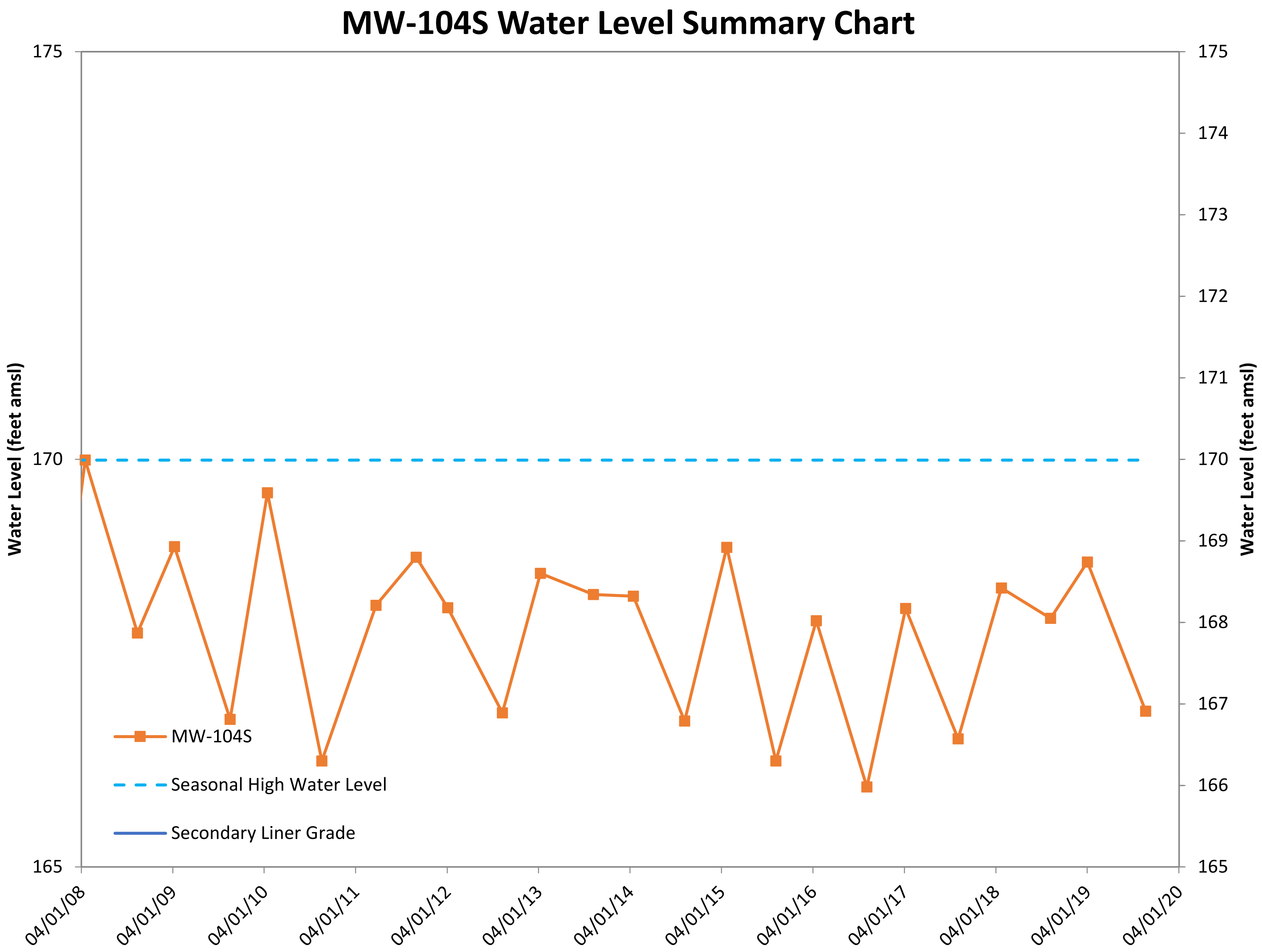


MW-102S Water Level Summary Chart

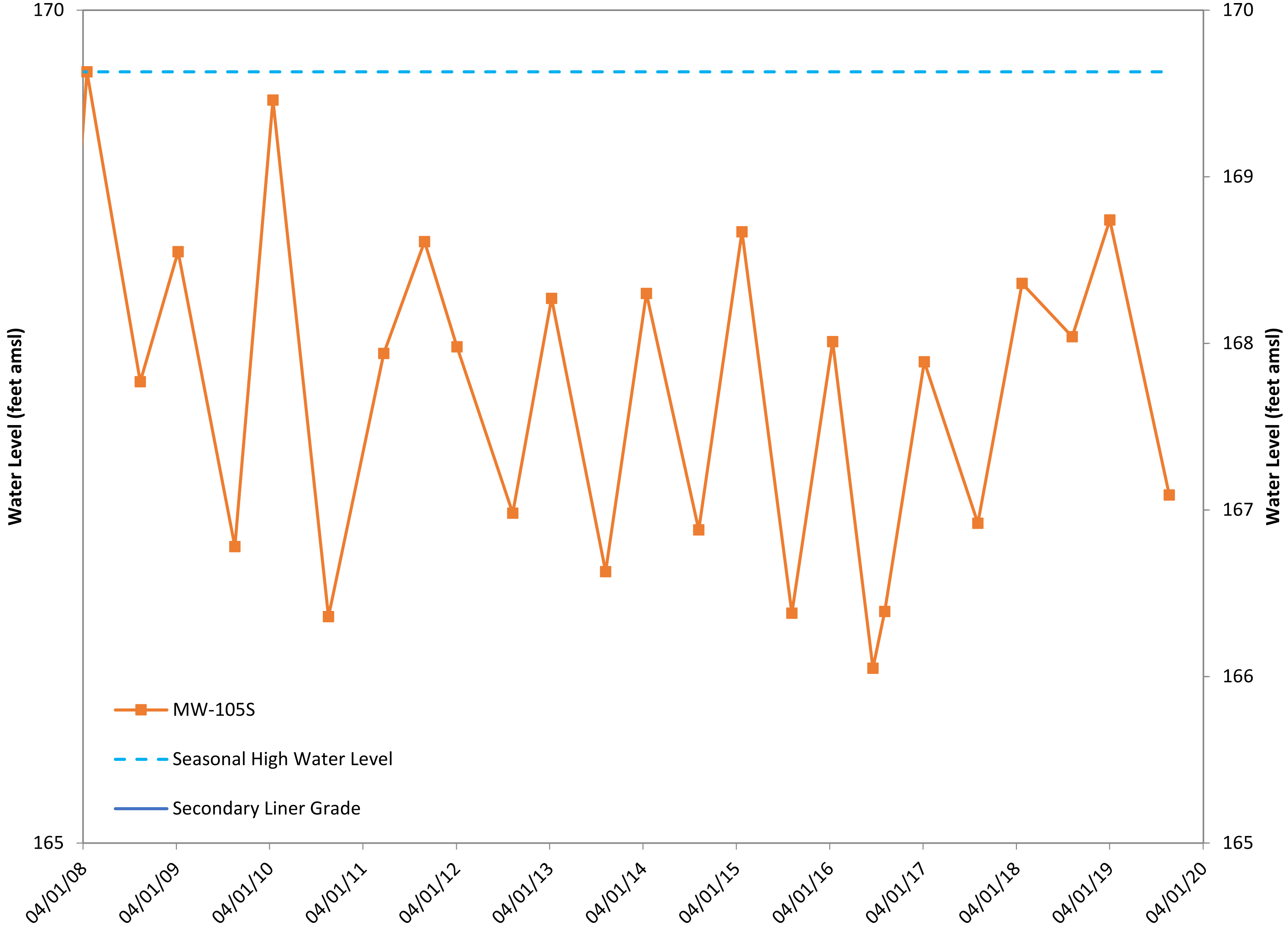


MW-103S Water Level Summary Chart

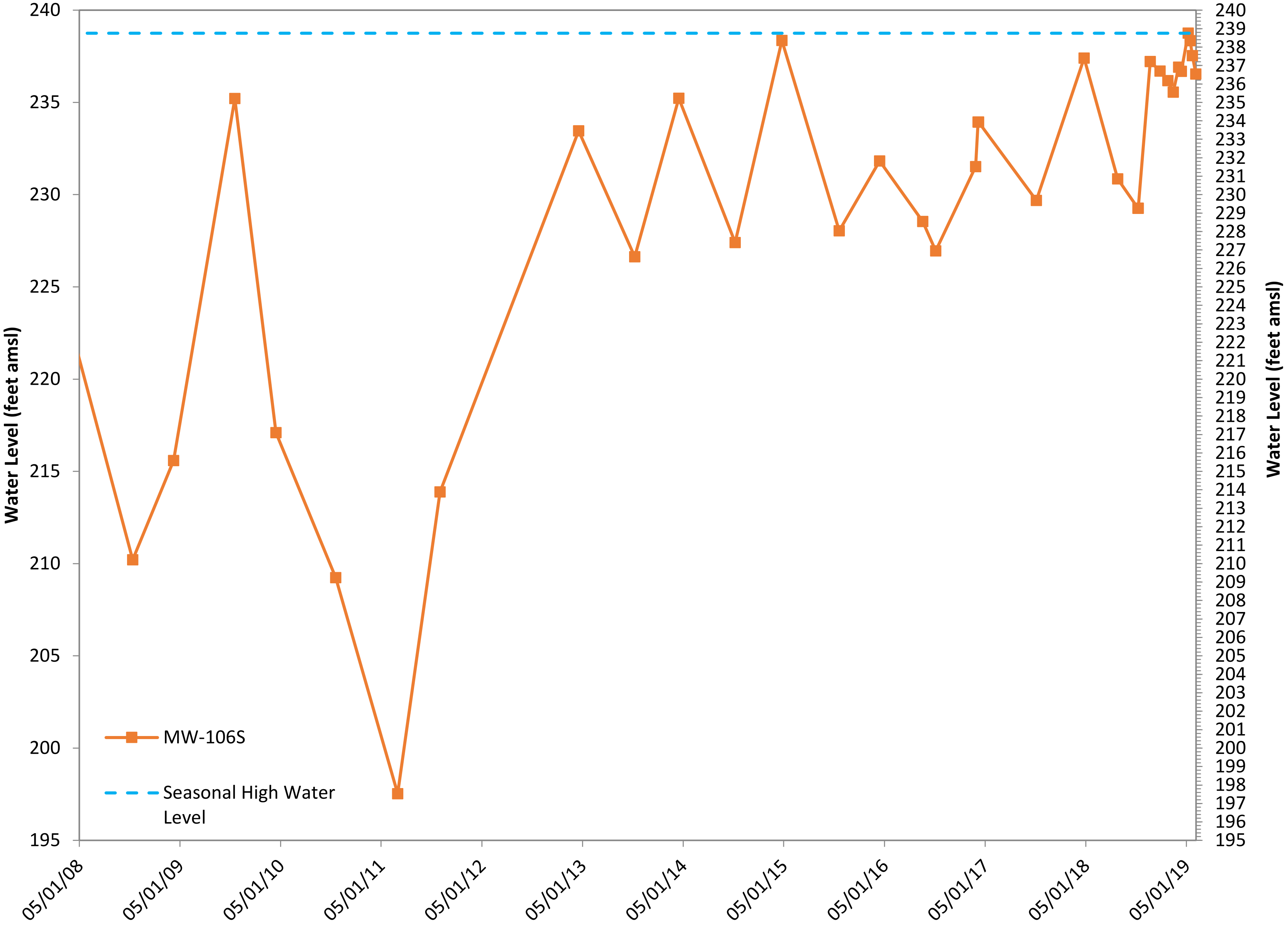



MW-104S Water Level Summary Chart
Water Level (feet amsl)
175
170
165
174
173
172
171
169
168
167
166
04/01/08
04/01/09
04/01/10
04/01/11
04/01/12
04/01/13
04/01/14
04/01/15
04/01/16
04/01/17
04/01/18
04/01/19
04/01/20
MW-104S
Seasonal High Water Level
Secondary Liner Grade

MW-105S Water Level Summary Chart



MW-106S Water Level Summary Chart



APPENDIX D

OPERATION PLAN

SANBORN HEAD

Building Trust. Engineering Success.

OPERATING PLAN

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Nashua
NEW HAMPSHIRE'S GATE CITY

Prepared for the City of Nashua
File No. 3066.11
July 2020

City of Nashua, New Hampshire

Four Hills Landfill

Operating Plan

Phase I/II/III/IV Secure Landfill Expansion

August 2007
Revised January 2008
Revised August 2008
Revised May 2011
Revised June 2012
Revised November 2012
Revised February 2013
Revised June 2013
Revised April 8, 2019
Revised January 6, 2020
Revised July 2020

Prepared For:

City of Nashua
Division of Public Works
9 Riverside Street
Nashua, NH 03062

City of Nashua, New Hampshire

Nashua Four Hills Landfill: Phase I/II/III/IV Secure Landfill Operating Plan

August 2007
Revised January 2008
Revised August 2008
Revised May 2011
Revised June 2012
Revised November 2012
Revised February 2013
Revised June 2013
Revised April 8, 2019
Revised January 6, 2020
Revised June 2020

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~~8.6 Landfill Gas Collection System Reporting 42~~

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Appendix B	Sequenced Gas Collection System Plans, Revised February 2013
Appendix C	Technical Specifications, Revised February 2013
Appendix D	Industrial Discharge Permit
Appendix E	Alternate Leachate Disposal Site
Appendix F	Removed May 2011
Appendix G	Locus Map – Four Hills Recycling Center

By Reference: Phase IV Type I-A Permit Modification Drawings, prepared by Sanborn, Head & Associates. Inc. of Concord, New Hampshire, dated July 2020; Phase III Construction Drawings~~-~~, prepared by Sanborn, Head & Associates, Inc. of Concord, New Hampshire, ~~Dated~~ dated December 2017, Revised July 2019, and Phase I and Phase II Construction Drawings prepared by CMA Engineers of Portsmouth, New Hampshire.

Section 1
FACILITY IDENTIFICATION

Facility Name: Nashua Four Hills Landfill
Phase I/II/III/IV- Secure Landfill Expansion

Mailing Address: City of Nashua
Division of Public Works
9 Riverside Street
Nashua, NH 03062
Phone: (603) 589-3140

Location: 840 West Hollis Street
Nashua, New Hampshire 03062

Permittee: City of Nashua, NH
Division of Public Works
9 Riverside Street
Nashua, NH 03062
Phone: (603) 589-3140

Permit No.: DES-SW-SP-95-002

Service Type: Limited

Operator: City of Nashua, NH
Division of Public Works, Solid Waste Department
9 Riverside Street
Nashua, NH 03062
Phone: (603) 589-3410

Capacity: The Phase I Expansion of the Nashua Four Hills Landfill is a lined landfill with a capacity of approximately 857,000 cubic yards (cy) of solid waste. The Phase I portion of the landfill consists of three stages with the volumes shown in Table 1.1.

The Phase II Expansion of the Nashua Four Hills Landfill is a lined landfill with a current capacity of 1,451,000 cubic yards of solid waste with an additional estimated 218,000 cy~~ubic yards~~ of soil for daily cover and intermediate cover requirements.

The Phase III Stage 1 expansion area volume is shown in Table 1.1. The estimated life of Phase III Stage 1 was estimated assuming a waste acceptance rate of 80,000 tons per year s, and a waste density of 1300 lb/cy (AUF of 0.65 tons/cy). Actual life will vary with tonnage, waste density, compaction, and cover soil use.

The Phase IV Expansion is a lined landfill will a proposed disposal capacity of 3.9 million cy. Actual life will vary with tonnage, waste density, compaction, and cover soil use.

TABLE 1.1: Capacity Summary

Phase / Stage	Capacity (CY)	Cumulative Capacity (inclusive of cover material) (CY)	Estimated Life (years)	Cumulative Life (years)
I/I	174,000	174,000	1.1	1.1
I/II	288,000	462,000	1.9	3.0
I/III	395,000	857,000	2.6	5.6
II/I	680,000	680,000	4.0	4.0
II/II	989,000	1,669,000	5.5	9.5
III/I	1,056,000	1,056,000	8.6	8.6
IV/I	1,499,000	1,499,000	12.2	12.2
IV/II	862,000	2,361,000	7.0	19.2
IV/III	730,000	3,091,000	5.9	25.1
IV/IV	809,000	3,900,000	6.6	31.7
		TOTAL PHASES I - ~~III~~ IV LIFE		**~~23.7~~55.4**

Section 2

ACCEPTABLE AND PROHIBITED WASTES

The secure expansion to the Nashua Four Hills landfill will be used for the disposal of mixed municipal solid waste from sources within the City of Nashua.

Acceptable wastes will include waste materials which are currently disposed at the existing landfill on the site, or otherwise are produced within the service area and meet state and federal restrictions for disposal in solid waste landfills, and may include:

- Mixed waste from residential, commercial, institutional, and industrial sources;
- Construction and demolition waste (C/D);
- Bulky waste;
- Street sweepings;
- Brush/Stumps (periodically);
- Digested wastewater sludge, grease, and grit from the Nashua WWTP (as a contingency and under a separate permit modification), and;
- Asbestos waste.

It is noted that the City will be voluntarily restricting C/D waste from the landfill as practicable.

Data from the landfill scales indicates that disposal of digested wastewater sludge, grease, and grit in the landfill averages approximately 320 tons per year. Increases to over 1,000 tons per year could occur due to operating, maintenance or equipment issues at the wastewater treatment plant.

Unacceptable wastes will include materials which may not be reasonably managed at the facility or which are not allowed for disposal by applicable regulations. Such materials will include, at a minimum:

- Hazardous waste as defined by Federal or State regulations which are in quantities and forms unsuitable for disposal in RCRA Subtitle D landfills;
- Polychlorinated biphenyls (PCBs) that are regulated under the Toxic Substances Control Act, as amended (ref. 40 CFR Part 761);
- Chlorofluorocarbons (CFCs), as prohibited by Title 6 of the Clean Air Act, as amended (ref. 40 CFR Part 82);
- Containerized liquids or drums;
- Explosive material;
- Highly flammable material;
- Untreated medical or pathological wastes;
- Whole tires;
- Bulky metals;
- Leaf and yard waste;
- Source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended, and;
- Other materials precluded by applicable regulations.

Recyclable wastes are accepted at the Four Hills facility from residential and commercial sources within Nashua. These materials are managed, collected, stored and transferred to off-site recycling facilities for processing. These wastes include:

- Mixed containers (glass, #1 plastic, #2 plastic, aluminum cans, and metal containers)
- Mixed paper (newspaper, cardboard, magazines, office paper, books, etc.)
- Scrap metal (ferrous and non-ferrous metals, and other incidental non-metal components, such as lawn mowers, household appliances, wire, cable, metal furniture, etc.)
- Used oil
- Lead acid batteries
- Tires

Universal wastes are accepted from residents of Nashua. These wastes are collected, stored and managed consistent with Chapter Env-~~Wm~~ Sw 1100 of the New Hampshire ~~DES Hazardous~~Solid Waste ~~Program~~ Rules, and are shipped off site for recycling. These wastes include:

- Video display devices
- Used anti-freeze
- Fluorescent lamps
- Mercury containing devices
- Rechargeable batteries (except lithium ion batteries)

To conserve landfill capacity, some C&D waste may be diverted from the landfill for off-site recycling. Loads containing 10% or more C&D waste may be diverted to a designated area at the Four Hills facility. Carpet and other undesirable materials will be removed and the remaining C&D (primarily wood, metal, masonry, plastic, and gypsum wall board) will be loaded into trailers and transferred to an off-site recycling facility.

Recyclable and universal wastes are collected and stored at the Four Hills Landfill Recycling Center. This area of the facility, as well as the scrap metal storage area and C&D diversion area are shown on the Locus Map in Appendix G.

ROUTINE OPERATIONS

3.1 GENERAL

This facility operating plan provides an outline of the procedures for the operation of the proposed Nashua Secure Landfill Expansion. Operations are outlined to be environmentally sound, in accordance with the standards, regulations, and guidelines of the NHDES Waste Management Division (particularly Env-Sw 800, and related sections, including Env-Sw 1105).

Additional information with respect to operations is contained in the Phase IV Type I-A Permit Modification Drawings, dated July 2020, the Phase III Construction Drawings, dated December 2017, Revised July 2019 and the Phase I/II Record Drawings. Specific information is presented herein on waste delivery, handling and placement, compaction, cover systems, staffing and general maintenance, site management, leachate management, contingencies, and other issues.

This plan addresses operations based on current expectations and the "state-of-the-practice." For operations to remain most effective, the operating history will be reviewed periodically and procedures adjusted as warranted. Any temporary or permanent departures of significance from the procedures outlined herein shall be coordinated with the NHDES, in accordance with provisions of permits obtained for the facility. Operations will remain flexible so that activities which would be adversely affected by inclement weather conditions or other temporary conditions will be avoided during those periods.

Copies of the facility's permits, and the approved operating plan, as may be updated from time to time, will be available at the facility at all times. The permit will be posted at a prominent location at the facility.

The landfill, at all times, is intended to be operated in full compliance with the applicable provisions of the New Hampshire Solid Waste Rules and other applicable state or federal regulations.

3.2 WASTE DELIVERY

Solid waste is anticipated to be delivered to the landfill primarily in packer trucks operated by the City of Nashua and commercial haulers, which will include mixed municipal waste from the City. Individual small deliveries will generally be excluded, being accepted only by special arrangement. Regular deliveries of small loads will be accepted in open-top containers to be provided at the residential drop-off facility, located near the entrance to the site.

C/D waste will be delivered in municipal and privately-owned vehicles, commonly dump trucks or open top roll on/roll off containers. C/D waste will be segregated from municipal solid waste and stockpiled at a designated area of the facility. Separation of C/D waste materials will occur as practical to recover scrap metal and clean wood, and remove mixed in municipal solid waste and other un-recyclable materials. In general, C/D material will be loaded out in bulk form to an approved C/D recycling facility. Un-recyclable C/D waste and mixed in municipal solid waste will be transported to the landfill for disposal.

Grease and grit from the Nashua Wastewater Treatment Plant will be accepted for disposal in the landfill. Digested wastewater sludge will generally be delivered only as a contingency to other off-site management options. Grease, grit, and/or sludge will be transported in enclosed containers having 18 to ~~-~~24 ~~-~~c~~ubic~~ y~~ard~~ capacity. Plant personnel will coordinate with landfill personnel so that the operators are aware of the delivery and can coordinate the delivery with other landfill operations. Deliveries will be weighed at the scales and then proceed to the landfill. Grease, grit, and/or sludge will be deposited within the landfill adjacent to the area of the working face for the operating day. This material will be covered with municipal solid waste, soil or other approved alternate daily cover (except tarps) in a timely manner to mitigate odors.

The landfill will accept deliveries up to six days per week during hours which will not typically exceed 7:00 a.m. to 5:00 p.m. on weekdays, and 8:00 a.m. and 1:00 p.m. on Saturdays. Operations will be generally limited to daylight hours between 6:00 a.m. and 6:00 p.m. On a normal basis, deliveries of waste will be scheduled such that the landfill will be open during a limited period; on the order of nine hours per day. In the event of the occurrence of extreme weather or emergency conditions, or other possible reasons, the City may, on a temporary basis, accept deliveries outside the normal delivery schedule. No deliveries of waste will be allowed when the landfill is not attended by City landfill personnel.

Deliveries to the landfill site shall be made as deliveries are currently being made via the City road network to West Hollis Street, to the existing landfill entrance road. The landfill entrance has a sign which identifies the facility, permit holder, emergency telephone number, operating hours, and a list of solid wastes banned or restricted. The landfill entrance gate shall be closed and locked when the landfill is not open for waste deliveries.

Upon entering the landfill site, waste delivery vehicles will proceed across the existing platform scale and scale house to be weighed and checked in. Records will be kept at the site of all deliveries including date, time, vehicle and/or container number, and weight of waste. From there, vehicles will be directed by appropriate signage and operating personnel along on-site access roadways to the active stage of the landfill. The vehicles will exit the site using the same route. Waste shall be delivered only to locations within the permitted vertical and horizontal limits of the landfill at which active operations are occurring.

3.3 PERSONNEL AND EQUIPMENT

The City intends to continue to operate the landfill with municipal employees under the Nashua Division of Public Works. At its option, the City may choose to contract with a private firm for portions of facility operations. The staffing description below is generally applicable to either option, in terms of on-site personnel and general management. It is recognized that contracting with a private entity for any functions will not relieve the City of all of its operational responsibilities as outlined herein and in appropriate permit conditions.

The landfill gas collection system in the existing unlined landfill and Phase I/II landfill expansion, and gas combustion flare are owned and operated by the City. A private firm, under a gas lease agreement with the City, operates the gas to energy facility on the site.

The landfill staff will generally consist of supervisory staff, a scale operator, equipment operators and laborers and security personnel. In addition, other municipal employees will be available, under the direction of the Division of Public Works, for supplemental labor on an as-needed basis. The landfill supervisor will be responsible for operating and managing the landfill on a day-to-day basis. The landfill supervisor and equipment operators will have experience in the operation and maintenance of heavy equipment and have appropriate certifications pursuant to the requirements of the NH Solid Waste Rules. The City will continue to maintain adequate security during non operating hours by utilizing remote monitored cameras installed at the site. Staff will be on-site at all times during periods of waste delivery, to perform the duties described below, and other actions as required:

- Direct the deliveries of waste to the appropriate location at the active working face;
- Inspect the delivered wastes;
- Place and compact waste, and apply daily cover as required;
- Place and compact intermediate cover systems;
- Monitor and maintain leachate collection, piping, and storage systems;
- Maintain records of waste deliveries;
- Maintain on-site surface drainage facilities;
- Maintain equipment on a daily basis;
- Monitor and maintain the landfill gas collection and control system;
- Coordinate with the operators of the gas to energy facility as necessary; and,
- Monitor leachate discharge to the City sewerage system, in accordance with the leachate management plan.

Administrative and management support will be provided by the City through its Division of Public Works. Those personnel will be under the direction of the Solid Waste Department of the Division of Public Works. The Superintendent of the Department will be assisted by the Department’s environmental engineering technician in landfill operations.

The landfill equipment will include steel-wheeled articulated landfill compaction machines equipped with a front end blade modified for trash placement, to be owned or leased by the City. The machines will be used for placement and compaction of waste, daily cover, and placement and compaction of intermediate cover systems. Other major equipment to be utilized includes a D-8 dozer (or equivalent), large capacity construction dump trucks, and water truck. Arrangements will be in-place for lease of key equipment during downtime. Other equipment will include auxiliary pumps, tools, and incidental equipment. A spare parts inventory will be maintained by the City for day-to-day maintenance. The City will establish arrangements for a watertight tank truck, to be City-owned or available on a contract basis, for the contingency pumping and hauling of leachate to off-site disposal locations, in the event discharge on-site to the City's sewerage system must be interrupted. Periodically, the landfill supervisor may arrange for additional equipment and personnel for significant operations of limited duration, which may include excavation and stockpiling of soil cover material, actions for establishment of intermediate or final cover systems, and any contingency actions.
All equipment should be maintained in accordance with the manufacturer's recommendations regarding daily and periodic maintenance.

3.4 LIFT CONSTRUCTION AND LANDFILL COVER

Lift construction will proceed in a manner generally consistent with the plans developed for the facility.

Using survey equipment and control as necessary and appropriate, the City will maintain accurate elevation information as lifts are constructed to assure that sequenced development continues in accordance with the final landfill plans. The City will maintain boundary markers located at the bottom liner anchor trenches to assure that waste is not deposited outside of the bottom liners.

Survey control will be established for each lift to delineate the limits of the 500-foot residential setback included in the permit, as well as final grades above the anchor trench elevation. Survey control will be overseen by a qualified person, and reviewed by a licensed engineer.

The procedures outlined below describe the general actions and methods planned for filling of the landfill. Detailed lift sequencing design to guide the construction of lifts are shown in Appendix A.

3.4.1 Waste Handling and Placement

3.4.1.1 General

Waste delivered to the landfill will be directed to the working face where it will be deposited and compacted.

Wastes which may be accepted at the landfill include municipal solid waste, construction and demolition debris, non-recyclable residential bulky wastes, street sweepings, screenings, grit, scum and grease, digested sludge, and other non-hazardous municipal wastes as may be appropriately handled.

Wastes excluded will be containerized liquid waste, hazardous waste, non-treated medical/pathological waste, radioactive waste, whole tires, bulky metal wastes, leaf and yard waste, and wastes which are not to be accepted in accordance with applicable state or federal regulations.

Upon delivery to the landfill, waste will be deposited at the working face and compacted using several passes of the steel-wheeled landfill machine. In general, daily deposits of waste will be limited to the smallest practical area (generally 50' x 50'). Waste will be pushed to a final cell configuration with approximately a two horizontal to one vertical (2H:1V)~~2:1~~ side slope. In general, waste layers of two to three feet thickness will be placed with successive passes of the compacting machine. Placement of numerous layers will establish the total daily deposit. A minimum of four passes of the compacting equipment will be made over each 2 to ~~-~~3-~~-~~foot thick~~ness~~ layer of waste. In-place waste densities are anticipated to be approximately 1,200 lb/cy~~pounds per cubic yard~~, based on measurements and evaluations of existing operations.

3.4.1.2 Asbestos

The City, at its option, may accept wastes containing asbestos at the facility. Such wastes will generally be in small quantities. Deliveries of asbestos-containing waste will be by arrangement and will be received as previously packaged and labeled.

Prior to receiving asbestos-containing waste, the landfill operator will prepare a disposal area within the permitted area to allow the waste to be placed and covered without the release of asbestos fibers to the air and without direct contact between the asbestos waste and personnel and equipment. The containers of waste will be unloaded in such a manner as to prevent the release of asbestos fibers, personal exposure to asbestos fibers, and direct contact with asbestos fibers by personnel and equipment. Water will be used as necessary to maintain wet placement of asbestos waste. Following the placement of waste in the disposal area, asbestos waste shall be covered with at least a 3-foo~~ee~~t thick layer of non-asbestos waste, or an 18-inch~~es~~ thick layer of soil. The Four Hills Landfill will compile records to include a map of the disposal area identifying the location, depth, area, and quantity of asbestos waste landfilled at the facility.

The co-disposal of asbestos work will comply with the requirements of Env-Sw 901.04, and applicable Federal regulations.

3.4.1.3 Hot Loads

Hot loads may be caused by improper disposal of ashes and coals in trash, or chemical reactions caused by improper disposal of hazardous materials.

In the event that a vehicle with a hot load enters the facility, it will be diverted to the Nashua Fire Rescue training ground. The load will be dumped on pavement near the existing fire hydrant. Nashua Fire Rescue will be called and landfill personnel will assist fire crews in extinguishing the fire.

3.4.2 Waste Inspection

The equipment operator at the working face will provide continuous observation of discharging loads of waste. Observations will include assessing loads for the obvious presence of unacceptable waste. The level of observation will not provide for complete inspection of all parts of every load, although most loads will be observed.

Material which is identified as unacceptable for landfilling will be immediately removed from the fill. In general, the hauler bringing such material will be responsible for removal. In the event the hauler cannot be identified, the City will be responsible for removal and proper disposal. The removal of unacceptable material will be conducted such that the hauler, or anyone else involved with the removal of unacceptable material, is not put at personal risk.

Each incoming load of waste crosses the facility scales and is recorded with respect to amount, type, and generator. In the event that the delivered waste must be removed due to its unacceptability for landfilling, such waste will similarly be weighed, identified, and recorded. In general, unacceptable waste will be removed during the operating day in ~~which~~ that it ~~h~~was ~~been~~ identified. The storage capacity will be limited by a designated "set aside" area near the working face of the landfill. In general, this capacity will be limited to 10 to~~-~~ 20 cy~~ubic yards~~. As soon as landfill operators determine that unacceptable waste is present, the operators will move the waste to the set-aside area. The operations manager will be notified and the transport and final disposal location will be determined. If the City directly disposes unacceptable waste at remote locations, the City will determine that the disposal/management facility is permitted for such use, the transportation method is acceptable, and record the amount of waste deposited. The City will keep records of any contingency disposal which may occur.

3.4.3 Construction of Initial Lifts

Heavy equipment will be restricted from traveling directly on the 18-inch thick sand drainage layer directly over the primary liner. Operating equipment and vehicle deliveries will access new daily cells by traveling only on waste that ~~has been~~was previously placed and compacted or, where that is not possible, on a 24 to 30-inch thick layer of compacted gravel installed above the 18-inch thick sand blanket.

The first landfill lift to be constructed above the 18-inch thick sand blanket will be a minimum of eight (8) feet thick throughout all areas of the landfill and shall be constructed carefully so as not to damage the geomembrane liner below. Prior to depositing waste on the sand, the load will be deposited over previously landfilled waste, when possible, and spread out. Any large metal objects such as rods or other potential items that may puncture the liner will be removed. The waste will then be placed on the sand layer and compacted using only one pass of the operating equipment.

For the initial lift over any stage, a single lift thickness will generally be eight (8) feet. If damage to the liner or leachate collection pipes is suspected in any way, waste shall not be placed and the liner and/or pipes shall be inspected and repaired.

3.4.4 Subsequent Lift Construction

Subsequent landfill lifts will be constructed with a total lift height of six (6) to eight (8) feet. The working face should have a width of about fifty (50) feet with a final slope at the face at the end of the day of about two horizontal to one vertical (2H:1V). Each two (2)-foot thick layer of waste should be compacted with four (4) passes of the steel-wheeled landfill machine. The lifts are to be constructed over a minimum horizontal ~~square footage~~area to the grades described in the drawings in Appendix A, to allow runoff over the perimeter berms, after the installation of intermediate or temporary cover.

3.4.5 Cover Systems

No less frequently than at the end of each working day, at least a six- (6-) inch thick layer of daily soil cover shall be applied on the active waste disposal areas utilizing soil or approved alternative daily cover materials. Sources of soil may be from excavations or stockpiles of previous excavations on-site, or from off-site sources. A working stockpile of a minimum of one to two weeks' capacity of daily cover material will be maintained on or near the landfill footprint at all times. Cover materials will be applied in a manner and at the frequency required to achieve the following performance objectives:

- ~~Minimize~~ Limit the dispersal of offensive odors;
- ~~Minimize~~ Limit the potential to attract and harbor vectors;
- Control drainage;
- Control unsightly conditions;
- Reduce the potential for fire;
- Provide stability; and,
- Assist in the proper development of final grades.

On-site soil (glacial till) is anticipated to be satisfactory for much of this daily cover requirement and to achieve the performance objectives listed above. Material with more sand/gravel may be generated from on-site sources or brought from off-site for areas of equipment movement and traffic, particularly during wet periods. The City also regularly uses sand, till, wood chips, or compost materials for daily cover.

The City currently uses approved alternative daily cover (ADC) from several sources~~,~~ and plans to continue to use ADC as sources become approved, and its use is effective. The use of ADC is subject to NHDES~~-~~ Solid Waste Management Bureau~~WMD~~ (SWMB) approval. Other materials, such as foam, wood chips, and contaminated soils meeting the requirements of Env-Sw 903.05 may also be used as appropriate, with approval of NHDES. The current list of approved ADC includes:

- Natural soil;
- Street Wastes (catch basin debris, roadside ditch soils, street sweepings, and asphalt grindings)
- Wood chips;
- Compost pursuant to Env-Sw 1503.10;
- Bottom ash from wood fired boilers (NHDES Certified Waste Derived Product No. 10);
- Synthetic tarps (Tarpomatic);
- C/D fines mixed with soil;
- C/D residuals mixed with soil (Certified Waste Derived Product No. 6);
- Non-hazardous, low level contaminated soil, and
- Aggregate for Construction Made with Crushed glass (Certified Waste-Derived Product No. 11).

The waste lifts will be constructed so as to maximize the area capable of discharging uncontaminated runoff over the berms to the stormwater system. For all areas so graded, intermediate cover shall consist of sheets of plastic over a 6-inch~~es~~ thick layer of daily cover, or a 12-inch thick layer of soil material cover. If soil only is to be used as intermediate cover, it shall:

- Be natural soil without contamination;
- Be applied and maintained in areas where active filling will not occur for at least one month or more;
- Be at least 12 inches thick over all waste;
- Be inspected for erosion and damage; and,
- Be promptly repaired.

A stockpile of intermediate cover will be maintained in a manner similar to the daily cover and will be covered by tarps to promote run-off. Contaminated soil meeting the requirements of Env-Sw 903.05 applied in a 12-inch thick layer may also be used for intermediate cover. Contaminated soil may only be stockpiled within the boundary of the landfill.

Certified waste derived products must be used and stored in accordance with their certification.

The use of plastic sheets may be used as a method to ~~maximize~~ promote runoff. The sheets will be anchored using tires, sand bags, soil deposits, or similar means. The sheets will be placed ~~on~~ over the~~a minimum of~~ 6-inch~~es~~ thick layer of daily cover material. Th~~e~~e~~is~~ plastic will generally be fiber- reinforced high-~~-~~density polyethylene of 10 to ~~-~~20 mil thickness, or other suitable material. The plastic will be either perforated, or rolled up and reused elsewhere, when landfilling is reinitiated in the area covered by the plastic.

If plastic is used on slopes which are at ~~ultimate~~ final grade, it will be placed over ~~at~~ the~~least~~ 12-inch~~es~~ thick layer of intermediate cover.

In general, the slope of the intermediate cover system will be between 4% and 15%. On temporary or permanent side slopes within a stage, slopes of 3H:1V to 3.5H:1V will receive cover systems as described above.

3.4.6 Solid Waste Footprint and Soil Fill

Due to the horizontal and vertical configuration of the Phase I and II landfill, liner systems in some areas on both the east and west sides of the landfill extend within 500-feet of residences existing at the time of permitting of this facility. However, placement of putrescible waste will not occur in areas closer than 500-feet to those residences. The Phase III landfill was designed and constructed with the liner system located entirely within 500-foot setback boundary. The Phase IV expansion was designed to be entirely within the 500-foot setback boundary.

This limitation of the landfill footprint and waste containment area will be accomplished by maintaining horizontal control of lifts in these areas. Lifts of waste will end at the 500-foot limit. The landfill operator will construct a concrete block wall lined with geomembrane at the 500-foot residential offset, the design of which was approved in 2013.

Within the 500-foot residential offset, each lift will be completed with soil or other NHDES approved fill materials. As sequential lifts are completed, a vertical separation between waste and soil/fill will be established within the liner system.

Operationally, the following specific considerations are part of the operating plan:

3.4.6.1 Horizontal Control

The landfill supervisor will be assisted by a qualified person, with review by a registered professional engineer. The required limit of waste which will become the landfill "footprint" will be clearly marked by grade stakes, flagging, or other monumentation. Each lift will have such control, in areas where the liner anchor trench is within 500-feet of pre-existing residences.

3.4.6.2 Concrete Block Wall

A. Completion of Lifts:

In areas where the concrete block wall is to be constructed the waste lift will be terminated about 10 feet from the 500-foot residential setback unless the preceding lift of the concrete block wall is present. Once the concrete block wall is constructed and lined, the waste fill may extend to the concrete block wall. The vertical elevation of the lift will be extended to the limit of the liner system (at that elevation) inside the 500-foot residential setback with common borrow fill or NHDES approved fill material that meets the filling specifications. The differential elevation on either side of the concrete block wall (i.e., waste or common borrow fill) should not exceed 5 feet.

B. Concrete Block Wall Footings:

- Footing above liner:

In locations where the concrete block wall is to be constructed directly above the existing drainage sand, a screened till footing at least 8-feet wide will be constructed. Screened till for the footing will meet liner-quality permeability of 1×10^{-7} cm/sec. The requirements for placing and compacting the screened till are included in Section 02223 of Appendix C. A detail of the footing is provided on Figure FS-12 in Appendix A.

- Footing in existing soil wall:
  In locations where the concrete block wall will be constructed on top of the existing soil wall, a 12-inch deep trench will be excavated into the top of the soil wall to seat the concrete block. A detail of the footing is provided on Figure FS-12 in Appendix A.

C. Concrete Blocks:
Concrete blocks will be used to support and anchor the geosynthetic liner and non-woven geotextiles at the 500-foot residential setback. Details of the concrete blocks and installation are shown on Figure FS-11 in Appendix A.

D. Waste/Concrete Block Interface:
A nonwoven geotextile will be installed on both sides of a smooth 60-mil HDPE geomembrane at waste/concrete block interface. Details of the installation are shown on Figure FS-11 in Appendix A. Specification for the geotextile and geomembrane is included in Sections 02275 and 02550, respectively, of Appendix C.

E. Select Waste Near Waste/Concrete Block Interface:
The landfill operator will selectively place MSW within 10 feet of the waste/concrete block interface.

F. Common Borrow Fill Lifts:
When a common borrow fill lift intersects the select drainage sand, the common borrow fill will be graded to drain toward the waste at the footprint boundary. When a common borrow fill lift is vertically above the liner anchor trench, the lift will be graded to drain to the site stormwater system outside the liner area.

The Landfill operator will place common borrow fill or other NHDES approved fill materials in the fill area behind the 500-foot residential setback. The requirements for the common borrow fill or other NHDES approved fill materials to be used as fill behind the low permeable soil are described in Section 02223 of Appendix C.

G. Concrete Block Wall/Final Cover System Interface:
The concrete block wall will terminate 2-feet vertically below the intermediate cover component of the final cover system. A 12-foot wide section of geogrid will be installed along with a 2-foot thick layer of screened till. The final cover system will be installed above the Screened Till. Details of the concrete block wall/final cover system interface are shown on Figures FS-11 and FS-12 in Appendix A.

3.4.7 Landfill Gas (LFG) Collection System ~~(Drawings and Text Last Revised February 2013)~~

The existing active landfill gas collection and conveyance system (GCCS) includes gas collection trenches, gas extraction wells, and associated well heads, conveyance pipe, and condensate handling components. A vacuum is applied to the GCCS conveyance pipe network from a blower station located within the landfill gas to energy (LFGTE) facility. A description of the individual GCCS components is provided below. Locations of existing GCCS components are shown in Figure LFG-2 in Appendix B.

As provided in the City's Additional Design Information letter to the NHDES, dated April 10, 2019, gas collection trenches will be installed within the waste mass at a horizontal spacing of approximately 100 feet and a vertical spacing of approximately 40 feet. Vertical gas extraction wells will be installed as the final waste grade is reached or as needed in both Phases I through III. Lateral pipe will be installed to connect the extraction features to the main header pipe as needed. Figures in Appendix B show the approximate layout and spacing of the LFG extraction features and piping.

3.4.7.1 Gas Collection Trenches

Gas collection trenches typically consist of perforated HDPE pipe installed in trenches excavated in the waste and bedded in aggregate. The extraction of gas from the trenches is controlled at a wellhead as described in Section 3.4.7.4.

3.4.7.2 Surface Collection Trenches

Surface collection trenches will be installed by the landfill operator on an as needed basis to control fugitive emissions and odors from the landfill surface. Surface collection trenches typically consist of perforated ADS pipe installed in trenches excavated in the waste, bedded in aggregate, and backfilled to the surface with intermediate cover. The extraction of gas from the trenches is controlled at a wellhead as described in Section 3.4.7.4.

3.4.7.3 Vertical Gas Extraction Wells

Gas extraction wells, constructed of schedule 80 PVC pipe, are installed in bore holes drilled to various depths within the waste. Gas extraction wells are typically drilled to a depth of about 15 feet above the liner system. The well screen is slotted to a depth of about 15 feet below the permitted intermediate cover grades to the base of the well. The slotted portion of the well is backfilled with large diameter aggregate.

3.4.7.4 Wellhead Assemblies

The wellhead assemblies are located between each gas extraction point (e.g., gas collection trench, well, or perimeter vent) and the gas conveyance system pipe. Using a valve, hose, fittings, sampling ports, and taps, the wellhead assemblies allow for:

- Differential settlement between the tie-in header and the well;
- Sampling of LFG;
- Measurement of the LFG extraction flow rate;
- Measurement of the LFG temperature; and
- Access to the well from the top for equipment or measurements.

The wellheads should be monitored on a regular basis to observe their general condition, with particular attention to the condition of the flexible hose between the well and the conveyance pipe. Additional data to be gathered includes:

- Valve position (percent open);
- LFG flow rate;
- Static pressure;
- Percent methane;
- Percent carbon dioxide;
- Percent oxygen; and
- Gas temperature.

3.4.7.5 Conveyance Pipe

LFG from the extraction points is conveyed through buried HDPE pipe to the LFGTE Facility. Condensate formed in the conveyance pipe is directed to a condensate trap or condensate knockout pot for removal.

3.4.7.6 Isolation Valves

Butterfly valves located at strategic locations along the conveyance pipe are to be used to isolate sections of the GCCS for maintenance. The valves should be monitored on a quarterly basis and exercised to confirm that they are operable. The valve position (percent open) shall be noted before and after the valve is exercised.

3.4.7.7 Condensate Management

LFG contains a high concentration of moisture that when cooled becomes condensate. The GCCS includes features designed to remove condensate that forms within the conveyance pipe network and discharge the liquid into the landfill’s leachate management system using traps and condensate sumps.

Condensate management features are located at the low points in the landfill gas conveyance pipe network. Traps typically consist of a U-shaped tube filled with condensate to provide a seal for the vacuum in the system. To maintain a seal, the liquid column in the trap must be at least as high as the maximum vacuum obtainable in that portion of the system. Condensate sump manholes are structures located outside the landfill that drain by gravity or incorporate pumps to convey the liquid.

3.4.7.8 LFG Conveyance Pipe Manholes and Condensate Sumps ~~#5~~

The Landfill operator will monitor and record the operation of condensate sumps #4 and #5 (located in Manholes #4 and #5 (MH-4 and MH-5), respectively) on a weekly basis. The sumps are located in the main LFG collection header from the Phase I/II landfill. (As part of the Phase IV Expansion, the LFG conveyance pipe network will be modified (see the Type I-A Permit Modification Drawings) and MH-4 and MH-5 will be eliminated. This Operating Plan will be revised again as part of a Type II Permit Modification Application associated with the initial construction of Phase IV.) The exterior of the sumps will be visually inspected for leaks and general condition of the pump and equipment. The pump counter readings will be recorded. The differential pressure measurement across the manholes will be recorded based on the available vacuum readings taken from the LFG header pipe on either side of the manhole.

Interior inspections of the sumps and pumps are not possible while the LFG collection system is in operation. Interior inspections can occur only when the landfill gas to energy facility is shut down. Therefore, interior sump inspections are performed only if vacuum and gas flow readings indicate a problem. Replacement pumps are kept on site so they can be replaced quickly in the event of a failure.

Corrective action will be taken if there are indications that the header pipe is blocked based on the results of the weekly inspections. Interior inspection of the sumps will be performed and accumulated sediment or condensate will be removed from the sumps to allow optimum operation of the LFG collection system, as required. Sediment removed from the sumps will be disposed of within the active landfill; condensate will be discharged to the municipal sewer. A summary of corrective actions performed will be included in the quarterly operating report.

3.4.7.9 LFG Well Dewatering Pumps

Compressed air driven dewatering pumps are installed to operate automatically in select vertical gas wells within the Phase I/II landfill. The dewatering pumps discharge to a dedicated condensate main that conveys the liquid to the Phase I leachate collection system at leachate collection clean-out LP-04. To facilitate sustained performance, pump maintenance will be performed regularly, or as needed, in accordance with the pump manufacturers recommendations. Pump hoses and connections will be inspected at least monthly for audible detection of air leaks or blockages, and repaired if needed. The dewatering pumps may be deactivated, removed, or relocated to adjacent wells as site conditions change over time. In these cases, the compressed air lines will be capped or the air valve turned off. Discharge lines (condensate mains) will be maintained for as long as the pumps are operated. Pump cycle counter readings will be recorded during pump inspections.

3.4.8 Bromide Addition to Waste

The groundwater management permit issued for the site in April 2011 was renewed without the requirement to test groundwater samples for bromide. Therefore, bromide addition to the waste mass to create a “trace” in landfill leachate and groundwater is no longer necessary. The details of this requirement were contained in Appendix F, which ~~has been~~was removed from the operating plan.

3.5 SURFACE WATER DRAINAGE CONTROL

3.5.1 General

The landfill ~~has been~~wasd designed to prevent surface runoff from outside the secure landfill to enter the landfill area, control erosion and sedimentation due to surface runoff, and control the peak rate of runoff flow off the site. The temporary and permanent drainage facilities include drainage swales, detention basins, and treatment swales. Much of the site drainage system is integrated with the drainage system for the closure of the existing landfills. The operator will maintain the drainage structures to be free of debris and obstructions. The operator shall inspect the drainage structures at least weekly and/or during large storm events and take required steps to remove obstructions and repair any erosion that may occur.

Due to the reduced footprint of Phase III in comparison to Phases I and II, and the geometry of the base grades, Phase III is not divided into separate cells. The leachate management system was sized in order to manage the contingency storm event during the condition when Phase III is initially opened. A temporary slope diversion swale was constructed on the southern Phase II sideslope to divert stormwater runon from Phase II into the Phase III perimeter swale.

Because Phase IV is located between Phases I and II and the closed, unlined landfill, Phase IV was not divided into separate cells. The Phase IV leachate management system was sized in order to manage the contingency storm event during the condition when Phase IV is initially opened. Temporary slope diversion swales will be constructed on the northern slope of Phase I and on the southern slope of the closed, unlined landfill to divert stormwater runoff away from Phase IV.

3.5.2 Operational Conditions

Reserved for future expansions.

3.6 LANDFILL MAINTENANCE

3.6.1 General

Proper facility maintenance is essential to operations. The landfill supervisor shall make a walking tour of the site on at least a weekly basis to inspect the general repair of the drainage ditches and structures, the liner and leachate collection systems, and the access roadways.

Access roads will be maintained in order to promote safety and free flow of traffic. Any potholes or surface roughness in the access road will be repaired properly by regrading and/or addition of compacted gravel.

All landfill equipment and instrumentation will be regularly maintained in accordance with manufacturer's recommendations and as otherwise prudent.

3.6.2 Leachate Collection System

Primary leachate is collected within each phase of the Landfill with perforated collection piping and is ultimately combined at the HDPE manhole located ~~within~~ west of Phase I The existing HDPE manhole connects the primary leachate collection pipe from Phase I through III (and Phase IV once constructed) and discharges it out of the landfill through a single pipe penetration to the leachate pipe which flows to the Flow Control Building and eventually into the municipal sewer system via the Trestle Brook Pump Station as described in Section 4.0.

Similar to the primary leachate, secondary leachate is collected within each phase of the landfill with perforated collection piping located within the secondary liner system. Secondary leachate is discharged out of the landfill through a single pipe penetration located within Phase I where is flows by gravity to the Secondary Witness Tank. From this tank, the secondary leachate is pumped into Leachate Manhole #1 and combined with the primary leachate where it flows to the Flow Control Building as stated above.

Primary and secondary leachate from Phase III is collected in a sump located in the southwest end of the phase. Pumps within the sump convey leachate to the Phase III Sump Riser Building located on the west perimeter of Phase III. Flow meters within in the building meter the flow of the primary and secondary leachate separately. Prior to exiting the building, the primary and secondary leachate is combined, and then flows through a 4-inch diameter force main to the gravity main that drains into the dedicated Phase III leachate conveyance pipe in Phase II.

For Phase IV, primary and secondary leachate will be collected in a sump located in the west end of the phase. Pumps within the sump will convey leachate to the Phase IV Sump Riser Building located on the west perimeter of Phase IV. Flow meters within in the building meter the flow of the primary and secondary leachate separately. Prior to exiting the building, the primary and secondary leachate is combined, and then flows through an 8-inch diameter gravity main that drains to the leachate manhole.

On a weekly basis, the landfill operator shall perform the following inspections:

- Check that the water level recorder in the manhole is functioning properly.
- Check and observe the instrumentation for recording leachate flow to the sewer, and that high-level alarms are functioning properly.
- Open the manhole containing the flow measurement flume, observe flow in primary pipe(s), and sample, analyze, and record data for pH and conductivity utilizing portable meters.
- Check that Phase III Sump Riser Building instrumentation is functioning properly.

If any unusual conditions are observed in the weekly inspections, the landfill operator shall take appropriate action.

If siltation or flow obstruction is observed, the leachate collection pipes should be flushed from the cleanouts by means of contracted hydraulic sewer pipe jetting equipment.

3.6.3 Litter and Vector Control

Vehicle unloading should be controlled such that waste is unloaded at the working face. Delivery vehicles will be covered when entering and leaving the site and daily cover will be applied to limit blowing of waste and to inhibit the attraction of birds, rodents, or other vectors. The operators of the landfill will inspect the landfill area and access road for litter and remove any litter on a regular basis.

A litter fence was installed as part of the Phase II and Phase III construction expansion and should be maintained on a regular basis. The fence is 20 feet high and is located along the western and southern perimeter of the landfill. Portable litter fencing is also utilized at the working face of the landfill. These fence sections are moved with heavy equipment as necessary to capture windblown litter at the working face.

The City has been contracting with the USDA to perform a gull harassment program at the existing facilities since 1995. This program has been effective in reducing the population of gulls and other birds at the facility. This, or similar programs, will be evaluated on an annual basis to be included as part of operations.

Particular efforts will be extended to ensure that litter does not remain in inactive cells that are discharging to the site's stormwater management system. Measures will be taken to limit windblown litter with the constructed and portable litter fences. Litter will manually be picked up, if necessary. Effective use of daily and intermediate cover will minimize rodent, bird, or other vector problems.

3.6.4 Fire Control

The use of daily soil cover will inhibit or eliminate the potential for fires in the landfill. The potential for "hot loads" to be delivered to the landfill is small. In the event of a "hot load" delivery, the vehicle will be directed to an area outside the landfill, waste discharged, and extinguished by fire extinguishers or covered with soil. The Nashua Fire Department will also be notified. When the waste is confirmed to have no fire potential, all waste will be moved to the landfill. The ground will be scraped in the area of deposit to assure that all waste is moved.

A dry hydrant and wet well ~~has been~~was installed at the location of Detention Pond #4 to aid in the fire protection management plan. The submersible screen was installed at elevation 194' and is connected to the dry hydrant by HDPE piping. The dry hydrant is fire truck pump ready to deliver 1250 gpm of fire flow to two hydrants near the active landfill area. See the Construction drawings dated July 2007.

The operator will have the ability to contact the Nashua Fire Department at all times by telephone and/or radio dispatch.

3.6.5 Dust Control

Dust control at the landfill will be achieved through the use of a water truck on landfill roadways. As conditions warrant, the water truck shall be operated to moisten the soils on the unpaved roadways to minimize dust production.

The existing, and all future areas with intermediate cover will be seeded to resist erosion from stormwater and wind.

3.6.6 Odor Control

3.6.6.1 General

LFG is made up of primarily methane and carbon dioxide, both of which are odorless. Landfill odors are generally associated with sulfuric compounds that may be present at relatively low concentrations within landfill gas, such as hydrogen sulfide and mercaptans. If fugitive LFG emissions occur, they may contain these compounds and under certain weather and atmospheric conditions, can cause potential nuisance odors at off site locations.

When such conditions exist, the source of odor-causing LFG emissions may come from any locations within the waste. Odors are associated more with atmospheric conditions than proximity to the landfill. For example odors are often noted at locations at greater distances from landfills than closely abutting properties; determined by migration patterns and not proximity.

Additionally, there may be odors associated with operations at the working face of waste disposal. At this point the anaerobic conditions which create methane, carbon dioxide, and sulfuric compounds are not active, and the potential odors are of a significantly different nature. Such odors typically do not migrate, and are local to the active face.

Atmospheric barometric pressure plays a role in the potential release of LFG, and associated potential for odors. When pressure is rising, gas emissions from landfills generally reduce. When barometric pressure is falling, there is a greater gradient for gas to migrate from within the landfill to the atmosphere. Rising barometer are often associated with clear conditions with atmospheric mixing that attenuates odors. Low pressure may be associated with moist conditions and less mixing under certain circumstances.

Among others, there are two primary approaches to management of LFG and associated odors:

1. Placement and maintenance of effective landfill cover systems that restrict and attenuate gas flow to the atmosphere, and

2. Effective LFG collection systems that collect and combust LFG thereby destroying odor causing compounds.

Additionally, the sulfate content of construction and demolition (C/D) waste is a contributing factor to hydrogen sulfide and reduced sulfur compounds in LFG. As a long-term odor control measure, the City is making plans to significantly reduce or eliminate C/D waste from disposal at the landfill, including any dirt fines received from C/D processing facilities. There is some C/D waste mixed with MSW in the landfilled waste to date. As C/D waste is eliminated over time, the reduced sulfur content of LFG should decline, reducing the odor potential of any fugitive LFG emissions.

Below is described the use of these and associated methods at the Four Hills Landfill.

3.6.6.2 Use of Cover Systems

A. Daily Cover

Daily cover is applied over waste deposits no less frequently than at the end of each working day. The primary material is soil placed over all exposed waste at least 6 inches thick. Alternative daily covers are possible as well, including deployable tarps such as the Tarpomatic system, and soil-like materials from other sources, including contaminated soils, street wastes, bottom ash from wood boilers, and construction residuals. It may also include approved applications of foams or other materials as approved by NHDES. A stockpile of daily cover material adequate for at least one week's worth of operations will be kept on or near the landfill footprint at all times. Daily cover materials will be applied in a manner to achieve the performance objectives of Env-Sw-806.03(a), which includes odor control.

B. Intermediate Cover over Completed Side Slopes

Intermediate cover will be placed over all finished side slopes that are filled to final grade, and over all areas where no additional waste will be placed for at least one month or more. Intermediate cover soil shall be at least 12 inches thick over all waste, be inspected for erosion and damage, and promptly repaired.

3.6.6.3 Landfill Gas Collection

There is a comprehensive landfill gas (LFG) collection and combustion system at the landfill. The gas collection system in the closed MSW landfill and Phase I/II expansion landfill and combustion flare are owned and operated by the City. The landfill gas to energy facility is owned and operated by EPP Service Company. A gas lease (contract) is in place between the City and EPP Service Co.

Headers extend vacuum to a system of laterals which connect to both horizontal and vertical LFG extraction wells. Engine/generator sets recover electric power (up to 2.4 MW), and a flare is also used to combust excess gas when the engines do not combust all LFG.

The NSPS & LFG Collection and Combustion Standards do not apply to this facility[1]. Accordingly, wells and laterals are periodically expanded as filling of waste continues in the expansion.

Performance of the system is measured periodically. Measurements of vacuum and gas quality at each collection well and valve adjustments are made to maintain as uniform a vacuum at all locations as possible. On a monthly or more frequent basis balancing of the collection system will be completed. If positive pressures are measured, that is indicative of more gas being produced that is being collected, or obstructions in laterals. Such conditions will be rectified immediately, to create consistent vacuum conditions throughout the landfill.

3.6.6.4 Expansion of LFG Collection System

The LFG collection system will be periodically expanded as new waste volumes are placed, and the potential for LFG generation and collection is present. A combination of horizontal and vertical collection wells will be placed.

In general, horizontal wells when used will be placed approximately every 40 feet of vertical landfill development, and every 100 feet laterally. Vertical wells, when used, will be on a spacing of approximately 160-180 feet between extraction wells.

The combustion capacity is projected to be sufficient for all ~~three~~ four Phases of the landfill, in accordance with modeled total LFG production of both the capped unlined MSW Landfill and the progressive filling of the lined expansion.

3.6.6.5 Excavation of Waste

Construction activities are common at landfills and may involve the excavation or exposure of waste for the installation of pipes and structures within the landfill limits. During construction activities, care will be taken to limit the production of odors. Contractors that perform work at the site will be instructed on proper construction methods for waste excavations to reduce odors during construction events. The instruction on methods will include the following:

1. Contractors will be required to implement odor control measures during construction activities that involve excavation, trenching, or drilling in landfilled waste.

2. The area of exposed waste as a result of the work will be limited to the degree practical. Trench excavations will be limited to the length of trench that may be backfilled in the same day.

3. Contractors will be required to apply odor neutralizing agent directly onto odorous spoils.

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[1] Although the NSPS & LFG Collection and Combustion Standards do not apply to this facility, the City complies with the standards and provisions within the facility's Landfill Gas Collection System Enhanced Monitoring Protocol and Standard Operating Procedures (EMP/SOP).

4. Excavated waste will be hauled promptly from the work area to the working face for disposal. Excavated waste must be hauled to the working face before the end of each working day. Work involving excavation in landfilled waste will cease when the working face is closed for the day unless other arrangements ~~have~~ wer~~been~~ made to have the refuse covered.

5. Contractors will be required to cover areas of exposed waste at the end of each day with approved daily cover, which may be obtained from on-site sources.

6. During the work, contractors will be required to regularly check for odors in the down-wind direction and employ additional odor neutralizing agent if odors are detected.

3.6.7 Health and Safety Requirements

Due to the nature of landfill operations in general, health and safety risks exist. All personnel shall be trained in the proper use of landfill equipment and all operating and safety equipment shall be maintained in good working order. The operating equipment shall be equipped with proper safety apparatus including fire extinguisher, under carriage protection, an enclosed cab, and a radio unit. A telephone, first aid station, and fire extinguishers will be provided in the maintenance building.

All structures that are associated with the landfill and are located below grade are considered confined spaces. These structures include the HDPE manhole, secondary witness tank, and valve chambers. Entrance to these facilities shall only be performed in accordance with procedures for confined space entry as set by applicable regulations and the operators of the landfill.

All personnel should be informed of the proper procedure for contacting appropriate help from off-site in the event of an emergency.

Section 4

BYPASS AND RESIDUAL MANAGEMENT PLAN

4.1 LEACHATE MANAGEMENT PLAN

Phase I/II/III/IV will be a lined, leachate controlled facility. The liner systems will limit precipitation or other moisture which has come in contact with waste in active landfill cells from migrating to the groundwater. Contaminated water that percolates through the landfilled waste, or that otherwise has the potential to contact waste, will be collected in the leachate collection system. Collected leachate will be managed as a wastewater and removed for treatment and disposal.

The plan for managing leachate from the Nashua Four Hills Secure landfill expansion has two basic components, as follows:

As final grades are achieved in portions of the landfill, the permanent, impermeable cap will be installed to preclude precipitation from infiltrating into as much surface area as possible. Low permeability glacial till (from on-site sources) or plastic sheets will be used as intermediate cover over areas brought to final grade prior to final capping systems being installed, as further described in Section 3.4.5. This cover system will direct the majority of precipitation (uncontaminated) from the completed areas to the stormwater management system.

Second, the leachate management plan allows for the discharge of leachate to the Nashua sewerage system for treatment and discharge at the Nashua WWTP, owned and operated by the City. The Nashua WWTP was expanded and upgraded to secondary treatment in 1989. The facility has a design capacity of 16 million gallons/day (MGD) and a current average flow in excess of 10 MGD. A 12" diameter gravity connection to the City's sewerage system was constructed in 1992, and leachate from the existing landfill is currently flowing to, and being treated by, the City's WWTP.

The 18-inch diameter leachate collection pipe exiting Phase I flows via gravity to the Leachate Flow Control Building. The flow through the 18-inch~~"~~ diameter pipe is limited to 0.34 cfs via a pinch valve and is measured in a flume downstream of the valve. A 12-inch~~"~~ diameter HDPE pipe connects the leachate flow from Phases I through III to the 12-inch~~"~~ diameter gravity connection to the City's sewerage system. An industrial discharge permit was approved by the Nashua WWTP and is included in Appendix D.

In the event that disposal of leachate to the City's WWTP becomes unavailable for any reason, arrangements will also be available for contingency disposal through commercial services at remote wastewater treatment facilities in Massachusetts. The remote commercial disposal option is readily available and will be arranged as a back-up to the local disposal option. Prior to commencement of operations, documentation of specific arrangements/commitments for remote disposal will be provided to ~~WMD~~NHDES SWMB.

The quality of the leachate is expected to vary depending upon rainfall patterns, the nature of the landfilled waste, and the status of operations. Based upon leachate quality data from other MSW landfills, it is anticipated that leachate will have a relatively high organic content (i.e., BOD/COD), compared to domestic wastewater with concentrations of various volatile organic compounds (VOC's), semi-volatile compounds (A/B/N extractables), metals, and other inorganic contaminants. Review of the Nashua wastewater treatment plant, and the contaminant loading of the proposed discharge versus existing permitted discharge, it is not anticipated that pretreatment of leachate will be required prior to introduction of leachate to the sewerage system and treatment facility.

4.1.1 Description of Leachate Management Facilities

The following is a description of the various components of the leachate management system. Additional information is presented in the Phase IV Expansion Type I-A Permit Modification Application, dated July 2020, the Phase III Construction Drawings, dated December 2017, Revised July 2019, and the Phase I and II Construction Drawings ~~and Technical Specifications~~.

4.1.1.1 Liners

The Phase I/II/III/IV landfill expansion consists of a dual liner system. The bottom (secondary) liner is proposed as a composite liner, consisting of a minimum ½-~~–~~foot thick layer of low permeability select native glacial till (maximum 1x10^{-}~~^{7}~~$^{-4}$ cm/sec permeability), directly overlain by a 60-mil thick textured HDPE liner. The bottom of the till layer was installed over a subgrade of native glacial tills which has a relatively low permeability. The 60-mil thick textured HDPE layer is located at least 6 feet above estimated seasonal high groundwater.

The primary liner is a 60-mil thick textured HDPE material overlying a geosynthetic clay liner (GCL) on the base lining system, resulting in a limited composite liner for the primary system. The secondary and primary liners are separated by a 12-inch thick~~es~~ layer of select drainage material within the base lining system limits, double sided drainage geocomposite on the bottom of the landfill, and by double sided drainage geocomposite on the side slopes. This dual liner system exceeds the current requirements of Env-Sw 800 and meets the current federal liner standards in CFR 258.

4.1.1.2 Sand Drainage Layer

A layer of drainage geocomposite and an 18-inch thick layer of select drainage sand with a permeability greater than 1 x 10^{-4} cm/sec is located over the primary liner to provide a mechanical buffer between the liner and the waste and to serve as a positive means of leachate drainage. The highly permeable sand layer and associated geosynthetic fabrics will serve as a primary hydraulic mechanism for leachate transport to the collection piping system. The hydraulic head on the system is predicted to be much less than 12 inches~~"~~ under normally expected conditions. Phases 1 through ~~III~~ IV are equipped with level transducers that will monitor the buildup of leachate within the individual phases.

4.1.1.3 Leachate Collection System

The leachate collection system will consist of the sand drainage layer, leachate collection pipes, and associated select soil/stone and geosynthetic materials.

Three separate primary leachate collection pipes ~~have been~~were installed as part of the Phase I construction, one ~~to~~ for each of the first three phases of the landfill. Phase IV has its own leachate collection system. This provides for separate collection from each phase. These pipes join at the

HDPE manhole at the low end of Phase I-Stage 1.

Lateral leachate collection pipes ~~have been~~were installed in each stage of the landfill. Cleanouts located at the upper end of each stage allow cleaning by means of conventional water jet sewer cleaning equipment.

The piping is HDPE perforated or solid wall pipe, as appropriate. Size of the leachate collection pipes were designed in accordance with the Solid Waste Rules. Piping is designed to convey leachate to the low point of the cell.

A separate collection and piping system was designed and installed for the Phase I and II secondary liner system. The select drainage sand and geosynthetic materials will provide rapid response time for the collection of a leak from the primary liner system meeting the requirements of the Solid Waste Rules. Phase III secondary leachate will be combined with Phase III primary leachate at the sump riser building after being collected and metered. Phase IV secondary leachate will be combined with Phase IV primary leachate at the sump riser building after being collected and metered.

4.1.1.4 Leachate Vaults, Piping, and Storage Tanks

The design of Phase I included leachate flow control devices to limit the maximum rate of discharge to the Nashua sewerage system. Facilities included the following:

- Polyethylene leachate manhole within Phase I-Stage 1, with sump.
- Vault near Phase I, including valves or primary and secondary leachate collection.
- Secondary leachate collection manhole and pump; pump empties manhole into primary leachate pipe.
- Leachate control valving/throttle at flow control building.
- Leachate discharge measurement device downstream of control building.

The leachate flow rate is expected to be approximately 75,000 gallons/day for Phases I through IV~~II~~. During the contingency storm and other design flow events, the anticipated total discharge rate is 250,000 gallons/day. At these times, the valves in the leachate control building will create hydraulic restrictions to limit flow to the maximum rate, and leachate will be stored in the 18-inch diameter piping between the flow control valve and the landfill, and landfill itself. Hydraulic head will increase temporarily within Phase I-Stage 1 of the landfill, and decrease over seven (7) days to routine levels (less than 12 inches). The landfill itself, and the piping between the landfill and the leachate flow control device, will act as a “tank” during these limited periods. The designed storage in this system for Phase I is approximately 1 million gallons.

The flow control valve in the flow control building will be adjusted manually to limit flow to the 250,000 gpd maximum. During a combined sewer overflow event, or during an event when the Trestle Brook pumping station wet well level is exceeded, signals/alarms will be evident, and the operator will adjust the valve to store additional leachate within the landfill until the condition has passed.

There is instrumentation for the following, which must be monitored and recorded received by the operator on a daily basis:

- Leachate level in Phase I-Stage 1.
- Leachate level in Phase II-Stage 1.
- Leachate level in Phase III.
- Leachate level in Phase IV.
- Flow level in flume, and associated discharge rate.
- Phases III and IV primary and secondary leachate flow rates (Sump Riser Building Instrumentation).
- High level indicators in the vaults, manholes, leachate structures, and Phases III and IV sumps.

Readouts of these levels will be provided in the leachate control building, and some duplicated in the landfill operations building. The high level alarms will be indicated at the respective locations, and will also trigger an automatic dialer to alert identified responsible personnel. Data will also be made available and recorded through a leachate telemetry, internet-based database system. The following information will be recorded:

- Primary Leachate Flow Rate (gpm) from Siemens Ultrasonic Flow Meter;
- Primary Leachate Flow Totalizer (gallons) from Siemens Ultrasonic Flow Meter;
- Secondary Leachate Pump Flow Rate (gpm) from Foxboro flow meter;
- Secondary Leachate Flow Totalizer (gallons) from Foxboro flow meter;
- Phase III Primary Leachate Flow Rate (gpm);
- Phase III Primary Leachate Flow Totalizer (gallons);
- Phase III Secondary Leachate Pump Flow Rate (gpm);
- Phase III Secondary Leachate Flow Totalizer (gallons);
- Phase I Landfill Head on Liner (ft) from transducer;
- Phase II Landfill Head on Liner (ft) from transducer; ~~and~~
- Phase III Landfill Head on Liner (ft) from transducer;~~.~~
- Phase IV Primary Leachate Flow Rate (gpm);
- Phase IV Primary Leachate Flow Totalizer (gallons);
- Phase IV Secondary Leachate Pump Flow Rate (gpm);
- Phase IV Secondary Leachate Flow Totalizer (gallons); and
- Phase IV Landfill Head on Liner (ft) from transducer.

4.1.2 Leachate Quantity

The anticipated average flow to the Nashua wastewater system is approximately 75,000 gallons a day. During certain operating scenarios, design flows of up to 250,000 gallons/day are estimated, for limited periods. During those periods, leachate concentrations are projected to be significantly diluted. With the recently completed modifications to the Trestle Brook pumping station, there is no hydraulic restriction to these flows in the Nashua sewerage system.

4.1.3 Leachate Disposal

The City of Nashua has a current Industrial Discharge Permit (Appendix D) for discharge of leachate to the Nashua sewerage system for ultimate treatment at the Nashua wastewater treatment facility. Alternatively, arrangements discussed in this section at another wastewater treatment facility ~~have been~~were established as a back-up in the unlikely event of the Nashua facility being unavailable.

Phase I through ~~III~~ IV of the secure landfill is connected to the City sanitary sewer system via a gravity line. This gravity sewer serving the site flows to a collector sewer on West Hollis Street, and to the Trestle Brook pumping station. Flow after discharge from the pumping station includes several thousand feet of flow through large diameter collector and interceptor sewers, to the City's wastewater treatment plant.

The Nashua wastewater treatment plant has a design capacity of 16 MGD. The facility currently receives an average daily flow of over 10 MGD. The facility includes grit removal, primary sedimentation, secondary treatment, and disinfection. Combined primary and secondary sludge are dewatered by belt filter process to a solids content of approximately 20% - 25%. An anaerobic sludge digestion system ~~has been~~was constructed. Effluent from the facility is discharged to the Merrimack River. Based on data provided by the plant staff, the present BOD_5 loading is estimated to be about 60 percent of the design conditions.

The characteristics of the leachate vary considerably depending upon waste characteristics and specific operating status and conditions, future recirculation practices, and age of the landfilled waste. The current leachate characteristics are presented in the following table, along with the current Nashua WWTP local limits:

TABLE 4.1: MSW Leachate Quality

Parameter	Mean Concentration (mg/l)	Current City of Nashua WWTP Local Limit (mg/L)
BOD_5	371.31	250
COD	640.08	N/A
Total Suspended Solids	100 - 200	300
Antimony	<0.006	N/A
Barium	0.023	N/A
Chloride	205.23	N/A
Sulfate	65	810
Arsenic	0.039	0.16
Cadmium	0.001	0.33
Chromium	0.024	1.85
Lead	0.004	1.20
Mercury	<0.001	0.006
Nickel	0.026	25.57
Selenium	0.026	0.11
Silver	<0.02	0.05
Iron	13.71	N/A
Manganese	3.96	N/A
pH	6.37	6 - 10.5
Specific Conductivity	1976.9	N/A
Bromide	8.491	N/A

The leachate characteristics meet the Nashua local limits, with the exception of BOD. The Nashua Wastewater Department has stated that there is capacity to treat the excess BOD at the plant.

It is noted that the closure plan for the existing landfill includes continued flow of leachate impacted groundwater to a collection pipe beneath the cap. This anticipated flow will be at a much lower flow rate, but possibly higher concentrations, than the existing flow.

In the unlikely event that the Nashua Wastewater Department is not able to accept leachate from the landfill expansion, a local transportation company will be contracted to transport leachate to a final disposal facility. Letters from the hauler and the final disposal facility are included in Appendix E. A pump will be installed in the leachate collection manhole within Phase I Stage 1 to pump leachate from the manhole and the sump area within Stage 1 to trucks waiting on the West Berm Road.

4.2 GAS MANAGEMENT PLAN

Phase I through III will generate landfill gas as the waste decomposes over time. As described in Section 3.4.7, the City proposes to expand the existing Phases I and II LFG collection system into Phase III as it is filled, which currently collects LFG from the landfilled waste. Collected gas is combusted in the system by the City owned flare or at the gas to energy facility operated by EPP Services Company.

FACILITY MONITORING PLAN

5.1 GENERAL

In accordance with the general procedures outlined in this operating plan, and as are included in facility permits, all key landfill components will be regularly inspected. A general schedule of inspection is included in the following table. Daily, weekly, and monthly inspection forms will be prepared in advance of operations to facilitate the inspection and record keeping.

TABLE 5.1: Inspection and Maintenance Schedule

Item	Recommended Frequency	Comments
x Record head on liner x Record leachate discharge rate (primary and secondary)	Daily and following storm events	Check head on the primary liner
x Visually inspect the following components:	Daily and following storm events	
x 1) Stormwater standpipes		Remove any obstructions including ice/ snow
x 2) Leachate standpipes		Inspect for signs of leakage and overall condition of structure
x 3) Stormwater discharge outlet pipe		
x 4) Valve vault and manholes		
x 5) Drainage swales, culverts, ponds		Remove obstructions and repair eroded areas
x 6) Daily and intermediate cover areas		
x 7) Landfill drainage sand on side slopes and lateral diversion berms		Inspect for bare spots, uneven and eroded areas and repair as needed; and inspect and repair all damage caused by erosion
x Litter	Daily	Inspect and remove litter from the landfill area and along access roadway
x Instrumentation and Alarms	Daily	Check tank levels, probes, alarms, enunciator, chart recorder, autodialer
x Sample and analyze flow at flume (primary flow) and secondary witness tank (secondary flow)	Weekly	Record the pH and conductivity
x Operate all gate valves in the landfill and valve vaults	Monthly	Ensure the valves are functioning properly
x Groundwater Monitoring Wells	Monthly	Inspect for damage
x Gas Migration Wells	Monthly	Inspect for damage
x Access Roadways	Bi-annual	Inspect and repair pot ~~-~~holes or surface roughness. Check grading on intermediate and perimeter berms.
x Landfill Gas Well Dewatering Pumps	Monthly	Inspect for air leaks and or discharge line blockages, record pump cycle counter

x	Equipment (landfill compactor, loader, and pumps)	As required by manufacturer	Perform per manufacturers recommendations
x	Phase Sump Riser Building pumps and meters	As required by manufacturer	Perform per manufacturers recommendations

5.2 GROUNDWATER MONITORING

Groundwater monitoring will be conducted prior to initiating landfill operations, throughout the landfill life and during the post-closure period. The permanent groundwater monitoring wells will be sampled. These include well pairs at nine locations (~~MW-101 through MW-111~~see Appendix C of the Type I-A Permit Modification Application). Initially, wells will be sampled by a contracted field services/laboratory. In the future, the City may choose to complete these services with properly trained City personnel.

Results will be submitted to the ~~WMD and WD of the~~ NHDES SWMB in April and November each year. (Other wells on site will be sampled relative to the closure and post-closure monitoring of the existing landfills, on a separate tri-annual schedule.) At a minimum, wells will be sampled for the following parameters:

TABLE 5.2: Groundwater Monitoring Parameters

Specific Conductance @ 25C	Arsenic
pH	Barium
Temperature	Cadmium
BOD	Chromium
COD	Lead
VOCs by EPA Method 8260	
Chloride	Mercury
TKN	Selenium
Nitrate	Silver
Iron	Antimony
Manganese	Nickel
Sodium	Thallium
Sulfate	Beryllium

Water elevations will be recorded when samples are taken.

Samples will be obtained, and laboratory analyses completed in accordance with the requirements of the Release Detection Permit (GWP-840399-N-005) for the project, and may be revised.

5.3 LEACHATE QUALITY MONITORING

At a minimum, in April, July, and November sampling of leachate will be done, with analyses obtained for pH, temperature, COD, BOD, specific conductance, iron, manganese, sulfates, chlorides, eight drinking water metals, antimony, beryllium, nickel, thallium, and VOCs. On a weekly basis, primary leachate will be analyzed with on-site portable equipment for pH and specific conductivity.

When future phases of the landfill are brought into service, separate collection pipes from both the primary and secondary liner systems of each phase will be used.

5.4 SECONDARY LEACHATE COLLECTION MONITORING

The secondary leachate collection system will be monitored regularly. On a weekly basis, the secondary collection system flow rate will be measured, and on-site analyses for pH and conductivity obtained.

Flow collected in the secondary leachate collection system will be analyzed at least weekly for pH and conductivity in the field. Tri-annually, along with primary leachate, composite secondary leachate samples will be obtained and analyzed for the full set of parameters outlined above for primary leachate.

Some secondary flow collection is anticipated. All secondary system flow will be managed as leachate regardless of flow rate or chemical quality. On a monthly basis the average flow rate for the secondary system will be evaluated, and the average gallons/day/acre of active phase of landfill calculated. If the average rate over 30 days exceeds 25 gallons/acre/day (gpapd), the ~~WMD of the~~ NHDES SWMB will be notified, and evaluation of appropriate responses completed with respect to the Solid Waste Rules, Section Env. Sw 806.08(k).

5.5 LANDFILL GAS MONITORING

Active gas extraction and management is planned for the long- term~~,~~ and will be expanded as gas production increases to collectible rates. This system will be implemented during the operation of the landfill, in advance of closure of the landfill, and be phased. The system will include a system of horizontal gas extraction wells and collection piping connected to the gas-to-energy system on-site. Energy recovery is a component of this system.

The potential for migration of gas through soil from the expansion is anticipated to be negligible. However, to monitor for landfill gas during operation of the landfill, the following measures will be taken:

- Quarterly gas sampling will be done at the existing soil gas monitoring wells for the unlined landfill, and also at the two proposed soil gas monitoring wells located along the western perimeter of Phase II. In the unexpected event landfill gas is detected, the sampling locations will be adjusted to provide additional detail.

- Quarterly monitoring will include vaults and leachate control structures outside the landfills.

- If explosive gases are detected that exceed 25% of the lower explosive limits at locations outside the landfill periphery within the soil, the NHDES ~~WMD~~ SWMB will be notified immediately. Appropriate steps necessary to evaluate the nature and mechanisms of the gas migration, and to ensure safety and health, will be taken.

Section 6

CONTINGENCY PLAN

6.1 GENERAL

In this section, specific contingency plans are presented to be followed in the event of the suspension of landfill operations, the appearance of landfill-~~–~~based contaminants in the monitoring well network, and spillage of fuel or leachate from a tank or truck.

6.2 SUSPENSION OF LANDFILL OPERATIONS

In the unlikely event that landfill operations are suspended for an extended period for any reason, the City will have waste hauled to another approved location, as available on a temporary basis, such that disposal service may proceed. The City does not propose to establish formal arrangements for such back-up service. Rather, depending on the time and circumstances of such a suspension, arrangements through the "spot market" at permitted waste to energy facilities, secure landfills, or other facilities as may be available, will be made by the City and/or private haulers.

6.3 RELEASE OF CONTAMINANTS FROM LANDFILL

The general approach to actions in response to an occurrence of unanticipated contaminant release from the landfill includes the following:

- Establishment and regular monitoring of the primary system of facility monitoring wells.
- Future establishment of additional groundwater monitoring wells, if appropriate, to be placed in the event of a confirmed presence of a leachate leak.
- Assessment through hydrogeologic evaluations of the nature of the type and extent of contamination in groundwater, due to the secure landfill. Assessment of the need to take actions to control the release.
- Remedial action as may be required, in consideration of landfill performance.

6.4 LANDFILL BASED CONTAMINANTS DETECTED IN MONITORING WELLS

Sequential steps to be taken:

1. Notify the NHDES SWMB ~~WMD and WD~~ immediately, as provided for in facility permits. All subsequent actions are to be taken in coordination with the NHDES.

2. Initiate more frequent sampling and analysis for an appropriate period, to establish confirmation of results.

3. Compare historical leachate flow data in an effort to estimate the order of magnitude of leakage quantity.

4. Review all data on landfill operations to investigate occurrences which may have resulted in a leak from both liners, or other contaminant spills.

5. Perform an intensive hydrogeological evaluation in the immediate area of contamination to determine the extent of the contaminant plume and to confirm flow directions and velocities. Assess the possibility of groundwater impacts from the existing unlined landfills and other sources other than the secure expansion.

6. Assess with the NHDES the need to intercept migrating contaminants with respect to anticipated impacts on surface and groundwater quality.

7. If required, develop a detailed work plan for remedial work to prevent or mitigate water quality impacts from migrating contamination. Appropriate actions may include diversion, interception, removal and treatment of groundwater.

8. Evaluate the need for, and benefits from, modifying operations at the landfill to minimize or abate generation of leachate in the vicinity of the leak.

6.5 FUEL OR LEACHATE SPILL

In the event of an accidental fuel spill from a vehicle or the known leakage of leachate from pipes or tanks, the City will respond as follows:

1. Construct temporary earthen berms around the spill area to contain surface runoff from entering the area of the spill.

2. Notify the NHDES immediately. Coordinate all further activities with appropriate agencies of the Department.

3. Contract with an emergency spill management firm to assist in on-site cleanup.

4. If determined to be necessary, remove contaminated soil for proper disposal, or dispose within secure landfill.

5. Take other actions as deemed necessary by the NHDES to mitigate impacts of spill.

6.6 OTHER CONTINGENCY EVENTS

Good operations in accordance with this operating plan and “state of the practice” operations will limit the potential for emergency events involving fire, explosion, or personal safety. The operations staff at the landfill will, however, have the potential to be in immediate direct radio contact with the Nashua Public Works Dispatch. Public Works Dispatch has direct access to the Nashua Fire and Police Departments. During emergency events involving the personal safety of staff, other persons, or property, staff will coordinate all on-site activities with the Nashua Fire and Police departments.

6.6.1 Fire

In accordance with this plan, use of daily cover is anticipated to reduce or eliminate the potential for fire to occur in landfill operations. In the unlikely event of fire, a fire prevention system ~~has been~~was installed as part of the Phase II landfill construction. The system consists of a wet well located within Detention Pond #4 connected to a water line and hydrant system adjacent to the landfill. If water is needed to extinguish a fire, a fire pumper truck can be utilized to pump water from the wet well to the hydrants. In the event of an occurrence of fire at the landfill, or anywhere on the site, the Nashua Fire Department will be notified immediately.

6.6.2 Explosion

Operations staff shall immediately contact the Nashua Fire Department and coordinate all subsequent actions with the Department. The landfill gas monitoring program is outlined in Section 5 of this plan. Risk of explosion is limited at the site, and is primarily associated with use of equipment.

6.6.3 Operator Injury

Operations staff shall limit their direct intervention in the event of operator injury to removal of an individual from a location where additional injury may occur~~,~~ and administering immediate first aid. Immediately upon the event of injury, staff shall contact the Nashua Public Works Dispatch, inform dispatch of the location and nature of the injury, and coordinate all subsequent actions with Police/Fire personnel.

6.6.4 Backup Power Supply

The Phase III Sump Riser Building is equipped with a generator transfer switch to provide electricity to the pumping station and alarm systems. The site has emergency generators available that will be used to power the building components in the event of a power failure.

The Phase III Sump Riser Building is equipped with redundant equipment in the event of pump failure. Two pumps are available to pump primary leachate; a primary sump riser pump and a cleanout pump. The primary and secondary sump riser pumps are identical. In the event that the secondary pump fails, the primary sump riser pump can be transferred and operated within the secondary riser pipe while the cleanout pump is used to pump primary leachate until the pump repairs are made.

6.7 IDENTIFICATION OF EMERGENCY CONTACTS

In the event of an emergency event at the landfill, the following contacts will be made, as appropriate:

Nashua Police Department:	(603) 594-3500 or 911
Nashua Fire Department:	(603) 594-3651 or 911
Nashua Public Works Director:	(603) 589-3140
NHDES ~~WMD~~ SWMB Compliance Section:	(603) 271-~~2900~~2925

Section 7

EMPLOYEE TRAINING PROGRAM

All landfill operations employees will receive appropriate training to implement the provisions of the latest approved operating plan. Employee training will be documented as to attendees, training content/subject, and the dates and length of training. The landfill operating plan, as finalized prior to commencement of operations, will be a key part in the training. Training will include the objectives and specific procedures associated with each element of the landfill operations, as relevant for that employee's responsibilities.

The landfill operators will be licensed through the NHDES Solid Waste Facility Operator Training and Certification program. The Four Hills Landfill is a Level IV facility per Env-Sw 1602.08 and therefore requires a certified Level IV operator/manager to be in responsible charge. The operators shall be required to be licensed in accordance with the State's Certification program and renew their operator certification annually. Prior to applying for certification renewal the operator must participate in an operator training update program organized by the State.

The supervisor and equipment operators will be familiar with all aspects of operations, including both routine and contingency actions, monitoring and inspections, and record keeping.

All employees, from the date of commencement of operations, or date of hire as appropriate, will receive specific training, under the supervisor of the Nashua Division of Public Works, and the supervisor. Such training will include review of operating objectives and procedures, and specific use of equipment.

The Nashua Division of Public Works, including Public Works Director, City Engineer, and staff will be available to assist as appropriate in resolving operational issues.

Section 8

RECORD KEEPING

8.1 OPERATING RECORDS

The City shall compile and maintain records at the facility which document all phases of facility operations, including the following information:

1. Identification of all facility operator(s) by name, address, certificate number, and date(s) of employment at the facility;
2. Quantity, type, and source of all waste received by the facility;
3. Quantity, type, and destination of all waste generated by the facility, if any, including bypass waste and residual waste;
4. Quantity and discharge of leachate, by location;
5. Quantity, type, and destination of all certified waste-derived products produced by the facility, if any;
6. Record of inspections, maintenance, and repairs;
7. Record of accidents, violations, remedial, and emergency event response actions;
8. Record of complaints received and related response actions;
9. Data from all environmental monitoring performed at or for the facility, whether required by the solid waste rules or the permit or undertaken voluntarily;
10. Documentation of contact with the waste management district(s) served by the facility as required to demonstrate that all operating requirements established by RSA 149-M:11, XI pertaining to the requirements of RSA 149-M:11,III(c) and RSA 149-M:12,I(b) are being met and that the facility operations meet other relevant planning needs and requirements identified or established by the district to the extent allowed by the permit;
11. Cost estimates and financial assurance documentation; and
12. Other information and documentation as required by the terms and conditions of the permit.

The operating records identified above shall be maintained at the facility at all times during the active life of the facility, unless approval is granted pursuant to the provisions for a Type V permit modification in Env-Sw 315 to relocate or destroy the record.

Operating records shall be available for inspection by the department and copies provided to the department pursuant to Env-Sw 1105.06.

Following closure of the facility, the operating records shall be maintained at a location approved by the department in the closure plan.

8.2 REPORTING REQUIREMENTS

The City shall notify the department in writing within 30 calendar days of any change in the facility address, telephone number, key certified operators and contact person(s).

An annual facility report shall be submitted by March 31 for the prior calendar year for each year that the facility operates and for each year of the facility's post-closure monitoring and maintenance period (see below).

The City shall report all changes in operational and City control in accordance with the provisions for a Type III or Type IV permit modification, as applicable, pursuant to Env-Sw 315.

The City shall notify the NHDES in writing prior to conducting the following activities at the facility not specifically authorized in the permit:

1. Any activity not regulated by the solid waste rules but involving a waste listed in Env-Sw 101.03; and
2. Any activity that is permit-exempt in Env-Sw 302.03.

8.3 QUARTERLY REPORTS

Quarterly reports shall be submitted to the NHDES in duplicate no later than 30 days following the end of the quarterly reporting period. Each copy of the report shall be signed by the person duly authorized to sign for the City. The signature affirms that the material and information submitted is complete to the best of their knowledge and belief.

The report shall contain the following information:

1. Name and permit number of the reporting facility;
2. Landfill gas monitoring results, leachate, and leachate management system data, excluding the tri-annual monitoring of primary leachate;
3. Quantity and type of wastes received by facility;
4. Data units for each type of data reported;
5. Reporting period and/or dates the data was collected, for each type of data recorded; and
6. Monthly and quarterly subtotals for each type of data reported.
7. Summary of LFG collection system condensate sumps: weekly inspection findings, operational data, and pump performance evaluation(s).
8. Description of corrective actions taken (if any) for the LFG collection system condensate sumps including quantities of sediment and condensate removed from the sumps, if any.
9. The location and description of leachate breakouts, if any, observed within the limits of the Phase I/II landfill. Corrective actions taken to remediate the leachate breakouts shall also be described in the report.

8.4 ANNUAL REPORT

An annual report shall be submitted to the department in duplicate no later than March 31st after operations commence. Each copy of the annual report shall be signed by the person duly authorized to sign for the City. The signature affirms that the material and information submitted is complete to the best of their knowledge and belief.

The report shall contain the following information:

1. Facility name, location by street and municipality, and permit number;
2. Name, address, and telephone number of the permittee;
3. Name, address, certificate number and telephone number of all facility operators;

4. Facility status, including analysis of remaining capacity based on site survey which identifies the remaining facility capacity;
5. Quantity in tons, type, and source of all waste received by the facility;
6. Destination of all wastes received by the facility (i.e., Phase II A)
7. Quantity, type, and destination of all waste generated by the facility, including bypass and residual waste (leachate);
8. A summary and assessment of all monitoring performed at or for the facility, whether required by the solid waste rules or the permit or undertaken voluntarily, specifically including as applicable:

    a. A summary of the facility inspection and maintenance activities;
    b. Summary of leachate management system monitoring:
        1. head;
        2. primary and secondary flow;
        3. primary leachate quality;
    c. Summary of landfill gas monitoring;
    d. Summary of groundwater and surface water quality monitoring; and
    e. A discussion, pursuant to RSA 149-M:11, XI, of how facility operations satisfied the public benefit requirements specified in the permit, if any.

    If monitoring information was already reported in writing to the department during the calendar reporting year, then it need not be submitted in the annual report if a written statement is provided which identifies:
    a. nature of information already submitted;
    b. date the information was submitted;
    c. title of document containing information; if applicable; and
    d. name of person who submitted information

    If monitoring information is unchanged from the previous calendar year reporting year, the City may mark the item “unchanged from last annual report” and cite the date of the last annual report that contained the information.

8.5 INCIDENT REPORT AND COMPLAINTS

8.5.1 Incident Involving Risk to Human Health, Safety or the Environment

In the event of an incident or situation at the facility which involves an imminent and substantial risk to human health, safety or the environment and/or which constitutes a violation of the NHDES Solid Waste Rules or the facility permit, the operator shall file a report to be placed in the operating record and submitted to NHDES as follows: (Also see section 7.0 - Contingency plan)

Provide a verbal report to the NHDES as soon as practicable.

Submit a written report to the NHDES and to be placed in the operating record within 5 working days to include the following information:

1. Facility name, location by street and municipality, and permit number;

2. Permittee name, mailing address, and telephone number;
3. Identification of all persons involved in the incident or situation, including name, title, and affiliation;
4. A description of the incident or situation, including:
    a. The date and time the incident or situation occurred
    b. The quantity and types of wastes and material(s) involved in the incident or situation and in the clean-up activities;
    c. Measures employed to contain releases caused by the incident or situation; and
    d. An assessment of actual or potential hazards to the environment, safety and human health related to incident; and
5. Measures the permittee has or intends to apply to reduce, eliminate, and prevent a recurrence of the incident or situation.

Leachate breakouts that occur and flow outside of the lined landfill foot print shall be considered an incident involving risk to human health, safety, and the environment and shall be reported to the Department as described above.

8.5.2 Complaints from Abutters or Third Parties

The operator shall maintain a record of all complaints occurring from abutters or other third parties with the operating record, and actions taken to respond to those complaints.

In the event of complaints made by abutters or other third parties which involve operating conditions or practices having the potential to adversely affect human health, safety or the environment or which involve a recurring or persistent situation such as noise, litter, odor, dust or vectors, the operator shall file a report to be placed in the operating record and submitted to the NHDES as follows:

The written report shall be made as soon as practicable and include the following information:

1. Facility name, location by street and municipality, and permit number;
2. Permittee name, mailing address, and telephone number;
3. Name, mailing address and, if available, telephone number of the complainant;
4. The nature of the complaint, date(s) of receipt by the permittee, and a complete description of the circumstances or situation giving rise to the complaint;
5. A description of the permittee’s response action(s); and
6. Such other information as required in the section on incident reporting above if the circumstances or situation giving rise to the complaint require reporting under incident reporting above.

If the incident or complaint persists, the NHDES shall be notified and informed of corrective action to remedy the problem, and a periodic update shall be made regarding the incident or complaint as appropriate (such as in the quarterly or annual reports).

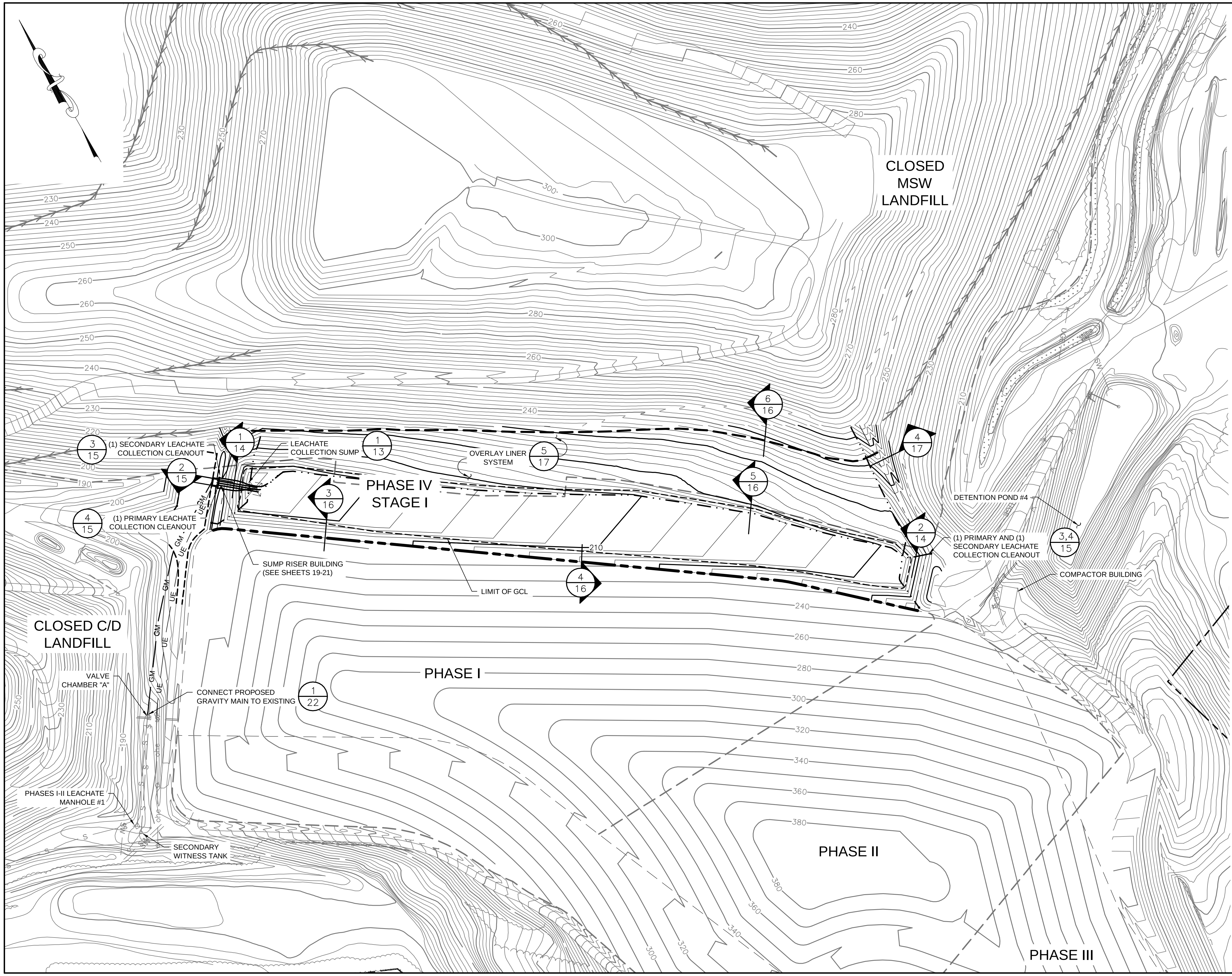
8.6 Landfill Gas Collection System Reporting

The landfill operator shall submit triannual reports to the NHDES in accordance with the Landfill Gas Collection System, Enhanced Monitoring Protocol and Standard Operating Procedures (EMP/SOP). The landfill operator will maintain all monitoring data sheets and calibration logs in accordance with the EMP/SOP.

APPENDIX A

SEQUENCED FILLING PLANS

(Revised ~~January 2020~~July 2020)



NOTES:

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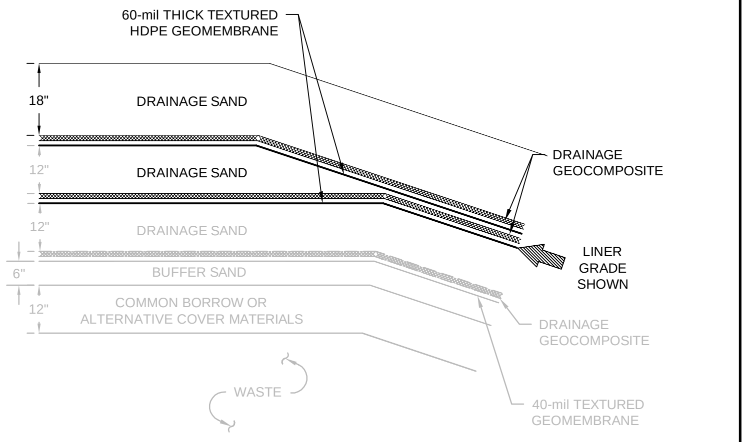
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED AS NECESSARY ACCORDING TO THE PERMITTED LIMIT OF WASTE.
3. EXISTING GAS EXTRACTION WELLS AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.



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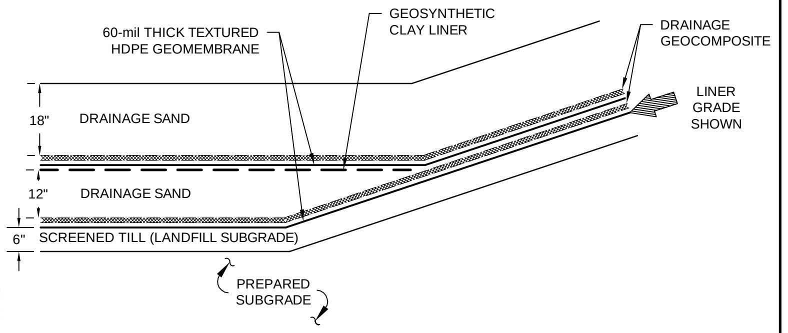

AREAS OUTSIDE EXISTING CAP AREA

GRADING KEY

- *NOT FOR CONSTRUCTION* -
FOR PERMITTING PURPOSES ONLY

SANBORN HEAD

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ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

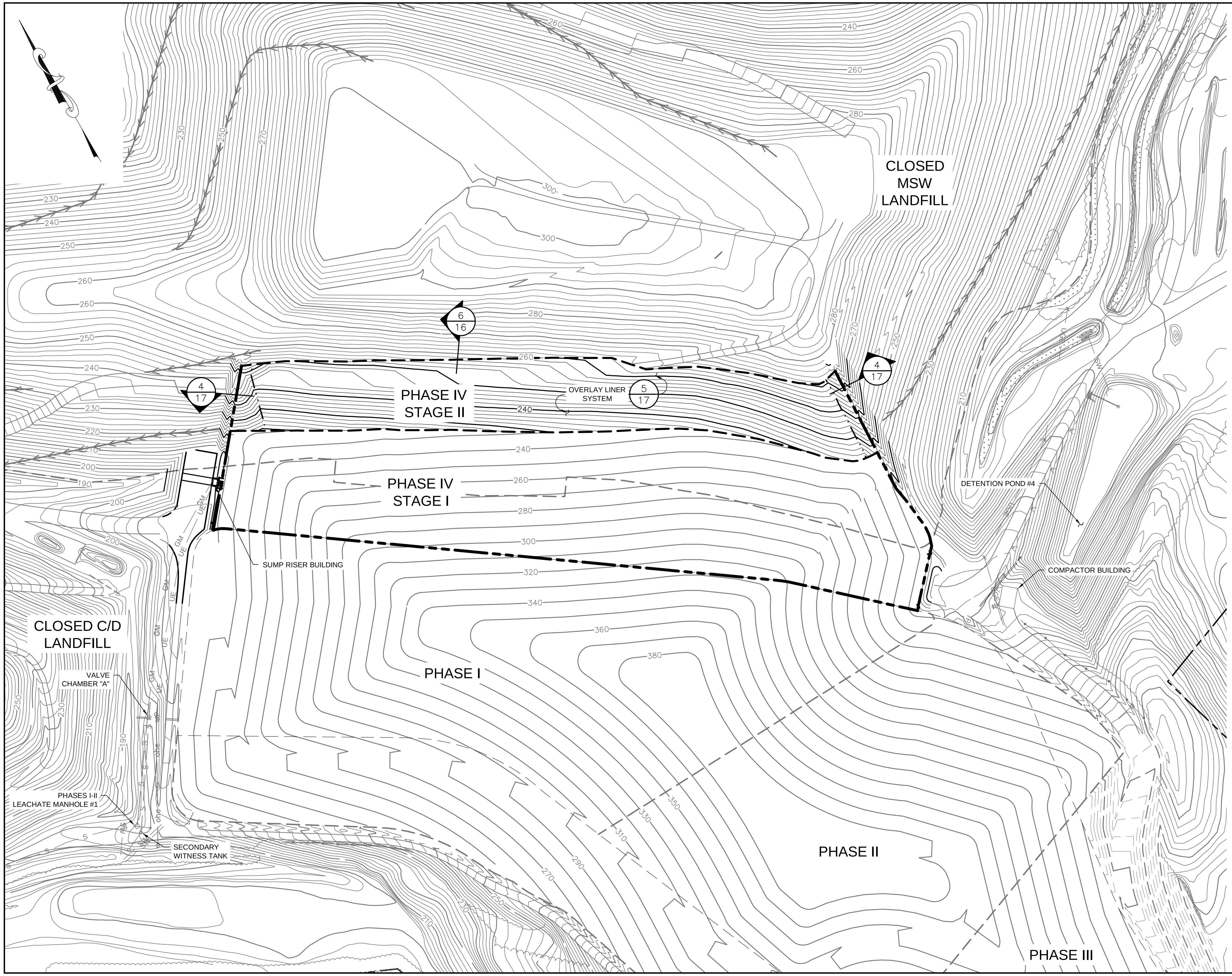
DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE I SECONDARY BASE GRADING PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
6 OF 28



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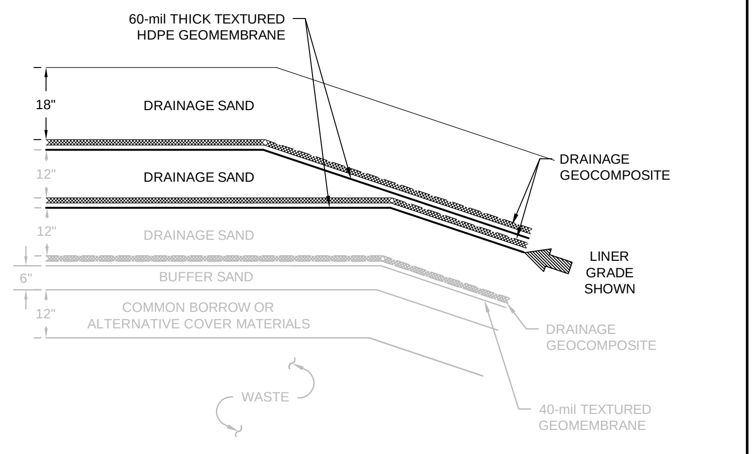

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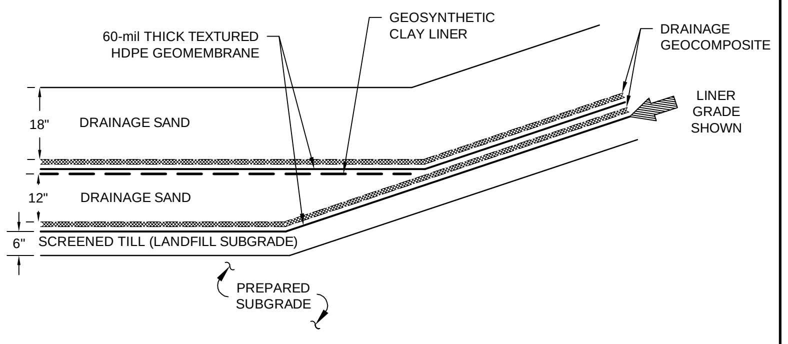

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PROJECT MGR: E. GALVIN
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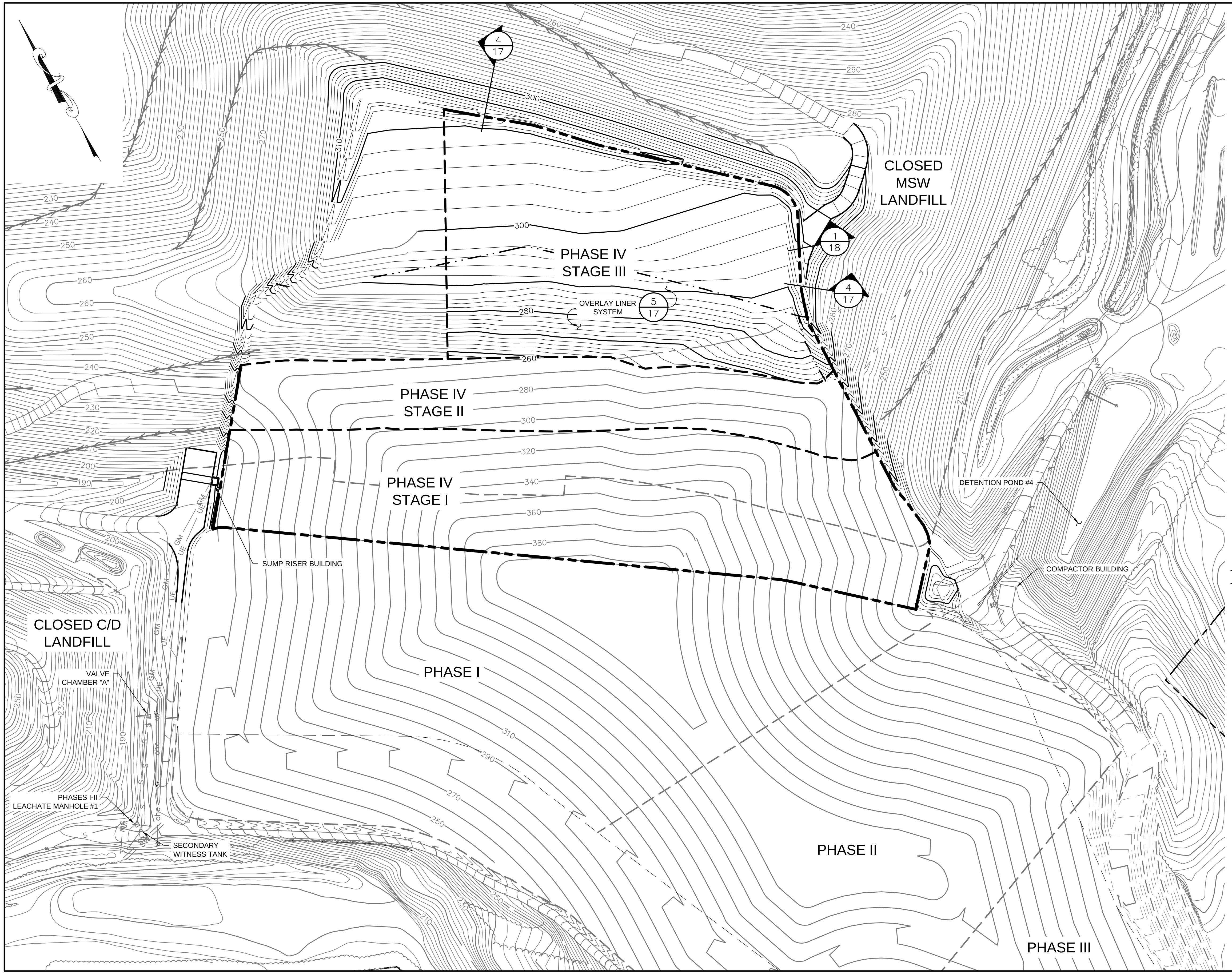
PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE II SECONDARY BASE GRADING PLAN

PROJECT NUMBER: 3066.11

SHEET NUMBER: 7 OF 28



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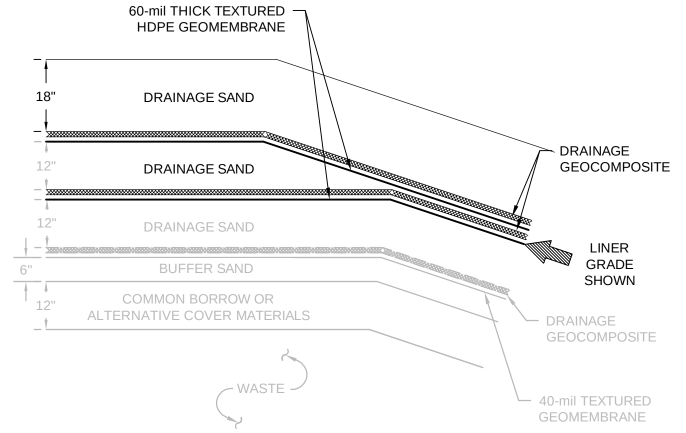

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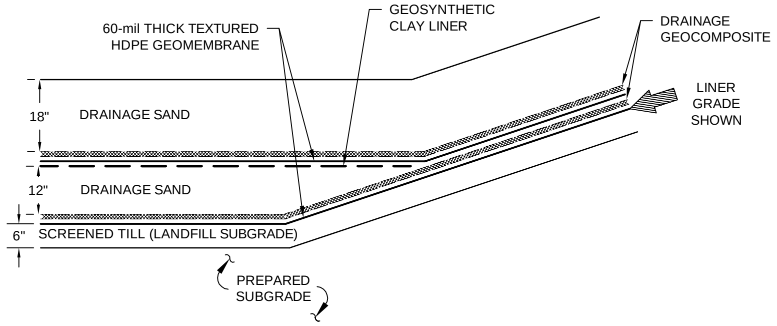

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ERIC SCOTT STEINHAUSER
No. 1149

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE III SECONDARY BASE GRADING PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
8 OF 28

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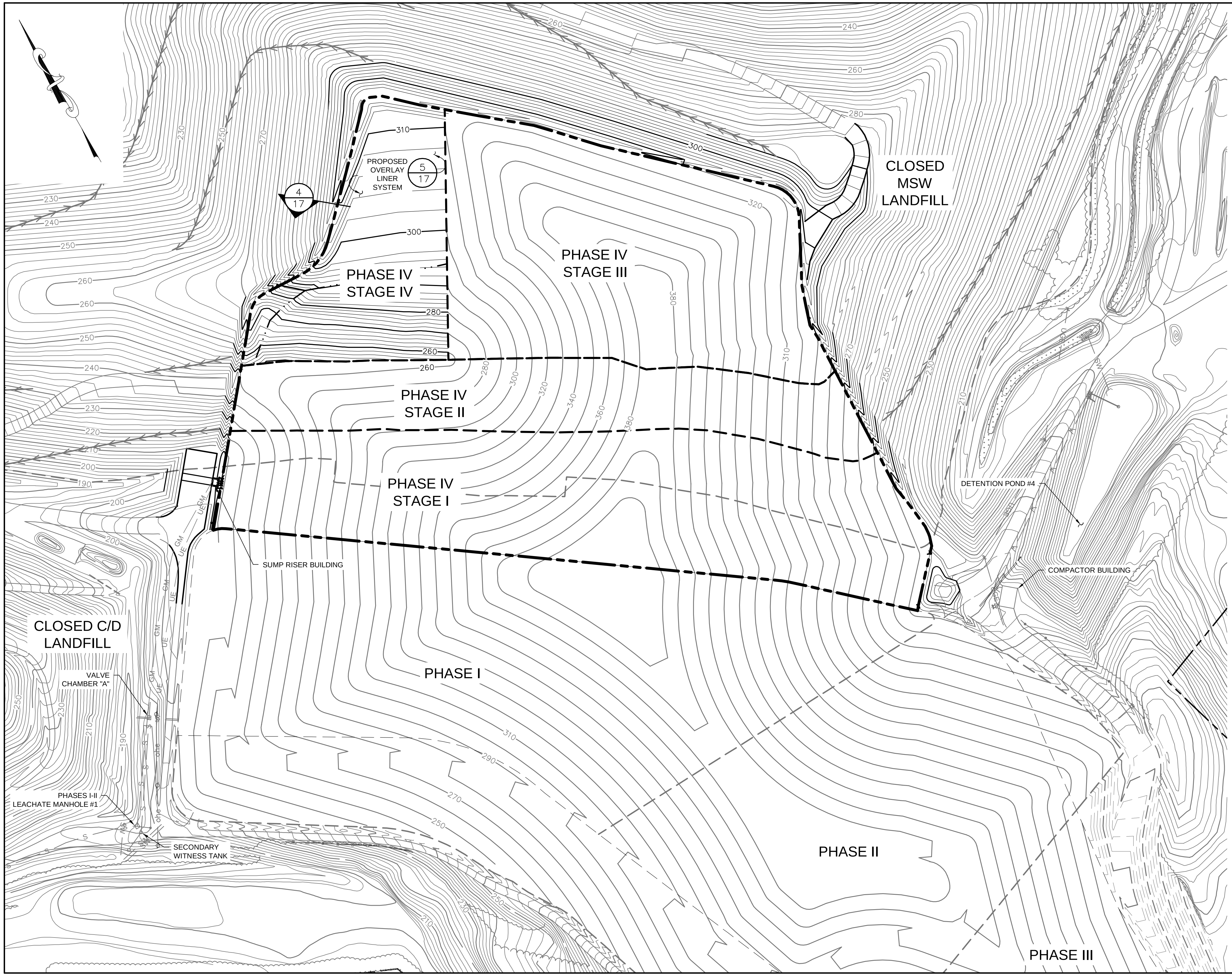

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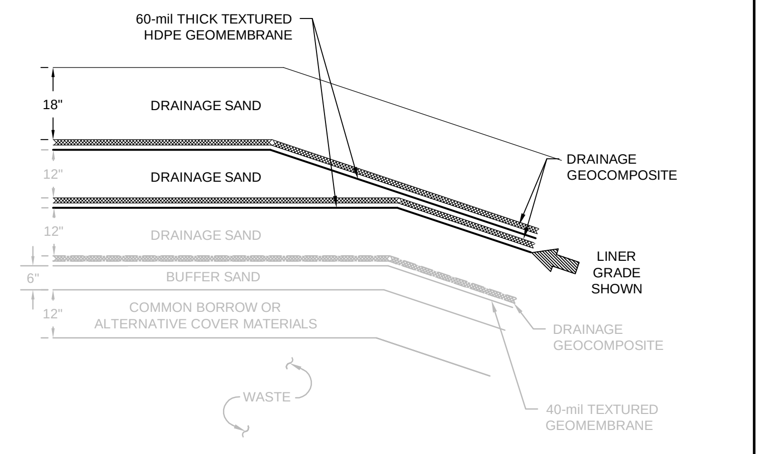

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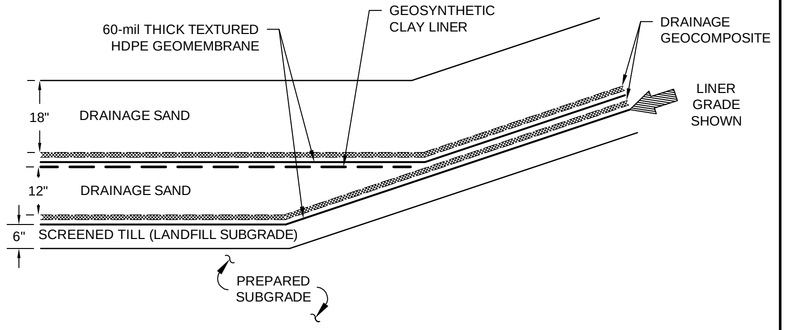

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PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

STAGE IV SECONDARY BASE GRADING PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
9 OF 28

IMAGES: E:\Steinhauser-NH.tif

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LAYOUT: D09
USER: ssantiago
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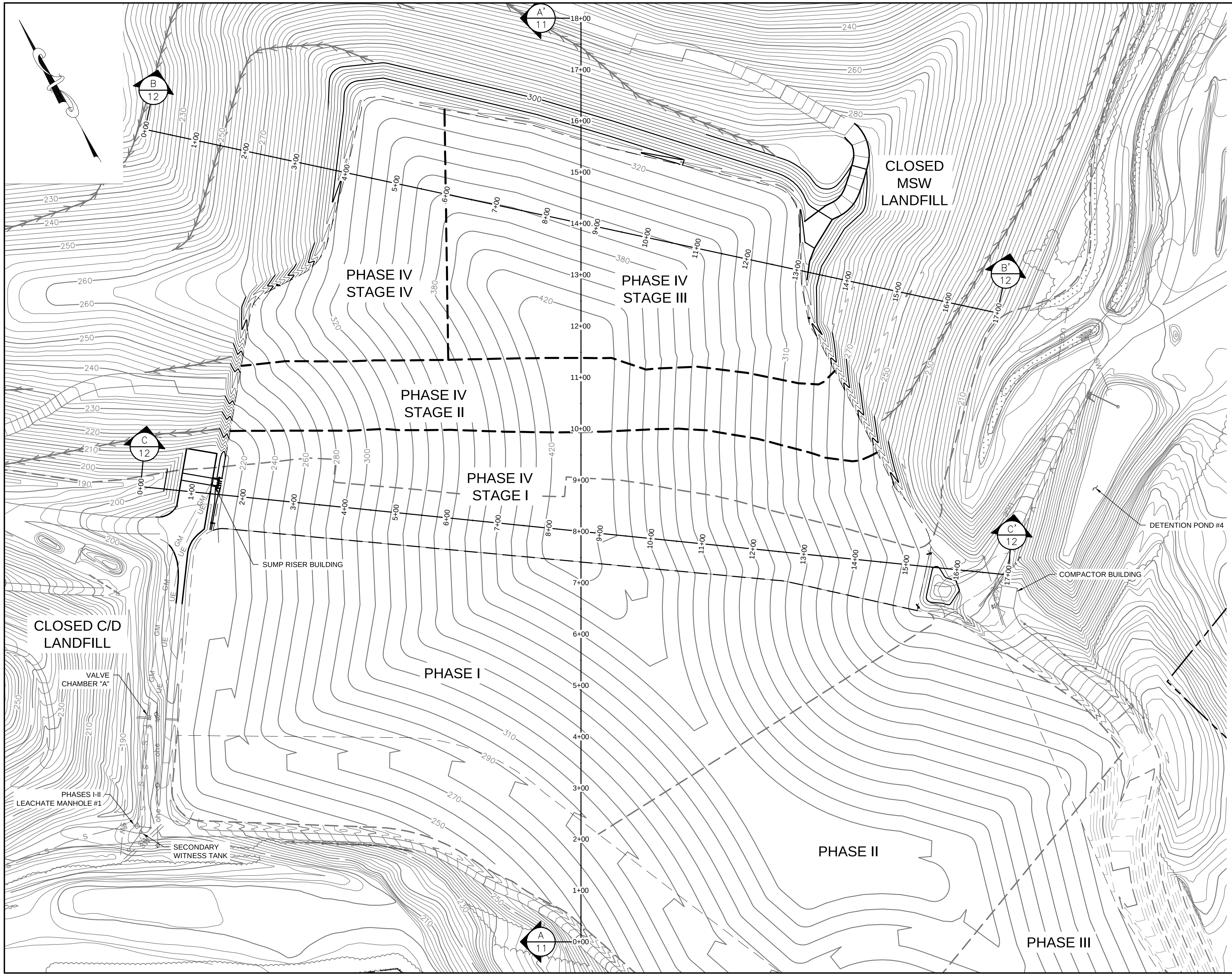

NOTES:

1. SEE SHEET 1 FOR ADDITIONAL NOTES AND LEGEND INFORMATION.
2. THE PROPOSED GRADES IN THE PROPOSED OVERLAY AREA ARE BASED ON HISTORICAL TOPOGRAPHY DATA AND SHOULD BE CONSIDERED CONCEPTUAL ONLY. THE EXISTING GRADES AT THE TIME OF CONSTRUCTION MAY BE LOWER DUE TO WASTE SETTLEMENT. THEREFORE, THE OVERLAY AREA WILL BE SURVEYED PRIOR TO PREPARING THE CONSTRUCTION DRAWINGS AND THE PROPOSED GRADING WILL BE ADJUSTED ACCORDING TO THE PERMITTED LIMIT OF WASTE AS NECESSARY.
3. EXISTING GAS EXTRACTION WELL AND COLLECTION TRENCHES NOT SHOWN FOR CLARITY.

- NOT FOR CONSTRUCTION -
FOR PERMITTING PURPOSES ONLY

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SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

ERIC SCOTT STEINHAUSER
No. 11494

NO.	DATE	DESCRIPTION	BY

DRAWN BY: J. GRACE
DESIGNED BY: J. GRACE
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JULY 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

FINAL GRADING AND GAS COLLECTION AND CONTROL SYSTEM PLAN

PROJECT NUMBER:
3066.11

SHEET NUMBER:
10 OF 28

APPENDIX E

CLOSURE PLAN

SANBORN HEAD
Building Trust. Engineering Success.

CLOSURE PLAN
PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Prepared for the City of Nashua
File No. 3066.11
July 2020

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Appendix A - Opinion of Landfill Closure Construction Costs
Appendix B - Opinion of Landfill Post-Closure Monitoring Cost

1.0 FACILITY IDENTIFICATION

Facility Name: Nashua Four Hills Landfill
Phase IV~~II Stage 1~~ Secure Landfill Expansion

Facility Location: 840 West Hollis Street
Nashua, NH 03061

Mailing Address: Nashua Division of Public Works
9 Riverside Street
Nashua, NH 03062

Permit Number: DES-SW-SP-95-002

2.0 CLOSURE SCHEDULE

The proposed Phase IV~~II Secure Landfill~~ ~~E~~expansion will be developed in ~~two~~ four stages ~~(i.e., Stage 1 and Stage 2~~following filling in ~~). Currently~~ Phases I, ~~and~~ II, and III.~~ are involved in active landfill operations with Phase III Stage 1 expected to be operational in early 2020.~~ Intermediate closure of the landfill will occur progressively as final grades are achieved. The first closure construction will include the southern and western portions of the landfill once the Phase III ~~Stage 2~~ final grades are achieved. The northern slopes of Phases I and II will remain as intermediate cover as they will be incorporated into Phase IV~~until final closure, as the City would reserve its ability to expand the operation landfill to the north~~. The final closure of the remainder of the landfill will be constructed once all filling is completed. Total life of the Phase IV expansion ~~(Phase III Stage 1~~) is approximately ~~9~~30 years.~~, which corresponds to the year 2029~~. ~~It is unlikely, however, that Phase III Stage 1 will be closed prior to Phase III Stage 2, which provides approximately 2 additional years of capacity, which corresponds to the year 2031 for final closure of the Phase III Secure Landfill Expansion.~~

3.0 WASTE IDENTIFICATION

The Nashua Four Hills Landfill (Landfill) was established in 1971 for the disposal of municipal solid waste, construction and demolition waste, and wastewater sludge from the City of Nashua. Two separate closed landfills ~~have~~ exist~~ed~~ at the site: the ~~main~~ approximately 60-acre closed, unlined municipal solid waste (MSW) ~~L~~landfill ~~(approximately 60 acres~~, and the approximately 15-acre closed, unlined construction and demolition debris~~separate~~ (C/~~I~~D) ~~L~~landfill.~~ (originally approximately 15 acres.~~ The lined Phase I ~~landfill~~ expansion ~~(Phase I)~~ was permitted and constructed over several years and became operational in May 2000~~3~~. The lined Phase II expansion became operational 2009 and the lined Phase III expansion became operational in 2020.

The ~~Phase III Stage I expansion~~Landfill is permitted to accept for the disposal only~~of municipal solid wastes (~~ MSW~~)~~ generated from within the City of Nashua. Should the City elect to change wastes for disposal, appropriate permit modifications will be pursued, including modifications to this closure plan, if appropriate.

Acceptable wastes will include waste materials which are currently disposed at the existing landfill on the site, or otherwise are produced within the service area and meet state and federal restrictions for disposal in solid waste landfills, and may include:

- Mixed waste from residential, commercial, institutional, and industrial sources;
- Construction and demolition waste (C/D);
- Bulky waste;
- Street sweepings;
- Brush/Stumps (periodically);
- Digested wastewater sludge, grease, and grit from the Nashua WWTP (as a contingency and under a separate permit modification), and;
- Asbestos waste.

For additional information, refer to the Operating Plan. It is noted that the City will be voluntarily restricting C/D waste from the landfill as practicable.

~~It is planned to develop permits for Phase IV of the landfill. If developed, the schedule for final closure will be extended. The presentation herein assumes that operations are discontinued after Phase III Stage 1, an unlikely event.~~

4.0 NOTIFICATIONS

At least one year prior to ultimate closure of the ~~facility~~Landfill, all users of the ~~l~~Landfill will be notified of the City's intentions to close the ~~facility~~Landfill. Notification will be in writing with a specific closure date. Notification will also be placed as a Public Notice in a least one newspaper of general circulation. Signs identifying the closing date will be posted at the landfill as well as notices on bulletin boards in public meeting places.

The notice of an intent to close ~~shall~~will be submitted to the New Hampshire Department of Environmental Services (NHDES) at least one year prior to the ultimate closure of the facility. The notice ~~shall~~will include the following:

1. Facility identification;
2. Date the facility intends to stop receiving waste;
3. A copy of the approved closure plan or file reference thereto;
4. If the provisions of the last approved closure plan are no longer applicable or no longer conform to the closure requirements of the solid waste rules, identification of such provisions and revisions is required; and
5. The date the facility intends to commence closure activities.

Prior to the ultimate closure of the landfill, the City reserves the right to close the landfill at any time. In the event of such premature closure, the City ~~shall~~will revise the Closure Plan~~,~~ and grade the landfill to the final closure shape presented in the revised Closure Plan.

5.0 CLOSURE REQUIREMENTS

The following tasks are required to implement and complete closure of the expansion:

1. Develop Final Design Plans and Specifications for Closure
2. Minor Regrading to Establish Closure Grades
3. Construct and Maintain Capping System
4. Construct and Maintain Stormwater Management System
5. Operate and Maintain Leachate Collection System
6. Operate and Maintain Groundwater Monitoring System
7. Construct and Maintain Landfill Gas Management System
8. Initiate Settlement Monitoring Program
9. Provide Access Control to Site

A description of the procedures required to complete each of the closure tasks is provided below.

5.1 Final Design Plans and Specifications

The City ~~shall~~will retain a qualified engineer to prepare~~complete~~ the final design ~~plans~~ drawings and specifications for the closure of the ~~Nashua Secure Solid Waste~~ Landfill ~~Expansion~~. The final design ~~plans shall~~will be developed prior to the landfill phases reaching capacity and should be based on current practices and applicable State and Federal rules. The preliminary closure design is presented in the Phase IV Expansion Type I-A Permit Modification Application, which~~plans~~ are based on the preliminary closure design plans approved pursuant to the Type I-B and II permit modification issued by the NHDES on December 5, 2018.

5.2 Regrading of Waste

The Phase IV~~II Stage 1~~ ~~E~~expansion will be constructed adjacent to Phase I~~I~~ and waste placement will extend over the Phase I~~I~~ final grades during Phase IV~~II~~ operations. Areas of Phases I, ~~and Phase~~ II, and III that~~ which~~ are at final ~~closure~~ grade~~s~~, will be covered with a 12-inch thick layer of intermediate soil cover and a vegetative stand established.

Closure of the lined landfill may require minor regrading of areas to establish appropriate slopes for landfill closure. The installation of intermediate drainage benches and perimeter swales may require some waste excavation and relocation. The Operating Plan of the landfill provides for placement of waste to appropriate closure grades so substantial regrading will not be necessary.

5.3 Capping System

The proposed capping system includes use of a single geomembrane (40-~~-~~mil thick textured polyethylene geomembrane~~HDPE~~ as the ~~primary ~~hydraulic barrier that~~o~~ prohibits infiltration of precipitation into the landfill~~,~~ and ~~to ~~that ~~minimize ~~limits leachate~~the~~ generation~~ of leachate~~. The system will consist of a total of 3.5 feet of material over most of the ~~site~~phases, with specific additional materials at toe-drains, intermediate drainage benches, swales, and other locations. The capping system ~~generally ~~consists of the following materials that meet~~ing~~ the minimum requirements of Env-Sw 805.10, listed from top to ~~(~~bottom~~ to top)~~:

- A 6-inch thick layer of topsoil with vegetation;
- A 6-inch thick layer of moisture retention soil;
- A 12-inch thick layer of drainage sand;
- A drainage geocomposite;
- A 40-mil thick textured geomembrane liner (barrier layer);
- A 6-inch thick layer of buffer sand; and
- A 12-inch thick layer (minimum) of common borrow (intermediate cover as required).~~;~~

- ~~A 6-inch thick layer of buffer sand;~~
- ~~A 40-mil thick textured geomembrane liner (barrier layer);~~
- ~~A drainage geocomposite;~~
- ~~A 12-inch thick layer of drainage sand;~~
- ~~A 6-inch thick layer of moisture retention soil; and~~
- ~~A 6-inch thick layer of topsoil with vegetation.~~

~~The landfill will be operated with the extension of t~~The existing active gas extraction system will be extended into Phase IV – ~~through~~ both ~~horizontal ~~collection trenches and vertical ~~collection ~~wells. Additional vertical wells may be installed through the waste prior to closure. Gas collection well heads and control valves will require extension through the capping system for operational access.

In addition, numerous other select materials including geotextiles, geosynthetic drainage media, crushed stone, rip~~-~~rap, and other materials will be part of construction. Typical cross sections of the final capping system and other closure design information are presented in ~~attached Preliminary Closure Plans~~the Type I-A Permit Modification Application.

On areas that have not received the 12-inch thick layer of intermediate cover, a 12-inch thick layer of common borrow ~~shall~~will be placed, compacted, and ~~to provide a ~~graded ~~base for ~~for the placement of overlying layers.

The buffer sand layer is intended to protect the geomembrane from underlying coarse soil materials. The sand will be constructed in accordance with the quality assurance/quality control ~~(QNQC plan~~ as described in ~~Part~~ Env-Sw 805.16~~ of the NH Solid Waste Rules~~.

The barrier layer is intended to minimize the infiltration of water into the waste to eventually eliminate leachate production. Current practices utilize a 40-mil thick geomembrane installed ~~in accordance with a QNQC plan established~~ pursuant to Env-Sw 805.16.

The drainage layer is intended to remove water that infiltrates through the topsoil and moisture retention layers. The drainage layer outlined herein consists of a drainage geocomposite overlain by a 12-inch thick layer of drainage sand. As an alternative, an 18-inch thick layer of select drainage sand with a ~~permeability~~ saturated hydraulic conductivity of no less than 1×10^{-3} cm/sec could be substituted if appropriate at the time of final closure.

The geocomposite drainage ~~shall~~will consist of a single-sided or double-sided laminated composite of nonwoven geotextile and a geonet or perforated drain tubes. The selection of the drainage geocomposite will be based on applicable stability calculations. Water collected in the drainage geocomposite will be relieved at regular intervals based on the hydraulic capacity of the system and development of-head above the barrier layer.

The drainage sand layer will be comprised of a 12-inch thick layer of sand specified to meet the necessary hydraulic characteristics and constructed ~~in accordance with a QNQC plan established~~ pursuant to Env-Sw 805.16.

The moisture retention soil ~~shall~~will be comprised of a 6-inch thick layer of soil to support the vegetative.

The topsoil and vegetative layer will serve to stabilize the capping system against wind and water erosion. The layer ~~shall~~will promote evapotranspiration while providing ease of visual inspection of the capping surface. Alternate or supplemental materials to the topsoil may be utilized if necessary, or advisable, with the concurrence of the NHDES.

5.4 Stormwater Management System

The stormwater management system ~~shall~~will be designed to accommodate the ~~25-year storm~~ peak flow from a 25-year, 24-hour storm for the drainage area being served. Peak surface runoff from the L~~l~~andfill ~~site~~ for the 25-year, 24-hour storm ~~shall~~will be controlled and maintained ~~at the NHDES approved discharge rate~~ through the use of detention ponds. The permanent sedimentation/detention ponds ~~shall~~will be sized to handle the 25-year,~~/~~24-hour storm event with no less than one foot of freeboard above the emergency spillway invert.

Stormwater runoff from the cap will be collected in intermediate drainage benches, spaced at intervals to limit surface erosion and necessary to convey the water. Intermediate benches will be constructed at a minimum slope of 4~~%~~percent, while perimeter swales, outside the limit of waste will be constructed at a minimum slope of 1~~%~~percent.

Prior to closure construction, an Alteration of Terrain Permit (AoT) will need to be obtained. The permit application will include appropriate drainage calculations used to design new and confirm existing sizes of drainage structures.

5.5 Leachate Collection System

~~All l~~Leachate collected ~~by the secure landfill expansion~~ will be managed in accordance with the Residual Waste Management Plan as outlined in the Operating Plan. Leachate from Phases I, II, ~~and~~ III, and IV is collected and discharged to the Nashua sewerage system for treatment at the Nashua Wastewater Treatment Plant. Alternative back-up arrangements for leachate discharge have been established through the Town of Palmer, Massachusetts, a combined industrial and municipal wastewater treatment facility.

Scheduled inspections and maintenance to the leachate management system ~~shall~~will be completed in accordance with the post-closure requirements as outlined in Section 6.0

5.6 Groundwater Monitoring System

Groundwater quality at the ~~site~~ Landfill is currently monitored in accordance with a Groundwater Management and Release Detection Permit. Monitoring in accordance with the permit ~~shall~~will continue following the closure of Phases I – IIV~~II~~ and during the post-closure period. The monitoring program, including frequency and monitored parameters, ~~shall~~will be reviewed at the time of closure and periodically based on data at that time. The monitoring program currently includes tri-annual monitoring of indicator compounds as well as heavy metals and VOCs.

5.7 Landfill Gas Management System

Landfill gas will be generated from the proposed facility. The Operating Plan includes the installation of horizontal and vertical gas extraction wells to capture the generated landfill gas. The liner system will minimize migration of gases through the underlying soil. After closure, the landfill gas will continue to be managed through the active gas collection system, in compliance with applicable permits.

Gas migration monitoring will be accomplished by constructing a series of gas monitoring wells outside the footprint of ~~the landfill~~Phases I, II, III, and IV. The concentration of methane and other explosive gases ~~shall~~is not exceed 25~~%~~percent of the lower explosive limit (LEL) in structures on or off-site, excluding leachate collection and gas control and recovery components or exceed 50~~%~~percent LEL at and beyond the property boundary in the soil. Monitoring of the gas wells and on-site structures ~~shall~~will be ~~conducted~~ performed quarterly as described in Section 6.4.

5.8 Settlement Monitoring

Permanent landfill settlement monuments ~~shall~~will be incorporated into the construction of the cap. Monuments will be installed adjacent to each of the active gas collection wells or at a typical spacing of 1 per acre. An instrument settlement survey will be completed following cap construction and will be performed initially on an annual basis until the landfill has achieved a decrease in the rate of settlement to that which has negligible impact on the capping system. The frequency of the instrument settlement survey should be reviewed periodically and may be reduced or eliminated if reviewed and approved by NHDES, upon which visual observations should be made.

The settlement monitoring program ~~shall~~will include a survey of the settlement monuments, and the center lines of the drainage benches and swales located on the side slopes of the landfill at a 50-foot spacing. If settlement has occurred such that surface drainage is impeded, then the affected areas ~~shall~~will be repaired to establish proper drainage. If differential settlement is detected such that affected areas must be mitigated, then excavations will be completed to expose the liner to allow for inspection. Appropriate repairs, if necessary, will be made. ~~Any s~~Significant remedial actions will be performed in conjunction with the notification and design review by the NHDES. A letter report summarizing the results of the settlement monitoring ~~shall~~will be provided to the NHDES each year after completion of the survey.

5.9 Access Control

Access to the ~~site~~ Landfill is currently restricted by the ~~landfill~~ entrance gate and a perimeter fence~~ surrounding the site~~. After closure, the ~~site~~ landfill may continue to serve as a transfer station/recycling facility, where vehicle access would be maintained through the existing gate and scale house. Security fence will be constructed as necessary to limit access to the ~~l~~Landfill.

6.0 POST-CLOSURE REQUIREMENTS

The post-closure period for the ~~l~~Landfill is proposed to be 30 years from the date the complete capping system is installed. The post-closure period ~~shall~~will be subject to periodic adjustment by implementing a permit modification in the event that monitoring data indicate that the required performance standards are unlikely to be achieved during the 30-year period or that the data indicates that the performance standards of Env-Sw 807.04 are~~have been~~ met for Phases I, II, III, and IV prior to the 30-year period:~~.~~

~~The performance standards which the closure plan shall assure shall be that the facility and site have:~~

~~1. ceased generating leachate;~~

~~2. ceased generating decomposition gases;~~

~~3. achieved maximum settlement, with the capping system intact and no expectation that the capping system will be at risk without regular maintenance;~~

~~4. no adverse impact to air, groundwater or surface water; and~~

~~5. not otherwise pose a risk to human health or the environment.~~

6.1 Record Drawings

The City ~~shall~~will file record drawings for the closed facility no later than 90 days following completion of construction of the capping system. The record drawings ~~shall~~will explicitly identify the ~~all~~ features different than the features provided in the approved plans and specifications. Written certification must also be provided that the facility, as-built, meets or exceeds ~~all~~ the applicable requirements of the permit including the approved plans and specifications.

6.2 Property Deed Notification

The City ~~shall~~will attach notification to the property deed that a landfill exists on the property and cause the notification to be recorded at the registry of deeds in Hillsborough County. Proof of notification to the property deed ~~shall~~will be provided to the NHDES with the submission of the record drawings.

The notification ~~shall~~will include the following information in accordance with Env-Sw 807.05(n:

1. A statement that a landfill exists on the property;
2. Identification of the registry of deeds, book and page numbers where the title to the property is located;
3. Identification of the property tax map and lot numbers in which the facility is located;
4. USGS coordinates for the site;
5. Description of facility, including size, type of waste received, type of liner and type of cap;
6. Description of closure implemented, and permit issued for closure by NHDES, including a statement that the permit might contain certain legal obligations regarding the site;
7. A statement that post-closure use of the property ~~shall~~will not disturb the integrity of the final cover, liners, or any other components of the containment system or the function of the monitoring system unless approved by NHDES;
8. A statement that any future change in the use ~~shall~~will be subject to review and approval by NHDES pursuant to a permit modification; and
9. A statement that access ~~shall~~will be assured to department inspection personnel and the permittee for monitoring/maintenance purposes.

6.3 General Maintenance

The primary maintenance function for the closed site will be annual mowing of the landfill. This mowing is necessary to prevent growth of shrubs, trees, or other deep-~~–~~rooted vegetation. Annual mowing of the cap is a critical maintenance responsibility.

The facility leachate collection systems ~~shall~~will be inspected and maintained until generation of leachate has ceased.

During facility inspections, the drainage swales inside and outside the landfill footprint ~~shall~~will be inspected and cleaned as necessary. Failure of vegetative cover, differential settlement, or erosion problems on the landfill surface ~~shall~~will be identified and repaired.

6.4 Facility Inspections

~~All f~~Facility systems ~~shall~~will be ~~thoroughly~~ inspected in a manner that is initially the same as required in the Operating Plan. The City may request a decrease in the frequency of inspections based on favorable comparison of the performance expectations and actual performance, but in no case ~~shall~~will the inspections occur less than semi-annually. Facility inspections ~~shall~~will include, but may not be limited to, ~~all facility components, including~~ the following components, and ~~. These shall~~will be monitored monthly initially. After the first year of post closure monitoring, ~~T~~the City anticipates requesting a reduction of the ~~site~~ inspections to semi-annually.

1. roads;
2. berms;
3. pipes;
4. vaults;
5. valves;
6. tanks;
7. drainage benches and swales;
8. landfill surface;
9. sedimentation ponds;
10. equipment;
11. groundwater monitoring wells; and
12. gas management devices.

~~Any r~~Repairs, cleaning, or remedial activities to facility components ~~shall~~will be implemented as necessary to assure compliance with the above performance standards.

6.4.1 Inspection Reports

Inspection reports ~~shall~~will be submitted in duplicate to the NHDES within 30 days of completing the inspection. Each copy of the inspection report ~~shall~~will be signed by the person duly authorized to sign for the City.

6.5 Monitoring Requirements

Monitoring of the leachate management system, landfill gas collection and control, and the surrounding groundwater and surface water quality must continue to be monitored after closure. In accordance with State and Federal rules the following monitoring is required.

6.5.1 LeachateManagement System

After closure, the leachate management system will be monitored until leachate generation has ceased. At that time, the City may request a decrease in the frequency of monitoring to semi-annually for the duration of the post-closure monitoring period. The following ~~shall~~will be initially monitored and recorded at the frequency indicated:

1. Hydraulic head at the low points in each Phase:
    a. Monthly.
    b. If the hydraulic head is found to be 12 inches or greater, then monitor daily until the hydraulic head is less than 12 inches.
2. Quantity of leachate collected and discharged to wastewater treatment facility, ~~shall~~will be measured daily.
3. Flow in the secondary collection system:
    a. Weekly.
    b. More frequently as required to understand why the 30-day average exceeds 25 gallons per tributary acre per day.

    Average flow occurring during the 30-day operating period preceding the last measurement ~~shall~~will be calculated and reported as follows:
        1) Rates less than or equal to 25 gallons per tributary acre per day ~~shall~~will be reported to NHDES no less than quarterly;
        2) Rates that exceed 25 gallons per tributary acre per day ~~shall~~will be reported to NHDES within one week of identification of the rate; and
        3) Rates that exceed 100 gallons per tributary acre per day ~~shall~~will require the permittee to file an investigation report with the NHDES for the purpose of identifying the potential cause and appropriate response actions to be taken, which ~~shall~~will be reported to the NHDES in writing in the form of a proposed response action plan.

The City will implement the approved response action plan to include the following actions as deemed necessary on the basis of the likely cause and remedy of the problem:
    1) Increasing monitoring and reporting;
    2) Instituting operational changes to limit head on the liner;
    3) Locating and repairing leak(s);
    4) Retrofitting the overlying liner; and/or

5) Closing part or all of the facility, if necessary, to protect human health and environment.

4. Quality of primary leachate will be evaluated by collecting representative samples taken in April, July, and November and analyzed for the following parameters:
    a. pH;
    b. temperature;
    c. Chemical oxygen demand (COD;
    d. Specific conductance;
    e. Iron;
    f. Manganese;
    g. Sulfates;
    h. Chlorides;
    i. Chromium;
    j. Lead;
    k. Cadmium; and
    l. Volatile organic compounds (VOCs;

    The results of the tri-annual monitoring ~~shall~~will be submitted in duplicate to the NHDES within 30 days of receiving the results

6.5.2 Landfill GasMonitoring

Landfill gas monitoring wells will be installed around the perimeter of the landfill at locations approved by the NHDES during construction of the Phase II expansion. Landfill gas monitoring will be ~~conducted~~ performed quarterly at each of the gas monitoring wells, in the ambient air at the property line, and inside the compactor building adjacent to the landfill. The Operating Plan ~~has~~ incorporated the landfill gas monitoring of the lined and unlined landfill into a single site monitoring program.

Gas monitoring will be conducted with a combustible gas indicator, with the capability to detect the percent of the lower explosive limit (LEL or the actual concentrations of methane and other combustible gases. Representative samples taken from the gas monitoring wells ~~shall~~will require that the volume of the gas well be evacuated prior to measurement of the equilibrated concentration.

Representative sampling within structure ~~shall~~will be ~~conducted~~ performed with ~~all~~ the doors, windows, and other ventilation locations having been closed for at least an hour.

The concentration of methane and other explosive gases ~~shall~~will not exceed 25~~%~~percent LEL in structures on or off ~~-~~site, excluding leachate collection and gas control and recovery components, exceed 50~~%~~percent LEL at and beyond the property boundary in the soil, or 10~~%~~percent LEL in the ambient air (breathing zone at the property boundary.

If the above levels of gas are exceeded, then the City ~~shall~~will notify the NHDES immediately and implement the contingency procedures outlined in the Operating Plan to ensure the protection of public health and safety. The contingency procedures include, subsequent monitoring, submittal of a remedial action plan to the NHDES and submitting an air emissions monitoring plan to the Air Resources Division in accordance with the NHDES Landfill Gas Policy.

6.5.3 *Groundwater and Surface Water Monitoring*

Monitoring in accordance with the Groundwater Management and Release Detection Permit ~~shall~~will continue following closure.

The monitoring program currently requires bi-annual monitoring of indicator compounds as well as heavy metals and VOCs less frequently at locations which will adequately detect a leak in the secondary liner. A review of the appropriateness of the monitoring program ~~shall~~will be completed annually for the first five years after closure, and recommendations made to the NHDES regarding suggested reduction, expansion, or consistency in the program. After five years, the review period may be modified. Reporting requirements are established in the permit by NHDES in accordance with RSA 485-A.

6.5.4 *Landfill Settlement Monitoring*

Annually for the first five year after closure, the elevations of the settlement plates, and the center lines of intermediate benches and perimeter drainage swales, ~~shall~~will be surveyed and compared to existing data. The frequency and type of settlement monitoring should be reviewed after five (5) years or periodically and may be modified if reviewed and approved by the NHDES. A letter report ~~shall~~will be provided to the NHDES~~,~~ that ~~which~~ summarizes the settlement monitoring results and evaluates the effect, if any, that settlement has on the performance of the capping and stormwater management system.

6.6 Annual Report

An annual report will be prepared following closure to summarize facility inspections, evaluate all post-closure monitoring data, and to identify any concerns with achieving post-closure performance requirements. The report ~~shall~~will be submitted to the NHDES in duplicate no later than March 31st of each year after closure. Each copy of the annual report ~~shall~~will be signed by the person duly authorized to sign for the City.

The report ~~shall~~will be completed on the NHDES provided forms and contain the following information:

1. Facility name, location by street and municipality, and permit number;
2. Name and address of the permittee;
3. Name, address, certificate number and telephone number of all facility operators, if applicable
4. Name, address, affiliation and telephone number of the person or persons responsible for managing all post-closure activities at the facility;
5. Facility status, including, as applicable:
    a. Date the facility discontinued receipt of waste;

b. Anticipated or scheduled date for completing all required post-closure monitoring and maintenance activities.

6. A summary and assessment of all monitoring performed at or for the facility, whether required by the solid waste rules or the permit or undertaken voluntarily, specifically including as applicable:
    a. A summary of the facility inspection and maintenance activities;
    b. Summary of leachate management system monitoring
        1) head;
        2) primary and secondary flow;
        3) primary leachate quality; and
        4) level in storage tanks
    c. Summary of landfill gas monitoring
    d. Information concerning emergency events or other unexpected or unusual events at the facility relevant to assessing whether the facility is achieving post-closure performance expectations; and
    e. A statement by a qualified professional engineer identifying whether the facility is achieving post-closure performance expectations and whether adjustments to the approved post-closure monitoring and maintenance period and/or provisions are recommended in light of the performance evaluation.

    If monitoring information was already reported in writing to the NHDES during the calendar reporting year, then it need not be submitted in the annual report if a written statement is provided which identifies:
    a. nature of information already submitted;
    b. date the information was submitted;
    c. title of document containing information; if applicable; and
    d. name of person who submitted information

    If monitoring information is unchanged from the previous calendar year reporting year, then the City may mark the item "unchanged from last annual report" and cite the date of the last annual report which contained the information.

6.7 Damage or Sub-Standard Performance

If damage, malfunction or sub-standard performance occurs at the facility, the the City ~~shall~~will notify the NHDES within 30 days of identification. The notification ~~shall~~will include the following

1. Facility name, location by street and municipality, and permit number
2. A description of the problem;
3. A site plan showing the location of the problem;
4. Proposed corrective actions;
5. Date corrective actions will commence or anticipated duration of sub-standard performance.

7.0 RECORD KEEPING AND RECORDING

Following facility closure the City ~~shall~~will maintain all facility operating records and monitoring reports at the Department of Public Works. The following information ~~shall~~will be recorded and maintained following closure.

7.1 Inspection Reports

The inspection reports will be submitted to the NHDES on an annual basis. The facility components identified in Section 6.4 ~~shall~~will be inspected and maintained by the City.

7.2 Leachate Management System

The City ~~shall~~will maintain the records relating to head monitoring, leachate collection, secondary flow rates, primary leachate quality, and liquid levels in storage tanks. The monitoring frequency of each of the leachate system components is specified in Section 6.5.1. The quarterly reports on secondary leachate flow ~~shall~~will ~~also~~ be maintained.

7.3 Landfill Gas Monitoring

The results and letter reports of the quarterly landfill gas compliance monitoring ~~shall~~will be maintained by the City. The written plan for confined space entry, based on the Federal Occupational Health and Safety (OSHA) requirements ~~shall~~will be kept with the operating record. The contingency plan for landfill gas concentrations detected above the limits described in Section 6.5.2 will be~~should~~ ~~also~~ be maintained.

7.4 Groundwater and Surface Water Monitoring

The annual water quality reports for the site during operations ~~shall~~will be maintained by the city after closure. Groundwater and surface water monitoring will continue through the post-closure monitoring period, and these annual summary reports ~~shall~~will ~~also~~ be maintained.

7.5 Landfill Settlement Monitoring

The landfill settlement monitoring~~ as~~ described in Section 6.5.4 will be summarized and reported to the NHDES in~~generate~~ an annual letter report ~~and~~ along with the survey data, both of which ~~shall~~will be maintained by the City.

7.6 Annual Reports

Copies of the annual reports compiled during operation ~~shall~~will be maintained by the City. An annual report ~~which~~ that summarizes monitoring and evaluates whether the facility is meeting post-closure performance expectations ~~shall~~will be ~~conducted~~ performed each year of the post-closure monitoring program as described in Section 6.6. The post-closure annual reports ~~shall~~will ~~also~~ be maintained by the City.

8.0 OTHER PERMITS AND APPROVALS

In order to implement facility closure, the City will need to obtain ~~an AoT~~ and receive construction approval from NHDES. An evaluation of the existing groundwater management and release detection permit also will ~~also~~ need to be made at facility closure.

~~The facility permit application includes stormwater management calculations for the closed conditions of the landfill. Appropriate stormwater management controls will be identified to conform to the requirements in the solid waste rules. The AoT Permit application will need to verify that the proposed and existing stormwater management system is applicable, as well as provide a more detailed evaluation of specific components incorporated into the closure~~.

9.0 CLOSURE COST ESTIMATE

Closure of the Phases I, II, ~~and~~ III, and IV is proposed to be performed progressively as the landfill is developed. An opinion of the costs to close Phase I, II, ~~and~~ III, and IV are summarized below and represents the complete closure of the landfill. Note that actual costs will be established based on final design requirements at the time of closure, bidding, and performance of the selected contractor. A summary breakdown of the preliminary estimates is ~~as follows~~provided below.~~:~~ A detailed opinion of landfill closure costs is provided as Appendix A.

I	**Design of Final Closure Plans**	$~~165,000,000~~332,000.00
II	**Mobilization, Demobilization & Insurance**	$~~200,000.00~~367,000.00
III	**Erosion Control**	$~~2,000.00~~5,400.00
IV	**Waste Relocation**	$~~36,000.00~~48,000.00
V	**Capping**	
A	Cap (Material and Installation)	$~~1,880,716.74~~3,074,116.86
B	Gas Vents Devices	$~~128,250.00~~264,000.00
C	Layers	~~$4,074,076.72~~6,682,346.04
VI	**Stabilization, Run-off Control**	$~~700,393.25~~1,092,466.20
VII	**Monitoring Devices**	$0.00
VIII	**Roadway**	$~~120,482.00~~342,400.00
IX	**Miscellaneous**	$~~25,000.00~~41,700.00
X	**Surveying**	$0.00
XI	**Construction Phase Testing**	~~$321,600.00~~275,000.00
XII	**Engineering**	$~~320,000.00~~370,000.00
XIII	**Other (list)**	$0.00
XIV	**Contingency (minimum 10percent)**	$~~797,351.87~~1,289,442.91
	Total	$~~8,771,000.00~~14,184,000.00

~~A detailed and certified landfill closure cost estimate is attached.~~

The cost for the annual post-closure monitoring is estimated at $~~92,767~~116,483 (for year 1-10) and $~~91,887~~115,603 (for year 11-30). A summary breakdown of the preliminary estimate is ~~as follows~~provided below. A detailed opinion of the post-closure monitoring cost estimate is provided as Appendix B.

Item		**Annual Cost Year 1-10**	**Annual Cost Year 11-30**
I	Water Monitoring	$32,419 ~~$31,439~~	$32,419 ~~$31,439~~
II	Gas Monitoring	$2,500 ~~$2,500~~	$2,500 ~~$2,500~~
III	Settlement Monitoring	$5,700 ~~$3,500~~	$5,700 ~~$3,500~~
IV	Leachate Collection/Monitoring	$19,990 ~~$11,170~~	$19,990 ~~$11,170~~
V	Clean Air Act Requirements	$4,305 ~~$2,625~~	$4,305 ~~$2,625~~
VI	Repair and Site Maintenance Costs	$34,180 ~~$26,300~~	$33,380 ~~$25,500~~
VII	Inspections	$4,800 ~~$4,800~~	$4,800 ~~$4,800~~
VIII	Other	$2,000 ~~$2,000~~	$2,000 ~~$2,000~~
IX	Contingency (10~~%~~percent)	$10,589 ~~$8,433~~	$10,509 ~~$8,353~~
	TOTAL	$116,483 ~~$92,767~~	$115,603 ~~$91,887~~

~~A detailed and certified post-closure monitoring cost estimate is attached.~~

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APPENDIX F

FINANCIAL ASSURANCE PLAN

SANBORN HEAD
Building Trust. Engineering Success.

FINANCIAL ASSURANCE UPDATE

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Nashua
NEW HAMPSHIRE'S GATE CITY

Prepared for the City of Nashua
File No. 3066.11
July 2020

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Table 2 Sinking Fund for Combined Closure & Post Costs (30 Years) Fund

APPENDICES

Appendix A Cost Estimate Form for Closure of a Lined Landfill
Appendix B Cost Estimate Form for Post Closure of a Landfill
Appendix C Post Closure Costs Supporting Documentation

1.0 INTRODUCTION

Sanborn, Head & Associates, Inc. (Sanborn Head) prepared this financial assurance update for the closure and post-closure monitoring and maintenance of the Phases I – IV Landfill (Landfill) at the Four Hills Landfill (Facility) in Nashua, New Hampshire. The update was prepared as part of the Type I-A Permit Modification Application for the Phase IV expansion in accordance with Env-SW 1403.02 of the New Hampshire Department of Environmental Services (NHDES) Solid Waste Rules.

2.0 BACKGROUND

The City of Nashua owns and operates the Facility for the express purpose of providing municipal solid waste services to the residents and business of Nashua. The City's currently waste disposal operations are within Phases I, II, and III. Waste disposal in Phase IV is not anticipated begin until around 2030 and the anticipated operating life is estimated to be about 30 years. Closure construction is anticipated to occur over multiple years as described in the Landfill's Closure Plan and is not anticipated to begin until after Phase IV becomes operational.

Sanborn Head understands that the City of Nashua (the City) maintains a capital reserve fund for expenses associated with Closure and Post-Closure for the Landfill. The current account balance of the capital reserve fund is $6,391,294.00 (as of the end of 2019). The City makes annual contributions to the capital reserve fund, the last of which was made in 2019 (FY 2020) in the amount of $355,000. The contribution was in accordance with the previously prepared financial assurance plan update. The City will continue to make annual contributions to the capital reserve fund for each year the Landfill accepts waste.

3.0 CLOSURE COSTS

The closure cost estimate forms in Appendix A were prepared using available applicable cost estimating data, including New Hampshire Department of Transportation Weighted Average Unit Prices, R.S. Means construction cost data, manufacturer quotations, and reflect Sanborn Head's opinion of costs. Please note that in developing the opinion of costs, assumptions were made as to the means, methods, and extent of labor, equipment, and materials that a contractor might employ to perform the work. Actual costs may vary from our estimate due to variations in contractor techniques for determining prices, market conditions at the time the work is performed, and other factors over which we have limited or no control.

Amendments to the financial assurance rules (Env-Sw 1400) became effective on July 1, 2014 and were incorporated in the calculations. These amendments required the inclusion of additional closure costs for replacing 20 percent of the existing active gas collection system and for having a qualified professional oversee all closure activities (Env-Sw 1403.02 [g][3] and [7]).

The Closure Cost Estimate is summarized on the enclosed NHDES Cost Estimate Form for Closure of a Lined Landfill and presents our opinion of the closure costs in year 2020 dollars. As indicated, the estimated cost to close the Facility, including a 10 percent contingency is about $14,184,000. This is an increase of approximately $5,476,000 from the 2020 financial assurance update. The increase in closure costs is attributed to the inclusion of Phase IV.

4.0 POST-CLOSURE COSTS

The NHDES Cost Estimate Form for Post-Closure of a Landfill provided as Appendix B presents expected post-closure costs in 2020 dollars. The costs presented were developed based on Sanborn Head's experience in conjunction with unit cost data provided by the City and represent Sanborn Head's opinion of the post-closure costs associated with the identified items. According to our calculations, the annual post-closure cost is expected to be about $116,483. Extending these costs over a 30-year post-closure period and accounting for cost reductions and increases over time, the total post-closure cost, in 2020 dollars, is expected to be about $3,477,000.

Expected post-closure cost reductions and increases are presented in Table 1. To be conservative, we assumed most of the items will remain constant over the 30-year period; however, the cost for repairs and site maintenance will be lower over time, consistent with the reduced burden on the gas collection and control (GCCS) system. We understand that the GCCS infrastructure inside and outside of the landfill up to the landfill gas-to-energy (LFGTE) facility will be maintained and operated by the City; however, the LFGTE facility and utility flare will be maintained and operated by a third party under contract to the City. Furthermore, we understand that the expansion of the GCCS infrastructure will be made throughout the active life of the landfill and that no additional GCCS infrastructure will be required at closure. As noted above, an allowance was included in the closure cost to replace 20 percent of the well field at that time.

A sinking fund calculation was prepared and is presented as Table 2. The sinking fund calculation is combined for both closure and post-closure needs and assumes an investment interest rate of 1.23 percent[1] and an annual inflation rate of 1.55 percent, which is based on the average inflation rate over the previous 5 years. Our calculations indicate that the City has set aside sufficient funds and is on track to satisfy closure and post-closure requirements for Phases I – IV, assuming an increase in annual deposits to the fund as shown in Table 2.

5.0 CLOSING

Considering the NHDES's April 10, 2020 approval of the previous Financial Assurance Plan, this update includes the capping of Phases I through IV. This area was added to the cost estimate forms and we understand that the City affirms that they will adjust deposits into their capital reserve fun based on this change, as indicated in the attached Table 2.

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[1] Conservative rate based on financial information provided to Sanborn Head by the City.

NHDES COST ESTIMATE FORMS

Cost Estimate Form for Closure of a Lined Landfill

Facility Name: City of Nashua Four Hills Landfill Expansion - Phases I - IV

Address of Facility: 840 West Hollis Street, Nashua, New Hampshire 03061

Owner: City of Nashua, New Hampshire

Phase: Phase I - IV

Acreage: 54.7 acres (planimetric), 57.4 acres (3-dimensional)

DES Permit #: DES-SW-SP-95-002

Site # (DES Use Only) **Facility #** (DES Use Only)

LOG#
(DES use only)

State of New Hampshire
Department of Environmental Services
Waste Management Division
29 Hazen Drive, PO Box 95, Concord, NH 03302-0095
PHONE (603) 271-2925 FAX (603) 271-2456
EMAIL solidwasteinfo@des.nh.gov
TDD Access: Relay NH 1-800-735-2964

Complete this form in accordance with the NH Solid Waste Rules Part Env-Sw 1400.

Task	DES Use Only	Unit	Unit Cost	Quantity	Total Cost
I Design of Final Closure Plans	**Cat1**				
Engineering Cost	100	*LS*	$317,000.00	1	$317,000.00
Plans	110	*LS*			$0.00
Modification/Closure Plan Review Fees	120	*LS*	$15,000.00	1	$15,000.00
II Mobilization, Demobilization & Insurance	**Cat 2**				
Total Cost	200	*LS*	$367,000.00	1	$367,000.00
Other	210				$0.00
III Erosion Control	**Cat 3**				
Silt Fence	300	*LF*			$0.00
Erosion Matting/ Blanket	310				$0.00
Hay Bale Sediment Barrier	320	*LF*	$5,400.00	1	$5,400.00
Hay Mulch Cover	330				$0.00
Check Dams	340	*EA*			$0.00
Other	350				$0.00
IV Waste Relocation	**Cat 4**				
Test Pits (to define limits of refuse and/or ground water to refuse contact)	400	*DAY*			$0.00
Clearing & Grubbing	410	*SY*			$0.00
Waste Regrading (Refuse Excavation/Relocation & Compaction)	420	*CY*			$0.00
Other (Misc. Grading)	430	*LS*	$48,000.00	1	$48,000.00
V Capping	**Cat 5**				
A Cap (Material and Installation)	500				$0.00
Geomembrane	510	*SF*	$0.48	2,499,282	$1,199,655.36
Soil	520	*CY*			$0.00
Testing	530				$0.00
Anchor Trench	540				$0.00
Other - Drainage Net Composite	550	*SF*	$0.75	2,499,282	$1,874,461.50
B Gas Vents Devices	**Cat 6**				$0.00
Gas Vents/Wells	600	*EA*			$0.00
Other - Replacing 20% of the Active Gas Collection System (Vertical Wells)	610	*LF*	$150.00	1760	$264,000.00
C Layers	**Cat 7**				$0.00
Drainage Layer - Free Draining Sand - 18" thick	700	*CY*	$29.36	46,283	$1,358,868.88
Intermediate Cover Placement	710	*CY*	$13.00	23,142	$300,846.00
Sand - Protective Gas Venting Layer - 12" thick	720	*CY*	$29.36	92,566	$2,717,737.76
Topsoil/Loam or Manufactured Soil	730	*CY*	$24.90	46,283	$1,152,446.70
Other - Moisture Retention Layer - 6" thick	740	*CY*	$24.90	46,283	$1,152,446.70
VI Stabilization, Run-off Control	**Cat 8**				
Seed & Mulch (Include Lime, Fertilizer, Seed & Hay Mulch)	800	*AC*	$3,200.00	57.4	$183,680.00
Surface Water Diversion Swales	810	*LF*	$24.35	14,792	$360,185.20
Stone Rip-Rap	820	*CY*			$0.00
Catch Basins, Manholes & Drop Inlets	830				$0.00
Toe Drain	840	*LF*	$28.50	6,946	$197,961.00
Detention Pond and Associated Outlet Devices	850				$0.00
Other - Downchute	860	*LF*	$240.00	1461	$350,640.00
VII Monitoring Devices	**Cat 9**				
Settlement Monuments/Plates	900	*EA*			$0.00
Groundwater Monitoring Wells	910	*EA*			$0.00
Gas Monitoring Probes	920				$0.00
Other	930				$0.00
VIII Roadway	**Cat 10**				
Access Roadway	1000	*LF*	$107.00	3,200	$342,400.00
Drainage Ditches	1010				$0.00
Culvert Inlet & Outlet Headwalls	1020				$0.00
Guide Rail	1030	*LF*			$0.00
Dust Control - Calcium Chloride	1040				$0.00
New/Replaced Pavement	1050	*SY*			$0.00
Other	1060				$0.00

Task	DES Use Only	Unit	Unit Cost	Quantity	Total Cost
IX Miscellaneous	**Cat 11**				
Signs	1100	*LS*			$0.00
Perimeter Fence	1110	*LF*			$0.00
Entry Gate - Double Unit	1120	*EA*			$0.00
Miscellaneous Work and Cleanup	1130	*LS*	$41,700.00	1	$41,700.00
Ledge Removal	1140	*CY*			$0.00
Other	1150				$0.00
X Surveying	**Cat 12**				
Baseline, Bench Marks, and Survey Control	1200				$0.00
Other	1210				$0.00
XI Construction Phase Testing	**Cat 13**				
Compaction Testing	1300				$0.00
QAQC	1310	*AC*	$10,000.00	27.5	$275,000.00
Other	1320				$0.00
XII Engineering	**Cat 14**				
Resident Engineer, Project Manager, Project Engineer	1400	*LS*	$250,000.00	1	$250,000.00
Record Drawings/ As-Built	1410	*LS*	$20,000.00	1	$20,000.00
Other	1420				$0.00
Qualified Professional Oversight of all Closure Activities	1430	*LS*	$100,000.00	1	$100,000.00
XIII Other (list)	**Cat 15**				
	1500				$0.00
	1510				$0.00
	1520				$0.00
XIV Contingency (minimum 10%)	**Cat 16**				
	1600	*LS*	**10%**		$1,289,442.91
Total Cost					$14,184,000.00

Signature of Preparer: ______________________ (Must be prepared by a Professional Engineer)

Date: 7/7/2020

STATE OF NEW HAMPSHIRE - PROFESSIONAL ENGINEER - LICENSED
EDWARD A. GALVIN
No. 15387

This form provides a basis for cost estimating closure costs for a lined landfill. This form is not inclusive of all costs that may be associated with the landfill closure. The cost estimate must include all items needed to comply with all DES permits. Please use the spaces provided above noted as "Other" or attach an additional sheet if necessary.

Date of Last Form Revision: 7/1/14

Cost Estimate Form for Post Closure of a Landfill
(lined or unlined)

Facility Name: City of Nashua Four Hills Landfill Expansion - Phases I - IV
Address of Facility: 840 West Hollis Street, Nashua, New Hampshire 03061
Owner: City of Nashua, New Hampshire
Phase: Phase I - IV
Acreage: 54.7 acres (planimetric), 57.4 acres (3-dimensional)
DES Permit #: DES-SW-SP-95-002
Site # (DES Use Only) **Facility #** (DES Use Only)

LOG#
(DES use only)

State of New Hampshire
Department of Environmental Services
Waste Management Division
29 Hazen Drive, PO Box 95, Concord, NH 03302-0095
PHONE (603) 271-2925 FAX (603) 271-2456
EMAIL solidwasteinfo@des.nh.gov
TDD Access: Relay NH 1-800-735-2964

Complete this form in accordance with the NH Solid Waste Rules Part Env-Sw 1400.

Task	Unit	Unit Cost	Quantity	Total Cost
I Water Monitoring				
Surface Water Sampling & Analysis	LS	$1,284.00	1	$1,284.00
Other (Permit Requirement) ____				$0.00
Ground Water Sampling & Analysis	LS	$26,135.00	1	$26,135.00
Other (Permit Requirement) ____				$0.00
Other (Annual Report)	LS	$5,000.00	1	$5,000.00
II Gas Monitoring				
Landfill Gas Migration Monitoring	LS	$2,500.00	1	$2,500.00
Replacing 20% of the Active Gas Collection System				$0.00
Other				$0.00
III Settlement Monitoring				
Field Survey	LS	$5,700.00	1	$5,700.00
Data Tabulation				$0.00
Other				$0.00
IV Leachate Collection/Monitoring				
Sewer Charges				$0.00
Electricity	LS	$11,500.00	1	$11,500.00
Maintenance of Collection System	LS	$4,080.00	1	$4,080.00
Sampling & Analysis	LS	$4,410.00	1	$4,410.00
Other				$0.00
V Clean Air Act Requirements				
Monitoring & Analysis	LS	$4,305.00	1	$4,305.00
Emissions Fees				$0.00
VI Repair & Site Maintenance Costs				
Snow Removal	LS	$4,260.00	1	$4,260.00
Roadway Maintenance				$0.00
Mowing	LS	$5,470.00	1	$5,470.00
Soil Cover Maintenance and Planting	LS	$3,200.00	1	$3,200.00
Maintenance of Gas System	LS	$17,110.00	1	$17,110.00
Subsidence Repair	LS	$1,140.00	1	$1,140.00
Stormwater Maintenance	LS	$3,000.00	1	$3,000.00
Other				$0.00
VII Inspections				
Annual Report	LS	$3,000.00	1	$3,000.00
Annual Site Inspections	LS	$1,800.00	1	$1,800.00
Other				$0.00
VIII Other				
Third Party Management of Post-Closure Activities	LS	$2,000.00	1	$2,000.00
				$0.00
				$0.00
IX Contingency (10 % minimum)				
	LS	10%		$10,589.40
Total Yearly Cost				$116,483.40
Total 30-Year Cost *				$3,477,000.00

Signature of Preparer: ____ (Must be prepared by a Professional Engineer)

Date: 7/7/2020

EDWARD A. GALVIN No. 15387

The cost estimate must include all expenses associated with compliance of all DES permits. Please use the spaces provided above noted as "Other" or attach additional sheet if necessary.

* The 30-year total costs (2020 dollars) assumes reductions in the repairs and maintenance costs beginning in the eleventh year following closure (see attached Table 1)

Date of Last Form Revision: 7/1/14

TABLES

TABLE 1
Post-Closure Cost Reductions
Four Hills Landfill
Nashua, New Hampshire

Item		**Annual Cost Year 1-10**	**Annual Cost Year 11-30**
I	Water Monitoring	$32,419	$32,419
II	Gas Monitoring	$2,500	$2,500
III	Settlement Monitoring	$5,700	$5,700
IV	Leachate Collection/Monitoring	$19,990	$19,990
V	Clean Air Act Requirements	$4,305	$4,305
VI	Repair and Site Maintenance Costs	$34,180	$33,380
VII	Inspections	$4,800	$4,800
VIII	Other	$2,000	$2,000
IX	Contingency (10%)	$10,589	$10,509
TOTAL		$116,483	$115,603

Notes:

1. Task designations are consistent with those identified on NHDES Cost Estimate Form For Post Closure of a Landfill.

2. Costs are 2020 dollars.

TABLE 2
Sinking Fund for Combined
Closure & Post-Closure (30-Years) Fund
Four Hills Landfill
Nashua New Hampshire

Sinking Fund for CLOSURE and POST CLOSURE of Phases I, II, III and IV
Assumes Phase III is the Last Phase Built

ASSUMPTIONS

Inflation Rate[1]	1.55%
Interest Rate Projected for 2020	1.23%

FUND REQUIREMENTS

Combined fund balance as of November 2019 for Closure & Post Closure	$6,391,294
Base Contribution (in 2020$) for 2020	$0
Base Contribution (in 2020$) annually after 2020 =	varies (see below)
Landfill Closure Cost (in 2020$)	$14,184,000

	Year	Closure/Post Closure Cost (2020 value)	Closure/ Post Closure Cost with Inflation	Deposit to Fund by City (2020 value)	Interest Accumulated by Fund	Balance of Fund (end of year)
Begin Phase I Oper.	2002					
	2003					
	2004					
	2005					
	2006					
	2007					
	2008					
	2009					
Begin Phase II Oper.	2010					
	2011					
	2012					
	2013					
	2014					
	2015					
	2016					
	2017					
	2018					
	2019					
Begin Phase III Oper.	2020					$6,391,294
	2021			$405,000	$81,104	$6,877,398
	2022			$430,000	$87,236	$7,394,634
	2023			$435,000	$93,629	$7,923,263
End Phase II Oper.	2024			$435,000	$100,131	$8,458,395
	2025			$435,000	$106,714	$9,000,108
	2026			$435,000	$113,377	$9,548,485
	2027			$435,000	$120,122	$10,103,606
	2028			$435,000	$126,950	$10,665,556
	2029			$435,000	$133,862	$11,234,418
Begin Phase IV Oper.	2030			$435,000	$140,859	$11,810,276
	2031			$435,000	$147,942	$12,393,218
	2032			$435,000	$155,112	$12,983,330
	2033			$435,000	$162,370	$13,580,700
End Phase III Oper.	2034			$435,000	$169,718	$14,185,418
	2035			$435,000	$177,156	$14,797,574
	2036			$435,000	$184,685	$15,417,259
	2037			$435,000	$192,308	$16,044,567
	2038			$435,000	$200,023	$16,679,590
	2039			$435,000	$207,834	$17,322,424
	2040			$435,000	$215,741	$17,973,165
	2041			$435,000	$223,745	$18,631,911
	2042			$435,000	$231,848	$19,298,758
	2043			$435,000	$240,050	$19,973,808
	2044			$435,000	$248,353	$20,657,161
	2045			$435,000	$256,758	$21,348,920
	2046			$435,000	$265,267	$22,049,187
	2047			$435,000	$273,880	$22,758,067
	2048			$435,000	$282,599	$23,475,666
	2049			$440,000	$291,457	$24,207,123
	2050			$440,000	$300,454	$24,947,577
	2051			$440,000	$309,561	$25,697,138
	2052			$440,000	$318,781	$26,455,919
	2053			$440,000	$328,114	$27,224,032
	2054			$440,000	$337,562	$28,001,594
	2055			$440,000	$347,126	$28,788,720
	2056			$440,000	$356,807	$29,585,527
	2057			$440,000	$366,608	$30,392,135
	2058			$440,000	$376,529	$31,208,664
	2059			$440,000	$386,573	$32,035,237
Close Phases I-IV	2060			$440,000	$396,739	$32,871,976
Start Post Closure - Yr 1	2061	$14,184,000	$26,648,684		$404,325	$6,627,618
Post Closure - Yr 2	2062	$116,483	$222,239		$81,520	$6,486,898
Post Closure - Yr 3	2063	$116,483	$225,684		$79,789	$6,341,003
Post Closure - Yr 4	2064	$116,483	$229,182		$77,994	$6,189,815
Post Closure - Yr 5	2065	$116,483	$232,735		$76,135	$6,033,215
Post Closure - Yr 6	2066	$116,483	$236,342		$74,209	$5,871,082
Post Closure - Yr 7	2067	$116,483	$240,005		$72,214	$5,703,291
Post Closure - Yr 8	2068	$116,483	$243,725		$70,150	$5,529,716
Post Closure - Yr 9	2069	$116,483	$247,503		$68,016	$5,350,229
Post Closure - Yr 10	2070	$116,483	$251,339		$65,808	$5,164,697
Post Closure - Yr 11	2071	$116,483	$255,235		$63,526	$4,972,988
Post Closure - Yr 12	2072	$115,603	$257,233		$61,168	$4,776,923
Post Closure - Yr 13	2073	$115,603	$261,220		$58,756	$4,574,459
Post Closure - Yr 14	2074	$115,603	$265,269		$56,266	$4,365,455
Post Closure - Yr 15	2075	$115,603	$269,381		$53,695	$4,149,770
Post Closure - Yr 16	2076	$115,603	$273,556		$51,042	$3,927,256
Post Closure - Yr 17	2077	$115,603	$277,796		$48,305	$3,697,765
Post Closure - Yr 18	2078	$115,603	$282,102		$45,483	$3,461,145
Post Closure - Yr 19	2079	$115,603	$286,475		$42,572	$3,217,242
Post Closure - Yr 20	2080	$115,603	$290,915		$39,572	$2,965,899
Post Closure - Yr 21	2081	$115,603	$295,424		$36,481	$2,706,955
Post Closure - Yr 22	2082	$115,603	$300,003		$33,296	$2,440,248
Post Closure - Yr 23	2083	$115,603	$304,653		$30,015	$2,165,609
Post Closure - Yr 24	2084	$115,603	$309,376		$26,637	$1,882,871
Post Closure - Yr 25	2085	$115,603	$314,171		$23,159	$1,591,859
Post Closure - Yr 26	2086	$115,603	$319,041		$19,580	$1,292,399
Post Closure - Yr 27	2087	$115,603	$323,986		$15,897	$984,309
Post Closure - Yr 28	2088	$115,603	$329,007		$12,107	$667,409
Post Closure - Yr 29	2089	$115,603	$334,107		$8,209	$341,511
Post Closure - Yr 30	2090	$115,603	$339,286		$4,201	$6,426

Notes:
1. Inflation rate based on the average of the last 10 years of historical annual U.S. inflation rate data.

POST CLOSURE COSTS SUPPORTING DOCUMENTATION

SANBORN HEAD

File No. 3066.11 Page 1 of 4
Project Four Hills Landfill, Phases I – IV
Location Nashua, New Hampshire
Subject Post-Closure Costs Supporting Documentation
Calculated By S. Santiago Date 6/24/2020
Checked By E. Galvin Date 7/7/2020
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The following assumptions were made in developing the post-closure cost estimate summarized in the New Hampshire Department of Environmental Services (NHDES) Post Closure Form and Table 1. The tasks identified on Table 1, and discussed below, are consistent with the tasks presented on the NHDES forms. Table 1 is provided, as the NHDES Post Closure form does not allow for consideration of reduced costs that are likely to occur over time.

Task I Water Monitoring

Years 1 Through 30

- The current program of annual water quality monitoring involves biannual sampling of:
    - 19 release detection wells associated with Phases I-IV of the landfill at an annual cost of $16,000;
    - 15 groundwater management wells sampled biannually at an annual cost of $10,135; and
    - 2 surface water sampling points sampled biannually at an annual cost of $1,284.
- Assume the current program of annual and semiannual water quality monitoring continues at an annual cost of $27,419 per year (price information provided by the City of Nashua).
- Assume annual report is prepared at a cost of $5,000.
- With these assumptions, the annual cost for years 1 through 30 is estimated to be $32,419.

Task II Gas Monitoring

- Assume an annual cost of $2,500 for the quarterly monitoring of landfill gas will continue throughout the post-closure monitoring period (inflated based on Eastern Analytical, Inc. quote dated 1/20/15 and information provided by the City of Nashua). NHDES may permit some reductions to the frequency and locations after several years; however, such reductions should not be relied upon.

Task III Settlement Monitoring

Years 1 through 30

- Assume an annual cost of $5,700 for settlement survey based upon information provided by the City of Nashua.

Task IV Leachate Collection/Monitoring

- Currently, the City of Nashua does not pay leachate disposal costs because leachate is discharged directly to the City of Nashua sewer system. Assume this agreement continues through the post-closure time period.
- Maintenance of the collection system is assumed to be an annual lump sum amount of $4,080 (Assume bi-yearly manhole cleaning at $1,800 and leachate pipe cleaning every 5 years at

$4,500, and $2,280 each year for routine maintenance of the Phase III and IV leachate pumps; therefore, a total yearly costs of $4,080).

- The current program of tri-annual sampling of the primary and secondary leachate has an annual total cost of $4,410. Assume this program continues at this same cost.
- Assume the annual electrical costs for the secondary leachate pump (0.4 hp submersible pump) used to transfer secondary leachate into the primary leachate discharge pipe, and electricity use by the flow control building (including heat) is $1,900.
- Assume the annual electrical costs for the Phase III sump riser building pumping system is $9,600 (based actual costs of an equivalent NH landfill pumping system).
- With these assumptions, the annual cost for years 1 through 30 is estimated to be $19,990.

Task V Clean Air Act Requirements

- Currently, the City of Nashua completes air monitoring (surface emissions monitoring) and reporting utilizing landfill employees. Assume it takes a field technician/engineer 41 hours each year to complete these tasks.
- Assume this program continues with the same scope and an hourly rate of $105 for an outside company to complete the monitoring/reporting.
- With these assumptions, the annual costs for years 1 through 30 is estimated to be $4,305.00

Task VI Repair and Site Maintenance Costs

Assume limited maintenance will be required to include; mowing the cap, snow removal, and repairs to soil cover and stormwater features. We understand that the City will maintain the GCCS infrastructure and utility flare.

Years 1 through 10

- Snow removal is assumed to be an annual lump sum amount of $4,260 (assumes plowing 3 times a year at $1,420/plowing).
- Mowing assumed to be $100/acre annually, the site is 54.7 acres, annual mowing cost is $5,470.
- Soil Cover Maintenance and Planting is assumed to be an annual lump sum amount of $3,200 (assumes Seeding & Mulching 1 Acre/year @ $3,200/acre).
- Maintenance/Operation of GCCS Infrastructure:
  - Routine maintenance of control system, monthly monitoring of collection system, and well field balancing. Assumed 15 hours per month for monthly maintenance tasks and

balancing the well field. Assuming an hourly rate of $60/hour, the annual cost is approximately $10,800 per year.

- ◻ Assume $1,600/year for minor repairs to wellheads that may be required.
- ◻ Assume that a condensate knockout pump will need to be replaced once every two years at a cost of $2,700 (based on a price quotation from QED on November 6, 2019). This equates to a cost of $1,350 per year.
- ◻ Semi-annual maintenance of blower bearings, testing automated devices, gas canister maintenance/refill, and coordinating any unscheduled maintenance. Assumed 4 hours at $60/hour labor per event or $240 per year.
- ◻ Replacement of blower/flare/control parts. Assumed 8 hours labor at $60/hour and $1,200 parts or total of $1,680 per year.
- ◻ Unscheduled responses to alarm conditions, expected to occur 4 times per year. Assumed 6 hours labor at $60/hour per event, which equates to an annual cost of $1,440.

Totaling these items, the annual cost of Maintenance/Operation of GCCS Infrastructure is $14,950.

- During the 30year post closure period, following closure of Phases I, II, and III, the City assumes a third party will continue to be responsible for operating the landfill gas-to-energy (LFGTE) facility.
- Subsidence Repair ($5,700/5 years) is assumed to be an annual lump sum amount of $1,140 (assume 1 day of bull dozer work @ $2,400/day and $3,300 of soil materials).
- Stormwater Maintenance is assumed to be an annual lump sum amount of $3,000.
- With these assumptions, the annual cost for years 1 through 10 is estimated to be $26,300.

Years 11 through 30

- Assume $800/year (reduced by about half from years 1-10) for minor repairs to wellheads that may be required.
- All other maintenance and repair costs will remain unadjusted.
- With these assumptions, the annual cost for years 11 through 30 is estimated to be $25,500.00.

Task VII Inspections

- Assume an annual facility report may be prepared at a lump sum annual cost of $3,000.
- Assume annual site inspections at a lump sum annual cost of $1,800.

- Therefore, the annual cost for years 1 through 30 for post-closure inspections and reporting is estimated to be $4,800.

Task VIII Other

- Assume $2,000 annual cost for third party management of post-closure activities.

Task IX Contingency (10 percent)

- Assume 10 percent contingency.

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APPENDIX G

PUBLIC BENEFIT DEMONSTRATION

SANBORN HEAD
Building Trust. Engineering Success.

PUBLIC BENEFIT DEMONSTRATION

PHASE IV EXPANSION

Four Hills Landfill
Nashua, New Hampshire
Solid Waste Permit No. DES-SW-SP-95-002

Nashua
NEW HAMPSHIRE'S GATE CITY

Prepared for the City of Nashua
File No. 3066.11
July 2020

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3.0 WASTE REDUCTION GOAL (RSA 149-M:2) 3

4.0 ACHIEVING GOALS, HIERARCHY (RSA 149-M:3) 3

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6.0 SUMMARY 5

1.0 INTRODUCTION

Sanborn Head prepared this public benefit demonstration as part of the application for a Type I-A Modification to Solid Waste Management Facility Permit (Type I-A PMA) for the Phase IV Secure Landfill Expansion (Phase IV expansion), a proposed double-lined disposal area at the Four Hills Landfill Facility (Facility) located in Nashua, New Hampshire. The Facility is a limited public facility, serving only the residents and businesses of the City of Nashua (City).

This document was prepared to fulfill the requirements of Env-Sw 1005.05(c), which requires that the City demonstrate that the Phase IV expansion at the Facility provides a substantial public benefit meeting the criteria listed under RSA 149-M:11 III (b) and (c), which are listed below.

> *(b) The ability of the proposed facility to assist the state in achieving the implementation of the hierarchy and goals under RSA 149-M:2 and RSA 149-M:3.*
>
> *(c) The ability of the proposed facility to assist in achieving the goals of the state solid waste management plan, and one or more solid waste management plans submitted to and approved by the department under RSA 149-M:24 and RSA 149-M:25.*

In considering the public benefit of a solid waste facility, the following items from RSA 149-M:11 V are to be considered:

> *(a) Project, as necessary, the amount of solid waste which will be generated within the borders of New Hampshire for a 20-year planning period. In making these projections the department shall assume that all unlined landfill capacity within the state is no longer available to receive solid waste.*
>
> *(b) Identify the types of solid waste which can be managed according to each of the methods listed under RSA 149-M:3 and determine which such types will be received by the proposed facility.*
>
> *(c) Identify, according to type of solid waste received, all permitted facilities operating in the state on the date a determination is made under this section.*
>
> *(d) Identify any shortfall in the capacity of existing facilities to accommodate the type of solid waste to be received at the proposed facility for 20 years from the date a determination is made under this section. If such a shortfall is identified, a capacity need for the proposed type of facility shall be deemed to exist to the extent that the proposed facility satisfies that need.*

Since 1971, the City has operated the Facility for the disposal of municipal solid waste (MSW) and construction and demolition debris (C&D). On June 26, 1995, the New Hampshire Department of Environmental Services (NHDES) issued Solid Waste Permit No. DES-SW-95-002 for the development and operation of a "Secure Landfill." At the time of the original permit, the Secure Landfill consisted of double-lined disposal areas Phases I, II, and III. MSW disposal operations began in the lined Phase I area in 2003 and in the lined Phase II area in 2009. MSW disposal operations are anticipated to begin in the lined Phase III area in 2020. Currently, the permitted disposal capacity (airspace) is anticipated to be exhausted by 2030, and, as such, the City anticipates that the Phase IV expansion will need to be operational no later than 2028.

The City of Nashua has a well-developed and managed waste management program for the residents and businesses of the City. The City promotes waste reduction, material reuse, recycling, and composting; provides for curbside recycling; and maintains a recycling center and a composting operation at the Facility. The Facility also has a landfill gas to energy facility, a residential drop-off area, and manages numerous other waste materials (e.g., recyclables, electronic waste, bulky waste, white goods, scrap metal, tires, etc.). Because not all waste materials can be reused, recycled, or composted (e.g., MSW, C&D, asbestos, contaminated soil), the City needs a secure disposal facility.

A key provision of the Solid Waste permit was that the Secure Landfill provided at least 20 years of disposal capacity and that the City expand its recycling efforts. As noted above, the Secure Landfill will provide more than 20 years of disposal capacity and the City has a robust recycling program. Considering the upcoming end of service life of the Secure Landfill, the Phase IV expansion is a benefit to the City residents and business and does not place a burden on other waste disposal locations in the State of New Hampshire. The proposed Phase IV expansion would provide the City with an estimated 30 years of new disposal capacity.

The remainder of this document provides the required demonstration of public benefit of the continued operation of double-lined disposal areas at the Facility.

2.0 WASTE GENERATION

Because the Facility is a limited public facility serving only the residents and businesses of the City, the requirements of RSA 149-M:11 III(a) and 149-M:11 V(a) do not apply. At present, the City estimates an upper end MSW generation rate of approximately 80,000 tons per year. Based on reports to the NHDES, the waste generation, which appears to be tied to economic conditions, has been relatively steady for the past few years.

As noted above, the City recycling and waste diversion initiatives reduce the volume of materials disposed of in the Secure Landfill. To the degree practical, recyclables, electronics, yard waste, tires, white goods, and other materials are diverted from the landfill and managed by appropriate and permitted means. The City intends to continue these important initiatives to extend the life expectancy of the disposal resource provided by the Secure Landfill.

In addition to the recycling and waste diversion initiatives described above, the City promotes efforts to further reduce the toxicity of the waste stream through the separate collection and recycling of mercury containing devices, rechargeable batteries, used motor oil, and used automotive anti-freeze. The City also hosts several regional household hazardous waste collection events each year in which residents have the opportunity to properly and safely dispose of unwanted flammables, corrosives, and other toxic materials.

3.0 WASTE REDUCTION GOAL (RSA 149-M:2)

The waste reduction goal of RSA 149-M:11 is a statewide goal. The City, through its well-developed and managed waste management program, actively seeks to reduce the amount of waste disposed of at the Facility. According to the values reported in the 2017, 2018, and 2019 Annual Reports, (see table below) the City's waste diversion rate is estimated to be between 20 and 30 percent. The City believes that the actual diversion rate is on the higher side of these values due to the fact that:

- The unit weight of recycles has been on a decreasing trend as manufactures are reducing the amount of materials used;
- Actions taken by businesses and residents to reduce their overall generation of waste is not measured; and
- Reuse of materials.

Year	Population[1] (estimate)	Waste Generation Projection[2] (tons)	MSW Landfilled (tons)	Materials Diverted (tons)	Percent Diversion[3, 4]
2017	89,246	94,467	67,925	14,963	28.1 / 22.0
2018	89,663	94,908	67,135	12,994	29.3 / 19.4
2019	90,080	95,350	67,669	6,317[A]	29.0 / 9.3[A]

Notes:

1. Population estimate from https://worldpopulationreview.com/us-cities/nashua-nh-population/
2. Waste generation projection calculated based on the product of the population estimate times the 5.8 pounds of waste generated per person per day (based on data from NHDES 2019 Biennial Solid Waste Report, see Footnote 1), times 365 day, divided by 2000 pounds per ton.
3. Percent diversion was calculated two ways:
   - the difference in the waste generation projection and the MSW landfilled, divided by the waste generation projection, times 100; and
   - materials diverted divided by the MSW landfilled times 100.

A – These values do not account for yard waste diversions.

4.0 ACHIEVING GOALS, HIERARCHY (RSA 149-M:3)

The City of Nashua, through its operations and activities at the Facility, assists the State towards the legislated waste reduction goal established in RSA 149-M:2. RSA 149-M:3 defines the hierarchy through which the goal is to be achieved and includes:

- Recycling and reuse;
- Composting;
- Waste-to-Energy (WTE);
- Incineration without resource recovery; and
- Landfilling.

As previously noted, the City maintains a robust recycling and composting operations and promotes material reuse. The City does not own or operate a waste-to-energy facility or other incinerator, nor is there one within the City limits. However, there is a landfill gas-to-energy operation at the Facility that is fueled by the decomposition gases extracted from the closed, unlined MSW landfill and the Secure Landfill. The landfill-gas-to energy plant has a total generating capacity of 2.4 megawatts, which is enough energy to power approximately 1500 homes.

While listed last, landfills are a necessary component in the waste management hierarchy and are required for disposal of waste that cannot be safely or economically managed in other ways. The City, through its Facility operations, takes proactive steps to preserve disposal capacity by using alternate daily cover (ADC) materials to replace virgin soil daily cover when appropriate. The City currently uses approved ADC materials from several sources and plans to continue to use ADC materials as sources become approved, and its use is effective. ADC materials included

- Natural soil;
- Street wastes (catch basin debris, roadside ditch soils, street sweepings, and asphalt grindings)
- Wood chips;
- Compost pursuant to Env-Sw 1503.10;
- Bottom ash from wood fired boilers (NHDES Certified Waste Derived Product No. 10);
- Synthetic tarps (Tarpomatic);
- C/D fines mixed with soil;
- C/D residuals mixed with soil (Certified Waste Derived Product No. 6);
- Non-hazardous, low level contaminated soil; and
- Aggregate for Construction Made with Crushed glass (Certified Waste-Derived Product No. 11).

5.0 PUBLIC NEED

Nashua is the second largest city in New Hampshire and constitutes nearly 7 percent of the state's total population. The continued MSW disposal operations at the Facility, through the development of Phase IV, will provide a much-needed service to the City, and its residents and businesses for the foreseeable future. According to the 2019 Biennial Solid Waste Report,[1] on or about 2033, there will be a precipitous drop in MSW disposal capacity in the State. The Phase IV expansion helps bridge the States disposal shortfall, at least as it concerns the City.

---

[1] NHDES (2019), Biennial Solid Waste Report, October 2019, https://www.des.nh.gov/organization/commissioner/pip/publications/documents/r-wmd-19-02.pdf

6.0 SUMMARY

The Phase IV expansion provides the City with the ability to continue to serve it residents and businesses with a safe and economical MSW disposal location, and therefore, provides a substantial public benefit. The solid waste management operations at the Facility will continue to fulfill the objectives of the State Solid Waste Management Plan.

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APPENDIX H

LEGAL NOTICES

THE CITY OF NASHUA

"The Gate City"

Division of Public Works

Solid Waste Department

Board of Aldermen
229 Main Street
Nashua, NH 03060

July 17, 2020
File No. 3066.11

Re: Four Hills Landfill
Nashua, New Hampshire
Type I-A Permit Modification
DES-SW-SP-95-002

To Whom it May Concern:

The purpose of this correspondence is to notify you that The City of Nashua (City) is filing a Type I-A permit modification application with the New Hampshire Department of Environmental Services (NHDES) on or about July 17, 2020. This application is being filed to obtain permit approval for the proposed Phase IV expansion at the Four Hills Landfill located at 840 West Hollis Street in Nashua, New Hampshire.

The facility, and the land where it is located, is owned and operated by the City's Department of Public Works. This notice is being provided in accordance with the RSA 149-M and the NHDES Solid Waste Rules.

This project is proposed to be constructed on the Four Hills Landfill property between two existing landfill units. The type of material managed, and the operation of the facility, are not proposed to change as part of this permit modification. Only waste generated within the City of Nashua is accepted at the facility including municipal solid waste, construction and demolition debris, and special non-hazardous wastes that are approved by NHDES. The project will add about 3.9 million cubic yards of capacity and extend the facility's site life by approximately 30 years.

Copies of this permit application will be available for review at the Four Hills Landfill office building, City of Nashua Town Hall, and at the NHDES office located at 29 Hazen Drive in Concord, New Hampshire. Appointments to review the application will be made with the City Solid Waste Department (603-589-3410), the City Clerk's Office (603-589-3010), or the NHDES Public Information & Permitting Office (603-271-2919) to review a hard copy of the permit application.

As part of this application, the City of Nashua is required to inform you of the basic steps that will be involved in the processing of this permit application. Upon receipt of this application, the NHDES will review its contents and determine whether it is complete and that it contains all the information required for their approval. If the application is complete, a technical review will then be made to determine whether the proposed activity meets all application requirements of the New Hampshire Solid Waste Rules. If it is decided that the application satisfies these requirements, then it will be approved, and the permit will be issued. A public hearing on this application is required

and will be scheduled upon completion of the technical review. Please refer to the enclosed application flow chart.

Included with the Type I-A permit modification is an Application for Waiver specific to Env-Sw 805.05(j).

Information regarding this application may be obtained by calling Ms. Jaime Colby, P.E., NHDES Permit Engineer, at (603) 271-5185, Jaime.Colby@des.nh.gov, or by writing to her at the following address:

NH Department of Environmental Services
Waste Management Division
PO Box 95
Concord, NH 03301

If you have any questions or comments regarding the application, please contact me at (603) 589-3410 or LafleurJ@nashuanh.gov. You may also contact Ms. Jamie Colby, P.E. at the NHDES, 29 Hazen Drive, Concord, New Hampshire 03301.

Very truly yours,
The City of Nashua

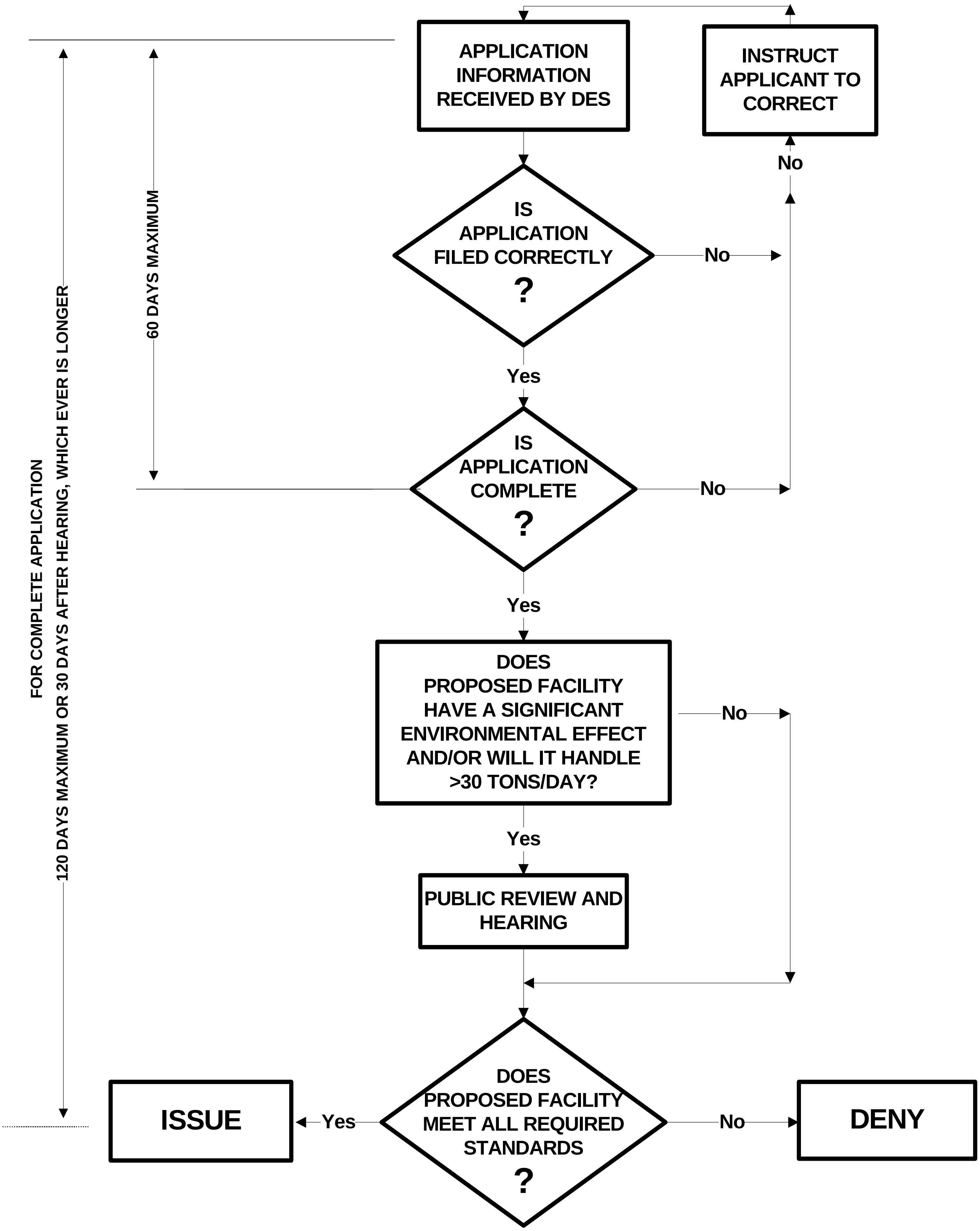
Jeffrey Lafleur
Superintendent of Solid Waste

Copies to: Jaime Colby – NHDES
Lisa Fauteux – City of Nashua
Kerry Converse – City of Nashua
Eddie Galvin – Sanborn, Head & Associates, Inc.

Enclosure: Permit Application Flow Chart
Type I-A Permit Application for Solid Waste Management Facility

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

STANDARD PERMIT APPLICATION PROCESSING PROVISIONS AS PROVIDED IN PARTS Env-Sw 303 - 305 OF THE *NEW HAMPSHIRE SOLID WASTE RULES*



THE CITY OF NASHUA
"The Gate City"
Division of Public Works
Solid Waste Department

City Clerk's Office
229 Main Street
Nashua, NH 03060

July 17, 2020
File No. 3066.11

Re: Four Hills Landfill
Nashua, New Hampshire
Type I-A Permit Modification
DES-SW-SP-95-002

To Susan Lovering:

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and will be scheduled upon completion of the technical review. Please refer to the enclosed application flow chart.

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NH Department of Environmental Services
Waste Management Division
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Concord, NH 03301

If you have any questions or comments regarding the application, please contact me at (603) 589-3410 or LafleurJ@nashuanh.gov. You may also contact Ms. Jamie Colby, P.E. at the NHDES, 29 Hazen Drive, Concord, New Hampshire 03301.

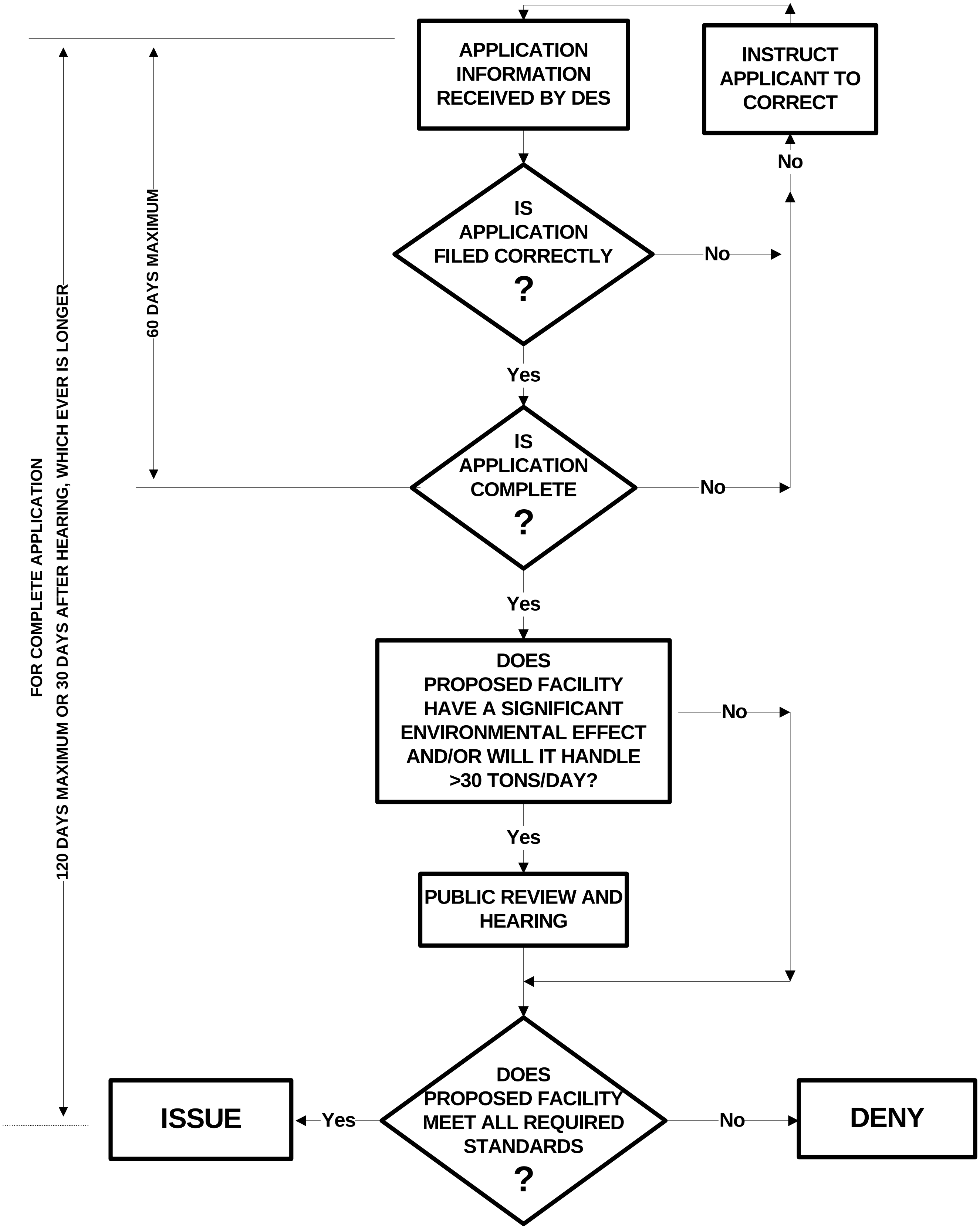
Very truly yours,
The City of Nashua

Jeffrey Lafleur
Superintendent of Solid Waste

Copies to: Jaime Colby – NHDES
Lisa Fauteux – City of Nashua
Kerry Converse – City of Nashua
Eddie Galvin – Sanborn, Head & Associates, Inc.

Enclosure: Permit Application Flow Chart
Type I-A Permit Application for Solid Waste Management Facility

STANDARD PERMIT APPLICATION PROCESSING PROVISIONS AS PROVIDED IN PARTS Env-Sw 303 - 305 OF THE *NEW HAMPSHIRE SOLID WASTE RULES*



THE CITY OF NASHUA
Division of Public Works
Solid Waste Department

"The Gate City"

City Mayor's Office
229 Main Street
Nashua, NH 03060

July 17, 2020
File No. 3066.11

Re: Four Hills Landfill
Nashua, New Hampshire
Type I-A Permit Modification
DES-SW-SP-95-002

To Mayor Donchess:

The purpose of this correspondence is to notify you that The City of Nashua (City) is filing a Type I-A permit modification application with the New Hampshire Department of Environmental Services (NHDES) on or about July 17, 2020. This application is being filed to obtain permit approval for the proposed Phase IV expansion at the Four Hills Landfill located at 840 West Hollis Street in Nashua, New Hampshire.

The facility, and the land where it is located, is owned and operated by the City's Department of Public Works. This notice is being provided in accordance with the RSA 149-M and the NHDES Solid Waste Rules.

This project is proposed to be constructed on the Four Hills Landfill property between two existing landfill units. The type of material managed, and the operation of the facility, are not proposed to change as part of this permit modification. Only waste generated within the City of Nashua is accepted at the facility including municipal solid waste, construction and demolition debris, and special non-hazardous wastes that are approved by NHDES. The project will add about 3.9 million cubic yards of capacity and extend the facility's site life by approximately 30 years.

Copies of this permit application will be available for review at the Four Hills Landfill office building, City of Nashua Town Hall, and at the NHDES office located at 29 Hazen Drive in Concord, New Hampshire. Appointments to review the application will be made with the City Solid Waste Department (603-589-3410), the City Clerk's Office (603-589-3010), or the NHDES Public Information & Permitting Office (603-271-2919) to review a hard copy of the permit application.

As part of this application, the City of Nashua is required to inform you of the basic steps that will be involved in the processing of this permit application. Upon receipt of this application, the NHDES will review its contents and determine whether it is complete and that it contains all the information required for their approval. If the application is complete, a technical review will then be made to determine whether the proposed activity meets all application requirements of the New Hampshire Solid Waste Rules. If it is decided that the application satisfies these requirements, then it will be approved, and the permit will be issued. A public hearing on this application is required

and will be scheduled upon completion of the technical review. Please refer to the enclosed application flow chart.

Included with the Type I-A permit modification is an Application for Waiver specific to Env-Sw 805.05(j).

Information regarding this application may be obtained by calling Ms. Jaime Colby, P.E., NHDES Permit Engineer, at (603) 271-5185, Jaime.Colby@des.nh.gov, or by writing to her at the following address:

NH Department of Environmental Services
Waste Management Division
PO Box 95
Concord, NH 03301

If you have any questions or comments regarding the application, please contact me at (603) 589-3410 or LafleurJ@nashuanh.gov. You may also contact Ms. Jamie Colby, P.E. at the NHDES, 29 Hazen Drive, Concord, New Hampshire 03301.

Very truly yours,
The City of Nashua

Jeffrey Lafleur
Superintendent of Solid Waste

Copies to: Jaime Colby – NHDES
Lisa Fauteux – City of Nashua
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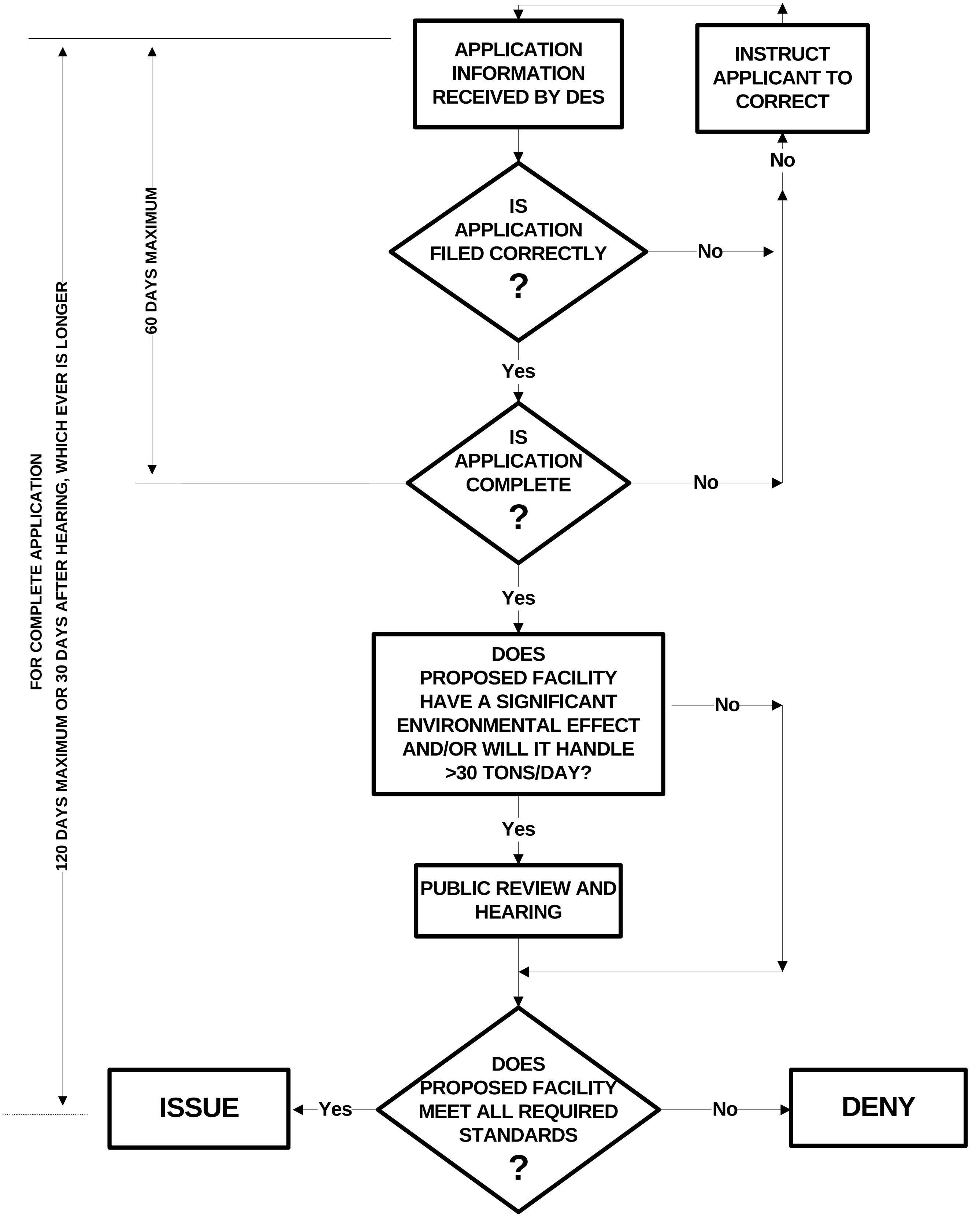
Enclosure: Permit Application Flow Chart
Type I-A Permit Application for Solid Waste Management Facility

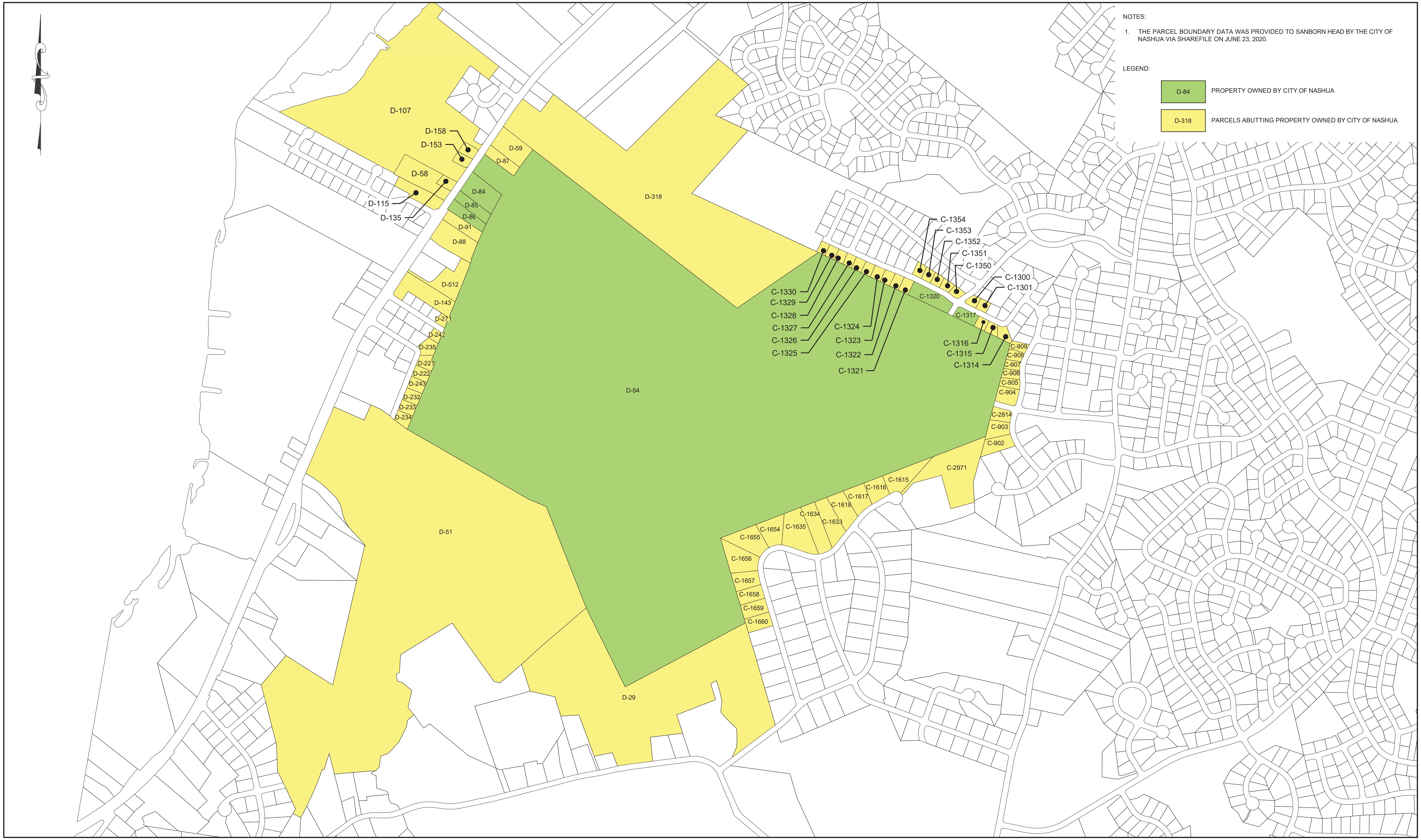
STANDARD PERMIT APPLICATION PROCESSING PROVISIONS AS PROVIDED IN PARTS Env-Sw 303 - 305 OF THE *NEW HAMPSHIRE SOLID WASTE RULES*



IMAGES:

XREFS: P:\3000s\3066.11\Graphics Files\CAD\Type 1A Permit Figs\XRefs\BORDER.dwg

FILE: P:\3000s\3066.11\Graphics Files\CAD\Type 1A Permit Figs\Figure-Abutters.dwg
LAYOUT: 01
USER: ssantiago
PLOT DATE: 6-24-20 7:49 AM



NOTES:

1. THE PARCEL BOUNDARY DATA WAS PROVIDED TO SANBORN HEAD BY THE CITY OF NASHUA VIA SHAREFILE ON JUNE 23, 2020.

LEGEND:

🟩 D-84	PROPERTY OWNED BY CITY OF NASHUA
🟨 D-318	PARCELS ABUTTING PROPERTY OWNED BY CITY OF NASHUA

SANBORN HEAD

GRAPHICAL SCALE
400' 200' 0' 400' 800'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: S. SANTIAGO
DESIGNED BY: S. SANTIAGO
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. GALVIN
PIC: E. STEINHAUSER
DATE: JUNE 2020

PHASE IV DESIGN DRAWINGS
TYPE I-A PERMIT MODIFICATION APPLICATION
FOUR HILLS LANDFILL
CITY OF NASHUA
NASHUA, NEW HAMPSHIRE

ABUTTERS PLAN

PROJECT NUMBER:
3066.11

FIGURE NUMBER:
1

ABUTTER TEMPLATE LETTER

THE CITY OF NASHUA
Division of Public Works
Solid Waste Department

"The Gate City"

Abutter Name
Abutter Address
City, State Zip

July 13, 2020
File No. 3066.11

Re: Four Hills Landfill
Nashua, New Hampshire
Type I-A Permit Modification
DES-SW-SP-95-002

To Whom it May Concern:

The purpose of this correspondence is to notify you that The City of Nashua (City) is filing a Type I-A permit modification application with the New Hampshire Department of Environmental Services (NHDES) on or about July 17, 2020. This application is being filed to obtain permit approval for the proposed Phase IV expansion at the Four Hills Landfill located at 840 West Hollis Street in Nashua, New Hampshire.

The facility, and the land where it is located, is owned and operated by the City's Department of Public Works. This notice is being provided in accordance with the RSA 149-M and the NHDES Solid Waste Rules because you own property which abuts the Four Hills Landfill.

This project is proposed to be constructed on the Four Hills Landfill property between two existing landfill units. The type of material managed, and the operation of the facility, are not proposed to change as part of this permit modification. Only waste generated within the City of Nashua is accepted at the facility including municipal solid waste, construction and demolition debris, and special non-hazardous wastes that are approved by NHDES. The project will add about 3.9 million cubic yards of capacity and extend the facility's site life by approximately 30 years.

Copies of this permit application will be available for review at the Four Hills Landfill office building, City of Nashua Town Hall, and at the NHDES office located at 29 Hazen Drive in Concord, New Hampshire. Please schedule an appointment with the City Solid Waste Department (603-589-3410), the City Clerk's Office (603-589-3010), or the NHDES Public Information & Permitting Office (603-271-2919) to review a hard copy of the permit application.

As part of this application, the City of Nashua is required to inform you of the basic steps that will be involved in the processing of this permit application. Upon receipt of this application, the NHDES will review its contents and determine whether it is complete and that it contains all the information required for their approval. If the application is complete, a technical review will then be made to determine whether the proposed activity meets all application requirements of the New Hampshire Solid Waste Rules. If it is decided that the application satisfies these requirements, then it will be approved, and the permit will be issued. A public hearing on this application is required

and will be scheduled upon completion of the technical review. Please refer to the enclosed application flow chart.

Included with the Type I-A permit modification is an Application for Waiver specific to Env-Sw 805.05(j).

Information regarding this application may be obtained by calling Ms. Jaime Colby, P.E., NHDES Permit Engineer, at (603) 271-5185, Jaime.Colby@des.nh.gov, or by writing to her at the following address:

NH Department of Environmental Services
Waste Management Division
PO Box 95
Concord, NH 03301

If you have any questions or comments regarding the application, please contact me at (603) 589-3410 or LafleurJ@nashuanh.gov. You may also contact Ms. Jamie Colby, P.E. at the NHDES, 29 Hazen Drive, Concord, New Hampshire 03301.

Very truly yours,
The City of Nashua

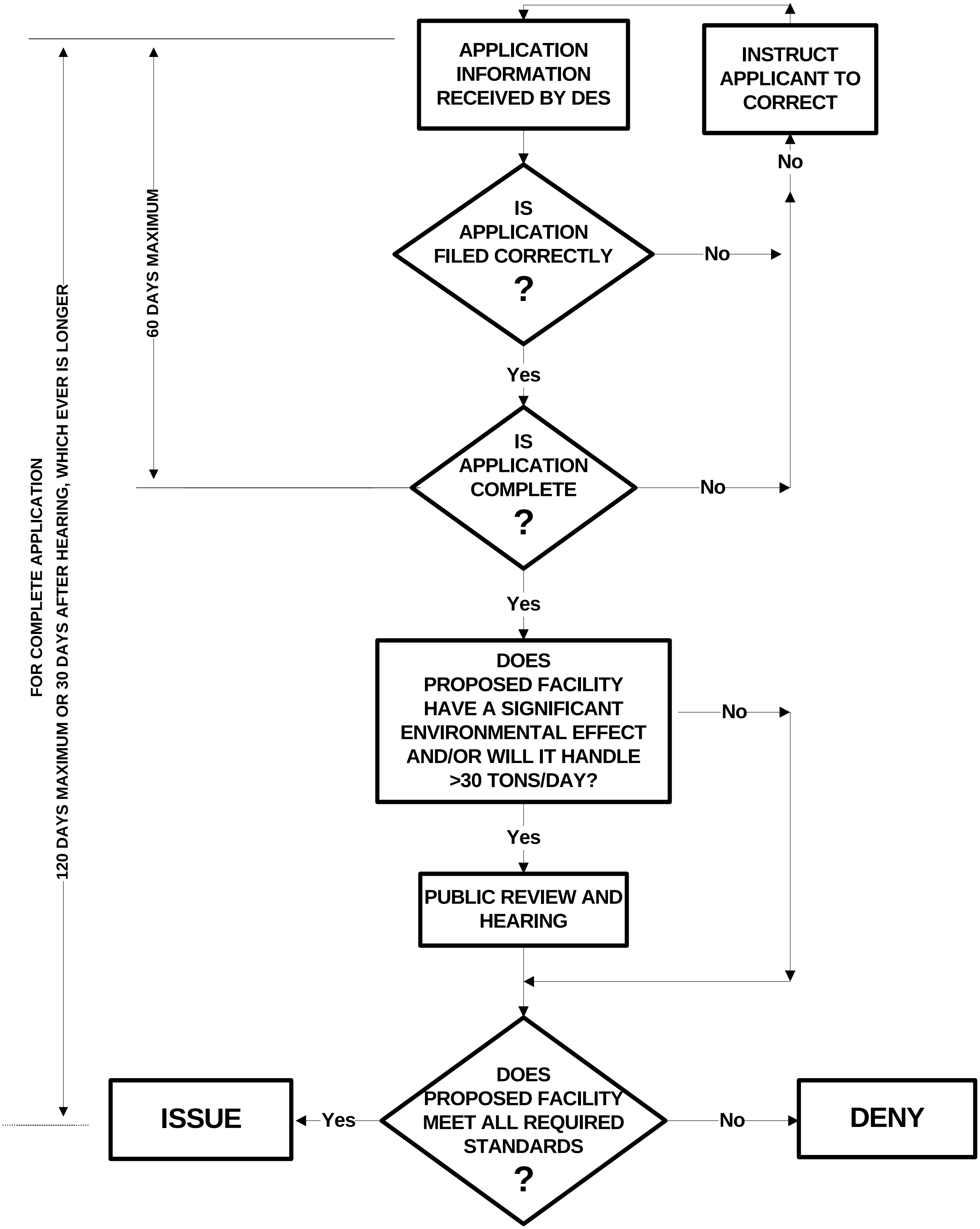
Jeffrey Lafleur
Superintendent of Solid Waste

Copies to: Jaime Colby – NHDES
Lisa Fauteux – City of Nashua
Kerry Converse – City of Nashua
Eddie Galvin – Sanborn, Head & Associates, Inc.

Enclosure: Permit Application Flow Chart

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

STANDARD PERMIT APPLICATION PROCESSING PROVISIONS AS PROVIDED IN PARTS Env-Sw 303 - 305 OF THE *NEW HAMPSHIRE SOLID WASTE RULES*



APPENDIX I

FEE CALCULATION

SANBORN HEAD

File No. 3066.11 Page 1 of 2
Project Phase IV – Type I-A Permit Modification Application
Location Nashua, New Hampshire
Subject Application Fee Calculation
Calculated By E. Galvin Date 5/8/2020
Checked By E. Steinhauser Date 5/11/2020
P:\3000s\3066.11\Source Files\Type I-A PMA\App I - Fee Calc\20200508 Fee Calculation.docx

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PURPOSE: Calculate the permit application fee (PAF) for the Type I-A Permit Modification Application associated with the development of Phase IV. The PAF is calculated based on capacity and life expectancy of the expansion. Refer to Env-Sw 310.07(a).

METHOD: Perform calculations in accordance with NH Solid Waste Rules.

Env-Sw 310.07 Type I Permit Modification Fees.

(a) The fee for filing an application for a type I-A permit modification as specified in Env-Sw 310.07 shall be the greater of the following:

(1) $1,500; or

(2) *If the modification will increase the capacity of the facility, the PAF calculated in accordance with Env-Sw 310.02 using the CF in Table 310-II that corresponds to the net increase in permitted facility capacity and the LI in Table 310-III that corresponds to the remaining life of the facility in modified as proposed.*

Because Phase IV will increase the permitted facility Capacity, the procedure outline in Env-Sw 310.02(a)(2) is followed.

Env-Sw 310.02 *Standard Permit Application Fees for Facilities Without a Temporary Permit*

(a) The permit application fee (PAF) for a standard permit for a facility without a temporary permit shall be:

(2) The sum of the minimum base fee (MBF) as specified in (b) below plus the product of a capacity factor (CF) as specified in (c) below multiplied by a lifespan index (LI) as specified in (d) below, plus the cost of completing a background investigation (BI) pursuant to Env-Sw 316, plus the cost of public notice and hearing (PNH) pursuant to Env-Sw 304, as illustrated in the following equation:

PAF = MBF + (CF)(LI) + BIF + PNH

TABLE 310-I
MBF for Singe Function Facilities

Facility Type	Capacity Factor
Landfill, lined	$15,000
Landfill, unlined	$5,000
Processing/Treatment	$2,000
Collection/Storage/Transfer	$2,000

TABLE 310-II
CF Based on Facility Capacity

Facility Capacity (tons per day, TPD)	Capacity Factor
601 or more	$20,000
301 to 600	$10,000
121 to 300	$5,000
31 to 120	$2,000
30 or fewer	$1,000

TABLE 310-III
LI Based on Facility Life Expectancy

Facility Life Expectancy	Lifespan Index
more than 10 years	1.0
more than 5, to 10 years	0.8
more than 1, to 5 years	0.4
1 year or less	0.1

For this calculation, the factors BI is not required and the PNH, if any, will be assessed at a later date.

CALCULATION:

Minimum Base Fee (MBF): Based Phase IV will be a lined facility the MBF = $15,000.

Capacity Factor (CF): Based on the Four Hills Landfill permitted acceptance rate of 80,000 tons/year, and the City accepting waste 6 days/week, the acceptance rate will be about 256 TPD. From Table 310-II (121 to 300 TPD), CF = $5,000

Lifespan Index (LI):

From Civil 3D volume calculation, the capacity of Phase IV = 3,900,000 CY

Airspace Utilization Factor from 2020 Waste Capacity Evaluation = 0.65 tons/CY

$$\text{Phase IV Lifespan} = \frac{3{,}900{,}000\ \text{CY}}{\frac{80{,}000\ tons/year}{0.65\ tons/CY}}$$

Phase IV Lifespan = 31.7 years, therefore, LI = 1.0

Permit Modification Fee:

PAF = MBF + (CF)(LI) + BIF + PNH

PAF = $15,000 + ($5,000) × (1.0) + $0 + $0 = $20,000

APPENDIX J

WAIVER APPLICATION

NEW HAMPSHIRE DEPARTMENT OF **Environmental Services**

Waste Management Division

For Office Use Only:
WMD Log #:___________________________
Date Rec'd.:___________________________
No. of Copies:_________________________

APPLICATION FOR WAIVER

pursuant to
the provisions of Part Env-Sw 202 of the New Hampshire Solid Waste Rules

APPLICATION FILING AND PROCESSING INSTRUCTIONS

(1) Complete this form by providing all of the information requested. If you need more space than provided on the form to answer a particular question and you are using a paper copy of this form, attach additional pages as necessary; mark each page clearly to show both the applicant name and the question being answered; and indicate on the form that the additional pages are attached

(2) Submit **THREE** copies of the completed waiver application, **EACH bearing ORIGINAL signatures**. Applications may be submitted to the department electronically. If the applicant chooses to submit an application electronically, a single paper copy shall also be submitted to the department to the following address:

:

New Hampshire Department of Environmental Services (DES)
Waste Management Division (WMD)
Permitting & Design Review Section (P&DRS)
29 Hazen Drive, PO Box 95
Concord, NH 03302-0095

(3) All references on this form that begin with "Env-Sw" are citations from the New Hampshire Solid Waste Rules. You may obtain a copy of the Rules from the DES Public Information and Permitting Office at (603) 271-2975. The Rules are also available on the Internet at http:\\www.des.nh.gov.

(4) DES will process your application in conformance with Env-Sw 202, Env-Sw 304 and Env-Sw 305.

(5) For further assistance with completing this form, contact the DES Permitting & Design Review Section (P&DRS) at (603) 271-2925 or at the above noted mailing address.

(6) You may also contact DES at TDD Access: Relay NH 1 (800) 735-2964.

SECTION I. APPLICANT IDENTIFICATION

(1)	Name: City of Nashua - Lisa M. Fauteux, Director Division of Public Works				
(2)	Mailing address: 9 Riverside Street, Nashua, NH 03062				
(3)	Telephone number: 603-589-3140				
(4)	If different than above, identify the individual associated with and designated by the applicant to be the contact individual for matters concerning this application:				
	(a)	Name: Kerry Converse		(b)	Title: Environmental Engineer
	(c)	Mailing address: 840 West Hollis Street, Nashua, NH 03062			
	(d)	Telephone number: 603-589-3420		(e)	E-mail: conversek@nashuanh.gov
(5)	If the applicant is an individual, provide date of birth and go to Section II:				
(6)	If the applicant is a corporation, partnership or other association, provide the following information as specified:				
	(a)	The facility is owned by a: ☐ corporation ☐ partnership ☐ other association			
	(b)	State of incorporation/formation:			
	(c)	Principal business address:			
	(d)	Provide on separate paper and attach/mark as "Attachment I(6)(c)," the names and addresses of all directors, officers and shareholders (*), if for a corporation; all partners (whether general or limited), if for a partnership; or all principals, members or participants, if for another type of association. (*) For a privately held corporation, identify all shareholders. For a publicly traded corporation, identify all shareholders owning 10% or more of the corporation's equity or debt.			

SECTION II. FACILITY OR ACTIVITY TO WHICH THIS REQUEST RELATES

Identify the particular facility or activity to which this application for waiver relates.

(1) Related activity [check that which applies]:

☐	Application for a Standard Permit	☐	Application for a Permit-by-Notification
☐	Application for an Emergency Permit	☐	Application for Research & Development Permit
☐	Application to certify a waste-derived product for distribution and use	☐	Application for Operator Certification
☒	Application to modify a permit (specify the permit number): DES-SW-SP-95-002		
☐	Other (specify):		

(2) If the requested waiver relates to a particular application, provide the date the application was/will be submitted to DES: July 2020

(3) If the requested waiver relates to a particular facility, provide the facility name and location in the space below. (Note: For a waiver relating to a particular facility, you must also notice the host municipality, host solid waste district and, in some instances, the abutters, as specified by Section IV of this form).

(a) Facility name: Four Hills Landfill

(b) Street address: 840 West Hollis Street, Nashua, NH 03062

(c) Town/City: Nashua

SECTION III. SPECIFIC RULE(S) FOR WHICH A WAIVER IS SOUGHT

Below, identify the specific solid waste rule(s) that you wish to have waived. Give the complete "Env-Sw" citation(s).

Env-Sw 805.05(j)

SECTION IV. NOTICE OF FILING REQUIREMENTS

(1) If this application for waiver relates to a particular facility, you must send by certified mail, or deliver in hand, a complete copy of this application and a “notice of filing” to the host municipality, host solid waste management district and other affected entities, as specified by Env-Sw 303. To identify the host solid waste management district, contact the host town/city office or the P&DRS at (603) 271-2925.

(2) In addition, if this application for waiver is to reduce the required setback distance to any residence or property line, a notice of filing must be provided to the affected property owner(s) as specified in Env-Sw 303.

(3) A copy of the required notice(s) of filing and proof of receipt [i.e., signature(s) of the recipient(s) acknowledging receipt] must be attached to and submitted with this application for waiver, unless you are combining the notice of filing with the notice requirements for a related permit application as indicated by item (4) below.

(4) If this application for waiver is being submitted as part of an application for a facility permit or permit modification, the required notice(s) of filing may be combined with the notice(s) of filing prepared for the permit application/permit modification application itself. If so, check here: ☒

(5) For assistance with preparing the required notice of filing, please refer to either Env-Sw 303 or "A Guide for Preparing Notices of Filing.” If the guide is not included with this application form, you may obtain a copy from the P&DRS at (603) 271-2925.

SECTION V. REASON FOR REQUESTING WAIVER

Explain why a waiver is being requested, including an explanation of the hardship that would be caused by having to comply with the rule. Use extra paper as necessary.

Please see attached Additional Information

SECTION VI. PROPOSED ALTERNATE PROCEDURE, METHOD OR ACTIVITY

Provide a full explanation of any alternate procedure, method, or other activity that you propose to substitute for the procedure, method or activity you wish to have waived. Include written documentation and/or data to support the proposed alternative. Use extra paper as necessary.

Please see attached Additional Information

SECTION VII. DURATION OF WAIVER

Specify the proposed duration for the requested waiver. If you are seeking a "permanent" waiver, including one that would expire when the facility to which it relates may close, so state and provide the desired starting date.

Proposed effective/starting date:

Proposed expiration date: ***OR*** ☒ I am seeking a "permanent" waiver

SECTION VIII. DEMONSTRATION OF CRITERIA

Provide a full explanation of why you believe that having the waiver granted will meet the below listed criteria. [Note: Economic, technological, practical application and safety issues shall be considered in evaluating a demonstration of the criteria; however, the merits of the application shall not be weighed solely on the basis of cost].

Criteria for Waiver, pursuant to Env-Sw 202.04:

- (a) Exemption from complying with the rule shall:
  1. Not result in an adverse effect to the environment or natural resources of the state, public health or to public safety.
  2. Not result in an impact on abutting properties that is more significant than that which would result from complying with the rule.
  3. Be in keeping with the intent and purpose of the rule being waived.
- (b) One or more of the following conditions shall be satisfied:
  1. Strict compliance with the rule will result in an adverse effect on the environment, public health or safety; AND/OR
  2. Strict compliance with the rule will result in a circumvention of the goals and objectives of the state's solid waste management program, as specified in RSA 149-M:1 through 3 and the state solid waste management plan; AND/OR
  3. Strict compliance with the standard will provide no benefit to the public and will cause an operational or economic hardship to the applicant.

Use the space below to provide your demonstration. Use extra paper as necessary.

Please see attached Additional Information

SECTION IX. CERTIFICATION OF COMPLIANCE/COMPLIANCE REPORT

If you are able to certify that each of the following statements is true, do so by your signature. If you are unable to certify that each of the following statements is true, you must prepare a separate Compliance Report as specified by Env-Sw 303.15.

COMPLIANCE STATEMENT

The applicant shall certify that each of the statements listed in (1)-(8) below are true for each of the following individuals and entities:

- ☒ **the applicant, and**
- ☒ **the facility owner, and**
- ☒ **the facility operator, and**
- ☒ **all individuals and entities holding 10% or more of the applicant's debt or equity, and**
- ☒ **all of the applicant's officers, directors, and partners, and**
- ☒ **all individuals and entities having managerial, supervisory or substantial decision making authority and responsibility for the management of facility operations or the activity(s) for which approval is being sought**

(1)	No individual or entity listed above has been convicted of or plead guilty or no contest to a felony in any state or federal court during the 5 years before the date of the application.	
(2)	No individual or entity listed above has been convicted of or plead guilty or no contest to a misdemeanor for a violation of environmental statutes or rules in any state or federal court during the 5 years before the date of the application.	
(3)	No individual or entity listed above has owned or operated any hazardous or solid waste facility which has been the subject of an administrative or judicial enforcement action for a violation of environmental statutes or rules during the 5 years before the date of the application.	
(4)	No individual or entity listed above has been the subject of any administrative or judicial enforcement action for a violation of environmental statutes and rules during the 5 years before the date of the application.	
(5)	All hazardous and solid waste facilities owned or operated in New Hampshire by any individual or entity listed above are in compliance with either.	
	(a)	All applicable environmental statutes, rules, and DES permit requirements.
	(b)	A DES approved schedule for achieving compliance therewith.
(6)	All individuals and entities listed above are in compliance with all civil and criminal penalty provisions of any outstanding consent agreement, settlement, or court order to which DES is a party.	
(7)	All individuals and entities listed above have paid, or are in compliance with the payment schedule for any administrative fine	

	assessed by DES.
(8)	All individuals and entities listed above are in compliance with all terms and conditions under every administrative order, court order or settlement agreement relating to programs implemented by DES.

Signature of the applicant certifying the above statements are true:

Applicant Name **(Print Clearly or Type)** Andrew Patrician, Asst. Director of Public Works, City of Nashua, for Lisa Fauteux, Director of Public Works

Applicant Signature

Date 7-15-2020

OR

Circle the untrue statement(s) and attach a Compliance Report, pursuant to Env Sw 303.15

SECTION X. APPLICANT SIGNATURE REQUIREMENTS

The applicant must sign the following statement prior to submitting this application. All copies of the application filed with DES must bear the applicant's original signature. If the applicant is not an individual, an individual duly authorized by the applicant shall sign the application.

To the best of my knowledge and belief, the information and material submitted herewith is correct and complete. I understand that any approval granted by DES based on false and/or incomplete information shall be subject to revocation or suspension, and that administrative, civil or criminal penalties may also apply.

Applicant Name **(Print Clearly or Type)** Andrew Patrician, Asst. Director of Public Works, City of Nashua, for Lisa Fauteux, Director of Public Works

Applicant Signature

Date 7-15-2020

SECTION XI. PROPERTY OWNER SIGNATURE

For applications relating a specific facility or activity, sited or to be sited on property not owned by the applicant, the property owner must also sign this form as follows. All copies of the application filed with DES must bear the property owner's ORIGINAL signature. If the property owner is not an individual, an individual duly authorized by the property owner shall sign the application.

(1)	I hereby affirm that the applicant has, or shall be granted, the legal right to occupy and use the property on which the subject facility is or will be located for the purposes specified in this application.
(2)	I hereby affirm that I shall grant access to the property for closure and post-closure monitoring of the subject facility and site as required by RSA 149-M and the New Hampshire Solid Waste Rules (Env-Sw 100-300 and Env-Sw 400-2000), as amended.

Property Owner Name **(Print Clearly or Type)** ____________________

Property Owner Signature ____________________

Date ____________

THE CITY OF NASHUA
Division of Public Works
Solid Waste Department

"The Gate City"

July 2020

ATTACHMENT

SECTION IX. Certification of Compliance/ Compliance Report

Application for Waiver

Nashua Four Hills Landfill
Permit #DES-SW-SP-95-002

This report has been prepared and submitted pursuant to the requirements of Env-Sw 303.15 to address Compliance Statement Item 4 in Section IX of the Application for Waiver dated July 15, 2020. This waiver application is being filed in conjunction with a Type I permit modification application requesting approval for the siting and future construction of Phase IV of the Four Hills secure expansion landfill.

The City of Nashua was subject to an Administrative Order by Consent (AOC) No. AF-18-032 issued January 3, 2019 by the New Hampshire Department of Environmental Services (NHDES) concerning violations to landfill cover requirements at the City's Four Hills Phase I/II landfill. The violations were identified during inspections by NHDES staff in May and June 2017.

Pursuant to Items 7 and 8 of the Compliance Statement, the City has paid the administrative fine assessed by NHDES, and has fully complied with the provisions, terms and conditions of the AOC.

As required by the AOC, an updated facility Operating Plan that revised and clarified landfill daily and interim cover requirements was submitted under a Type IB permit modification to NHDES on January 28, 2019. The NHDES approved the updated Operating Plan on April 8, 2019. The operating plan was further modified in January 2020 to include operation of the newly constructed Phase III landfill. The NHDES approved this plan on April 10, 2020.

The City continues to maintain compliance with the cover requirements of the approved Operating Plan and AOC; therefore, the NHDES should not find the AOC grounds for denying this Application for Waiver.

Additional Information
Application for Waiver
Four Hills Landfill – Phase IV
Permit No. DES-SW-SP-95-002

The information below is provided in the order referenced in the Application for Waiver form.

Section V. Reason for Requesting the Waiver

This Application for Waiver is associated with the proposed Phase IV Secure Landfill Expansion (Phase IV expansion), and includes the construction of a new double-lined disposal area at the City of Nashua's Four Hills Landfill (Facility). The Phase IV expansion will be located between the closed, unlined municipal solid waste (MSW) landfill and lined Phases I and II. The Phase IV expansion project includes the construction of liner, leachate collection and conveyance, landfill gas (LFG), and stormwater management systems. The Phase IV expansion project will secure approximately 30 years of additional safe and efficient solid waste disposal capacity for the City.

The Phase IV expansion was designed as double-lined facility in accordance with Env-Sw 805.05. The Phase IV expansion requires construction of new liner and leachate collection systems over the existing closed, unlined MSW landfill (herein referred to as the "overlay area") [pursuant to Env-Sw 805.17(a)(2)] and over the area between the closed, unlined MSW landfill, and the lined Phases I and II (herein referred to as the "base area").

The portion of the Phase IV expansion over Phases I and II is considered a vertical expansion over a permitted lined disposal area [see Env-Sw 805.17(a)(1)] and, as such, there is no need to construct additional liner or leachate collection systems over this area. However, because Phases I and II were permitted and constructed with liner penetrations as part of their leachate collection system, this Application for Waiver is specific to the vertical expansion component of the Phase IV expansion over Phases I and II that do not meet the requirements of Env-Sw 805.05(j).

Strict compliance with Env-Sw 805.05(j) with respect to Phases I and II would result in a hardship to the City for the following reasons:

- Prohibiting the vertical expansion of the Phase IV project would drastically reduce the disposal capacity making the Phase IV expansion project economically infeasible.
- Requiring the construction of an additional double liner system over the existing Phases I and II area, which is a permitted double-lined facility, is considered an unnecessary use of resources and City funding and also would reduce the disposal capacity of Phase IV, the combination of which would make the Phase IV expansion project economically infeasible.

- Requiring a modification to the constructed and filled Phases I and II would result in removing hundreds of thousands of tons of landfilled solid waste to access and modify the existing, well-functioning leachate management system. Excavation of the landfilled solid waste would result in a lengthy project that would expose construction workers to unnecessary health and safety risks, expose nearby residents to odors, and would impact the daily operations of the landfill. The expense of such an undertaking is considered economically infeasible.

The addition of waste in Phases I and II will not detrimentally impact the performance of the existing liner and leachate collection systems.

Section VI. Proposed Alternate Procedure, Method, or Activity

The City does not propose alternate procedure, method, or activity. Rather, as part of the Phase IV expansion, the City proposes to continue to place waste in Phases I and II to a higher elevation, thereby optimizing the disposal capacity of the proposed expansion. By doing so, the City will continue to provide its residents and businesses with a safe and cost effective municipal solid waste disposal resource for years to come.

Section VIII. Demonstration of Criteria

Granting a waiver from Env-Sw 805.05(j) for the Phase IV expansion complies with the criteria of Env-Sw 202.04 because exemption from complying with the rule will:

- Not result in an adverse effect to the environment or natural resources of the state, public health or to public safety because the vertical expansion will be located on a well-functioning, permitted double-lined landfill that otherwise meets the requirements of the New Hampshire Solid Waste Rules;
- Not result in an impact on abutting properties that is more significant than that which would result from complying with the rule because there is no change to the established setbacks; and
- Be in keeping with the intent and purpose of the rule being waived because there will be no change to the current operation of Phases I and II nor will there be an detrimentally impact to the performance of the existing liner and leachate collection systems.

Also, strict compliance with Env-Sw 805.05(j) will provide no benefit to the public and will cause an operational or economic hardship to the applicant as noted in the responses to Sections V and VI above.

Closing

The contents of this application were prepared under the direction of Eric S. Steinhauser, a New Hampshire licensed Professional Engineer experienced in solid waste facility design. The drawings were prepared to meet the requirements of the New Hampshire Solid Waste Rules (Env-Sw 800) and are consistent with the current state of practice in the solid waste industry in New Hampshire.

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7/17/2020
Date

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