Weaver Consultants Group

Project No. 0771-356-11-41
August 10, 2023

Asmerom T. Russom, P.E.
MC-124
Waste Permits Division
Texas Commission on Environmental Quality
P.O. Box 13087
Austin, TX 78711-3087

Re: Response to 2nd Technical Notice of Deficiency Letter – Major Permit Amendment Application
Fort Worth C&D Landfill
Fort Worth, Tarrant County, Texas
MSW Permit No. 1983E
Tracking No. 28325020

Dear Mr. Russom:

On behalf of Texas Regional Landfill Company, LP, please find enclosed one original and two copies of the replacement pages for the referenced permit amendment application. The attached replacement pages were developed to incorporate comments included in your letter dated July 7, 2023.

The enclosed table contains each comment identified by the TCEQ and a response to each below the comment.

During the course of your review, if you need additional information or have any questions, please call.

Sincerely,

Nevzat Turan, P.E.
Principal

Attachment: Attachment 1: NOD2 Table
Attachment 2: Replacement Pages (Redline/Strikeout)
Attachment 3: Replacement Pages (Clean)

cc: Gary Bartels, Texas Regional Landfill Company, LP

ATTACHMENT 1

NOD 2 TABLE

NOD1 Table - Permit Type IV (Permit 1983E)

NOD ID	MRI ID	App. Part	Citation	2nd NOD Type	NOD Description
NT1	208	Part II	330.561	Ambiguous	Part I/IIC-19, Section 11, Coastal Areas indicates that Class 1 Industrial Solid Waste will be accepted at the landfill. Revise according to the landfill's waste acceptance plan. **Response**: Parts I/IIC-19, Section 11 has been updated to be consistent with the landfill's waste acceptance plan. Class 1 waste will not be accepted at the site.
NT2	311	Part III	330.63(c)(1)(D)(ii)	Omitted	Appendix IIIF-E, identify the location of Attachments 2 of Part III. "Attachments 2A through 2G can be found in Volume 3 of the 2015 Geosynthetic Permit Amendment application" is not sufficient. Revise Attachment 2 Drainage Report Table of Contents as necessary to reflect the current application. **Response**: Attachments 2A through 2G have been added to Appendix IIIF-E. These attachments were used as reference and are not a part of this drainage analysis.
T3	335	Part III	330.63(c)(2)(D)(ii)	Incomplete	A. If levee construction to protect floodplains in the proposed landfill development is not appliable, discuss if infrastructure development is required to divert the floodway and floodplain from the proposed landfill development. Discuss any possible hydraulic communication between municipal solid waste in the proposed development and the floodway. **Response**: The development of the proposed perimeter berm will provide 3 feet of freeboard to the limit of waste as required by TCEQ. Also, the development of the proposed detention pond on the western side of the berm will create additional floodplain storage diverting the floodplain and floodway from the proposed landfill development. To prevent hydraulic communication between municipal solid waste and the floodway, a sidewall liner system (see L9 on Drawing A.4 in Appendix IIIA-A – Liner and Final Cover System Details) will be installed in the interior portion of the perimeter berm. B. The letter from FEMA dated September 22, 2023, indicates a comment document and not an approval document as indicated in the NOD1 response. Provide FEMA approval or any approvals and correspondence with an agency responsible for approving floodplain modification. **Response**: FEMA does not issue approvals of CLOMRs. A CLOMR submittal results in the issuance of a comment letter indicating that if the project is constructed as proposed, it meets the minimum floodplain management criteria. A LOMR will be submitted to FEMA for approval once the proposed project (berm and floodplain storage area) has been constructed. The approval from Tarrant County and the City of Fort Worth floodplain administrator is indicated by their signature on the MT-2 Form 1, which has been added to Appendix IIIF-G – Excerpts from Approved CLOMR. As indicated in their certification, the CLOMR meets or is designed to meet all of the community floodplain management requirements, including the requirements for when fill is placed in the regulatory floodway, and that all necessary federal, state, and local permits have been obtained.

NOD ID	MRI ID	App. Part	Citation	2nd NOD Type	NOD Description
T4	491	Part III	330.63(e)(4)(D)	Incomplete	Submit plugging reports for MW-1, MW-9, and all other abandoned monitoring wells. Your response indicated that MW-3 is the only abandoned well. You must ascertain that this well was plugged in accordance with 16 TAC §76.702: submit the plugging report for MW-3 or provide its coordinates and the results of a certified assessment that the well was duly plugged before abandonment. **Response:** The State of Texas Plugging Report for the former monitoring well MW-3 was located in Texas Water Development Board records that shows MW-3 was plugged and abandoned in 2003. A copy of the plugging report for MW-3 is provided in Appendix IIIH-A on page IIIH-A-23. Text has also been added to Section 2.2 in Appendix IIIH to reference the plugging report.
T5	495	Part III	330.63(e)(4)(H)	Incomplete	Discuss the distinguishing characteristics and the criteria used to differentiate the Quaternary alluvium from the Woodbine (in most cases, the submitted logs do not appear to show a defined lithologic boundary between the two). **Response:** As discussed on August 2, 2023, a stratigraphic interpretation narrative has been added as Section 3.1.7 in Appendix IIIG. Figure IIIG-C-33 (Surface Geology Map) and Figure IIIG-C-34 (Woodbine Formation Thickness Isopach Map) have also been added to Appendix IIIG-C which are referenced in the newly added Section 3.1.7 in Appendix IIIG.
T6	495	Part III	330.63(e)(4)(H)	Incomplete	Provide an isopach map of the Woodbine formation as interpreted from the site investigation. **Response:** As requested, Figure IIIG-C-34 (Woodbine Formation Thickness Isopach Map) has been added to Appendix IIIG-C.
T7	504	Part III	330.63(e)(5)(C)	Omitted	Submit, if in table format, groundwater levels in all borings, sitewide: the information will consist of depths where water was first encountered as well as records of after equilibrium measurements. Submitted Tables 4-1&2 show historic groundwater elevations in piezometers and monitoring wells. Provide groundwater level in all borings in table format. **Response:** Per our discussion on August 2, 2023, the requested tabulated historical water level data was provided in the response to the first NOD (NOD ID T27) in June 2023. The water level data provided in Table 4-1 and Table 4-2, and the water level data provided as excepts on pages IIIG-D-39 through IIIG-D-42 in Appendix IIIG-D, collectively comprise the historical sitewide groundwater level data for the facility.

NOD ID	MRI ID	App. Part	Citation	2nd NOD Type	NOD Description
T8	507	Part III	330.63(e)(5)(F)	Inaccurate	The cross-sections in Figures IIIG-C-2 through C-9 do not match or reflect groundwater levels shown on Pages IIIG-D-36 through D-38. Explain the differences and revise the drawings to adjust for the noted differences. **Response:** Per our discussion on August 2, 2023, The groundwater levels presented on figures IIIG-D-36 through IIIG-D-38 are from groundwater gauging conducted at existing groundwater monitoring wells in June 2020, June 2021, and June 2022. Note #4 on cross section drawing Figures IIIG-C-2 through IIIG-C-13 indicates that the groundwater levels were obtained from the facility's Subtitle D groundwater database and previous subsurface investigation data summary tables. These data are provided in Table 4-1 and 4-2 in Appendix IIIG and Pages IIIG-D-39 through IIIG-D-42 in Appendix IIIG-D. Review of the groundwater levels shown on Figures IIIG-C-2 through IIIG-C-9 indicate that the data reflect the groundwater levels listed Appendix IIIG Table 4-1, Appendix IIIG Table 4-2, and/or the data provided in table format on pages IIIG-D-39 through IIIG-42.
T9	650	Part III	330.421(d)	Omitted	Submit surveyed locations and elevations, sealed by a Texas-registered professional land surveyor (RPLS), for all existing monitoring wells. Acknowledge that new wells will be surveyed by a RPLS before groundwater monitoring begins. Table 3-1 and the submitted lithologic log do not address the request for surveyed well locations. Submit RPLS surveyed locations for all existing monitoring wells. **Response:** Per our discussion on August 2, 2023, the asbuilt condition of all existing monitoring wells was surveyed in May 2023 by WCG. The 2023 RPLS Signed/Sealed Groundwater Monitoring Well Asbuilt Survey Report was provided in the First NOD response and is located in Appendix IIIH-A on page IIIH-A-22.

ATTACHMENT 2

REPLACEMENT PAGES
(REDLINE/STRIKEOUT)

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

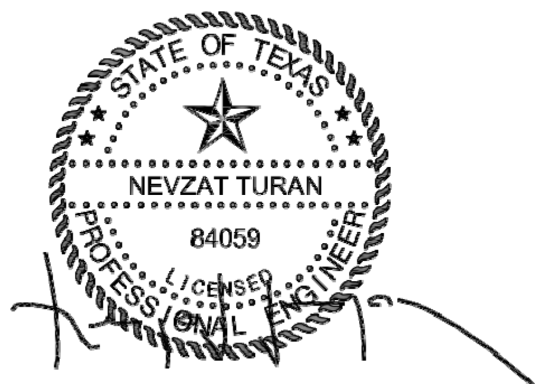
VOLUME 1 OF 4

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023



Prepared by

08/10/2023

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

This document intended for permitting purposes only.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

TCEQ PART I APPLICATION FORM, PART II APPLICATION FORM, CORE DATA FORM, WASTE ACCEPTANCE PLAN FORM, AND MAILING LABELS

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER

08/10/2023

Prepared by
Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

This document intended for permitting purposes only

Signature Page

Site Operator or Authorized Signatory

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: Gary Bartels Title: Southern Region Engineer

Email Address: gary.bartels@wasteconnections.com

Signature: [signature] Date: 08/10/2023

Operator or Principal Executive Officer Designation of Authorized Signatory

To be completed by the operator if the application is signed by an authorized representative for the operator.

I hereby designate ________________________ as my representative and hereby authorize said representative to sign any application, submit additional information as may be requested by the Commission; and/or appear for me at any hearing or before the Texas Commission on Environmental Quality in conjunction with this request for a Texas Water Code or Texas Solid Waste Disposal Act permit. I further understand that I am responsible for the contents of this application, for oral statements given by my authorized representative in support of the application, and for compliance with the terms and conditions of any permit which might be issued based upon this application.

Operator or Principal Executive Officer Name: ________________________

Email Address: ________________________

Signature: ________________________ Date: ____________

Notary

SUBSCRIBED AND SWORN to before me by the said Gary Bartels

On this 10th day of August, 2023

My commission expires on the 11th day of August, 2026

Stacy M. Wilson

Notary Public in and for

TARRANT County, Texas

STACY M. WILSON
Notary Public, State of Texas
Comm. Expires 08-11-2026
Notary ID 133903285

Note: Application Must Bear Signature & Seal of Notary Public

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT

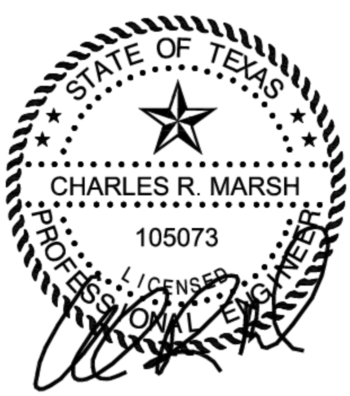
APPENDIX I/IIC
LOCATION RESTRICTION DEMONSTRATIONS

Prepared for

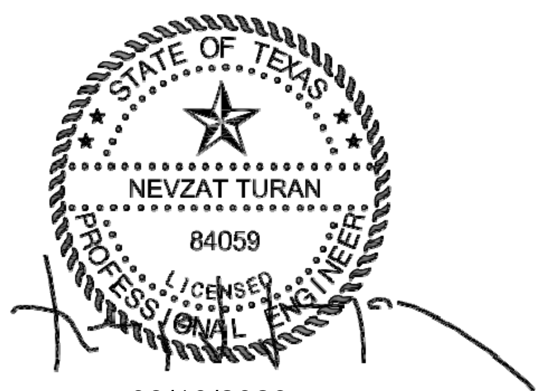
Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023



08/10/2023



08/10/2023

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11 COASTAL AREAS

The coastal areas location restriction within Title 30 TAC §330.561 requires that a new landfill cell or expansion of an existing cell of a landfill managing Class 1 Industrial Solid Waste not be located on a barrier island or peninsula, or within 1,000 feet of an active coastal shoreline erosion.

The Fort Worth C&D Landfill does not accept Class 1 Industrial Solid Waste ~~but is not located near the coast~~ and is not located in a coastal area. Therefore, the site is in compliance with the coastal areas location restriction.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

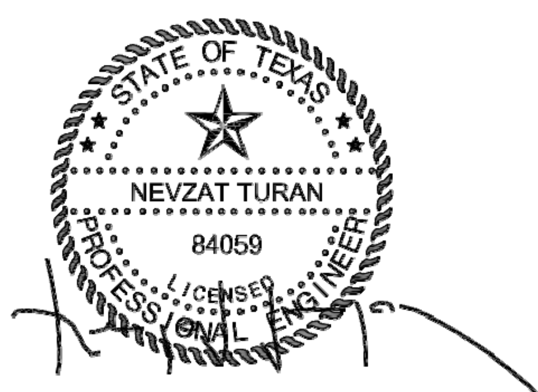
VOLUME 2 OF 4

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023



Prepared by

08/10/2023

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FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

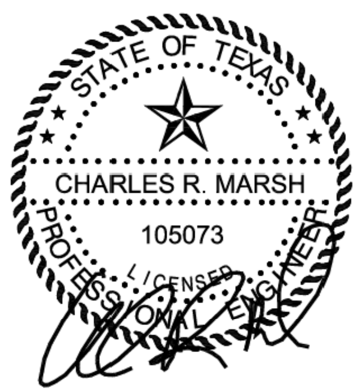
PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIF
SURFACE WATER DRAINAGE PLAN

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023



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Weaver Consultants Group, LLC
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6420 Southwest Boulevard, Suite 206
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817-735-9770

WCG Project No. 0771-356-11-35

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APPENDIX IIIF-E

PERMITTED LANDFILL CONDITION
HYDROLOGIC CALCULATIONS

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

08/10/2023

Includes pages IIIF-E-1 through IIIF-E-~~117~~ 346

EXISTING PERMITTED DRAINAGE CALCULATION EXCERPTS

ATTACHMENT 2B

ON-SITE DRAINAGE ANALYSIS – HYDROLOGY

Written by:	O. Bramlet	Date:	01/08/2020	Reviewed and Revised by:	S. Graves	Date:	01/19/2020; 09/15/2020
Client:	TRLC	Project:	Fort Worth C&D Expansion	Project No.:	GW6953	Phase No.:	04

ON-SITE DRAINAGE ANALYSIS – HYDROLOGY
FORT WORTH C&D LANDFILL EXPANSION

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

9/15/2020

SEALED FOR PERMITTING PURPOSES;
CALCULATION PAGES 1 TO 76

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the hydrology analysis for the estimation of surface water runoff as a part of the permit amendment application for the proposed lateral expansion of the Fort Worth C&D Landfill (site) in Fort Worth, Texas. The specific objectives of the hydrologic analysis include calculating peak discharges and total runoff volumes from the site for the: (i) pre-development conditions and (ii) post-development conditions. The calculated values of peak discharge and runoff volume of the proposed surface water system for lateral expansion presented in this calculation package are compared against currently permitted pre-development conditions in order to demonstrate that lateral expansion design does not adversely alter, to any significant degree, the drainage patterns of the watershed in the vicinity of the site.

The following definitions pertain to the two conditions analyzed in this package:

- Pre-Development Conditions – represent the currently permitted drainage conditions of the landfill facility. The currently permitted surface water management system is analyzed, while incorporating additional off-site run-on drainage areas.
- Post-Development Conditions – represent conditions of the site once the expansion design has been fully developed, with the final cover and permanent surface water management system installed, while incorporating additional off-site run-on drainage areas.

2 METHODOLOGY

2.1 HEC-HMS Computer Model

Surface water discharges for the pre-development and post-development conditions are estimated using the Hydrologic Modeling System (HEC-HMS) version 4.3 computer program developed through the Hydraulic Engineering Center (HEC) of the United States Army Corps of Engineers (USACE). The program simulates natural and controlled precipitation-runoff and routing processes of a watershed. HEC-HMS is the successor to and replacement for the HEC-1 program (USACE, 2000). For precipitation-runoff-routing simulation, HEC-HMS provides the following components:

- Precipitation-specification options can describe an historical precipitation event, a frequency-based hypothetical precipitation event (i.e., design rainfall or storm event), or an event that represents the upper limit of precipitation possible at a given location. For this analysis, the 25-year (4% annual chance), 24-hour duration hypothetical precipitation event (herein referred to as the 25-year, 24-hour event) was used to compare pre-development and post-development conditions. Additionally, the analysis is repeated for the 100-year (1% annual chance), 24-hour duration hypothetical precipitation event (herein referred to as the 100-year, 24-hour event) to obtain the design information needed for surface water pond sizing and discharge structure sizing to route the runoff without overtopping the pond crest for that hypothetical 100-year event.

- Water loss models can estimate the volume of runoff given the precipitation and properties of the watershed. For this analysis, the Soil Conservation Service (SCS) Curve Number Loss Model was used (USDA, 1986).

- Direct runoff transform models can account for overland flow, storage, and energy losses as surface water runs off a watershed and into the drainage channels. For this analysis, the SCS Unit Hydrograph Model was selected.

- Hydraulic routing models account for storage and energy flux as surface water flows through drainage channels. The Kinematic Wave Model was selected for these analyses.

- Hydraulic models of water-control measures such as surface water pond outfall structures (i.e., outlet control structures).

HEC-HMS was used to model the pre-development conditions and the post-development conditions. More specifically, HEC-HMS modeling calculates surface water runoff volumes, peak flow rates, and flow characteristics for the perimeter channels and the surface water ponds.

2.2 Pre-Development Condition

Drawing 2-2 in Attachment 2A of the Facility Surface Water Drainage Report (Drainage Report) presents the final configuration of the currently permitted landfill and surface water management system design including the natural conditions for the off-site areas adjacent to the landfill. Existing topographic information was compiled from photogrammetric methods based on aerial photography performed on 06 March 2019 by Dallas Aerial Surveys, Inc. The topographic information for the general site vicinity was used to model the natural conditions adjacent to the currently permitted landfill boundary. The pre-development drainage area of 207.14 acres includes the currently permitted surface water management system within the facility permit boundary area, as well as off-site areas. The consideration of off-site areas for the pre-development condition allows for direct comparison between the pre-development and post-development analysis since the total drainage areas are equivalent. The currently permitted surface water management system design utilizes drainage terraces, downchute channels, perimeter drainage channels, and storm water (detention) ponds to control surface water runoff from the site.

The currently permitted surface water management system maintains similar drainage patterns to the natural (or undeveloped) conditions. The currently permitted surface water management system discharges surface water at two locations (outfalls). The overall site outfall is located at the storm water pond outlet pipe in the northern portion of the site and discharges to Village Creek, which flows along the west boundary of the site. The midpoint site outfall is located where the permit boundary deviates from Village Creek near the midpoint along the western permit boundary. Both outfall locations are used for evaluation of the pre-development conditions. The entire drainage area of 207.14 acres drains to the overall site outfall, whereas 95.7 acres drain to the midpoint site outfall for pre-development conditions.

2.3 Post-Development Condition

Drawing 2-1 in Attachment 2A shows the final configuration of the lateral expansion and the proposed surface water management system design. Like the currently permitted facility, the proposed surface water management system will utilize drainage terraces, downchute channels, and perimeter drainage channels to control surface water runoff from the site. The drainage areas flowing to each of the drainage features are delineated on Drawing 2-3 in Attachment 2A.

The proposed surface water management system will maintain similar drainage patterns to the pre-development condition. The proposed surface water management system will discharge at the currently permitted outfalls described in the pre-development condition section above. The overall site outfall is located at the surface water pond outlet area in the northern portion of the site and discharges to Village Creek, which flows along the west boundary of the site. The midpoint site outfall is located where the permit boundary deviates from Village Creek near the midpoint along the western permit boundary. The midpoint site outfall and the overall site outfall locations used for evaluation of the post-development conditions coincide with the 207.14-acre drainage area for pre-development conditions. The entire drainage area of 207.14 acres drains to the overall site outfall, whereas 83.5 acres drain to the midpoint site outfall for post-development conditions. The proposed grading of the final cover system results in a slightly smaller area draining to the midpoint site outfall, but is the same where runoff leaves the overall site at the north end (i.e., 207.14 acres). As mentioned, the post-development drainage area includes the entire proposed facility permit boundary area.

3 DESIGN PARAMETERS

The following data and assumptions were utilized in selecting engineering parameters to estimate surface water runoff.

3.1 Rainfall

- Rainfall Return Periods, Durations, and Depths – The Texas Department of Transportation (TxDOT) *Hydraulic Design Manual* (2019) provides guidance for rainfall frequency and duration depths. The site is located in the Village Creek watershed, and outflow from the site drains into Village Creek. The rainfall depths corresponding to 24-hour duration hypothetical precipitation event and 25-year and 100-year frequency return periods for the site are 7.17 inches and 9.27 inches, respectively, using the latest available "Atlas 14" data (NOAA, 2018). The design rainfall hyetograph is defined using a SCS Type II rainfall distribution, which is selected based on Figure 2B-1 (USDA, 1986). The design rainfall depths in the hydrologic model were consistent with TxDOT (2019) methods and procedures; however, the design rainfall hyetograph was defined with a SCS Type II distribution in order to be consistent with the method utilized in the previous permit application. This rainfall intensity method for determining rainfall distribution was retained in the hydrologic model for this application for a more conservative approach, as it resulted in higher peak intensity values than the latest TxDOT (2019) Hydraulic Design Manual.

3.2 Drainage Areas and Reaches

- Drainage Areas – The contributing watershed areas for each basin (drainage area) or reach (perimeter channel) in the pre-development and post-development models are divided into multiple subbasins (subareas). Subbasins are modeled based on the receiving surface water drainage feature, and are delineated for the following areas: top deck surfaces draining to the top deck drainage terraces and the drainage downchutes; sideslope surfaces draining to the sideslope drainage terraces and the drainage downchutes and perimeter channel; off-site run-on areas; and surface water pond areas. The SCS Curve Number Loss Model was used to estimate the volume of runoff from a given subbasin. The SCS Unit Hydrograph Model was used to estimate the direct runoff flow rates from each subbasin. Each subbasin is assigned a curve number representing the type of ground cover for a given soil for the area. The subbasin area, curve number, and SCS Unit Hydrograph lag time input parameters are included in the HEC-HMS output in Appendix 2B-1.

- Hydrologic Soil Groups (HSGs) – Figure 2B-2 shows the approximate footprint of the landfill superimposed on a soil map from the Web Soil Survey tool operated by the USDA Natural Resources Conservation Service (USDA, 2019) for Tarrant County. The predominate soil types at the site include a combination of Frio silty clay, Gasil fine sandy loam, and Gasil sandy clay loam formations. The on-site soil types have a range of HSG designations as shown in Table 2B-1. To be conservative, the HSG within the landfill permit area is assumed to be a type D soil, which generally provides the highest calculated runoff volumes. Off-site natural areas are assumed to have an HSG of type C, corresponding to the Frio silty clay soil found adjacent to the expansion area.

- Curve Number (CN) – Curve numbers are obtained from the TR-55 (USDA, 1986) and are based on the predominant HSG of the drainage area. The curve number for the proposed final cover of the landfill was selected as 85 based on TCEQ's guidelines as described in Regulatory Guidance 417 (TCEQ, 2018). Table 2B-2 summarizes the CNs chosen for all off-site areas within the analyses detailed in this calculation package. Off-site natural conditions (HSG type C) are assumed to be meadow cover conditions (CN = 71). Off-site areas currently developed with buildings and driveways are assumed to represent farmstead conditions (CN = 82).

- Manning's Roughness Coefficients – Values of Manning's roughness coefficients used in the reach routing calculations were obtained from the TxDOT *Hydraulic Design Manual* (2019). Table 2B-3 summarizes the Manning's coefficients used in this calculation package. It should be noted that for design purposes, the culverts assume a Manning's coefficient for a reinforced concrete pipe (RCP). Any culvert material type may be used provided that the Manning's coefficient is equal to or less than that for RCP.

- Perimeter Channel Reaches – Reaches in the HEC-HMS program represent perimeter channels that route surface water from upstream subbasins to downstream subbasins through a junction. Reaches also may route surface water from upstream reaches. The Kinematic Wave Model is used to model the surface water flow in each of the reaches in the HEC-HMS program. The Kinematic Wave Model accounts for storage and energy flux as surface water moves through stream channels. Average geometric characteristics of the stream channel measured from the existing and proposed topography are input into HEC-HMS.

3.3 Surface Water Ponds

The pre-development analysis incorporated the currently permitted surface water ponds, the North Surface Water Pond and the South Surface Water Pond. The surface water ponds temporarily retain surface water runoff and reduce discharge flow rates from the upstream areas. The post-development analysis incorporates only the North Surface Water Pond which is comprised of a series of four connected sub-ponds. The existing North Surface Water Pond will be modified and portions of the drainage area to the south are diverted to the North Surface Water Pond to maintain post-development discharge flow rates at or below pre-development discharge flow rates for a 24-hour duration hypothetical precipitation event occurring at a 25-year frequency. Surface water ponds are accounted for in the HEC-HMS program as "reservoir" nodes. The elevation-area relationship is input for each surface water pond to describe the volume of storage provided by the surface water pond, which is computed based on the proposed surface water pond geometry. Specifically, the surface area at various elevations throughout the ponds was used to compute the elevation-area relationship. Design characteristics of the outflow structures include pond outflow pipe diameter and emergency spillway depth and breadth. Input and output files for the surface water ponds design are provided in Appendix 2B-1. The North Surface Water Pond discharges to a drainage channel and ultimately to Village Creek at the overall site outfall for both pre-development and post-development conditions. The South Surface Water Pond (only present under pre-development conditions) discharges to a drainage channel and ultimately to Village Channel at the midpoint outfall.

3.4 Nodal Network Diagrams

Nodal network diagrams used in HEC-HMS for the pre-development and post-development analyses are provided and correspond to the output files included in Appendix 2B-1.

- Pre-Development Nodal Network – Figure 2B-3 of this calculation package presents the nodal network drawing for the pre-development conditions. The pre-development nodal network diagram shows the subbasins, permitted storm water ponds, and discharge locations. The nodal network diagram represents the existing permitted surface water management system and discharge point shown on Drawing 2-2 in Attachment 2A
- Post-Development Nodal Network – Figure 2B-4 of this calculation package presents the nodal network drawing for the post-development conditions. The post-development nodal network diagram shows the subbasins, reaches, surface water ponds, and discharge locations. The nodal network diagram represents the proposed surface water management system and discharge point shown on

Drawing 2-3 in Attachment 2A.

4 RESULTS

Modeling results from calculations presented in this calculation package indicate that post-development peak discharges from the facility are less than the pre-development peak discharge rates at both the overall site outfall and midpoint discharge locations for the 25-year, 24-hour precipitation event. Thus, the lateral expansion is not anticipated to adversely affect or significantly alter the drainage patterns in the vicinity of the site. Table 2B-4 summarizes analysis results for the pre- and post-development peak discharges and total discharge runoff volumes from the site. The calculation results described in Table 2B-4 are provided in Appendix 2B-1.

5 REFERENCES

Chow, V.T. (1959). *Open-Channel Hydraulics*, McGraw-Hill Book Company, Inc., New York, NY.

NOAA (2018). *Precipitation-Frequency Atlas of the United States,* National Oceanic and Atmospheric Administration, Volume 11, Version 2.0. Available online: https://hdsc.nws.noaa.gov/hdsc/pfds/, accessed November 2019. Latitude: 32.6326°, longitude: -97.2375°.

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TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.

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TABLES

Table 2B-1. Hydrologic Soil Groups for On-Site Soils (from USDA, 2019)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
7	Arents, frequently flooded	A	19.8	9.3%
8	Arents, loamy	B	11.2	5.3%
12	Birome-Aubrey-Rayex complex, 5 to 15 percent slopes	D	34.7	16.3%
22	Crosstell fine sandy loam, 3 to 8 percent slopes	D	9.2	4.3%
27	Frio silty clay, frequently flooded	C	60.2	28.2%
30	Gasil fine sandy loam, 3 to 8 percent slopes	B	50.8	23.8%
31	Gasil sandy clay loam, graded, 1 to 5 percent slopes	B	25.2	11.8%
71	Silstid loamy fine sand, 1 to 5 percent slopes	B	0.1	0.0%
83	Whitesboro loam, frequently flooded	B	1.9	0.9%
Totals for Area of Interest			**213.1**	**100.0%**

Table 2B-2. Summary of Curve Numbers used in Analysis[1] (from USDA, 1986)

Cover description: Cover type	Hydrologic condition	Curve numbers for hydrologic soil group: A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Note that the curve number for the proposed final cover of the landfill was selected as 85 based on TCEQ's guidelines as described in Regulatory Guidance 417 (TCEQ, 2018). This is a conservative assumption since the information in this table would support the selection of a smaller CN for the expected soil types and cover types/conditions of the landfill final cover.

Table 2B-3. Manning's n Values (from TxDOT, 2019)

Type of channel	Manning's n
B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
3. Dragline-excavated or dredged	
a. No vegetation	0.025-0.033
b. Light brush on banks	0.035-0.060
4. Rock cuts	
a. Smooth and uniform	0.025-0.040
b. Jagged and irregular	0.035-0.050
5. Unmaintained channels	
a. Dense weeds, high as flow depth	0.050-0.120
b. Clean bottom, brush on sides	0.040-0.080
c. Clean bottom, brush on sides, highest stage	0.045-0.110
d. Dense brush, high stage	0.080-0.140
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2B-4. Summary of Peak Discharge and Total Discharge Volumes at Site Outfalls

Location	Item	Pre-Development (25-year)	Post-Development (25-year)
Midpoint Site Outfall	Peak Discharge (cfs)	515.4	515.4
	Total Runoff Volume (ac-ft)	36.3	33.6
Overall Site Outfall	Peak Discharge (cfs)	802.6	797.1
	Total Runoff Volume (ac-ft)	78.7	82.0

FIGURES

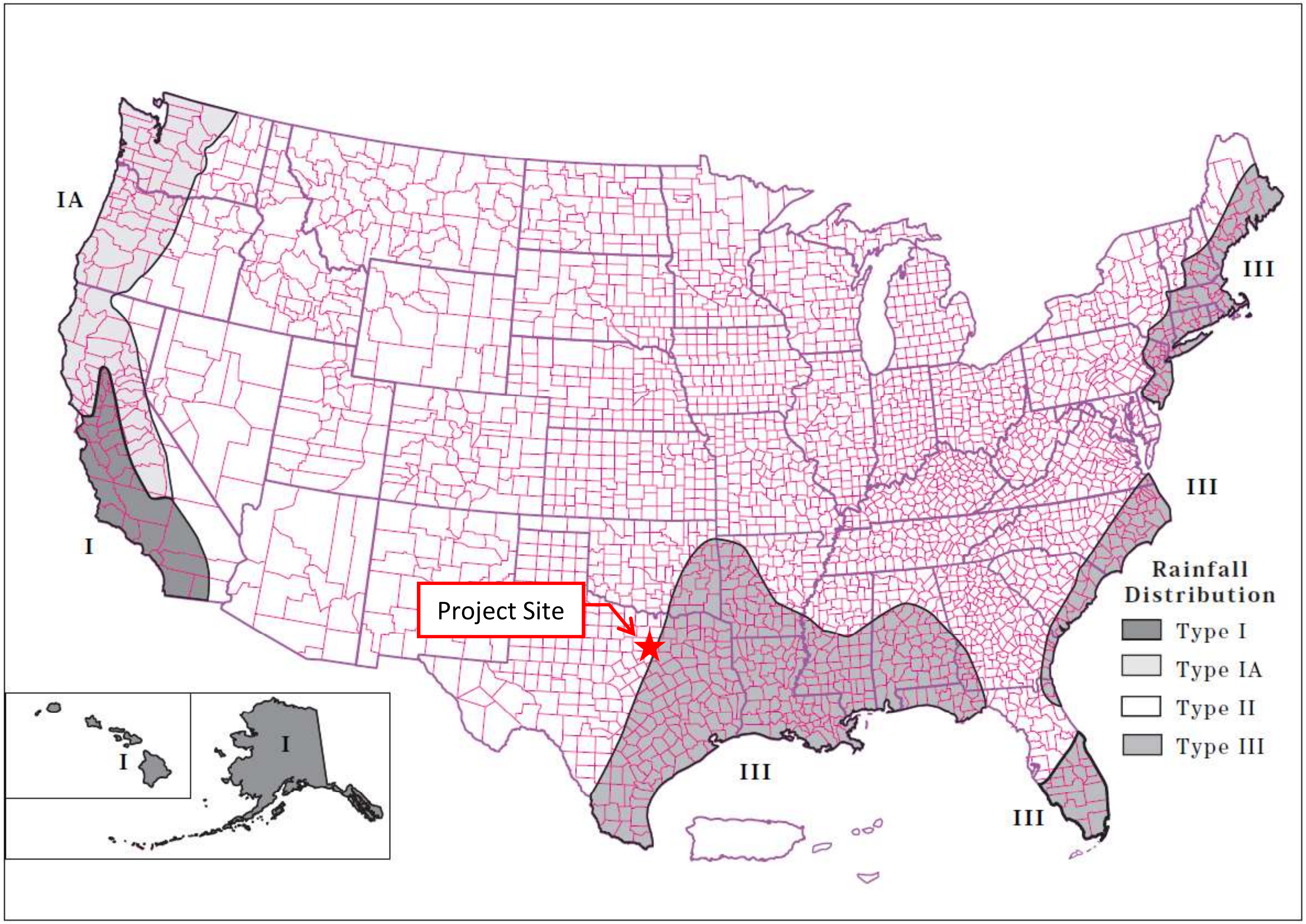

Figure 2B-1. SCS Rainfall Distributions (from USDA, 1986)

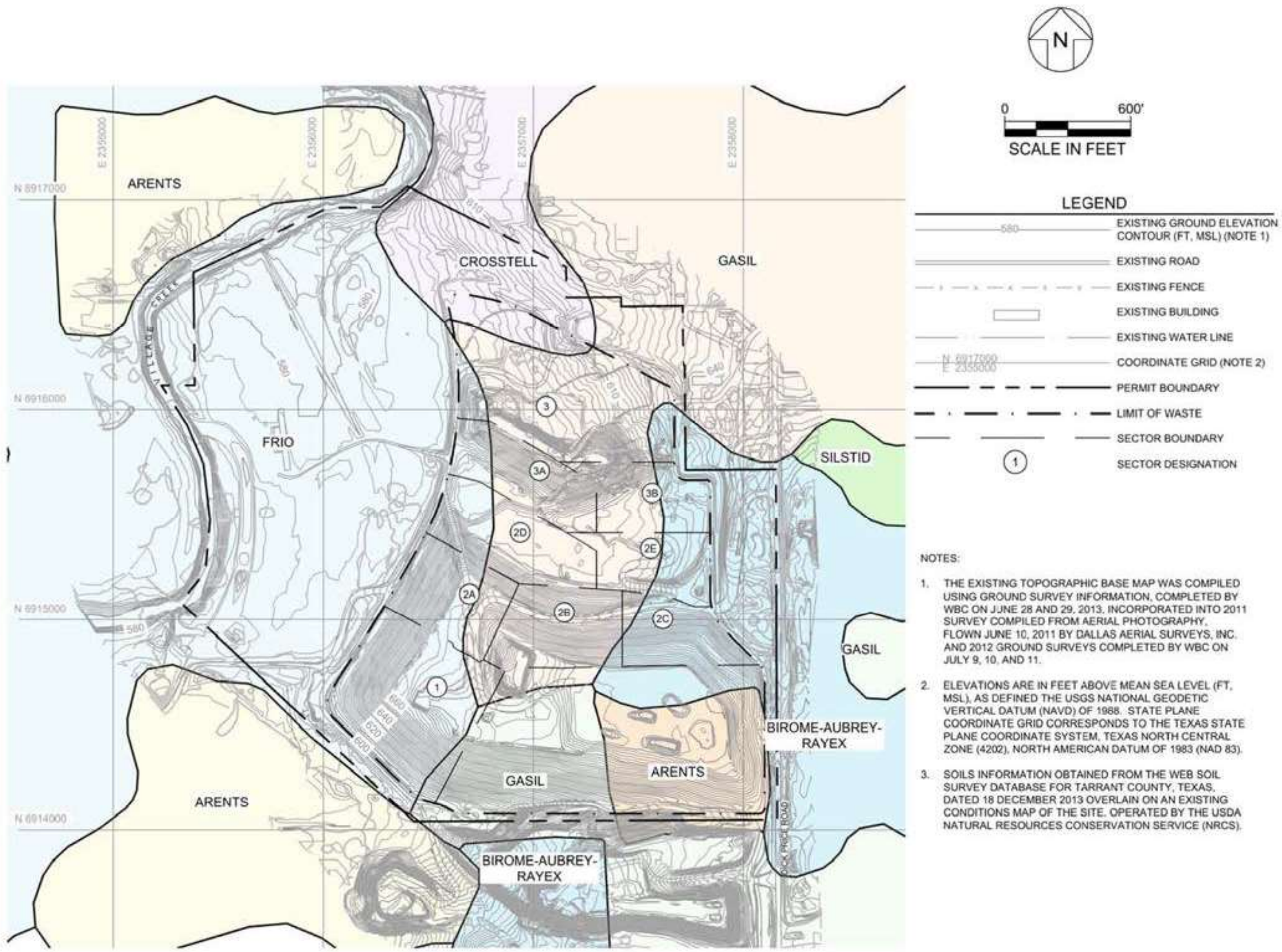

Figure 2B-2. Soil Survey Map

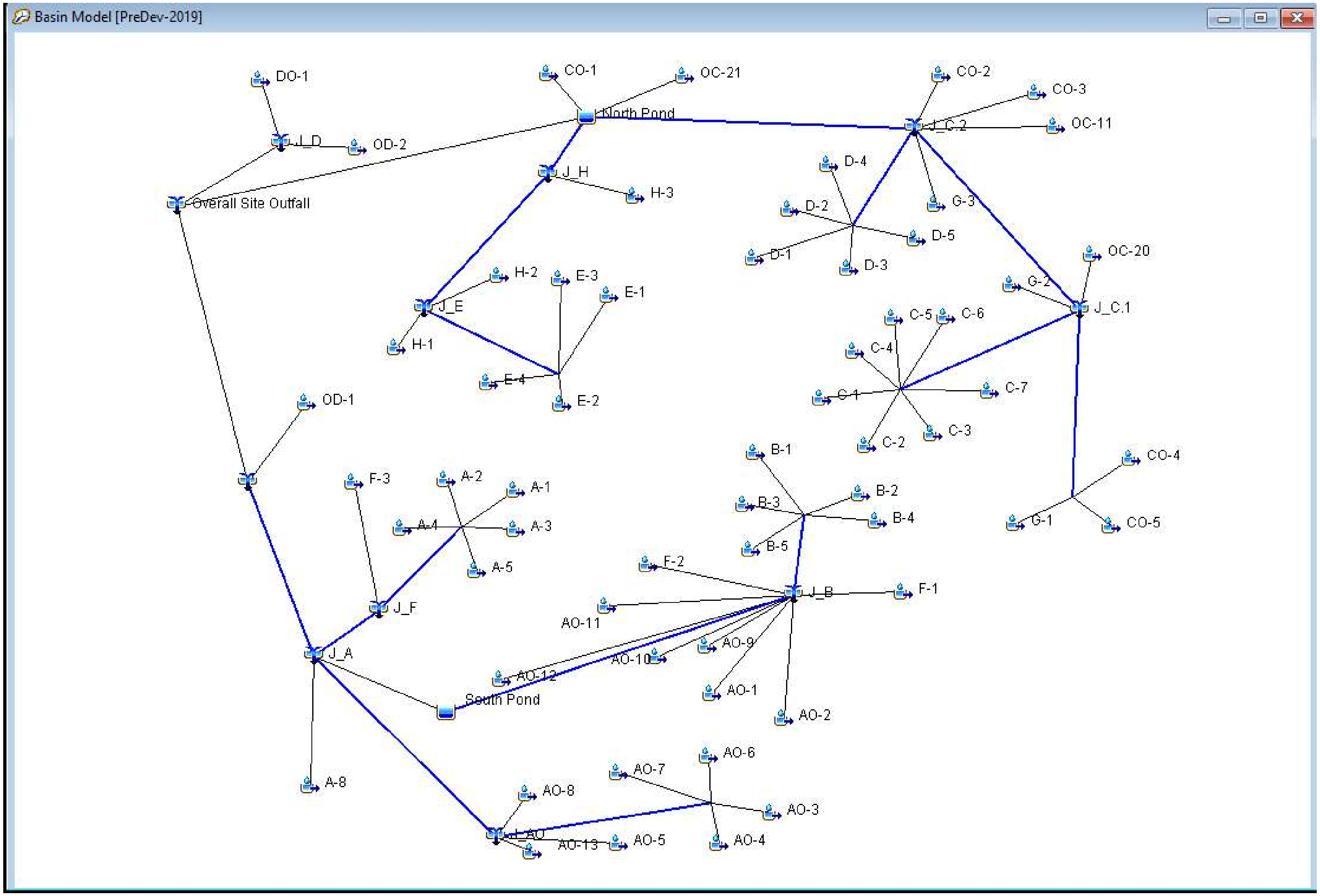

Figure 2B-3. Pre-Development HEC-HMS Nodal Network

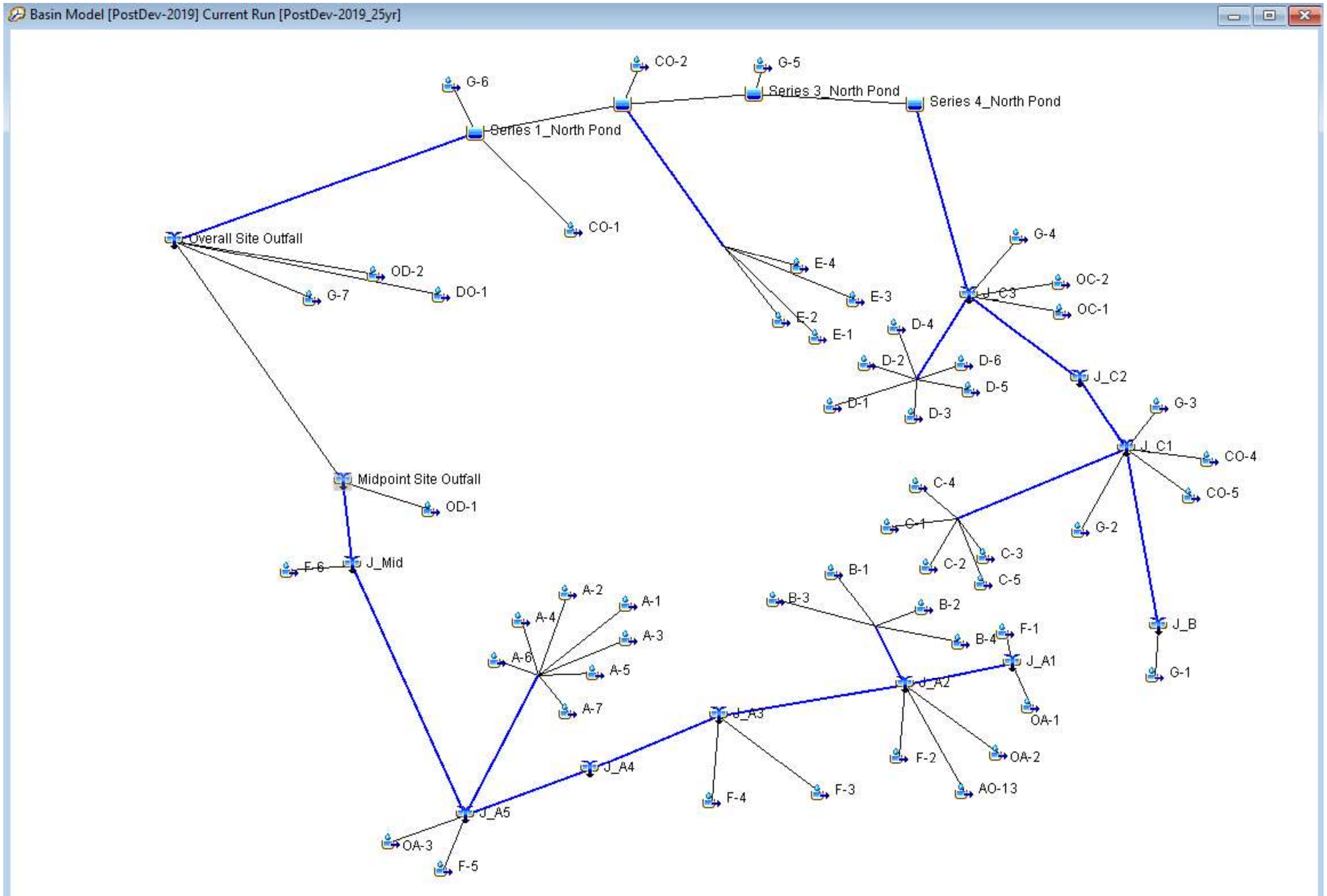

Figure 2B-4. Post-Development HEC-HMS Nodal Network

APPENDIX 2B-1
HEC-HMS HYDROLOGIC MODEL PARAMETERS

Table 2B-1-1. Pre-Development Permitted North Surface Water Pond Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
588.0	0.7703
588.5	0.8016
589.0	0.8331
589.5	0.8650
590.0	0.8971
590.5	0.9296
591.0	0.9623
591.5	0.9954
592.0	1.0287
592.5	1.0623
593.0	1.0963
593.5	1.1305
594.0	1.1650
594.5	1.1998
595.0	1.2350
595.5	1.2704
596.0	1.3061
596.5	1.3421
597.0	1.3784
597.5	1.4150
598.0	1.4519
598.5	1.4891
600.0	1.4891

Table 2B-1-2. Pre-Development South Surface Water Pond Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
591.0	0.0847
591.5	0.0961
592.0	0.1079
592.5	0.1200
593.0	0.1327
593.5	0.1458
594.0	0.1592
594.5	0.1731
595.0	0.1874
595.5	0.2021
596.0	0.2172
596.5	0.2327
597.0	0.2485
597.5	0.2648
598.0	0.2813
598.5	0.2981
599.0	0.3153
599.5	0.3328
600.0	0.3507

Table 2B-1-3. Pre-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PreDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PreDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PreDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 10:29:31 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
AO-1	0.01045	41.8	01Jan2019, 11:57	3.87
AO-10	0.00055	2.2	01Jan2019, 11:57	3.87
AO-11	0.00114	4.6	01Jan2019, 11:57	3.87
AO-12	0.00133	5.3	01Jan2019, 11:57	3.87
AO-13	0.01602	59.9	01Jan2019, 11:59	3.87
AO-2	0.00483	19.4	01Jan2019, 11:57	3.87
AO-3	0.00306	12.3	01Jan2019, 11:57	3.87
AO-4	0.00272	10.9	01Jan2019, 11:57	3.87
AO-5	0.00250	10.0	01Jan2019, 11:57	3.87
AO-6	0.00017	0.7	01Jan2019, 11:57	3.87
AO-7	0.00072	2.9	01Jan2019, 11:57	3.87
AO-8	0.00216	8.7	01Jan2019, 11:57	3.87
AO-9	0.00027	1.1	01Jan2019, 11:57	3.87
A-1	0.00880	42.7	01Jan2019, 11:59	5.42
A-2	0.00377	20.2	01Jan2019, 11:57	5.42
A-3	0.00330	17.7	01Jan2019, 11:57	5.42
A-4	0.00703	37.6	01Jan2019, 11:57	5.42
A-5	0.00453	24.3	01Jan2019, 11:57	5.42
A-8	0.00238	12.7	01Jan2019, 11:57	5.42
B-1	0.00345	16.8	01Jan2019, 11:59	5.42
B-2	0.00105	5.6	01Jan2019, 11:57	5.42
B-3	0.00291	15.6	01Jan2019, 11:57	5.42
B-4	0.00353	18.9	01Jan2019, 11:57	5.42
B-5	0.00353	18.9	01Jan2019, 11:57	5.42
Channel AO	0.02735	103.6	01Jan2019, 12:00	3.86
Channel A.1	0.04313	202.1	01Jan2019, 11:58	4.75
Channel A.2	0.11168	438.2	01Jan2019, 12:02	4.78
Channel North 1	0.01517	65.8	01Jan2019, 11:58	4.35
Channel North 2	0.04492	215.2	01Jan2019, 11:59	4.98
Channel North 3	0.07893	359.7	01Jan2019, 12:00	4.86
CO-1	0.00472	17.3	01Jan2019, 11:59	3.87
CO-2	0.01319	45.8	01Jan2019, 12:01	3.87
CO-3	0.01038	49.0	01Jan2019, 11:59	5.08
CO-4	0.00895	34.9	01Jan2019, 11:58	3.87
CO-5	0.00147	5.9	01Jan2019, 11:57	3.87
C-1	0.00417	21.4	01Jan2019, 11:58	5.42
C-2	0.00205	11.0	01Jan2019, 11:57	5.42
C-3	0.00358	19.2	01Jan2019, 11:57	5.42
C-4	0.00189	10.1	01Jan2019, 11:57	5.42
C-5	0.00273	14.6	01Jan2019, 11:57	5.42
C-6	0.00120	6.4	01Jan2019, 11:57	5.42
C-7	0.00217	11.6	01Jan2019, 11:57	5.42
Downchute A	0.02743	139.5	01Jan2019, 11:58	5.42
Downchute AO	0.00667	26.7	01Jan2019, 11:57	3.87
Downchute B	0.01447	74.6	01Jan2019, 11:57	5.42
Downchute C	0.01779	94.0	01Jan2019, 11:57	5.42

Table 2B-1-3 (continued). Pre-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PreDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PreDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PreDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time:06Jan2020, 10:29:31 Control Specifications:Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Downchute A	0.02743	139.5	01Jan2019, 11:58	5.42
Downchute AO	0.00667	26.7	01Jan2019, 11:57	3.87
Downchute B	0.01447	74.6	01Jan2019, 11:57	5.42
Downchute C	0.01779	94.0	01Jan2019, 11:57	5.42
Downchute D	0.00822	44.0	01Jan2019, 11:57	5.42
Downchute E	0.01144	61.2	01Jan2019, 11:57	5.41
DO-1	0.00272	9.9	01Jan2019, 12:00	3.87
Drop North	0.02895	154.2	01Jan2019, 11:57	5.41
Drop South	0.03882	199.8	01Jan2019, 11:57	5.42
D-1	0.00319	17.1	01Jan2019, 11:57	5.42
D-2	0.00211	11.3	01Jan2019, 11:57	5.42
D-3	0.00053	2.8	01Jan2019, 11:57	5.42
D-4	0.00181	9.7	01Jan2019, 11:57	5.42
D-5	0.00058	3.1	01Jan2019, 11:57	5.42
E-1	0.00086	4.6	01Jan2019, 11:57	5.42
E-2	0.00327	17.5	01Jan2019, 11:57	5.42
E-3	0.00320	17.1	01Jan2019, 11:57	5.42
E-4	0.00411	22.0	01Jan2019, 11:57	5.42
F-1	0.00173	9.3	01Jan2019, 11:57	5.42
F-2	0.00836	44.8	01Jan2019, 11:57	5.42
F-3	0.01139	60.5	01Jan2019, 11:57	5.42
G-1	0.00475	25.4	01Jan2019, 11:57	5.42
G-2	0.00230	12.3	01Jan2019, 11:57	5.42
G-3	0.00195	10.4	01Jan2019, 11:57	5.42
H-1	0.00503	26.9	01Jan2019, 11:57	5.42
H-2	0.00339	18.1	01Jan2019, 11:57	5.42
H-3	0.00909	48.7	01Jan2019, 11:57	5.42
J_A	0.11168	440.5	01Jan2019, 12:01	4.78
J_AO	0.02735	104.2	01Jan2019, 11:58	3.87
J_B	0.02456	128.6	01Jan2019, 11:57	5.42
J_C.1	0.04492	215.4	01Jan2019, 11:58	4.98
J_C.2	0.07893	361.1	01Jan2019, 11:59	4.86
J_D	0.05006	156.9	01Jan2019, 12:03	3.87
J_E	0.01986	106.3	01Jan2019, 11:57	5.41
J_F	0.03882	199.8	01Jan2019, 11:57	5.42
J_H	0.02895	154.3	01Jan2019, 11:57	5.41
Midpoint Site Outfall	0.14957	515.4	01Jan2019, 12:02	4.55
MSE North	0.01986	105.7	01Jan2019, 11:58	5.41
North Pond	0.12405	268.6	01Jan2019, 12:08	4.86
OC-11	0.00027	1.4	01Jan2019, 11:57	5.42
OC-20	0.00966	45.3	01Jan2019, 11:59	5.08
OC-21	0.01145	40.7	01Jan2019, 12:00	3.87
OD-1	0.03789	94.7	01Jan2019, 12:08	3.87
OD-2	0.04734	148.2	01Jan2019, 12:03	3.87
Overall Site Outfall	0.32368	802.6	01Jan2019, 12:05	4.56
South Pond	0.04313	168.0	01Jan2019, 12:02	4.75

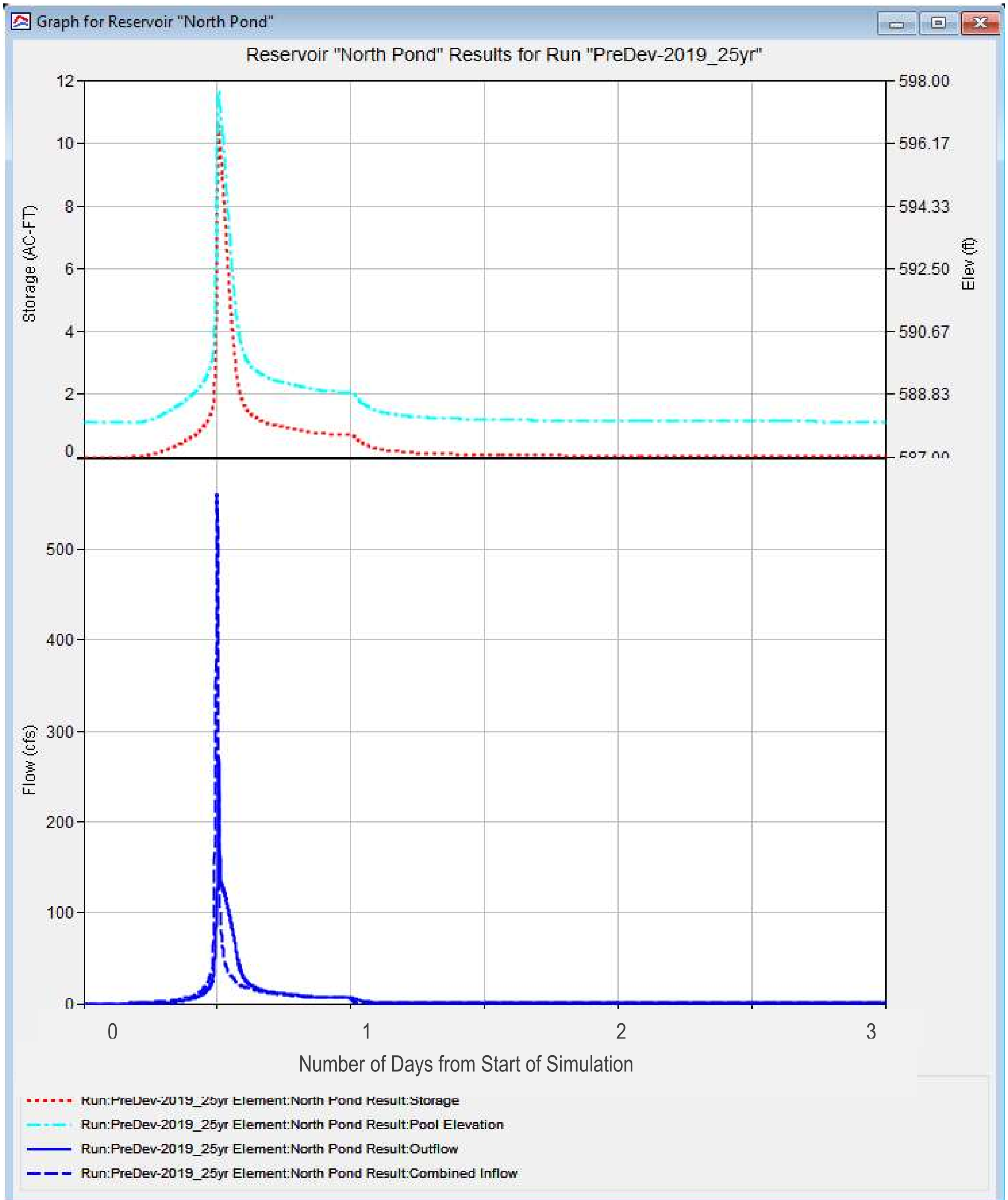

Figure 2B-1-1. Pre-Development 25-year, 24-hour Precipitation Event Permitted North Surface Water Pond Hydrograph and Elevation/Storage Relationships

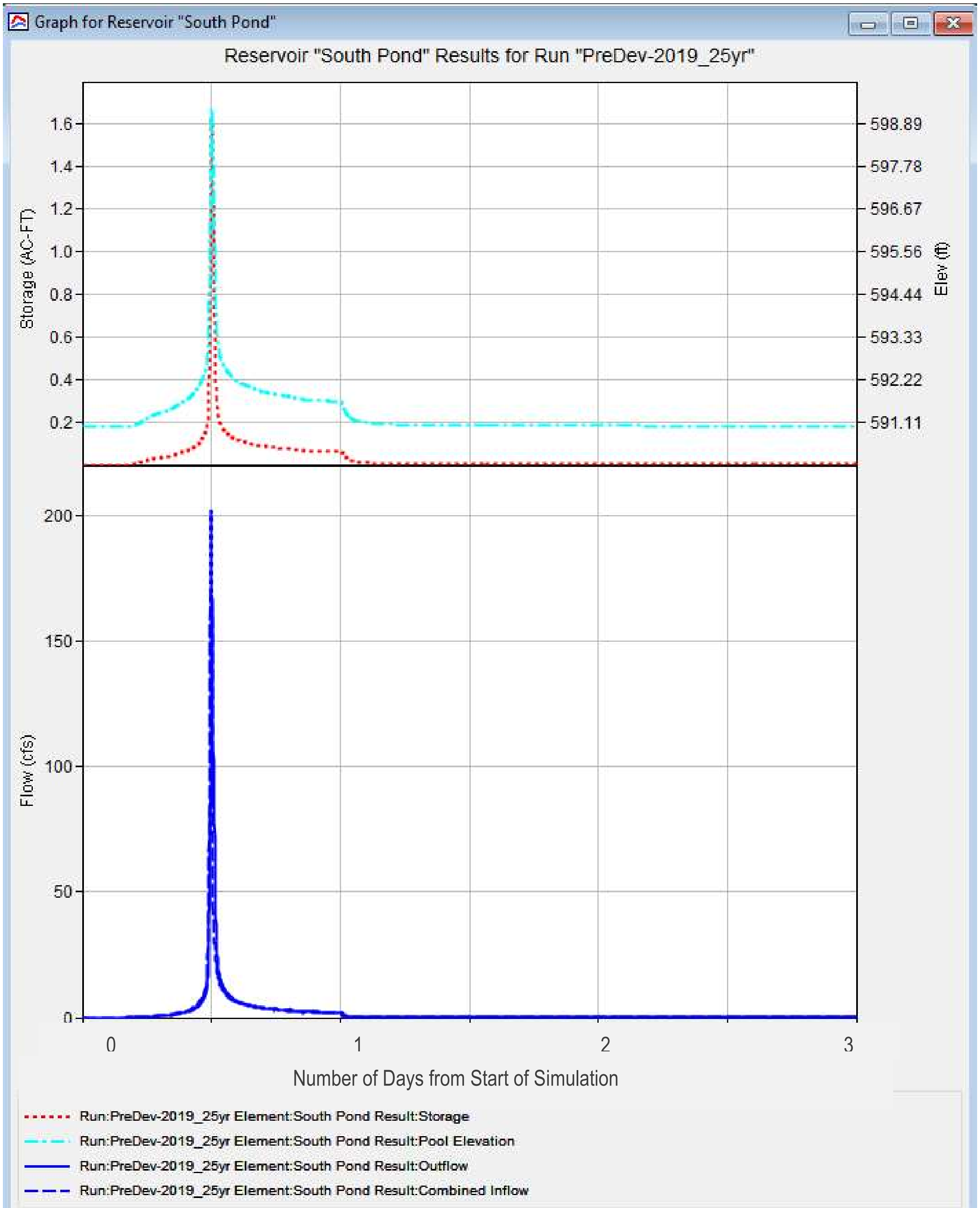

Figure 2B-1-2. Pre-Development 25-year, 24-hour Precipitation Event Permitted South Surface Water Pond Hydrograph and Elevation/Storage Relationships

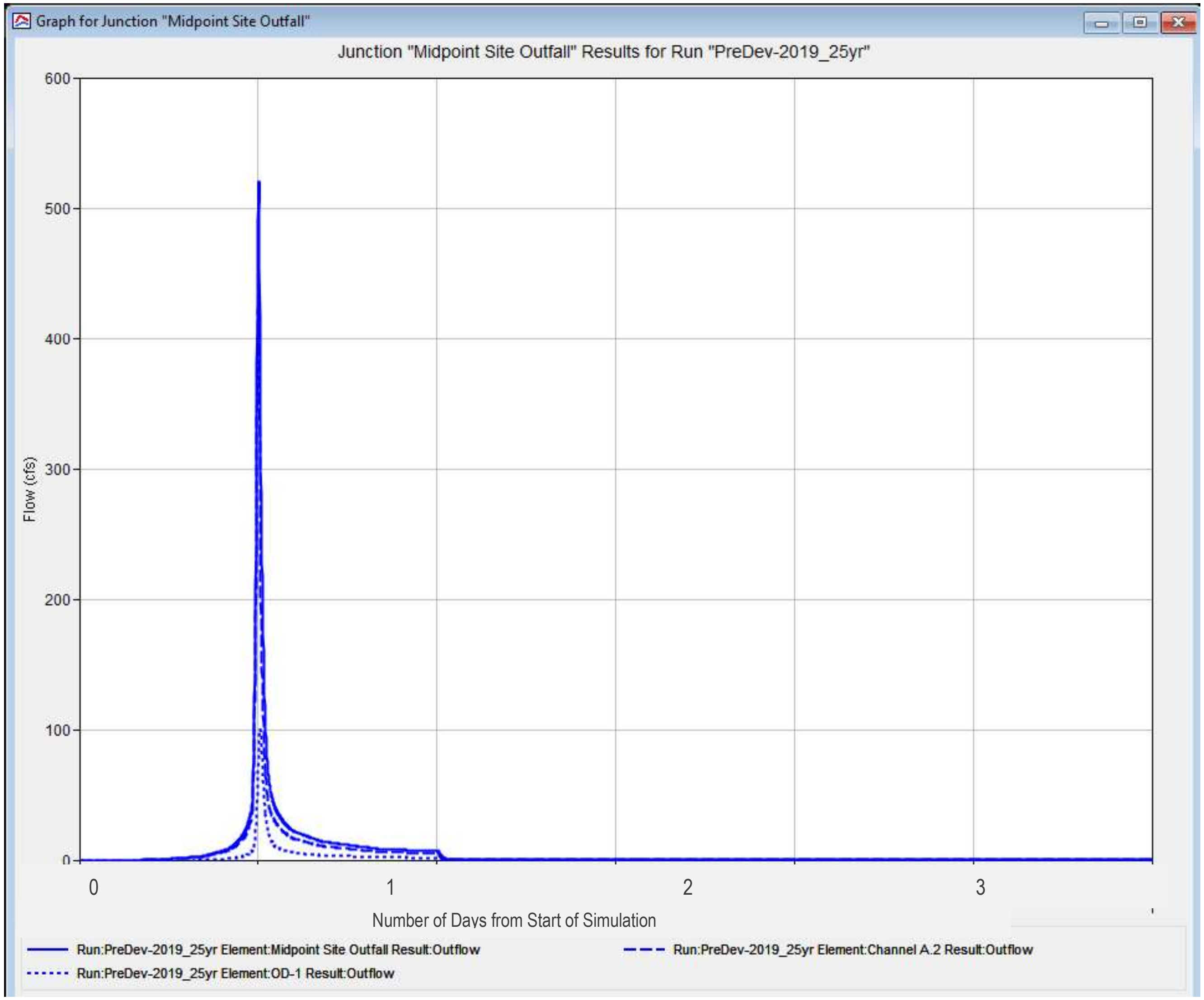

Figure 2B-1-3. Pre-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Midpoint Site Outfall

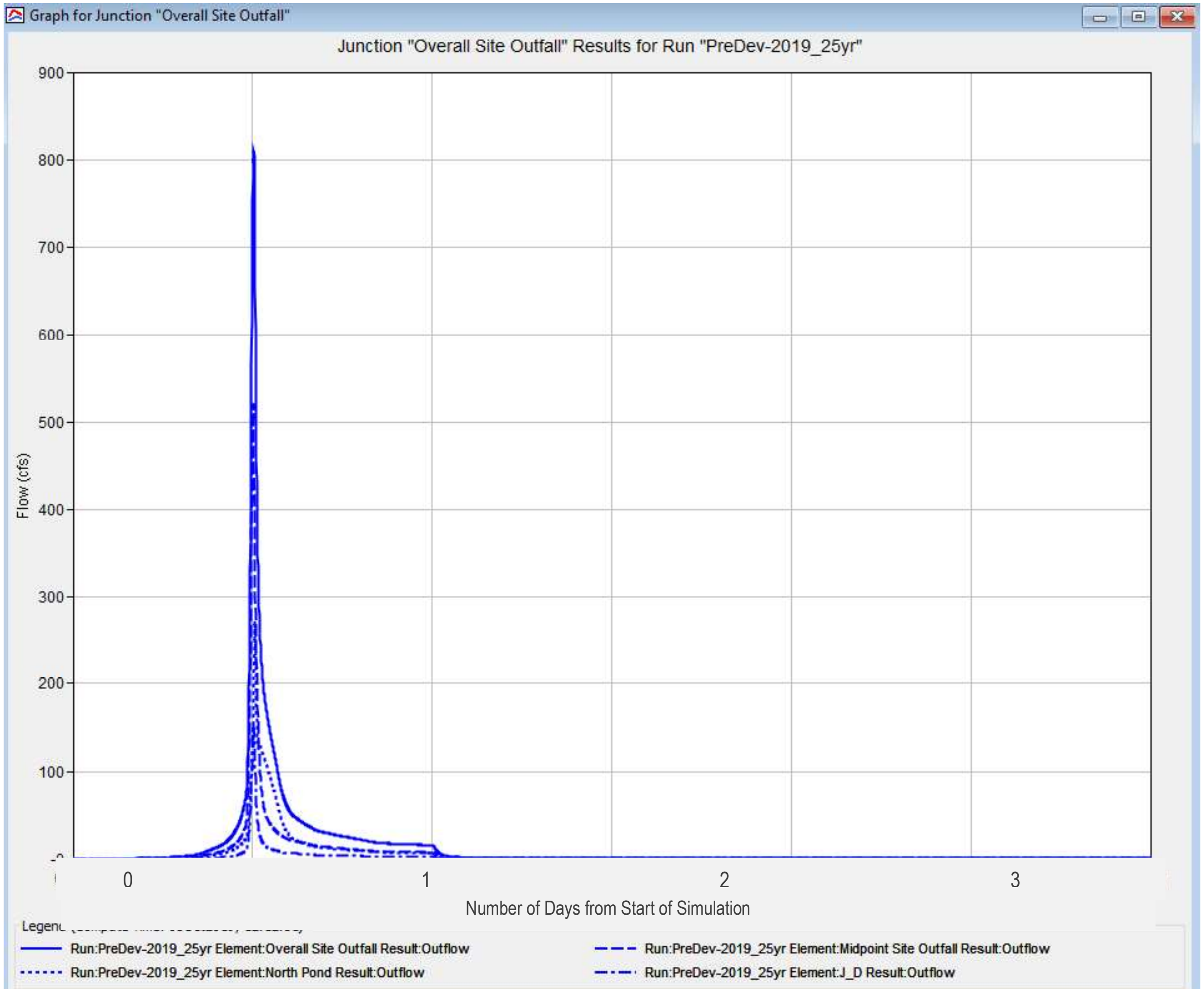

Figure 2B-1-4. Pre-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Overall Site Outfall

Table 2B-1-4a. Post-Development North Surface Water Pond Series 1 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
588.000	0.58107
589.000	0.67440
590.000	0.76805
591.000	0.86336
592.000	0.96296
593.000	1.06660
594.000	1.17050
595.000	1.27370
596.000	1.39090
597.000	1.48980
598.500	1.48980

Table 2B-1-4b. Post-Development North Surface Water Pond Series 2 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
597.000	0.0000000
598.000	0.0370574
599.000	0.1279600
600.000	0.1829600
601.000	0.2499000
602.000	0.3242600
603.000	0.3671600
604.200	0.4000000

Table 2B-1-4c. Post-Development North Surface Water Pond Series 3 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
603.000	0.0000000
604.000	0.0097720
605.000	0.0612539
606.000	0.1220700
607.000	0.1855800
608.000	0.2432300
609.000	0.2940500
610.000	0.3486000
611.000	0.4074200
612.000	0.4525400
613.000	0.4970200
614.200	0.5300000

Table 2B-1-4d. Post-Development North Surface Water Pond Series 4 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
613.000	0.0000000
615.000	0.0212961
616.000	0.0567124
617.000	0.0964187
618.000	0.1217600
619.000	0.1509500
620.000	0.1831400
621.000	0.2177300
622.000	0.2547100
623.000	0.2940900
624.000	0.3359000
625.000	0.3600000

Table 2B-1-5. Post-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PostDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PostDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PostDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 09:07:20 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
AO-13	0.0106400	39.8	01Jan2019, 11:59	3.87
A-1	0.0137800	66.2	01Jan2019, 12:00	5.42
A-2	.00039063	2.1	01Jan2019, 11:57	5.42
A-3	0.0019100	10.2	01Jan2019, 11:57	5.42
A-4	0.0026719	14.3	01Jan2019, 11:57	5.42
A-5	0.0044500	23.8	01Jan2019, 11:57	5.42
A-6	0.0038906	20.8	01Jan2019, 11:57	5.42
A-7	0.0064100	34.3	01Jan2019, 11:57	5.42
B-1	0.0038600	19.6	01Jan2019, 11:58	5.42
B-2	0.0034500	18.5	01Jan2019, 11:57	5.42
B-3	0.0047500	25.4	01Jan2019, 11:57	5.42
B-4	0.0061600	33.0	01Jan2019, 11:57	5.42
Channel A	0.0918631	446.9	01Jan2019, 12:00	5.23
CO-1	0.0047200	17.3	01Jan2019, 11:59	3.87
CO-2	0.0075800	26.7	01Jan2019, 12:00	3.87
CO-4	0.0089500	34.9	01Jan2019, 11:58	3.87
CO-5	0.0014700	5.9	01Jan2019, 11:57	3.87
C-1	0.0121400	61.9	01Jan2019, 11:58	5.42
C-2	0.0072200	36.1	01Jan2019, 11:59	5.42
C-3	0.0026700	14.3	01Jan2019, 11:57	5.42
C-4	0.0049400	26.4	01Jan2019, 11:57	5.42
C-5	0.0035500	19.0	01Jan2019, 11:57	5.42
Downchute A	0.0335031	167.7	01Jan2019, 11:58	5.42
Downchute B	0.0182200	96.0	01Jan2019, 11:57	5.42
Downchute C	0.0305200	156.2	01Jan2019, 11:58	5.42
Downchute D	0.0143062	76.6	01Jan2019, 11:57	5.42
Downchute E	0.0249231	133.4	01Jan2019, 11:57	5.41
DO-1	0.0027200	9.9	01Jan2019, 12:00	3.87
D-1	.00059	3.2	01Jan2019, 11:57	5.42
D-2	0.0012000	6.4	01Jan2019, 11:57	5.42
D-3	0.0011100	5.9	01Jan2019, 11:57	5.42
D-4	0.0081563	43.7	01Jan2019, 11:57	5.42
D-5	0.0013600	7.3	01Jan2019, 11:57	5.42
D-6	0.0018900	10.1	01Jan2019, 11:57	5.42
E-1	0.0029200	15.6	01Jan2019, 11:57	5.42
E-2	0.0089219	47.8	01Jan2019, 11:57	5.42
E-3	0.0033000	17.7	01Jan2019, 11:57	5.42
E-4	0.0097813	52.4	01Jan2019, 11:57	5.42
F-1	0.0032300	17.3	01Jan2019, 11:57	5.42
F-2	0.0011900	6.4	01Jan2019, 11:57	5.42
F-3	0.0015600	8.4	01Jan2019, 11:57	5.42
F-4	0.0026900	14.4	01Jan2019, 11:57	5.42
F-5	0.0024200	13.0	01Jan2019, 11:57	5.42
F-6	0.0083600	44.8	01Jan2019, 11:57	5.42
G-1	0.0057500	30.8	01Jan2019, 11:57	5.42
G-2	0.0079700	42.7	01Jan2019, 11:57	5.42

Table 2B-1-5 (continued). Post-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PostDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PostDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PostDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 09:07:20 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
F-1	0.0032300	17.3	01Jan2019, 11:57	5.42
F-2	0.0011900	6.4	01Jan2019, 11:57	5.42
F-3	0.0015600	8.4	01Jan2019, 11:57	5.42
F-4	0.0026900	14.4	01Jan2019, 11:57	5.42
F-5	0.0024200	13.0	01Jan2019, 11:57	5.42
F-6	0.0083600	44.8	01Jan2019, 11:57	5.42
G-1	0.0057500	30.8	01Jan2019, 11:57	5.42
G-2	0.0079700	42.7	01Jan2019, 11:57	5.42
G-3	0.0011900	6.4	01Jan2019, 11:57	5.42
G-4	0.0016300	8.7	01Jan2019, 11:57	5.42
G-5	.00041	2.2	01Jan2019, 11:57	5.42
G-6	0.0014700	7.9	01Jan2019, 11:57	5.42
G-7	0.0034800	18.6	01Jan2019, 11:57	5.42
J_A1	0.0067300	36.0	01Jan2019, 11:57	5.42
J_A2	0.0409400	197.2	01Jan2019, 11:58	5.01
J_A3	0.0451900	218.1	01Jan2019, 11:58	5.05
J_A4	0.0451900	217.7	01Jan2019, 11:59	5.05
J_A5	0.0835031	406.0	01Jan2019, 11:59	5.22
J_B	0.0057500	30.8	01Jan2019, 11:57	5.42
J_C1	0.0558500	275.6	01Jan2019, 11:57	5.13
J_C2	0.0558500	275.6	01Jan2019, 11:58	5.12
J_C3	0.10014	466.8	01Jan2019, 11:59	5.01
J_Mid	0.0918631	447.4	01Jan2019, 11:59	5.23
Midpoint Site Outfall	0.13049	515.4	01Jan2019, 12:01	4.83
OA-1	0.0035000	18.7	01Jan2019, 11:57	5.42
OA-2	0.0041600	22.1	01Jan2019, 11:57	5.42
OA-3	0.0023900	12.8	01Jan2019, 11:57	5.42
OC-1	0.0164400	71.8	01Jan2019, 12:01	5.08
OC-2	0.0119100	42.3	01Jan2019, 12:00	3.87
OD-1	0.0386300	96.6	01Jan2019, 12:08	3.87
OD-2	0.0477500	149.5	01Jan2019, 12:03	3.87
Overall Site Outfall	0.32368	797.1	01Jan2019, 12:01	4.75
Peri A1	0.0067300	36.0	01Jan2019, 12:00	5.42
Peri A2	0.0409400	196.1	01Jan2019, 11:59	5.01
Peri A3	0.0451900	217.7	01Jan2019, 11:59	5.05
Peri A4	0.0451900	216.9	01Jan2019, 11:59	5.05
Peri A5	0.0835031	405.9	01Jan2019, 11:59	5.22
Peri B1	0.0057500	30.8	01Jan2019, 11:58	5.41
Peri C1	0.0558500	275.6	01Jan2019, 11:58	5.12
Peri C2	0.0558500	275.2	01Jan2019, 11:59	5.12
Peri C3	0.10014	465.1	01Jan2019, 11:59	5.01
Peri C4	0.13924	358.6	01Jan2019, 12:14	4.99
Series 1_North Pond	0.13924	360.3	01Jan2019, 12:13	4.99
Series 2_North Pond	0.13305	467.4	01Jan2019, 12:02	5.03
Series 3_North Pond	0.10055	369.4	01Jan2019, 12:07	5.02
Series 4_North Pond	0.10014	412.8	01Jan2019, 12:03	5.02

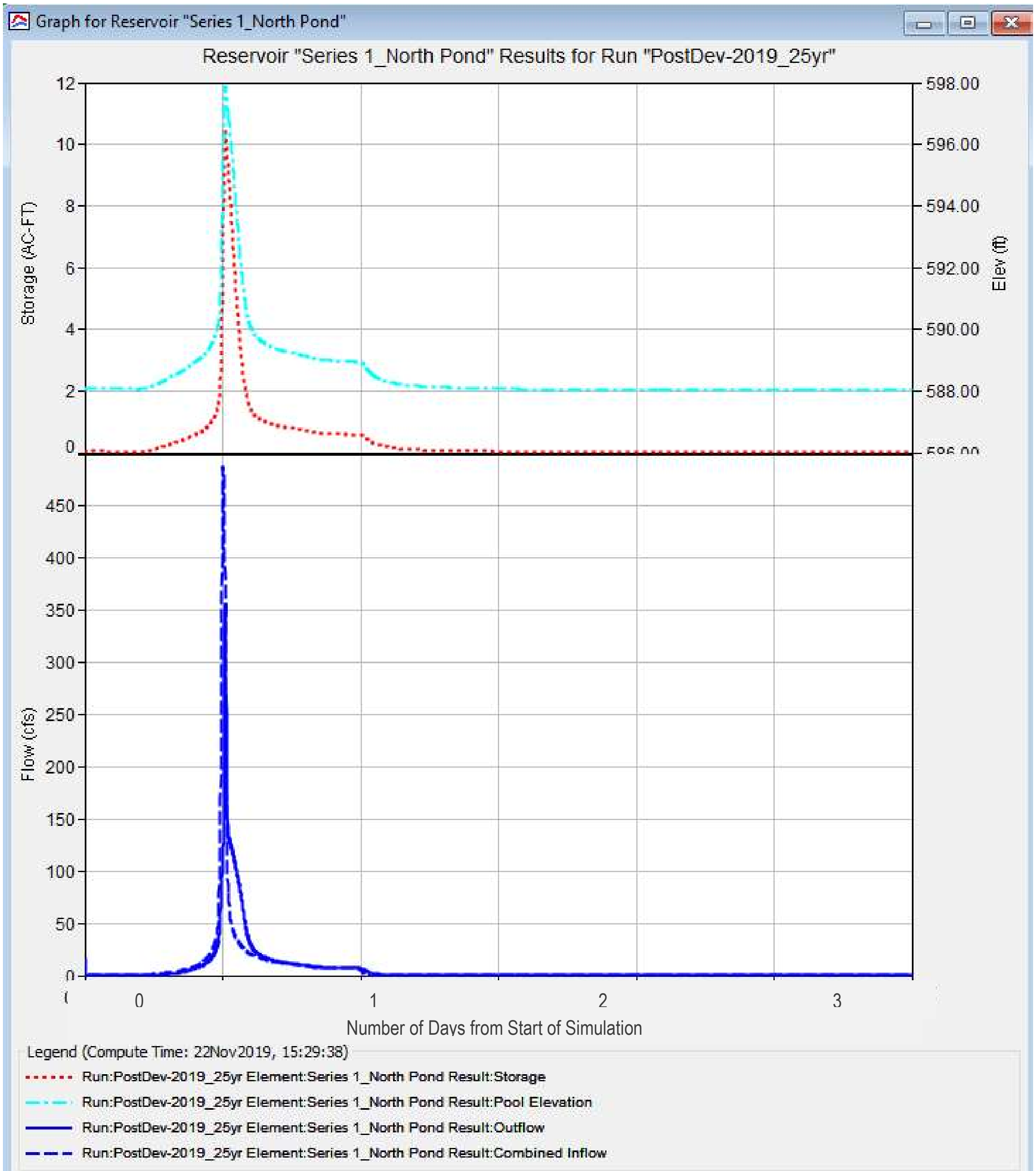

Figure 2B-1-5a. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 1 Hydrograph and Elevation/Storage Relationships

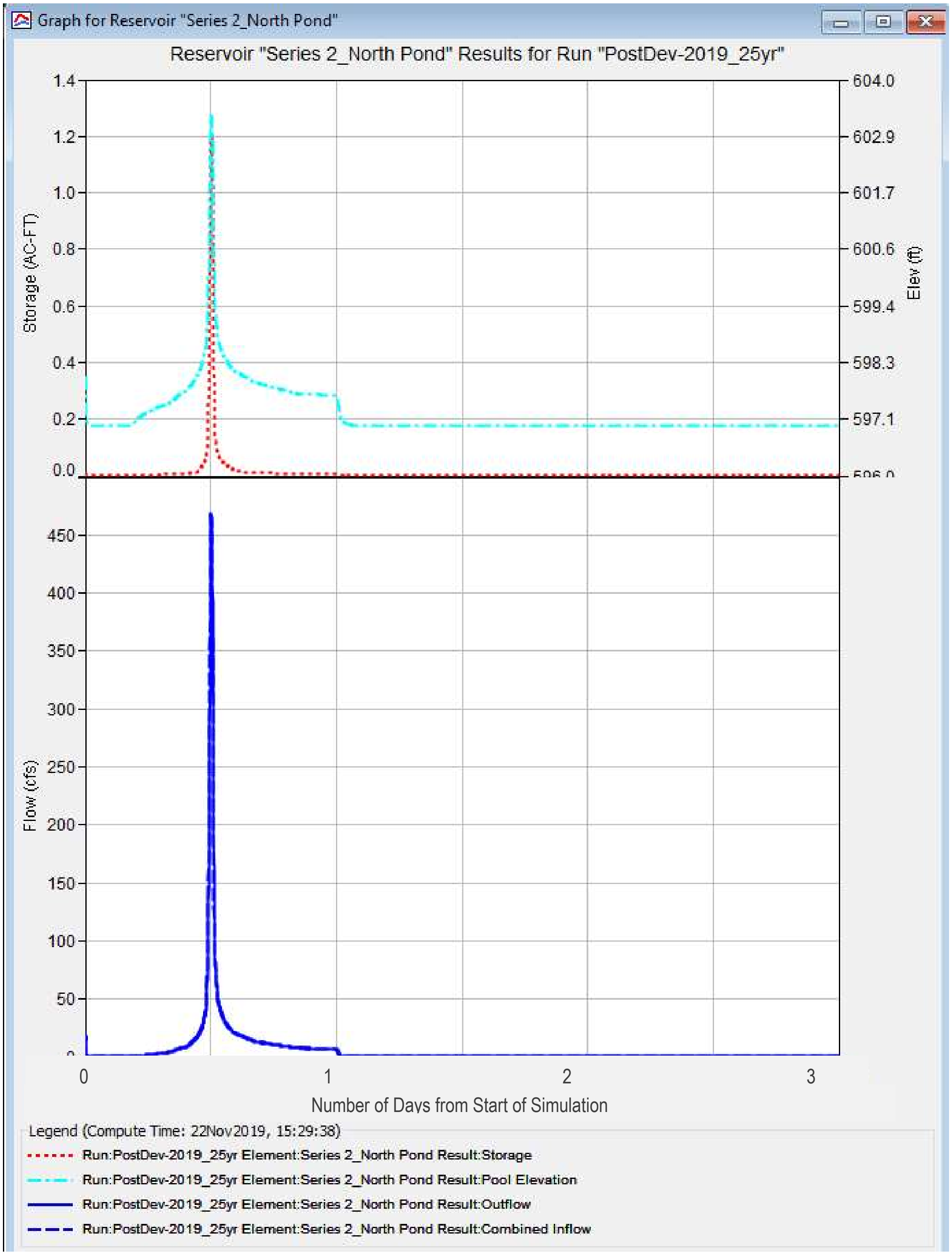

Figure 2B-1-5b. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 2 Hydrograph and Elevation/Storage Relationships

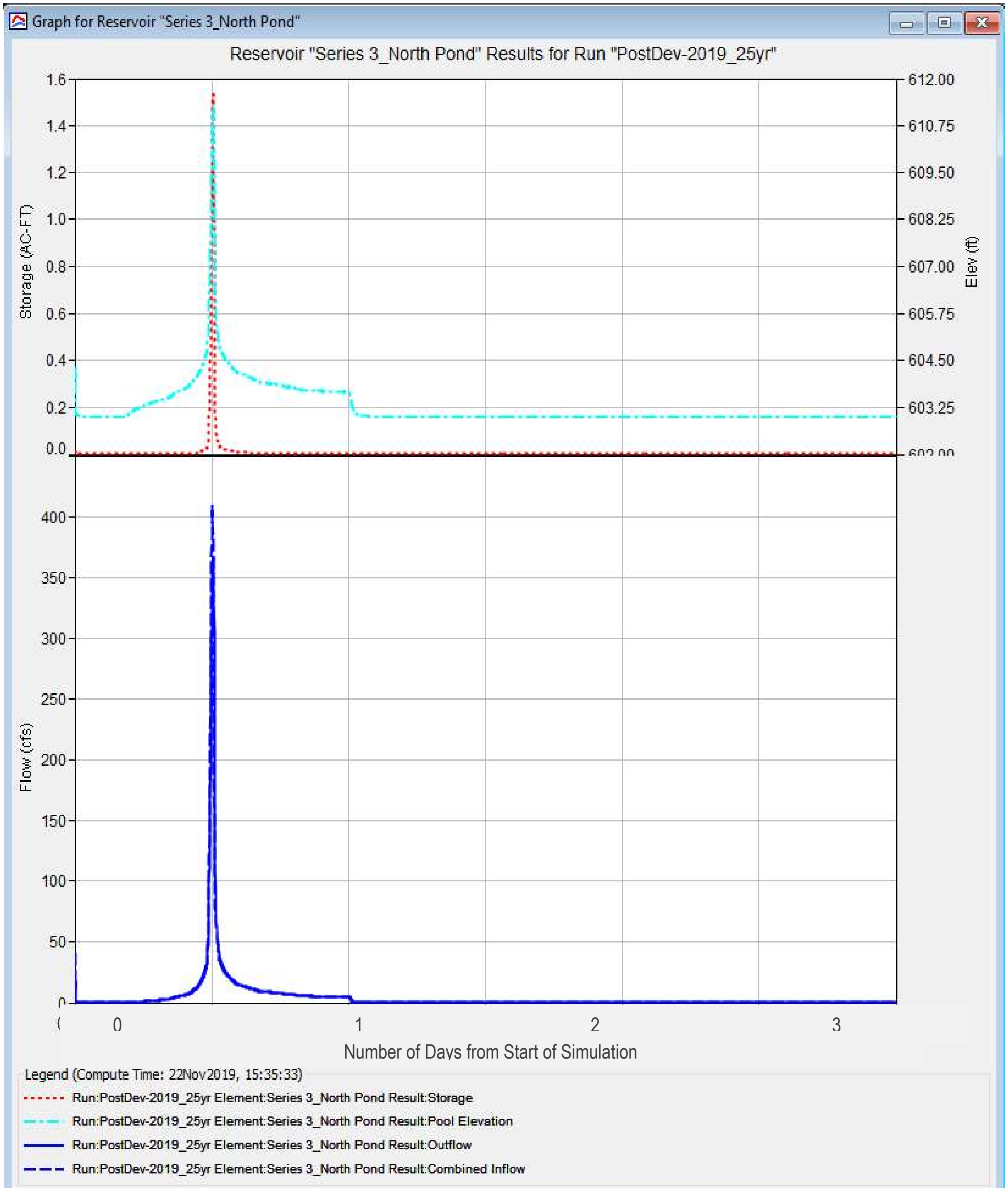

Figure 2B-1-5c. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 3 Hydrograph and Elevation/Storage Relationships

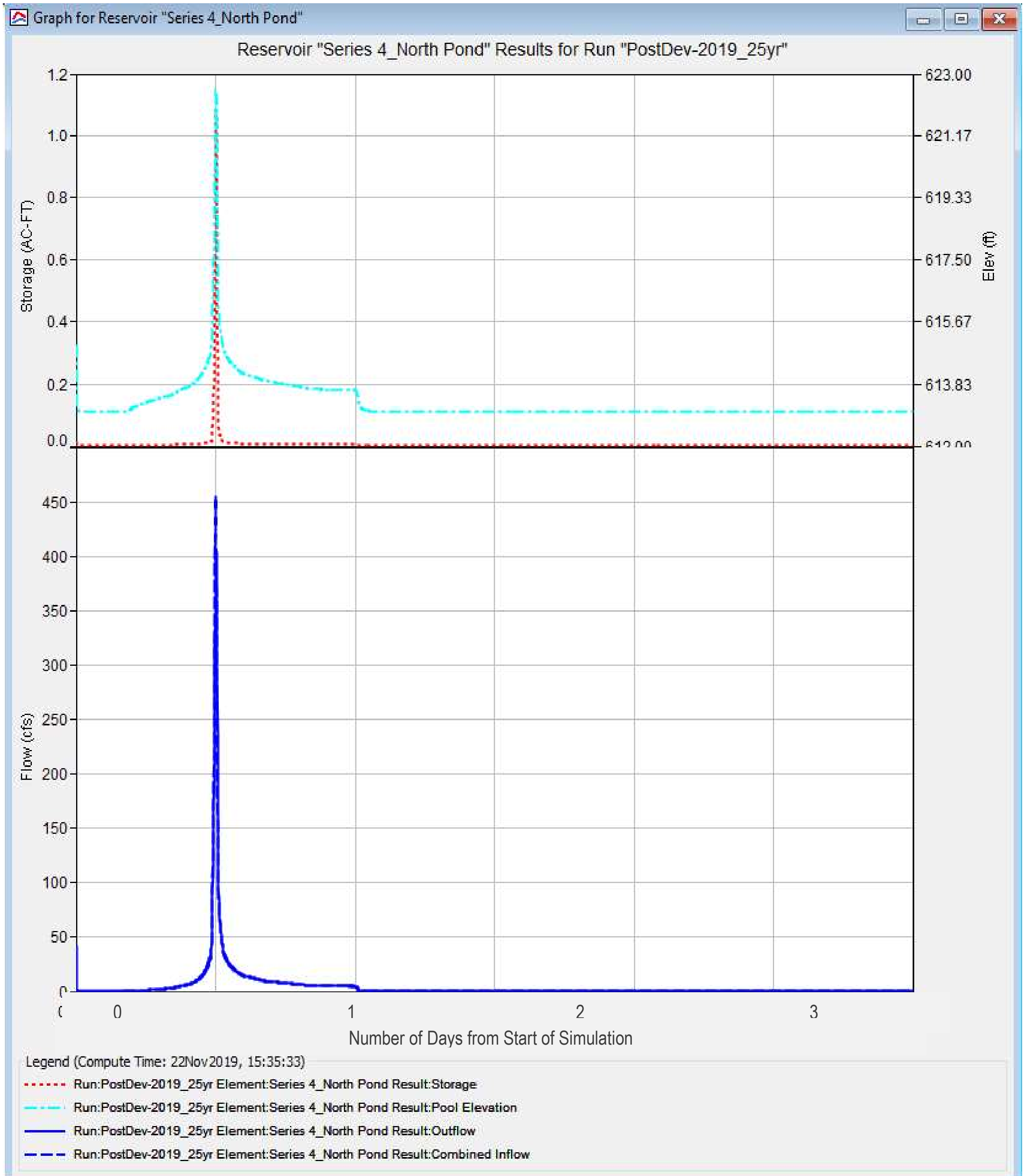

Figure 2B-1-5d. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 4 Hydrograph and Elevation/Storage Relationships

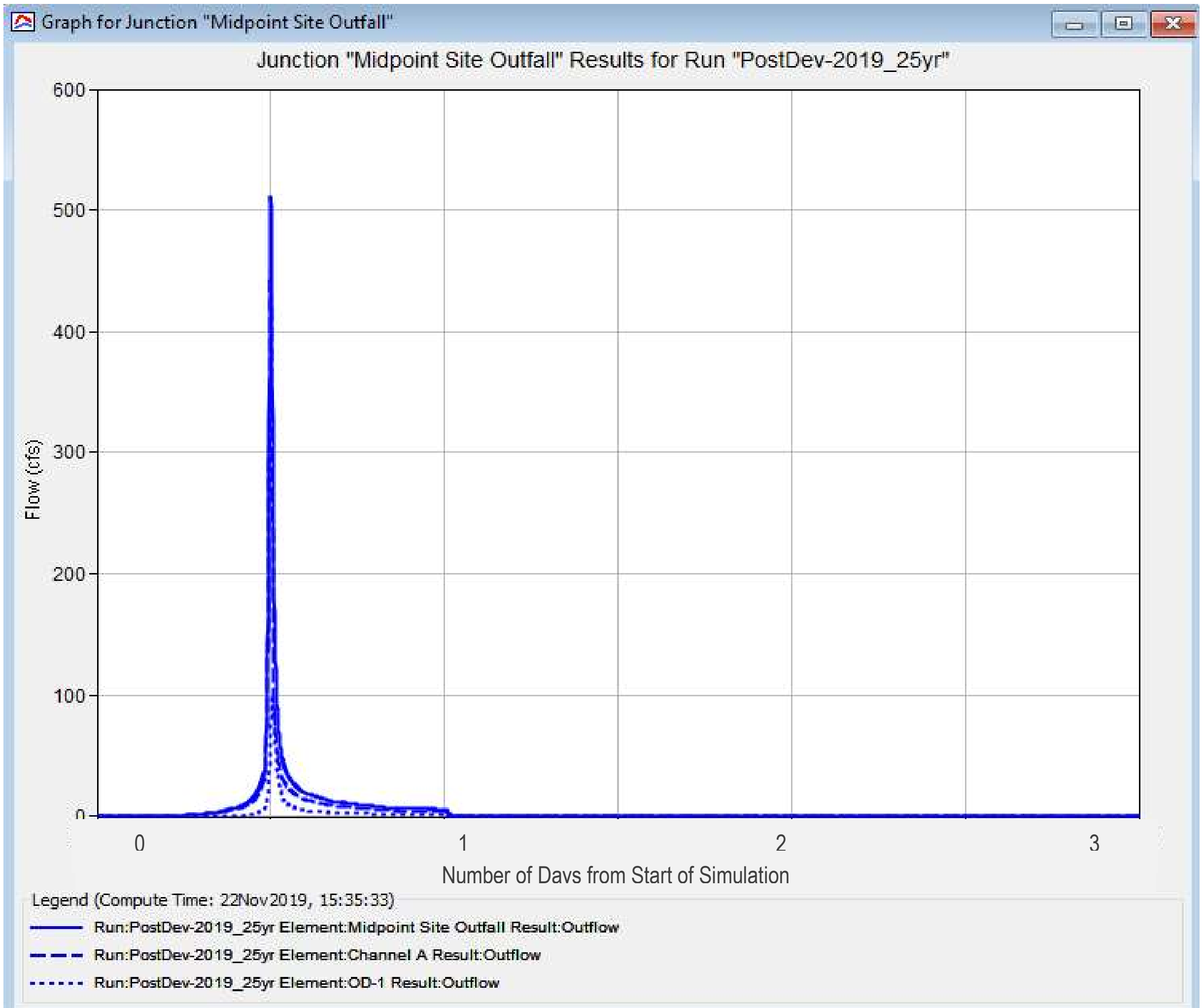

Figure 2B-1-6. Post-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Midpoint Site Outfall

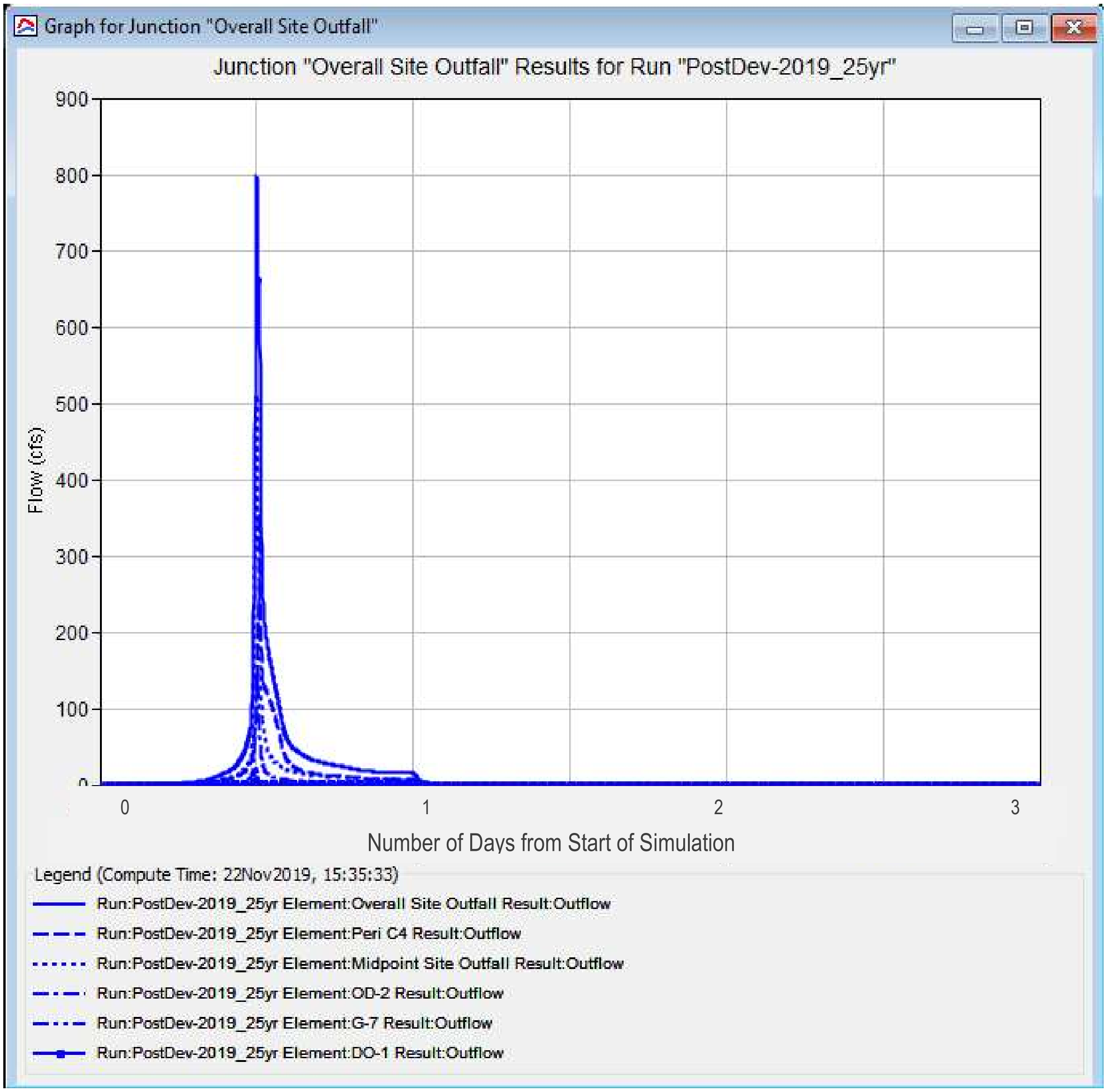

Figure 2B-1-7. Post-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Overall Site Outfall

HEC-HMS PRE-DEVELOPMENT HYDROLOGIC MODEL INPUT PARAMETERS

Pre-Development HEC-HMS Basin Input Parameters for Kinematic Wave Model

PRE-DEVELOPMENT CONDITIONS

			Watershed Characterization			Sheet Flow				Shallow Concentrated Flow					Open Channel Flow												
Subcatchment Designation	Area A (mi²)	Area A (acres)	Initial Abstraction (in)	Curve Number	Impervious Cover (%)	Flow Length (ft)	Manning's n	Slope (ft/ft)	Time T_t (min)	Flow Length (ft)	Velocity Factor (ft/s)	Slope (ft/ft)	Average Velocity (ft/s)	Time T_t (min)	Flow Length (ft)	Depth d (ft)	Area A (ft²)	Wetted P (ft)	Hydraulic Radius (ft)	Manning's n	Slope (ft/ft)	Velocity (ft/s)	Time T_t (min)	Design T_c (min)	SCS Lag Time (min)	HMS 25-yr Flow (cfs)	HMS 100-yr Flow (cfs)
A-1	0.00880	5.63	0.35	85	0.00	100	0.15	0.050	6.15	400	7.00	0.050	1.57	4.26								0.00	0.00	10.41	6.25	42.70	57.60
A-2	0.00377	2.41	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	900	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.00	6.00	3.60	20.20	27.20
A-3	0.00330	2.11	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	17.70	23.80
A-4	0.00703	4.5	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	1150	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.56	6.00	3.60	37.60	50.80
A-5	0.00453	2.9	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	800	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.78	6.00	3.60	24.30	32.70
A-6	0.00238	1.52	0.35	85	0.00	75	0.15	0.133	3.30						800	3.0	51.00	25.56	1.99	0.027	0.020	12.37	1.08	6.00	3.60	12.70	17.20
B-1	0.00345	2.21	0.35	85	0.00	100	0.15	0.050	6.15	350	7.00	0.050	1.57	3.73	150	1.0	11.50	23.19	0.50	0.027	0.020	4.89	0.51	10.39	6.23	16.80	22.70
B-2	0.00105	0.67	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	5.60	7.60
B-3	0.00291	1.86	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	15.60	21.00
B-4	0.00353	2.26	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	850	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.89	6.00	3.60	18.90	25.50
B-5	0.00353	2.26	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	18.90	25.50
C-1	0.00417	2.67	0.35	85	0.00	100	0.15	0.050	6.15	180	7.00	0.050	1.57	1.92								0.00	0.00	8.07	4.84	21.40	28.80
C-2	0.00205	1.31	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	150	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.33	6.00	3.60	11.00	14.80
C-3	0.00358	2.29	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	200	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.45	6.00	3.60	19.20	25.90
C-4	0.00189	1.21	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	400	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.89	6.00	3.60	10.10	13.70
C-5	0.00273	1.75	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	450	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.00	6.00	3.60	14.60	19.70
C-6	0.00120	0.77	0.35	85	0.00	100	0.15	0.333	2.88						350	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.78	6.00	3.60	6.40	8.70
C-7	0.00217	1.39	0.35	85	0.00	100	0.15	0.333	2.88						500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	11.60	15.70
D-1	0.00319	2.04	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.67	6.00	3.60	17.10	23.00
D-2	0.00211	1.35	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.67	6.00	3.60	11.30	15.20
D-3	0.00053	0.34	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	100	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.22	6.00	3.60	2.80	3.80
D-4	0.00181	1.16	0.35	85	0.00	100	0.15	0.333	2.88	30	7.00	0.333	4.04	0.12	300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.67	6.00	3.60	9.70	13.10
D-5	0.00058	0.37	0.35	85	0.00	100	0.15	0.333	2.88	30	7.00	0.333	4.04	0.12	100	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.22	6.00	3.60	3.10	4.20
E-1	0.00086	0.55	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	250	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.56	6.00	3.60	4.60	6.20
E-2	0.00327	2.09	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16	650	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.45	6.00	3.60	17.50	23.60
E-3	0.00320	2.05	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	750	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.67	6.00	3.60	17.10	23.10
E-4	0.00411	2.63	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	600	2.0	11.00	11.71	0.94	0.027	0.020	7.39	1.35	6.00	3.60	22.00	29.70
F-1	0.00173	1.11	0.35	85	0.00	80	0.15	0.333	2.41						350	3.0	36.00	20.56	1.75	0.027	0.010	8.02	0.73	6.00	3.60	9.30	12.50
F-2	0.00836	5.35	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	800	3.0	36.00	20.56	1.75	0.027	0.010	8.02	1.66	6.00	3.60	44.80	60.40
F-3	0.01139	7.29	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	1550	3.0	36.00	20.56	1.75	0.027	0.010	8.02	3.22	6.52	3.91	60.50	81.50
G-1	0.00475	3.04	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	600	3.0	27.00	18.97	1.42	0.027	0.010	6.98	1.43	6.00	3.60	25.40	34.30
G-2	0.00230	1.47	0.35	85	0.00	80	0.15	0.333	2.41						600	3.5	64.75	28.49	2.27	0.027	0.010	9.54	1.05	6.00	3.60	12.30	16.60
G-3	0.00195	1.25	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16	400	3.5	64.75	28.49	2.27	0.027	0.010	9.54	0.70	6.00	3.60	10.40	14.10
H-1	0.00503	3.22	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	3.0	36.00	20.56	1.75	0.027	0.010	8.02	1.25	6.00	3.60	26.30	36.30
H-2	0.00339	2.17	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	500	3.0	36.00	20.56	1.75	0.027	0.010	8.02	1.04	6.00	3.60	18.10	24.50
H-3	0.00909	5.82	0.35	85	0.00	100	0.15	0.333	2.88	150	7.00	0.333	4.04	0.62	1000	3.0	36.00	20.56	1.75	0.027	0.010	8.02	2.08	6.00	3.60	48.70	65.70
OD-1	0.03789	24.25	0.82	71	0.00	100	0.15	0.033	7.23	600	7.00	0.01	0.70	14.29	1000	2.0	40.00	40.20	1.00	0.027	0.006	4.26	3.91	25.43	15.26	94.70	139.60
OD-2	0.04734	30.3	0.82	71	0.00	100	0.15	0.033	7.23	475	7.00	0.02	1.03	7.66	900	6.0	444.00	99.48	4.46	0.027	0.007	12.21	1.23	16.12	9.67	148.20	217.30
AO-1	0.01045	6.69	0.82	71	0.00	100	0.15	0.167	3.80	200	7.00	0.040	1.40	2.38								0.00	0.00	6.18	3.71	41.80	61.00
AO-2	0.00483	3.09	0.82	71	0.00	100	0.15	0.333	2.88	150	7.00	0.040	1.40	1.79								0.00	0.00	6.00	3.60	19.40	28.30
AO-3	0.00306	1.96	0.82	71	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60	500	3.0	22.50	16.16	1.39	0.027	0.010	6.88	1.21	6.00	3.60	12.30	17.90
AO-4	0.00272	1.74	0.82	71	0.00	100	0.15	0.333	2.88						700	3.0	22.50	16.16	1.39	0.027	0.010	6.88	1.70	6.00	3.60	10.90	15.90
AO-5	0.00250	1.6	0.82	71	0.00	100	0.15	0.333	2.88						800	3.0	22.50	16.16	1.39	0.027	0.010	6.88	1.94	6.00	3.60	10.00	14.60
AO-6	0.00017	0.11	0.82	71	0.00	100	0.15	0.333	2.88													0.00	0.00	6.00	3.60	0.70	1.00
AO-7	0.00072	0.46	0.82	71	0.00	100	0.15	0.333	2.88						150	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.36	6.00	3.60	2.90	4.20
AO-8	0.00216	1.38	0.82	71	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60	150	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.36	6.00	3.60	8.70	12.70
AO-9	0.00027	0.17	0.82	71	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60	100	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.24	6.00	3.60	1.10	1.60
AO-10	0.00055	0.35	0.82	71	0.00	100	0.15	0.333	2.88						200	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.48	6.00	3.60	2.20	3.20
AO-11	0.00114	0.73	0.82	71	0.00	100	0.15	0.333	2.88						300	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.73	6.00	3.60	4.60	6.70
AO-12	0.00133	0.85	0.82	71	0.00	100	0.15	0.333	2.88						300	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.73	6.00	3.60	5.30	7.80
AO-13	0.01602	10.25	0.82	71	0.00	100	0.15	0.104	4.59	150	7.00	0.040	1.40	1.79	1100	3.0	22.50	16.16	1.39	0.027	0.010	6.88	2.66	9.04	5.42	59.90	87.50
CO-1	0.00472	3.02	0.82	71	0.00	100	0.15	0.087	4.94	400	7.00	0.040	1.40	4.76								0.00	0.00	9.70	5.82	17.30	25.40
CO-2	0.01319	8.44	0.82	71	0.00	100	0.15	0.100	4.66	650	7.00	0.044	1.48	7.34								0.00	0.00	12.00	7.20	45.80	66.30
CO-3	0.01038	6.64	0.44	82	0.00	100	0.15	0.050	6.15	350	7.00	0.064	1.77	3.29								0.00	0.00	9.45	5.67	49.00	67.10
CO-4	0.00895	5.73	0.82	71	0.00	100	0.15	0.160	3.86	200	7.00	0.040	1.40	2.38	500	3.0	46.50	24.16	1.93	0.027	0.010	8.54	0.98	7.22	4.33	34.90	50.90
CO-5	0.00147	0.94	0.82	71	0.00	50	0.15	0.160	2.22						700	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.37	6.00	3.60	5.90	8.60
OC-11	0.00027	0.17	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60								0.00	0.00	6.00	3.60	1.40	2.00
OC-20	0.00966	6.18	0.44	82	0.00	100	0.15	0.053	6.00	200	7.00	0.040	1.40	2.38	700	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.37	9.74	5.85	45.30	62.00
OC-21	0.01145	7.33	0.82	71	0.00	100	0.15	0.040	6.73	200	7.00	0.040	1.40	2.38	1000	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.95	11.06	6.64	40.70	59.50
DO-1	0.00272	1.74	0.82	71	0.00	100	0.15	0.067	5.48	500	7.00	0.06667	1.81	4.61								0.00	0.00	10.09	6.06	9.90	14.50
		207.14																									

2-year, 24-hour Design Rainfall Depth = 3.90 inches

Bench Left Side Slope = 2.5 H:V
Bench Right Side Slope = 3.0 H:V

Notes:

1) *Curve number = 85 landfill final cover surface in accordance with TCEQ RG-417 guidance (TCEQ, 2018).*
2) *Curve number = 71 represents meadow with continuous grass for hydrologic soil group C (USDA, 1986).*
3) *Curve number = 82 represents farmsteads of buildings, lanes, driveways, and surrounding lots for hydrologic soil group C (USDA, 1986).*
4) *Manning's roughness coefficient: n = 0.15 represents short grass prairie for sheet flow (USDA, 1984).*
5) *Manning's roughness coefficient: n = 0.027 represents an excavated earth channel that is straight and uniform with short grass and few weeds (Chow, 1959).*
6) *Travel Time (T_t) is calculated using Manning's kinematic solutions for sheet flow (USDA, 1986).*

$$T_t = 0.007(nL)^{0.8} / (P_{2\text{-}24})^{0.5} S^{0.4}$$

7) *Velocity factor of 7.0 ft/s corresponds to short grass pasture from the Upland Method as reported by HydroCAD v.8 Owner's Manual.*
8) *Open channel flow velocity is calculated using Manning's equation (USDA, 1986).*

$$V = (1.49 r^{2/3} S^{1/2}) / n \quad \text{where: } r = \text{hydraulic radius (ft) and is equal to A/P [area (ft}^2\text{)/wetted perimeter (ft)]}$$

9) *Design rainfall depth taken from NOAA Atlas 14, Volume 11, Version 2.*

Basin: PreDev-2019
Last Modified Date: 9 September 2019
Last Modified Time: 18:31:47
Version: 4.3
Filepath Separator: \
Unit System: English
Missing Flow To Zero: No
Enable Flow Ratio: No
Compute Local Flow At Junctions: No

Enable Sediment Routing: No

Enable Quality Routing: No
End:

Subbasin: B-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1662.3588258448644
Canvas Y: -471.9875563540154
Area: 0.00353
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 244.1077441077441
Canvas Y: -791.2457912457912
Area: 0.00353
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-1
Last Modified Date: 9 September 2019
Last Modified Time: 22:20:27
Canvas X: 294.61279461279446
Canvas Y: 286.1952861952859
Area: 0.00345
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 6.15
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 176.76767676767668
Canvas Y: -286.1952861952859
Label X: -2.0
Label Y: -1.0
Area: 0.00291
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1473.0639730639732
Canvas Y: -168.35016835016813
Area: 0.00105
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute B
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 715.4882154882152
Canvas Y: -1313.1313131313127
From Canvas X: 834.0466727105622
From Canvas Y: -408.14049818109606
Downstream: J_B

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 380
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -900.6734006734005
Canvas Y: -959.5959595959594
Area: 0.00836
Downstream: J_B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1944.4444444444443
Canvas Y: -1262.6262626262624
Area: 0.00173
Downstream: J_B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_B
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: 715.4882154882152
Canvas Y: -1313.1313131313127
Downstream: Channel A.1
End:

Subbasin: AO-1
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:37
Canvas X: 996.2663676564744
Canvas Y: -2531.711135770982
Area: 0.01045
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.71
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-2
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:36
Canvas X: 1731.322500553625
Canvas Y: -2439.829119158838
Area: 0.00483
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60

Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-12
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:43
Canvas X: -1978.4139201616827
Canvas Y: -1831.1107591033851
Area: 0.00133
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-11
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1364.709605095608
Canvas Y: -1430.8400124873501
Label X: -51.0
Label Y: -17.0
Area: 0.00114
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-10
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:40
Canvas X: -577.2131668264892
Canvas Y: -2095.2715568632984
Label X: -52.0
Label Y: -5.0
Area: 0.00055
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-9
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:39
Canvas X: 123.38720984110842
Canvas Y: -2141.2125651693705
Area: 0.00027
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Channel A.1
Last Modified Date: 3 October 2019
Last Modified Time: 17:10:17
Canvas X: -3142.4154250057254
Canvas Y: -2587.809713810464
From Canvas X: 715.4882154882152
From Canvas Y: -1313.1313131313127
Downstream: South Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1000
Energy Slope: 0.02
Mannings n: 0.027
Shape: Triangular
Number of Subreaches: 2
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reservoir: South Pond
Last Modified Date: 3 October 2019

Last Modified Time: 17:10:17
Canvas X: -3142.4154250057254
Canvas Y: -2587.809713810464
Label X: 3.0
Label Y: 8.0
Downstream: J_A

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 591
Elevation-Area Table: Pond_South_Pre-Dev-2019
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 3.5
Number Barrels: 1
Culvert Length: 58.5
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 591
Outlet Invert Elevation: 590
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 50
Spillway Crest Elevation: 598.8
Spillway Coefficient: 3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: A-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2382.154882154882
Canvas Y: -134.68013468013487
Area: 0.00880
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 6.25
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -3644.781144781145
Canvas Y: -555.5555555555557
Area: 0.00703
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2819.86531986532
Canvas Y: -1026.9360269360268
Area: 0.00453
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -3156.5656565656564
Canvas Y: -16.835016835017086
Area: 0.00377
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2382.154882154882
Canvas Y: -572.3905723905718
Area: 0.00330
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute A
Last Modified Date: 9 July 2019
Last Modified Time: 14:15:50
Canvas X: -3914.1414141414143
Canvas Y: -1481.4814814814818
From Canvas X: -2993.1005899385354
From Canvas Y: -543.0818241872967
Label X: -26.0
Label Y: 17.0
Downstream: J_F

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 370
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-3
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4187.685949171736
Canvas Y: -47.25801621843857
Area: 0.01139
Downstream: J_F

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.91
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_F
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -3914.1414141414143
Canvas Y: -1481.4814814814818
Downstream: Drop South
End:

Reach: Drop South
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4629.810222140172
Canvas Y: -1992.38891005
From Canvas X: -3914.1414141414143
From Canvas Y: -1481.4814814814818
Downstream: J_A

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 100
Energy Slope: 0.333
Mannings n: 0.012
Shape: Circular
Number of Subreaches: 2
Width: 2
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: AO-13
Last Modified Date: 10 September 2019
Last Modified Time: 14:35:07
Canvas X: -2199.935105183882
Canvas Y: -4174.1021827130535
Label X: 9.0
Label Y: 3.0
Area: 0.01602
Downstream: J_AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.42
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 479.7979797979797
Canvas Y: -3737.3737373737367
Area: 0.00306
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -109.42760942760924
Canvas Y: -4074.074074074073
Area: 0.00272
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-7
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1237.3737373737376
Canvas Y: -3282.8282828282827
Area: 0.00072
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-6
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -227.27272727272793
Canvas Y: -3097.6430976430975
Area: 0.00017
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute AO
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -2598.7503998533884
Canvas Y: -4016.6546416546407
From Canvas X: -204.96464241452122
From Canvas Y: -3629.2192170299622
Label X: 1.0
Label Y: 0.0
Downstream: J_AO

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 180
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: AO-5
Last Modified Date: 4 September 2019

Last Modified Time: 21:33:46
Canvas X: -1237.3737373737376
Canvas Y: -4074.074074074073
Area: 0.00250
Downstream: J_AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-8
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2247.4747474747473
Canvas Y: -3518.5185185185182
Area: 0.00216
Downstream: J_AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_AO
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -2598.7503998533884
Canvas Y: -4016.6546416546407
Downstream: Channel AO
End:

Reach: Channel AO
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4629.810222140172
Canvas Y: -1992.38891005
From Canvas X: -2598.7503998533884
From Canvas Y: -4016.6546416546407
Downstream: J_A

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1100
Energy Slope: 0.010
Mannings n: 0.027
Shape: Triangular
Number of Subreaches: 2
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: A-8
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -4679.962010455659
Canvas Y: -3432.873026874046
Area: 0.00238
Downstream: J_A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_A
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4629.810222140172
Canvas Y: -1992.38891005
Downstream: Channel A.2
End:

Reach: Channel A.2
Last Modified Date: 2 October 2019
Last Modified Time: 20:29:17
Canvas X: -5360.92723353286
Canvas Y: -120.86952857206597
From Canvas X: -4629.810222140172
From Canvas Y: -1992.38891005
Downstream: Midpoint Site Outfall

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 600
Energy Slope: 0.02
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None

End:

Subbasin: OD-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:17:00
Canvas X: -4720.250832037668
Canvas Y: 840.6577778645565
Area: 0.03789
Downstream: Midpoint Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 15.26
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: Midpoint Site Outfall
Last Modified Date: 2 October 2019
Last Modified Time: 20:29:17
Canvas X: -5360.92723353286
Canvas Y: -120.86952857206597
Downstream: Overall Site Outfall
End:

Subbasin: C-1
Last Modified Date: 9 September 2019
Last Modified Time: 22:20:27
Canvas X: 1035.3535353535344
Canvas Y: 892.2558922558919
Area: 0.00417
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 4.84
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2281.8909353676954
Canvas Y: 502.0809022661042
Area: 0.00358
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1839.5918238944487
Canvas Y: 1792.8721867696622
Area: 0.00273
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-7
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2913.746808900907
Canvas Y: 980.4860636555345
Area: 0.00217
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1532.6903996068904
Canvas Y: 366.6832150804162
Area: 0.00205
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1406.3192249002477
Canvas Y: 1422.7851751287817
Area: 0.00189
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-6
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2417.288622553384
Canvas Y: 1810.9252117277538
Area: 0.00120
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute C
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 3914.1414141414143
Canvas Y: 1868.6868686868688
From Canvas X: 1905.995085080246
From Canvas Y: 990.3198726987312
Label X: -12.0
Label Y: -12.0
Downstream: J_C.1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: CO-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 4498.424361875559
Canvas Y: 222.9024133227049
Area: 0.00895
Downstream: Channel North 1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 4.33
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 3197.537994489234
Canvas Y: -505.46398417894306
Area: 0.00475
Downstream: Channel North 1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 4270.023332175082
Canvas Y: -534.0635931838988
Area: 0.00147
Downstream: Channel North 1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Channel North 1
Last Modified Date: 18 November 2019
Last Modified Time: 22:35:43
Canvas X: 3914.1414141414143
Canvas Y: 1868.6868686868688
From Canvas X: 3920.080986953666
From Canvas Y: 422.0224808591647
Downstream: J_C.1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 400
Energy Slope: 0.05
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OC-20
Last Modified Date: 9 September 2019
Last Modified Time: 18:43:45
Canvas X: 4053.2349742144634
Canvas Y: 2505.934055570371
Area: 0.00966
Downstream: J_C.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 82

Transform: SCS
Lag: 5.85
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 3156.5656565656564
Canvas Y: 2154.8821548821547
Area: 0.00230
Downstream: J_C.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C.1
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: 3914.1414141414143
Canvas Y: 1868.6868686868688
Downstream: Channel North 2
End:

Reach: Channel North 2
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 3914.1414141414143
From Canvas Y: 1868.6868686868688
Downstream: J_C.2

Route: Kinematic Wave

Channel: Kinematic Wave
Length: 800
Energy Slope: 0.01
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: CO-2
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: 2363.7124639404365
Canvas Y: 4506.206566449147
Area: 0.01319
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 7.20
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-3
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: 3442.760942760943
Canvas Y: 4309.7643097643095
Area: 0.01038
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 82

Transform: SCS
Lag: 5.67
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 289.6228803903232
Canvas Y: 2463.842885230684
Area: 0.00319
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 677.6034236804571
Canvas Y: 3002.8530670470755
Area: 0.00211
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1119.5286195286199
Canvas Y: 3501.6835016835016
Area: 0.00181
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60

Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2095.9595959595963
Canvas Y: 2676.7676767676767
Area: 0.00058
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1338.3838383838383
Canvas Y: 2340.06734006734
Area: 0.00053
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute D
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 1380.3723569916438
From Canvas Y: 2814.7465042631334
Downstream: J_C.2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.236
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: G-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2314.814814814815
Canvas Y: 3063.973063973064
Area: 0.00195
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OC-11
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 3649.4075759431453
Canvas Y: 3927.280120004649
Area: 0.00027
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C.2
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
Downstream: Channel North 3

End:

Reach: Channel North 3
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -1589.7849110216812
Canvas Y: 4030.647141124137
From Canvas X: 2062.289562289562
From Canvas Y: 3905.723905723906
Downstream: North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1300
Energy Slope: 0.023
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: E-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2685.185185185185
Canvas Y: 1060.6060606060605
Area: 0.00411
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:24:07
Canvas X: -1860.2693602693607
Canvas Y: 824.9158249158254
Label X: -58.0
Label Y: -8.0
Area: 0.00327
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1877.104377104377
Canvas Y: 2222.222222222222
Area: 0.00320
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1338.3838383838383
Canvas Y: 2037.037037037037
Area: 0.00086
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute E
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -3409.090909090909
Canvas Y: 1885.5218855218855
From Canvas X: -1911.1462629730354

From Canvas Y: 1164.4265473514447
Downstream: J_E

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 460
Energy Slope: 0.16
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: H-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -3712.1212121212125
Canvas Y: 1464.6464646464647
Area: 0.00503
Downstream: J_E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: H-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2567.3400673400674
Canvas Y: 2272.727272727273
Area: 0.00339
Downstream: J_E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_E
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -3409.090909090909
Canvas Y: 1885.5218855218855
Downstream: MSE North
End:

Reach: MSE North
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -2028.6195286195289
Canvas Y: 3383.838383838384
From Canvas X: -3409.090909090909
From Canvas Y: 1885.5218855218855
Downstream: J_H

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 500
Energy Slope: 0.01
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 3
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: H-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1052.1885521885524
Canvas Y: 3148.1481481481483
Area: 0.00909
Downstream: J_H

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_H
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -2028.6195286195289
Canvas Y: 3383.838383838384
Downstream: Drop North
End:

Reach: Drop North
Last Modified Date: 9 July 2019

Last Modified Time: 14:16:39
Canvas X: -1589.7849110216812
Canvas Y: 4030.647141124137
From Canvas X: -2028.6195286195289
From Canvas Y: 3383.838383838384
Downstream: North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 100
Energy Slope: 0.333
Mannings n: 0.012
Shape: Circular
Number of Subreaches: 2
Width: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OC-21
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -497.8103794894987
Canvas Y: 4492.179493687236
Area: 0.01145
Downstream: North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.64
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-1
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -2012.7342377759342
Canvas Y: 4520.233639211058
Area: 0.00472
Downstream: North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.82
Unitgraph Type: STANDARD

Baseflow: None
End:

Reservoir: North Pond
Last Modified Date: 10 September 2019
Last Modified Time: 14:52:30
Canvas X: -1589.7849110216812
Canvas Y: 4030.647141124137
Downstream: Overall Site Outfall

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 588
Elevation-Area Table: Pond_North_Pre-Dev-2019
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 2.5
Number Barrels: 2
Culvert Length: 64.5
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1.0
Top Manning's n: 0.011
Inlet Invert Elevation: 588
Outlet Invert Elevation: 587.4
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 80
Spillway Crest Elevation: 597
Spillway Coefficient: 3
End Spillway:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 420
Spillway Crest Elevation: 598.5
Spillway Coefficient: 3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: OD-2
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -4149.83164983165
Canvas Y: 3686.868686868687
Area: 0.04734
Downstream: J_D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 9.67
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: DO-1
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -5227.272727272728
Canvas Y: 4461.279461279461
From Canvas X: -841.654778887304
From Canvas Y: -142.65335235378052
Area: 0.00272
Downstream: J_D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.06
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_D
Last Modified Date: 9 September 2019
Last Modified Time: 18:31:45
Canvas X: -4999.380073210335
Canvas Y: 3725.3760549215094
Downstream: Overall Site Outfall
End:

Junction: Overall Site Outfall
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -6169.687038971845
Canvas Y: 3035.1950238313875
End:

Basin Layer Properties:
Element Layer:
Name: Icons
Layer shown: Yes
End Layer:
End:

Basin Spatial Properties:
End:

Basin Schematic Properties:
Last View N: 5493.85041812838
Last View S: -5494.996284046745
Last View W: -7557.92807960787
Last View E: 6581.220047344323
Maximum View N: 4520.233639211058
Maximum View S: -4273.324274832017
Maximum View W: -16812.32574325535
Maximum View E: 4498.424361875559
Extent Method: Elements
Buffer: 0
Draw Icons: Yes
Draw Icon Labels: Name
Draw Map Objects: No
Draw Gridlines: No
Draw Flow Direction: No
Draw HillShade Layer: Yes
Draw Elevation Layer: Yes
Elevation Layer Color Palette: Default
Ignore Elevation Color Ramp Scale: No
Use Interpolated Color Ramp for Elevation Layer: Yes
Color Ramp Opacity Level for Elevation Layer: 33.0
Fix Element Locations: No
Fix Hydrologic Order: No
End:

HEC-HMS POST-DEVELOPMENT HYDROLOGIC MODEL INPUT PARAMETERS

Post-Development HEC-HMS Basin Input Parameters for Kinematic Wave Model

POST-DEVELOPMENT CONDITIONS			Watershed Characterization			Sheet Flow				Shallow Concentrated Flow					Open Channel Flow												
Subcatchment Designation	Area A (mi²)	Area A (acres)	Initial Abstraction (in)	Curve Number	Impervious Cover (%)	Flow Length (ft)	Manning's n	Slope (ft/ft)	Time T_t (min)	Flow Length (ft)	Velocity Factor (ft/s)	Slope (ft/ft)	Average Velocity (ft/s)	Time T_t (min)	Flow Length (ft)	Depth d (ft)	Area A (ft²)	Wetted P (ft)	Hydraulic Radius (ft)	Manning's n	Slope (ft/ft)	Velocity (ft/s)	Time T_t (min)	Design T_c (min)	SCS Lag Time (min)	HMS 25-yr Flow (cfs)	HMS 100-yr Flow (cfs)
A-1	0.01378	8.82	0.35	85	0.00	100	0.15	0.050	6.15	435	7.00	0.050	1.57	4.63										10.78	6.47	66.20	89.30
A-2	0.00039063	0.25	0.35	85	0.00	90	0.15	0.333	2.65						775	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.73	6.00	3.60	2.10	2.80
A-3	0.00190625	1.22	0.35	85	0.00	100	0.15	0.333	2.88						600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	10.20	13.80
A-4	0.00267188	1.71	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	1000	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.23	6.00	3.60	14.30	19.30
A-5	0.00445313	2.85	0.35	85	0.00	100	0.15	0.333	2.88	75	7.00	0.333	4.04	0.31	550	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.22	6.00	3.60	23.80	32.20
A-6	0.00389063	2.49	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	1300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.89	6.10	3.66	20.80	28.00
A-7	0.00641	4.10	0.35	85	0.00	100	0.15	0.333	2.88	85	7.00	0.333	4.04	0.35	650	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.45	6.00	3.60	34.30	46.30
B-1	0.00386	2.47	0.35	85	0.00	100	0.15	0.050	6.15	200	7.00	0.160	2.80	1.19	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	8.45	5.07	19.60	26.50
B-2	0.00345	2.21	0.35	85	0.00	100	0.15	0.333	2.88	45	7.00	0.333	4.04	0.19	750	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.67	6.00	3.60	18.50	24.90
B-3	0.00475	3.04	0.35	85	0.00	100	0.15	0.333	2.88	75	7.00	0.333	4.04	0.31	900	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.00	6.00	3.60	25.40	34.30
B-4	0.00616	3.94	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	945	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.10	6.00	3.60	33.00	44.50
C-1	0.01214	7.77	0.35	85	0.00	100	0.15	0.050	6.15	200	7.00	0.050	1.57	2.13										8.28	4.97	61.90	83.60
C-2	0.00722	4.62	0.35	85	0.00	100	0.15	0.050	6.15	200	7.00	0.160	2.80	1.19	780	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.74	9.08	5.45	36.10	48.70
C-3	0.00267	1.71	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	400	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.89	6.00	3.60	14.30	19.30
C-4	0.00494	3.16	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	800	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.78	6.00	3.60	26.40	35.70
C-5	0.00355	2.27	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	19.00	25.60
D-1	0.00059	0.38	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	200	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.45	6.00	3.60	3.20	4.30
D-2	0.00120	0.77	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16	900	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.00	6.00	3.60	6.40	8.70
D-3	0.00111	0.71	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	150	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.33	6.00	3.60	5.90	8.00
D-4	0.00815625	5.22	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	250	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.56	6.00	3.60	43.70	58.90
D-5	0.00135938	0.87	0.35	85	0.00	100	0.15	0.333	2.88	20	7.00	0.333	4.04	0.08	200	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.45	6.00	3.60	7.30	9.80
D-6	0.00189063	1.21	0.35	85	0.00	100	0.15	0.333	2.88	20	7.00	0.333	4.04	0.08	250	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.56	6.00	3.60	10.10	13.70
E-1	0.00292188	1.87	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	400	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.89	6.00	3.60	15.60	21.10
E-2	0.00892188	5.71	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	870	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.94	6.00	3.60	47.80	64.50
E-3	0.00329688	2.11	0.35	85	0.00	100	0.15	0.333	2.88	100	8.00	0.333	4.62	0.36	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	17.70	23.80
E-4	0.00978125	6.26	0.35	85	0.00	100	0.15	0.333	2.88	60	9.00	0.333	5.20	0.19	1290	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.87	6.00	3.60	52.40	70.70
F-1	0.00323	2.07	0.35	85	0.00	100	0.15	0.333	2.88						1000	3.0	51.00	25.56	1.99	0.027	0.005	6.18	2.70	6.00	3.60	17.30	23.30
F-2	0.00119	0.76	0.35	85	0.00	100	0.15	0.333	2.88															6.00	3.60	6.40	8.60
F-3	0.00156	1.00	0.35	85	0.00	100	0.15	0.333	2.88															6.00	3.60	8.40	11.30
F-4	0.00269	1.72	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16										6.00	3.60	14.40	19.40
F-5	0.00242	1.55	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	300	3.0	51.00	25.56	1.99	0.027	0.005	6.18	0.81	6.00	3.60	13.00	17.50
F-6	0.00836	5.35	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41										6.00	3.60	44.80	60.40
G-1	0.00575	3.68	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	800	3.0	51.00	25.56	1.99	0.027	0.005	6.18	2.16	6.00	3.60	30.80	41.50
G-2	0.00797	5.1	0.35	85	0.00	100	0.15	0.333	2.88						500	3.0	51.00	25.56	1.99	0.027	0.005	6.18	1.35	6.00	3.60	42.70	57.60
G-3	0.00119	0.76	0.35	85	0.00	100	0.15	0.333	2.88						230	3.0	51.00	25.56	1.99	0.027	0.005	6.18	0.62	6.00	3.60	6.40	8.60
G-4	0.00163	1.04	0.35	85	0.00	90	0.15	0.333	2.65						300	3.0	51.00	25.56	1.99	0.027	0.005	6.18	0.81	6.00	3.60	8.70	11.80
G-5	0.00041	0.26	0.35	85	0.00	70	0.15	0.333	2.17															6.00	3.60	2.20	3.00
G-6	0.00147	0.94	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21										6.00	3.60	7.90	10.60
G-7	0.00348	2.23	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33										6.00	3.60	18.60	25.10
OD-1	0.03863	24.72	0.82	71	0.00	100	0.15	0.033	7.23	600	7.00	0.010	0.70	14.29	1000	2.0	40.00	40.20	1.00	0.027	0.006	4.26	3.91	25.43	15.26	96.60	142.30
OD-2	0.04775	30.56	0.82	71	0.00	100	0.15	0.033	7.23	475	7.00	0.022	1.03	7.66	900	6.0	444.00	99.48	4.46	0.027	0.007	12.21	1.23	16.12	9.67	149.50	219.20
OA-1	0.00350	2.24	0.35	85	0.00	100	0.15	0.167	3.80						500	3.0	51.00	25.56	1.99	0.027	0.005	6.18	1.35	6.00	3.60	18.70	25.30
OA-2	0.00416	2.66	0.35	85	0.00	100	0.15	0.167	3.80						950	3.0	51.00	25.56	1.99	0.027	0.005	6.18	2.56	6.36	3.81	22.10	29.90
OA-3	0.00239	1.53	0.35	85	0.00	50	0.15	0.200	2.03						600	3.0	51.00	25.56	1.99	0.027	0.005	6.18	1.62	6.00	3.60	12.80	17.30
AO-13	0.01064	6.81	0.82	71	0.00	100	0.15	0.104	4.59	150	7.00	0.040	1.40	1.79	1100	3.0	22.50	16.16	1.39	0.027	0.010	6.88	2.66	9.04	5.42	39.80	58.10
OC-1	0.01644	10.52	0.44	82	0.00	100	0.15	0.040	6.73	500	7.00	0.040	1.40	5.95										12.68	7.61	71.80	98.40
OC-2	0.01191	7.62	0.82	71	0.00	100	0.15	0.040	6.73	200	7.00	0.040	1.40	2.38	1000	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.95	11.06	6.64	42.30	61.90
CO-1	0.00472	3.02	0.82	71	0.00	100	0.15	0.087	4.94	400	7.00	0.040	1.40	4.76										9.70	5.82	17.30	25.40
CO-2	0.00758	4.85	0.82	71	0.00	100	0.15	0.100	4.66	600	7.00	0.044	1.48	6.78										11.44	6.86	26.70	39.00
CO-4	0.00895	5.73	0.82	71	0.00	100	0.15	0.160	3.86	200	7.00	0.040	1.40	2.38	500	3.0	46.50	24.16	1.93	0.027	0.010	8.54	0.98	7.22	4.33	34.90	50.90
CO-5	0.00147	0.94	0.82	71	0.00	50	0.15	0.160	2.22	0	0.00	0.000	0.00	0.00	700	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.37	6.00	3.60	5.90	8.60
DO-1	0.00272	1.74	0.82	71	0.00	100	0.15	0.067	5.48	500	7.00	0.0667	1.81	4.61										10.09	6.06	9.90	14.50
		207.14	2-year, 24-hour Design Rainfall Depth =	3.90	inches																						

Bench Left Side Slope = 2.5 H:V
Bench Right Side Slope = 3.0 H:V

Notes:

1) *Curve number = 85 landfill final cover surface in accordance with TCEQ RG-417 guidance (TCEQ, 2018).*
2) *Curve number = 71 represents meadow with continuous grass for hydrologic soil group C (USDA, 1986).*
3) *Curve number = 82 represents farmsteads of buildings, lanes, driveways, and surrounding lots for hydrologic soil group C (USDA, 1986).*
4) *Manning's roughness coefficient: n = 0.15 represents short grass prairie for sheet flow (USDA, 1984).*
5) *Manning's roughness coefficient: n = 0.027 represents an excavated earth channel that is straight and uniform with short grass and few weeds (Chow, 1959).*
6) *Travel Time (T_t) is calculated using Manning's kinematic solutions for sheet flow (USDA, 1986).*

   $$T_t = 0.007(nL)^{0.8} / (P_{2\text{-}24})^{0.5} S^{0.4}$$

7) *Velocity factor of 7.0 ft/s corresponds to short grass pasture from the Upland Method as reported by HydroCAD v.8 Owner's Manual.*
8) *Open channel flow velocity is calculated using Manning's equation (USDA, 1986).*

   $V = (1.49r^{2/3} S^{1/2}) / n$ where: r = hydraulic radius (ft) and is equal to A/P [area (ft²)/wetted perimeter (ft)]

9) *Design rainfall depth taken from NOAA Atlas 14, Volume 11, Version 2.*

Basin: PostDev-2019
Last Modified Date: 13 December 2019
Last Modified Time: 16:42:00
Version: 4.3
Filepath Separator: \
Unit System: English
Missing Flow To Zero: No
Enable Flow Ratio: No
Compute Local Flow At Junctions: No

Enable Sediment Routing: No

Enable Quality Routing: No
End:

Reservoir: Series 3_North Pond
Description: Third basin of the North Pond Series
Last Modified Date: 4 December 2019
Last Modified Time: 14:50:44
Canvas X: -738.8990558096202
Canvas Y: 6539.7288686574675
From Canvas X: -2686.2212969881784
From Canvas Y: 5196.47027005563
Downstream: Series 2_North Pond

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 604
Elevation-Area Table: Pond_North_Series3_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 4.5
Number Barrels: 2
Culvert Length: 10
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 603
Outlet Invert Elevation: 602.5
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 60
Spillway Crest Elevation: 613
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Junction: J_C3
Last Modified Date: 19 November 2019
Last Modified Time: 16:54:18
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
Downstream: Peri C3
End:

Subbasin: E-4
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -143.73704479314074
Canvas Y: 4284.420573576127
From Canvas X: -143.73704479314074
From Canvas Y: 4284.420573576127
Area: 0.0097813
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-2
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -380.6904669830892
Canvas Y: 3589.357201818946
Area: 0.0089219
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-3

Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 582.9201165893664
Canvas Y: 3857.9044136342204
From Canvas X: 582.9201165893664
From Canvas Y: 3857.9044136342204
Area: 0.00330
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 85.96448372417399
Canvas Y: 3366.5102757543623
Area: 0.00292
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute E
Last Modified Date: 16 December 2019
Last Modified Time: 19:36:17
Canvas X: -2474.1427739564424
Canvas Y: 6417.821941121796
From Canvas X: -1142.1200473700083
From Canvas Y: 4560.254810942866
Downstream: Series 2_North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 460
Energy Slope: 0.16
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: CO-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -2240.9130882934473
Canvas Y: 6934.043847122182
Area: 0.00758
Downstream: Series 2_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.86
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute D
Last Modified Date: 28 August 2019
Last Modified Time: 19:43:04
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 1380.3723569916438
From Canvas Y: 2814.7465042631334
Downstream: J_C3

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.236
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reservoir: Series 4_North Pond
Description: Fourth basin of the North Pond Series
Last Modified Date: 16 December 2019
Last Modified Time: 16:31:11
Canvas X: 1356.876944391328
Canvas Y: 6402.03323920955
From Canvas X: -3659.8441744480297
From Canvas Y: 5295.243605450108
Downstream: Series 3_North Pond

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 615
Elevation-Area Table: Pond_North_Series4_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 4.5
Number Barrels: 2
Culvert Length: 10
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 613
Outlet Invert Elevation: 612.5
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 60
Spillway Crest Elevation: 624
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Reach: Peri C3
Last Modified Date: 16 December 2019
Last Modified Time: 16:31:11
Canvas X: 1356.876944391328
Canvas Y: 6402.03323920955
From Canvas X: 2062.289562289562
From Canvas Y: 3905.723905723906
Downstream: Series 4_North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 339.32
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: D-4
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: 1119.5286195286199
Canvas Y: 3501.6835016835016
Area: 0.0081563
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-6
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 1994.037977450369
Canvas Y: 3023.8939475440548
From Canvas X: 1922.295663466335
From Canvas Y: 3044.3917515394933
Area: 0.00189
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OC-2

Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 3273.4627608045475
Canvas Y: 4082.0409898726684
From Canvas X: 1737.8154275073903
From Canvas Y: 5350.394701026314
Area: 0.01191
Downstream: J_C3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.64
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2095.9595959595963
Canvas Y: 2676.7676767676767
Area: 0.00136
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C1
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:46
Canvas X: 4121.424554625923
Canvas Y: 1899.0894568639842
Downstream: Peri C1
End:

Reach: Peri C1
Last Modified Date: 19 November 2019
Last Modified Time: 17:14:50
Canvas X: 3506.0190584361662
Canvas Y: 2818.1354023946215
From Canvas X: 4121.424554625923
From Canvas Y: 1899.0894568639842
Downstream: J_C2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 522.75
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reach: Peri B1
Last Modified Date: 19 November 2019
Last Modified Time: 17:14:19
Canvas X: 4121.424554625923
Canvas Y: 1899.0894568639842
From Canvas X: 4532.143819755165
From Canvas Y: -423.0540805975061
Downstream: J_C1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 631.25
Energy Slope: 0.025
Mannings n: 0.027
Shape: Triangular
Number of Subreaches: 2
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: C-1
Last Modified Date: 13 December 2019
Last Modified Time: 16:49:57
Canvas X: 1035.3535353535344
Canvas Y: 892.2558922558919
Area: 0.01214
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0

Curve Number: 85

Transform: SCS
Lag: 4.97
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C2
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:35
Canvas X: 3506.0190584361662
Canvas Y: 2818.1354023946215
From Canvas X: 3506.0190584361662
From Canvas Y: 2818.1354023946215
Downstream: Peri C2
End:

Subbasin: C-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 2281.8909353676954
Canvas Y: 502.0809022661042
Area: 0.00267
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-2
Last Modified Date: 13 December 2019
Last Modified Time: 16:49:57
Canvas X: 1532.6903996068904
Canvas Y: 366.6832150804162
Area: 0.00722
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 5.45
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-1
Last Modified Date: 16 December 2019
Last Modified Time: 16:01:05
Canvas X: 4497.635771417183
Canvas Y: -1049.9496403118637
Area: 0.00575
Downstream: J_B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-5
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 2258.3534371140413
Canvas Y: 150.7523695898717
Area: 0.00355
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-5
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09

Canvas X: 4970.13310982375
Canvas Y: 1288.3064189821735
From Canvas X: 5637.9264566415895
From Canvas Y: -454.64787022283235
Area: 0.00147
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-4
Last Modified Date: 13 December 2019
Last Modified Time: 16:49:57
Canvas X: 1406.3192249002477
Canvas Y: 1422.7851751287817
Area: 0.00494
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_B
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:46
Canvas X: 4532.143819755165
Canvas Y: -423.0540805975061
From Canvas X: 3510.875473112812
From Canvas Y: -870.6888115892416
Downstream: Peri B1
End:

Subbasin: CO-4
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 5208.551172036108
Canvas Y: 1772.764211828372
From Canvas X: 47.390684437988966
From Canvas Y: 410.71926512924347
Area: 0.00895
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 4.33
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-3
Last Modified Date: 13 December 2019
Last Modified Time: 16:46:35
Canvas X: 4545.703207967837
Canvas Y: 2467.685464480591
Area: 0.00119
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-2
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:37
Canvas X: 3528.410461865249
Canvas Y: 840.0397133144043
Area: 0.00797
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute C
Last Modified Date: 13 December 2019
Last Modified Time: 16:41:59
Canvas X: 4121.424554625923
Canvas Y: 1899.0894568639842
From Canvas X: 1905.995085080246
From Canvas Y: 990.3198726987312
Label X: -12.0
Label Y: -12.0
Downstream: J_C1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reach: Peri C2
Last Modified Date: 19 November 2019
Last Modified Time: 17:17:26
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 3506.0190584361662
From Canvas Y: 2818.1354023946215
Downstream: J_C3

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 545.79
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None

End:

Subbasin: OC-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 3284.1538569991963
Canvas Y: 3686.4704306706362
From Canvas X: 3254.6529231698314
From Canvas Y: 3843.806107361591
Area: 0.01644
Downstream: J_C3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 82

Transform: SCS
Lag: 7.61
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-2
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 733.2896603298632
Canvas Y: 3016.5309027832345
Area: 0.00120
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 1338.3838383838383
Canvas Y: 2340.06734006734
Area: 0.00111
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 289.6228803903232
Canvas Y: 2463.842885230684
Area: 0.00059
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -632.2364776272752
Canvas Y: 6922.715350750865
From Canvas X: 1081.8856996533614
From Canvas Y: 4202.517677281763
Area: 0.00041
Downstream: Series 3_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-4
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 2717.525758682771
Canvas Y: 4670.051280578392
From Canvas X: 1532.837387553005
From Canvas Y: 3720.8192833889602
Area: 0.00163
Downstream: J_C3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reservoir: Series 2_North Pond
Description: Secind basin of the north pond series
Last Modified Date: 16 December 2019
Last Modified Time: 19:36:17
Canvas X: -2474.1427739564424
Canvas Y: 6417.821941121796
From Canvas X: -2700.3317734731045
From Canvas Y: 5379.906464359659
Downstream: Series 1_North Pond

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 598
Elevation-Area Table: Pond_North_Series2_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 4.5

Number Barrels: 3
Culvert Length: 10
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 597
Outlet Invert Elevation: 596.5
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 60
Spillway Crest Elevation: 603
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: CO-1
Last Modified Date: 4 November 2019
Last Modified Time: 21:34:19
Canvas X: -3106.1843766466563
Canvas Y: 4773.342403746244
Area: 0.00472
Downstream: Series 1_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.82
Unitgraph Type: STANDARD

Baseflow: None
End:

Reservoir: Series 1_North Pond
Last Modified Date: 16 December 2019
Last Modified Time: 16:19:52
Canvas X: -4383.237509402856
Canvas Y: 6038.025981164064
Downstream: Peri C4

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 588
Elevation-Area Table: Pond_North_Series1_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 2.5
Number Barrels: 2
Culvert Length: 64.5
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1.0
Top Manning's n: 0.011
Inlet Invert Elevation: 588
Outlet Invert Elevation: 587.4
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 80
Spillway Crest Elevation: 597
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: G-6
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -4694.308916577716
Canvas Y: 6667.773565879497
From Canvas X: -1066.1123501521834
From Canvas Y: 4826.889360949745
Area: 0.00147
Downstream: Series 1_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri C4
Last Modified Date: 16 December 2019
Last Modified Time: 16:19:52
Canvas X: -8322.890474947622
Canvas Y: 4620.729306795858
From Canvas X: -4383.237509402856
From Canvas Y: 6038.025981164064
Downstream: Overall Site Outfall

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 300
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Junction: J_A5
Last Modified Date: 19 November 2019
Last Modified Time: 16:42:03
Canvas X: -4520.20202020202
Canvas Y: -2895.622895622895
Downstream: Peri A5
End:

Junction: J_Mid
Last Modified Date: 19 November 2019
Last Modified Time: 16:42:58
Canvas X: -6004.385020291189
Canvas Y: 382.58755484831636
From Canvas X: -6461.306170667974
From Canvas Y: 953.6157440047755
Downstream: Channel A
End:

Reach: Downchute A
Last Modified Date: 28 August 2019
Last Modified Time: 19:22:07
Canvas X: -4520.20202020202
Canvas Y: -2895.622895622895
From Canvas X: -3561.915769552974
From Canvas Y: -1050.7338501924505
Label X: -26.0
Label Y: 17.0
Downstream: J_A5

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 370
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reach: Channel A
Last Modified Date: 19 November 2019
Last Modified Time: 16:43:14
Canvas X: -6121.783716957593
Canvas Y: 1463.9154354050097
From Canvas X: -6004.385020291189
From Canvas Y: 382.58755484831636
Downstream: Midpoint Site Outfall

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1000
Energy Slope: 0.02
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -4811.960947673597
Canvas Y: -3594.1660778856867
From Canvas X: -5282.682440930265
From Canvas Y: -3156.1939570806235
Area: 0.00242
Downstream: J_A5

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OA-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -5488.145209808417
Canvas Y: -3229.3883540208517
From Canvas X: -2083.62512379237
From Canvas Y: 1749.9932448612153
Label X: -3.0
Label Y: -6.0
Area: 0.00239
Downstream: J_A5

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OD-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -4969.3722022933725
Canvas Y: 1114.6912851458305
Area: 0.03863
Downstream: Midpoint Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 15.26
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_A3
Last Modified Date: 19 November 2019
Last Modified Time: 16:39:36
Canvas X: -1208.471880248624
Canvas Y: -1592.2778760698557
From Canvas X: 1040.8900916624807
From Canvas Y: -1618.8586574227438
Downstream: Peri A3
End:

Reach: Peri A3
Last Modified Date: 19 November 2019
Last Modified Time: 17:11:22
Canvas X: -2900.809063630636
Canvas Y: -2287.481982732451
From Canvas X: -1208.471880248624
From Canvas Y: -1592.2778760698557
Downstream: J_A4

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 907.45
Energy Slope: 0.078
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Junction: J_A2
Last Modified Date: 19 November 2019
Last Modified Time: 16:38:49
Canvas X: 1228.268204870441
Canvas Y: -1194.1384419832398
Downstream: Peri A2
End:

Junction: J_A1
Last Modified Date: 19 November 2019
Last Modified Time: 16:43:24
Canvas X: 2620.5934752466883
Canvas Y: -899.4126548233039
From Canvas X: 2620.5934752466883
From Canvas Y: -899.4126548233039
Downstream: Peri A1
End:

Reach: Peri A1
Last Modified Date: 19 November 2019
Last Modified Time: 17:10:46
Canvas X: 1228.268204870441
Canvas Y: -1194.1384419832398
From Canvas X: 2620.5934752466883
From Canvas Y: -899.4126548233039
Downstream: J_A2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1238.52
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: B-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: 294.61279461279446

Canvas Y: 286.1952861952859
Area: 0.00386
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 5.07
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: 1473.0639730639732
Canvas Y: -168.35016835016813
Area: 0.00345
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri A2
Last Modified Date: 19 November 2019
Last Modified Time: 17:11:00
Canvas X: -1208.471880248624
Canvas Y: -1592.2778760698557
From Canvas X: 1228.268204870441
From Canvas Y: -1194.1384419832398
Downstream: J_A3

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 379.41
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: B-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: -455.7170339722252
Canvas Y: -70.82049518426084
Label X: -2.0
Label Y: -1.0
Area: 0.00475
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-4
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 1962.7636351605634
Canvas Y: -621.3689401900992
Area: 0.00616
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-2
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 1150.8225006942284
Canvas Y: -2112.7270628718834
Label X: 2.0
Label Y: -4.0
Area: 0.00119
Downstream: J_A2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2539.289809823257
Canvas Y: -482.73136952822324
Area: 0.00323
Downstream: J_A1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_A4
Last Modified Date: 19 November 2019
Last Modified Time: 16:44:15
Canvas X: -2900.809063630636
Canvas Y: -2287.481982732451
From Canvas X: -3050.8519929059894
From Canvas Y: -2407.391501669781
Downstream: Peri A4
End:

Subbasin: F-4
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -1298.5631198702758
Canvas Y: -2698.5940825632706
From Canvas X: -5282.682440930265
From Canvas Y: -2776.9845831650136
Area: 0.00269
Downstream: J_A3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-3
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 114.49385549810722
Canvas Y: -2587.6133866395203
Area: 0.00156
Downstream: J_A3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute B
Last Modified Date: 19 November 2019
Last Modified Time: 16:37:58
Canvas X: 1228.268204870441
Canvas Y: -1194.1384419832398
From Canvas X: 834.0466727105622
From Canvas Y: -408.14049818109606
Downstream: J_A2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 380
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OA-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2866.3747602812073
Canvas Y: -1450.2860913481982
Label X: -13.0
Label Y: -15.0
Area: 0.00350
Downstream: J_A1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OA-2
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2441.733111868589
Canvas Y: -2061.77006506237
Label X: -3.0
Label Y: -6.0
Area: 0.00416
Downstream: J_A2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.81
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-13
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: 2000.1057975194653
Canvas Y: -2571.340043157512
Area: 0.01064
Downstream: J_A2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.42
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri A4
Last Modified Date: 19 November 2019
Last Modified Time: 17:10:37
Canvas X: -4520.20202020202
Canvas Y: -2895.622895622895
From Canvas X: -2900.809063630636
From Canvas Y: -2287.481982732451
Downstream: J_A5

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 344.3
Energy Slope: 0.009
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: A-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -2382.154882154882

Canvas Y: -134.68013468013487
Label X: -1.0
Label Y: 0.0
Area: 0.01378
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 6.47
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-7
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: -3173.4306729211057
Canvas Y: -1526.2753714659148
From Canvas X: -3304.6443553704594
From Canvas Y: -1198.653675516257
Area: 0.00641
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -2819.86531986532
Canvas Y: -1026.9360269360268
Area: 0.00445
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-6
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -4108.333852092885
Canvas Y: -856.3666906972885
From Canvas X: -3960.5740832244883
From Canvas Y: -798.9464976052077
Area: 0.0038906
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.66
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-4
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -3785.7850767766695
Canvas Y: -340.9506800670415
Area: 0.0026719
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60

Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: -2382.154882154882
Canvas Y: -572.3905723905718
Area: 0.00191
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-2
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -3181.120147163824
Canvas Y: 25.030724698628546
Area: .00039063
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri A5
Last Modified Date: 19 November 2019
Last Modified Time: 17:13:19
Canvas X: -6004.385020291189
Canvas Y: 382.58755484831636
From Canvas X: -4520.20202020202
From Canvas Y: -2895.622895622895
Downstream: J_Mid

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 626.81
Energy Slope: 0.009
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-6
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -6816.037184104709
Canvas Y: 319.4910817090595
From Canvas X: -7137.733702517441
From Canvas Y: 728.1399000549532
Area: 0.00836
Downstream: J_Mid

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: Midpoint Site Outfall
Last Modified Date: 4 November 2019
Last Modified Time: 21:44:15
Canvas X: -6121.783716957593
Canvas Y: 1463.9154354050097
Downstream: Overall Site Outfall
End:

Subbasin: OD-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -5688.768051608007
Canvas Y: 4190.02150773637
Area: 0.04775
Downstream: Overall Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 9.67
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-7
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -6518.1942682149465
Canvas Y: 3869.5297384327723
From Canvas X: -4814.418668820334
From Canvas Y: 5021.606572309131
Area: 0.00348
Downstream: Overall Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: DO-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -4833.71764781123
Canvas Y: 3917.4727632773665
From Canvas X: -841.654778887304
From Canvas Y: -142.65335235378052
Area: 0.00272
Downstream: Overall Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.06
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: Overall Site Outfall
Last Modified Date: 4 December 2019
Last Modified Time: 14:23:56
Canvas X: -8322.890474947622
Canvas Y: 4620.729306795858
End:

Basin Layer Properties:
Element Layer:
Name: Icons
Layer shown: Yes
End Layer:
End:

Basin Spatial Properties:
End:

Basin Schematic Properties:
Last View N: 6371.9254009410415
Last View S: -4117.212754667324
Last View W: -8195.442757096444
Last View E: 6581.0295032464455
Maximum View N: 5124.918857076491
Maximum View S: -3594.1660778856867
Maximum View W: -6816.037184104709
Maximum View E: 5590.535772203601
Extent Method: Elements
Buffer: 0
Draw Icons: Yes
Draw Icon Labels: Name
Draw Map Objects: No
Draw Gridlines: No
Draw Flow Direction: No
Draw HillShade Layer: Yes
Draw Elevation Layer: Yes
Elevation Layer Color Palette: Default
Ignore Elevation Color Ramp Scale: No
Use Interpolated Color Ramp for Elevation Layer: Yes
Color Ramp Opacity Level for Elevation Layer: 33.0
Fix Element Locations: No
Fix Hydrologic Order: No
End:

ATTACHMENT 2C

ON-SITE DESIGN –
SURFACE WATER POND APPURTENANCES
DESIGN CALCULATIONS

Written by:	O. Bramlet	Date:	01/08/2020	Reviewed & Revised by:	S. Graves	Date:	01/19/2020
Client:	TRLC	Project:	Fort Worth Landfill Expansion	Project No.:	GW6953	Phase No.:	04

ON-SITE DESIGN – SURFACE WATER POND APPURTENANCES DESIGN CALCULATIONS FORT WORTH C&D LANDFILL EXPANSION

5/7/2020

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 24

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the methodology, parameters, and calculations for the design of the North Surface Water Pond, pond outlet pipe structures, and pond appurtenances of the Fort Worth C&D Landfill (site) facility surface water management system. "Appurtenances" refers to: (i) the anti-seep collars of pond outlet pipes associated with the surface water pond; and (ii) riprap apron for pond outlet pipes. Note that hydraulic sizing/design information for each pond is described within Attachment 2B, since the outlet pipe performance (discharge flows, pond elevations, etc.) is based on the hydrology analyses routed through the pond and associated pond outlet pipes. Also note that the hydraulic design of the other culvert at the site and the inlet of the perimeter channel into the North Surface Water Pond, which is not associated with the sizing/hydraulic performance of the surface water pond, is presented in Attachment 2E.

Surface water diversion structures on the final cover system convey runoff through a system of drainage terraces, downchute channels, and perimeter channels to the south towards the midpoint site outfall location to Village Creek or to the north towards the North Surface Water Pond. The North Surface Water Pond consists of four sub-ponds in series (referred to as Series 1, Series 2, Series 3, and Series 4), each with outlet pipes that connect to a downstream sub-pond in the series. The North Surface Water Pond Series 1 is the most downstream pond, and has an existing outlet pipe that discharges into a drainage channel and ultimately to Village Creek at the overall site outfall location. The post-development site outfalls are in the same locations as the current (existing) site outfalls.

The Drainage Report (Attachment 2) in Section 8 describes the construction schedule for the installation of the North Surface Water Pond and other drainage features at the site. The hydrologic modeling and design supporting the surface water management system is described in Attachment 2B: *On-Site Drainage Analysis – Hydrology*. The following sections describe the methodology, design parameters, and results for the appurtenances (anti-seep collars and riprap aprons) supporting the North Surface Water Pond outlet pipes.

2 METHODOLOGY

2.1 Pond Outlet Pipe Design

The pond outlet pipes are designed by utilizing the Hydrologic Modeling System (HEC-HMS) computer program developed through the Hydraulic Engineering Center (HEC) of the United States Army Corps of Engineers (USACE) and the HY-8 Culvert Analysis Program v.7.5 (HY-8). HY-8 was originally developed by the Federal Highway Administration (FHWA) and has since been updated and revised to its current version (Version 7.5). The pond outlet pipes are modeled and their performance assessed based on inflow and elevation-storage relationships of the sub-ponds in series. HEC-HMS is applied for the surface water drainage system to model the pond outlet pipes conveying the peak discharge from North Surface Water Pond. The HEC-HMS model developed to compute the peak inflows for each design rainfall event is discussed within Attachment 2B of the Drainage Report. The HY-8 model simulates flow through the pond outlet pipe and over the pond spillway separately using the discharge flow rate provided by the HEC-HMS model. This is because the HEC-HMS model does not differentiate the amount of discharge flow through the culvert and the spillway separately. The HY-8 model was used to size the riprap aprons at the pond outlet pipes that had flow both through their outlet pipes and spillways during the simulated rainfall events. The North Surface Water Pond Series 1 and Series 2 were the only sub-ponds that had flow through both the outlet pipe and spillway during the rainfall event associated with the riprap apron design (described in detail below). The portion of the total flow that is being conveyed through the outlet pipe was used to size the riprap aprons.

The HEC-HMS model results are considered to be more precise predictions of water levels within the sub-ponds and are the basis for the headwater predictions. Results from the HEC-HMS and HY-8 models were evaluated in order to demonstrate that the computed headwater elevation will not overtop the surface water pond berms at the culvert inlet during the design rainfall event. The tailwater at the ultimate pond outlet pipe of the North Surface Water Pond Series 1 was calculated using Manning's equation as described in Attachment 2E: *On-Site Design – Culverts and Perimeter Drainage Channels*. The performance of each outlet pipe for the surface water pond series was evaluated for the 24-hour rainfall event with a 4% annual chance of occurrence (referred to herein as the "25-year, 24-hour rainfall event") and the 24-hour rainfall event with a 1% annual chance of occurrence (referred to herein as the "100-year, 24-hour rainfall event").

2.2 Anti-Seep Collar Design

Anti-seep collars are required for penetrations through a basin berm to control seepage. The methodology utilized to design the anti-seep collars follows guidance provided in the *Kentucky Division of Water Engineering Memorandum No.* 5, (KDNREP, 1999) and the Tennessee Department of Transportation Drainage Manual (TDOT, 2007). Although these guidance documents are from different states, the methods provided are an industry-standard practice and have a sound technical basis for design at this site. KDNREP (1999) recommends placing anti-seep collars along the length of the outlet structure culvert within the saturated zone such that the anti-seep collars: (i) provide an increase in flow length along the pipe of 15%, and (ii) are spaced at distance of no more than 25 ft apart. This relationship may be described as (KDNREP, 1999):

$$\frac{L_s+2nV}{L_s} \geq 1.15 \quad (1)$$

where: L_s = length of pipe within the saturated zone (ft),

V = vertical and horizontal projection of the collar (ft), and

n = number of anti-seep collars.

The length of pipe in the saturated zone, L_s, is computed based on the following assumptions: (i) the groundwater table is located below the elevation of the outlet pipe; (ii) the phreatic surface slopes at a 4 horizontal :1 vertical (4H:1V) slope from the elevation of ponded surface water runoff due to the 25-year, 24-hour rainfall event; and (iii) the interior sideslopes of the North Surface Water Pond Series 1, Series 2, Series 3, and Series 4 are all 3H:1V.

Based on these assumptions, L_s can be computed as follows (TDOT, 2007):

$$L_s = y \times (z + 4) \times \left(1 + \frac{S}{0.25 - S}\right) \qquad (2)$$

where:

- L_s = length of pipe within saturated zone (ft);
- y = depth of surface water in the pond after a 25-year, 24-hour rainfall event;
- z = slope of the interior embankment sideslope; and
- S = slope of the outlet pipe (ft/ft).

Figure 2C-1 further depicts the geometry behind the calculation of L_s.

2.3 Riprap Outlet Apron Design

The riprap apron at the pond series outlet pipes were designed to protect against erosion and scour from the surface water pond outflows. The riprap aprons were sized from the outflow based on the 25-year, 24-hour rainfall event using HEC-HMS and HY-8 model results. The North Surface Water Pond Series 1 and Series 2 outlet pipe riprap aprons were designed using results from the HY-8 model because a portion of the total flow in these pond series discharges from the spillway during the simulated rainfall event. The HY-8 model has the capability of differentiating the amount of flow through both the outlet pipe and spillway separately. The calculated flow through the outlet pipe from HY-8 was used to size the riprap apron for the North Surface Water Pond Series 1 and Series 2. The North Surface Water Pond Series 3 and Series 4 outlet pipe riprap aprons were designed using outflow results from the HEC-HMS model because the water surface elevation during the 25-year, 24-hour rainfall event does not reach the spillway elevation and all outflow is conveyed through the outlet pipe.

The design guidance from the FHWA provides a methodology for calculating the required length of apron (L_a) and d_{50} of the riprap based on the culvert diameter and flow rate. The d_{50} is the stone size of the riprap for which to 50% of the riprap stones are smaller than d_{50} by mass. The riprap size is calculated using the following equation (FHWA, 2006):

$$d_{50} = 0.2D\left(\frac{Q}{D^{2.5}\sqrt{g}}\right)^{4/3} \frac{D}{TW} \qquad (3)$$

where: d_{50} = riprap size (ft);

Q = design discharge (cfs);

D = pipe diameter (ft);

TW = tailwater depth (ft); and

g = gravitational constant.

The tailwater depth should be limited to between 0.4D and D. FHWA (2006) recommends the use of a tailwater depth equal to 0.4D if the tailwater is unknown.

The required length and depth of the riprap apron can be estimated based on the pond outlet pipe rise and riprap size as provided in Table 2C-1. The width of the riprap apron at the outlet is recommended as 3D by the FHWA (2006) detail for riprap aprons. The apron width will also widen from the outlet along the required length at a rate of 1 ft width per 3 ft length on each side. Figure 2C-2 provides the standard geometry for the riprap apron.

3 DESIGN PARAMETERS

3.1 Pond Outlet Pipe Parameters

The design parameters for the pond outlet pipes, including geometry and calculated peak discharges as computed by the HEC-HMS, are described in the appendices of Attachment 2B to the Drainage Report for the 25-year, 24-hour and 100-year, 24-hour rainfall events.

The pond outlet pipes were designed to convey both the peak 25-year, 24-hour rainfall discharge and 100-year, 24-hour rainfall discharge while maintaining a water surface elevation in the pond with 0.5 feet of freeboard for the 25-year event and that does not overtop the pond berms for the 100-year event. The proposed pond outlet pipe design parameters are provided in Table 2C-2. It is noted that the peak discharge from the North Surface Water Pond Series 1 and Series 2 outlet pipes were computed in the HY-8 model as some of the outflow from this pond series is also conveyed over the spillway. A Manning’s roughness coefficient is selected as 0.012 for concrete pipe culverts, based on guidance in Table 2C-3 (TxDOT, 2019).

The inflow structure into the culverts influences the conveyance of surface water through the culvert. The culvert inflow structures were modeled with a square edge entrance with a headwall. The culvert headwall is to be installed according to the TxDOT standard detail FW-0 for concrete wingwalls with flared wings. TxDOT standard details for wingwalls are available in Figure 2C-3.

3.2 Anti-Seep Collar Design Parameters

Anti-seep collars were designed for each surface water pond outlet pipe, and the design parameters and structure geometry is described herein. Design parameters utilized in Equations (1) and (2) are also provided in Table 2C-2.

3.3 Riprap Outlet Apron Design Parameters

The North Surface Water Pond Series 1 has a computed peak outflow of 360.30 cfs during a 25-year, 24-hour rainfall event, where 149.96 cfs and 210.27 cfs flow through the pipes and the spillway, respectively. The North Surface Water Pond Series 2 has a computed peak outflow into Series 1 of 467.40 cfs during a 25-year, 24-hour rainfall event, where 433.91 cfs and 33.29 cfs flow through the pipes and the spillway, respectively. The HY-8 model divides these peak flow rates obtained from the HEC-HMS model between the pond outlet pipe and overflow spillway. The North Surface Water Pond Series 3 and Series 4 outlet pipe riprap aprons were designed using computed outflows from the HEC-HMS model, as all the pond discharge was routed through the outlet pipe during the 25-year, 24-hour rainfall event. The computed outflows for these pond series and the proposed design parameters used in Equation (3) are listed in Table 2C-4. The riprap aprons were designed for the 25-year, 24-hour peak flow rates through the pond outlet pipes only, as each of the spillways are lined with riprap. For the purposes of riprap apron design, the North Surface Water Pond discharge from outlets were evenly divided between the number of proposed culvert barrels. Also for the purposes of riprap apron design, the tailwater depth of the pipe is considered to be 0.4*D* (FHWA, 2006). The computed tailwater depths for each North Surface Water Pond series are 1.0 foot for Series 1 and 1.8 feet for the three remaining sub-ponds.

4 RESULTS

4.1 Pond Outlet Pipe

The results of the computations of the performance of the North Surface Water Pond Series 1 and Series 2 outlet pipes from the HY-8 model is presented in Table 2C-5 for both the 25-year, 24-hour and 100-year, 24-hour rainfall events. The output graphs for the 25-year and 100-year events for North Surface Water Pond Series 1 are shown on Figure 2C-4 and Figure 2C-5, respectively. The output graphs for the 25-year and 100-year, 24-hour rainfall events for North Surface Water Pond Series 2 are shown on Figure 2C-6 and Figure 2C-7, respectively. The pond outlet pipes provide the capacity to convey the peak flows from the surface water pond without overtopping the perimeter berms. It is important to note that the headwater elevations reported in Table 2C-5 are from the HY-8 output and do not account for storage restrictions within the ponds. The headwater elevations from the HY-8 output are used solely for calculating the flow through the pond outlet pipes for sizing of the riprap aprons as described in Section 4.3. The HEC-HMS headwater values reported previously and in Attachment 2B are considered to be more precise predictions of water levels within the ponds.

The North Surface Water Pond Series 3 and Series 4 water surface elevation does not reach the spillway during the 25-year, 24-hour rainfall events; therefore, all discharge is conveyed through the outlet pipes for this event. The peak water surface elevations do not overtop the perimeter berm for the 100-year, 24-hour rainfall event, as shown in Table 2C-2.

4.2 Anti-Seep Collars

Based on the design parameters described above, the length of the North Surface Water Pond outlet pipes within the saturated zone, L_s, are calculated using Equation (2) and are provided in Table 2C-6.

Anti-seep collars should be spaced no more than 25 ft apart (KDNREP, 1999). The minimum number of seep collars necessary for each of the North Surface Water Pond outlet pipes are provided in Table 2C-6. The minimum vertical and horizontal projection (V) of each seep collar was back calculated by Equation (1). Based on recommendations by Tennessee Department of Transportation (TDOT), the anti-seep collar should extend at least two feet in all directions around the outlet pipe (TDOT, 2007).

To describe the spacing of the anti-seep collars, the first anti-seep collar should be constructed approximately 12.5 feet from the up gradient inlet of the pond outlet pipe. The second anti-seep collar should be spaced 25 feet from the first collar or 37.5 feet from the up gradient end of the pond outlet pipe. The third anti-seep collar, if necessary, should be spaced 25 feet from the second collar or 62.5 feet from the up gradient end of the pond outlet pipe. The anti-seep collars should extend two feet in every direction from the pipe.

4.3 Riprap Outlet Apron

Equation (3) was applied to size the riprap aprons for the surface water pond outlet pipes using the design discharges through the pond outlet pipes based on the HEC-HMS and HY-8 model outputs. The HY-8 model was used to calculate the outflow through the North Surface Water Pond Series 1 and Series 2, while the HEC-HMS model results were used for the North Surface Water Pond Series 3 and Series 4, as previously described.

The flow was assumed to be evenly split between each barrel pipe and the tailwater depth was computed as described in Section 3.3. Based on Equation (3) a minimum d_{50} size for the riprap of was selected. The minimum apron lengths and widths were selected based on Table 2C-1. FHWA (2006) recommends a 3:1 rate of expansion. Results for the riprap outlet aprons dimensions for each pond series are provided in Table 2C-7.

It is noted that since the outlet pipe of the North Surface Water Pond Series 1 is discharging into a stabilized trapezoidal channel lined with geomembrane, the dimensions of the riprap apron are restricted by the downstream channel dimensions. Therefore, the entire width of the channel (8 feet) should be lined with riprap, and the necessary length of the riprap apron is less than the length of the stabilized channel.

5 REFERENCES

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TABLES

Table 2C-1. Riprap Classes and Apron Dimensions (from FHWA, 2006)

Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1]D is the culvert rise.

Table 2C-2. North Surface Water Pond Design Parameters

North Pond Series	Number of Barrels	Manning's Roughness Coefficient	Diameter (ft)	Length of Pipe (ft)	Inlet Elevation (ft)	Outlet Elevation (ft)	Slope of Pipe (ft/ft)	Slope of Interior Embankment Sideslope (H: 1V)	Berm Elevation (ft)	Spillway Elevation (ft)
Series 1	2	0.012	2.5	64.5	588.0	587.4	0.009	3	598.5	597.0
Series 2	3	0.012	4.5	40	597.0	596.5	0.013	3	604.0	603.0
Series 3	2	0.012	4.5	60	603.0	602.5	0.008	3	614.0	613.0
Series 4	2	0.012	4.5	70	613.0	612.5	0.007	3	625.0	624.0

**Table 2C-3. Manning's n Values
(from TxDOT, 2019)**

Material		Manning's n
Asbestos-cement pipe		0.011-0.015
Brick		0.013-0.017
Cast iron pipe		
	Cement-lined & seal coated	0.011-0.015
Concrete (monolithic)		
	Smooth forms	0.012-0.014
	Rough forms	0.015-0.017
	Concrete pipe	0.011-0.015
	Box (smooth)	0.012-0.015
Corrugated-metal pipe -- (2-1/2 in. x 1/2 in. corrugations)		
	Plain	0.022-0.026
	Paved invert	0.018-0.022
	Spun asphalt lined	0.011-0.015
	Plastic pipe (smooth)	0.011-0.015
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. annular)		0.022-0.027
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. helical)		0.011-0.023
Corrugated-metal pipe -- (6 in. by 1 in. helical)		0.022-0.025
Corrugated-metal pipe -- (5 in. by 1 in. helical)		0.025–0.026
Corrugated-metal pipe -- (3 in. by 1 in. helical)		0.027–0.028
Corrugated-metal pipe -- (6 in. by 2 in. structural plate)		0.033–0.035
Corrugated-metal pipe -- (9 in. by 2-1/2 in. structural plate)		0.033–0.037
Corrugated polyethylene		0.010–0.013
	Smooth	0.009-0.015
	Corrugated	0.018–0.025
Spiral rib metal pipe (smooth)		0.012-0.013
Vitrified clay		
	Pipes	0.011-0.015

Table 2C-4. Summary of Calculated Results for North Surface Water Pond

	25-year, 24-hour Rainfall Event			100-year, 24-hour Rainfall Event		
North Surface Water Pond Series	**Total Flow Rate (cfs)**	**Peak Water Surface Elevation (ft)**	**Pond Water Depth (ft)**	**Total Flow Rate (cfs)**	**Peak Water Surface Elevation (ft)**	**Pond Water Depth (ft)**
Series 1	360.30	597.9	9.9	578.00	598.4	10.4
Series 2	467.40	603.3	6.3	639.20	603.9	6.9
Series 3	369.40	611.3	8.3	522.40	613.5	10.5
Series 4	412.80	622.6	9.6	619.80	624.8	11.8

Table 2C-5. North Surface Water Pond Series 1 and Series 2 Outlet Pipe HY-8 Results

	25-Year, 24-Hour Rainfall Event						100-Year, 24-Hour Rainfall Event					
	Total Flow Rate Q_{25}[b] (cfs)	Pipe Flow (cfs)	Pipe Velocity (fps)	Spillway Flow (cfs)	Tailwater Elev (ft)	Headwater Elev[a] (ft)	Total Flow Rate Q_{100}[b] (cfs)	Pipe Flow (cfs)	Pipe Velocity (fps)	Spillway Flow (cfs)	Tailwater Elev (ft)	Headwater Elev[a] (ft)
North Pond Series 1 Outlet	360.30	149.96	15.27	210.27	589.85	597.92	578.00	154.59	15.75	423.23	590.48	598.46
North Pond Series 2 Outlet	467.40	433.91	12.54	33.29	597.90	603.27	639.20	468.39	12.89	170.55	598.40	603.80

[a] Headwater elevations predicted from HY-8 modeling are generally smaller than those predicted from the HEC-HMS model. The HEC-HMS model results (Attachment 2B) are considered to be more precise predictions of water levels within the ponds. The HY-8 model was used to size the riprap aprons at the pond outlet pipe using the portion of the total flow that is being conveyed through the pond outlet pipe. The smaller headwater predicted by the HY-8 model predicts more of the total outflow being conveyed through the pond outlet pipes because less water is allowed to discharge from the pond over the emergency spillway due to the smaller headwater predictions (i.e., conservative for the purposes of riprap sizing).

[b] These values are the total outflow rate from the pond predicted from HEC-HMS model results. These values are used as input to the HY-8 model.

Table 2C-6. North Surface Water Pond Anti-Seep Collar Results

North Pond Series	Length of Pipe Within Saturated Zone, L_s (ft)	Number of Collars Required	Vertical and Horizontal Projection of Each Seep Collar (ft)
Series 1	72.0	3	2.00
Series 2	46.4	2	2.00
Series 3	60.1	2	2.25
Series 4	69.2	3	2.00

Table 2C-7. North Surface Water Pond Outlet Pipe Riprap Apron Results

North Pond Series	d_{50} (in)	Riprap Class	Apron Length (ft)	Downstream Apron Width (ft)	Apron Depth (ft)
Series 1	23	6	20	21	3.7
Series 2	14	4	32	35	2.2
Series 3	19	5	32	35	3.1
Series 4	22	6	36	38	3.4

FIGURES

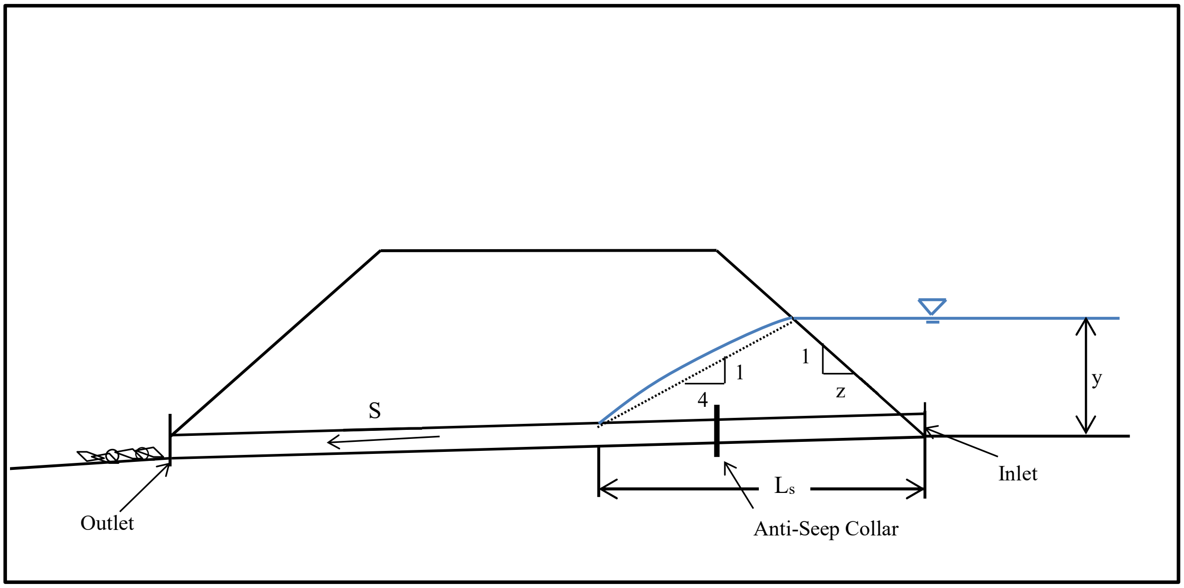
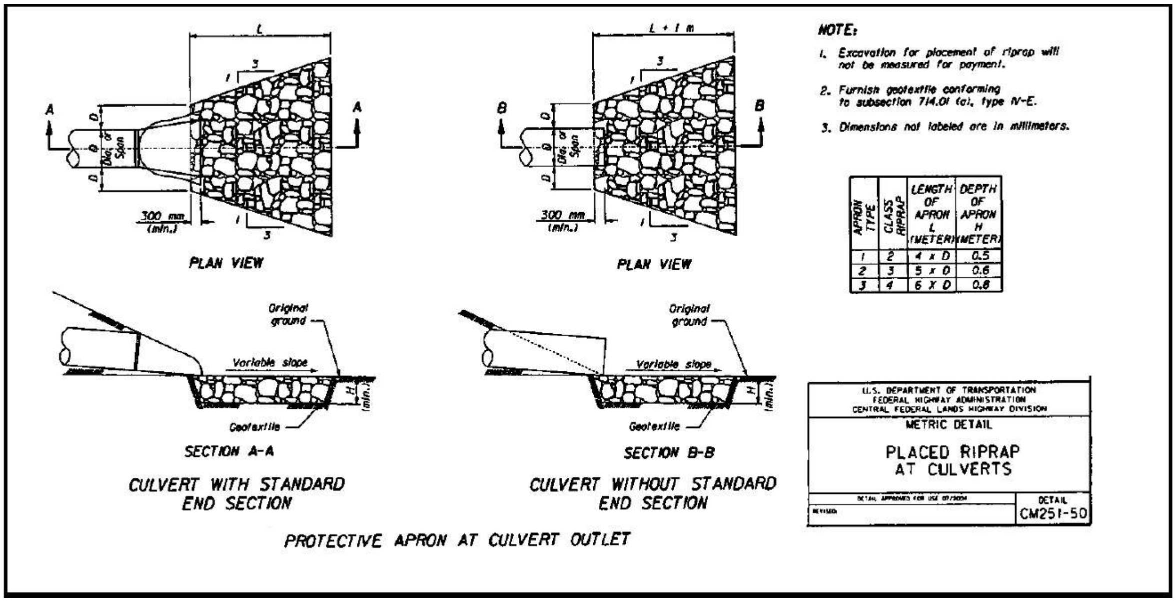


Figure 2C-1. Anti-Seep Collar Design Schematic (not to scale)



APRON TYPE	CLASS RIPRAP	LENGTH OF APRON L (METER)	DEPTH OF APRON H (METER)
1	2	4 x D	0.5
2	3	5 x D	0.6
3	4	6 X D	0.8

Figure 2C-2. Placed Riprap Apron Standard Detail (from FHWA, 2006)

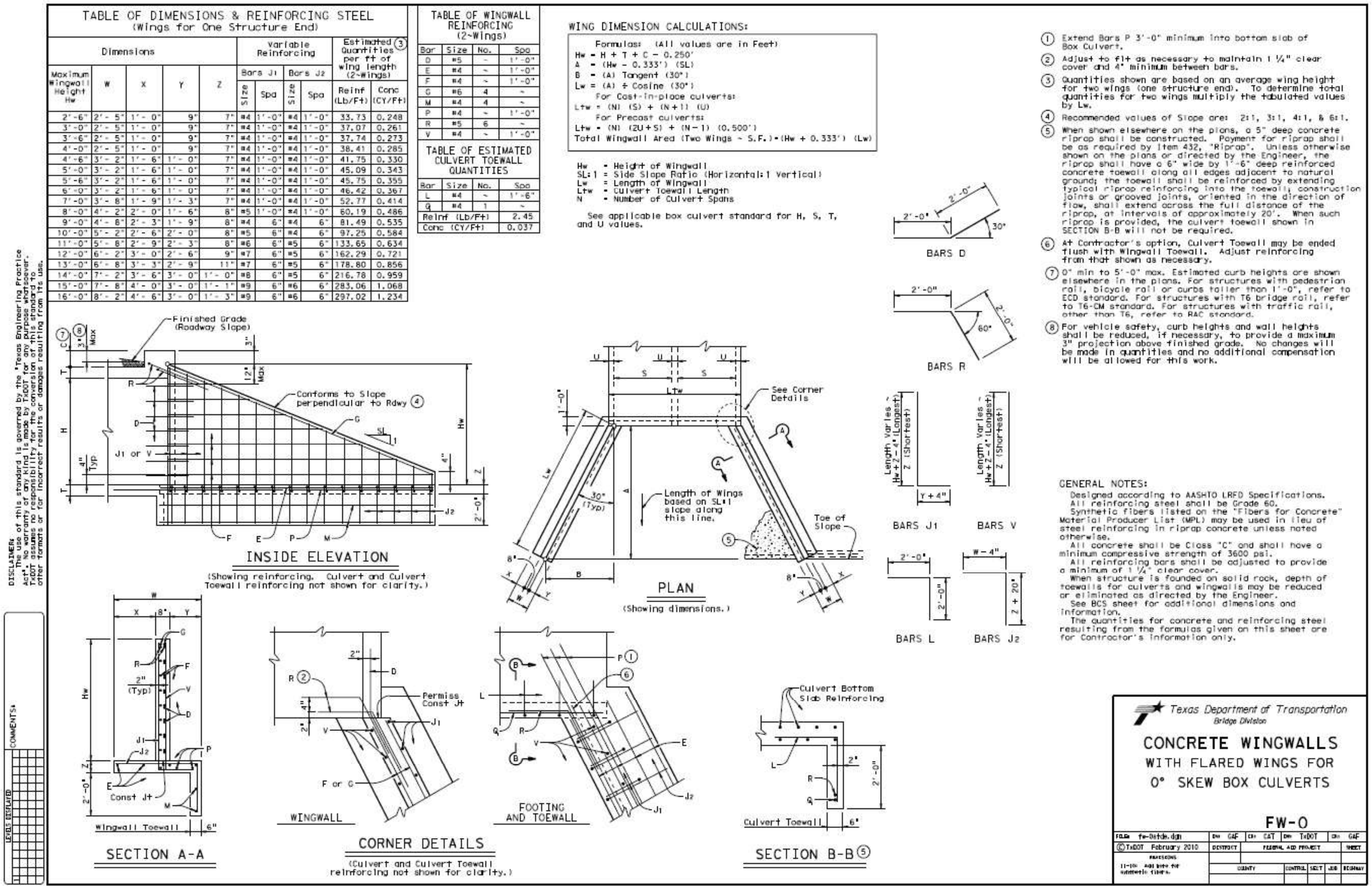


Figure 2C-3. TxDOT Standard Detail FW-0 for Concrete Wingwalls

Source: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/bridge/fw-0stde.pdf (Date Accessed: 12/4/2019)

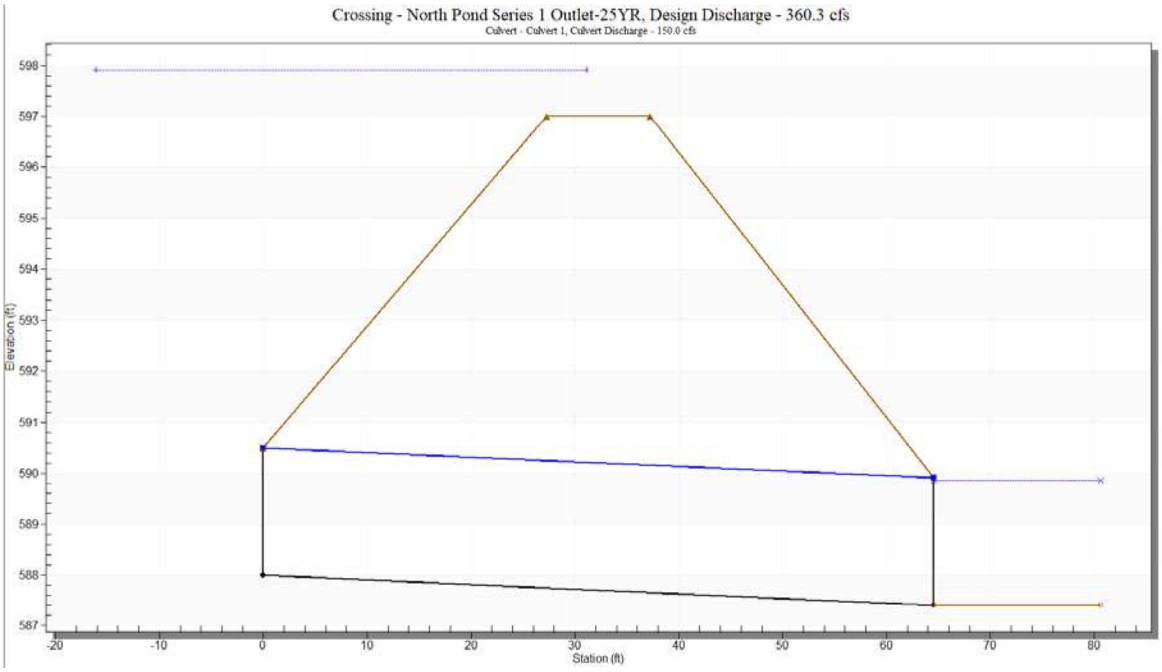


Figure 2C-4. HY-8 Modeling Output for 25-Year Event North Surface Water Pond Series 1 Outlet Pipe

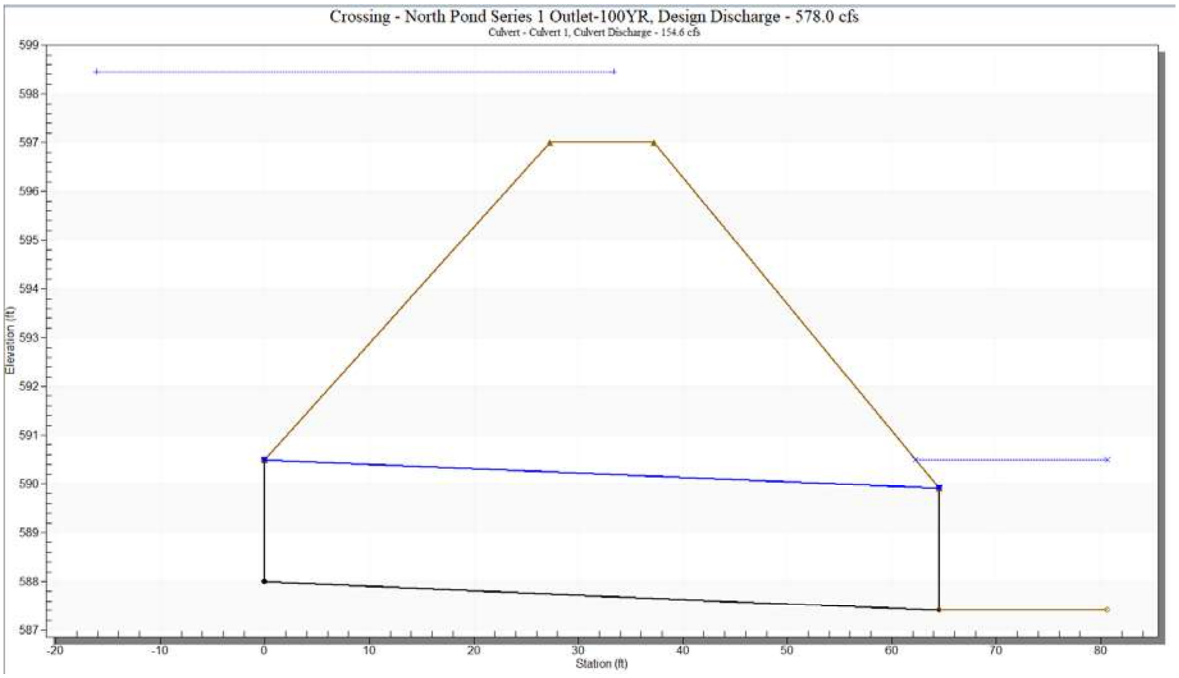


Figure 2C-5. HY-8 Modeling Output for 100-Year Event North Surface Water Pond Series 1 Outlet Pipe

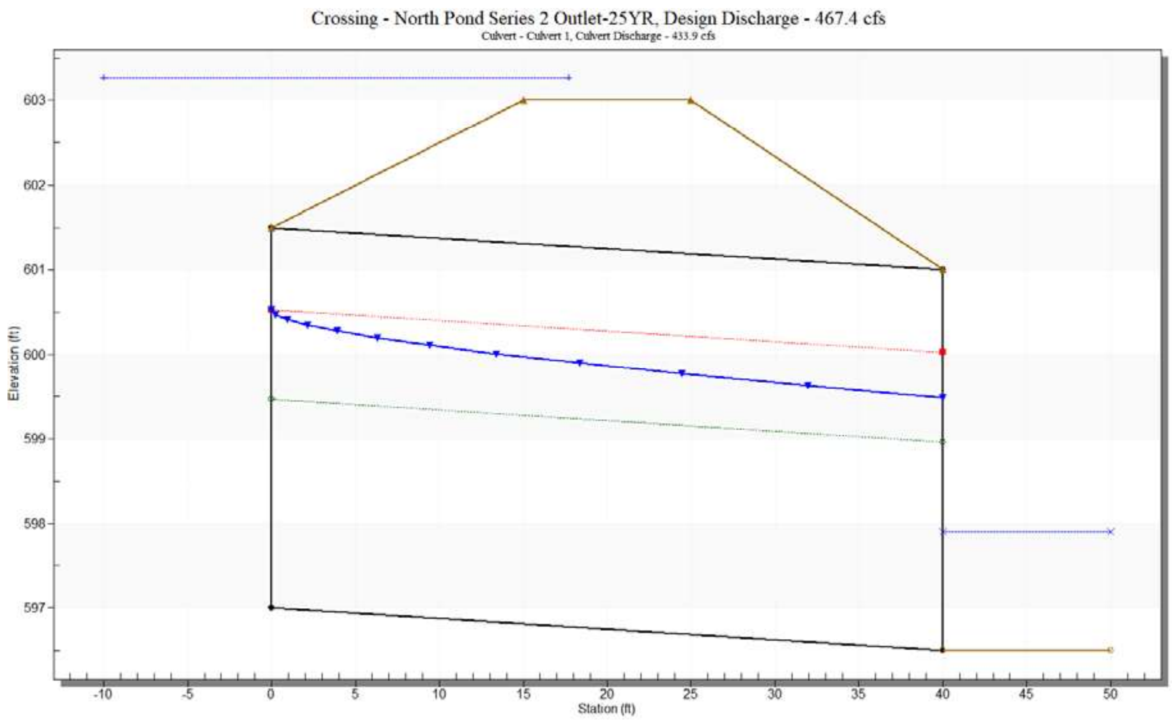


Figure 2C-6. HY-8 Modeling Output for 25-Year Event North Surface Water Pond Series 2 Outlet Pipe

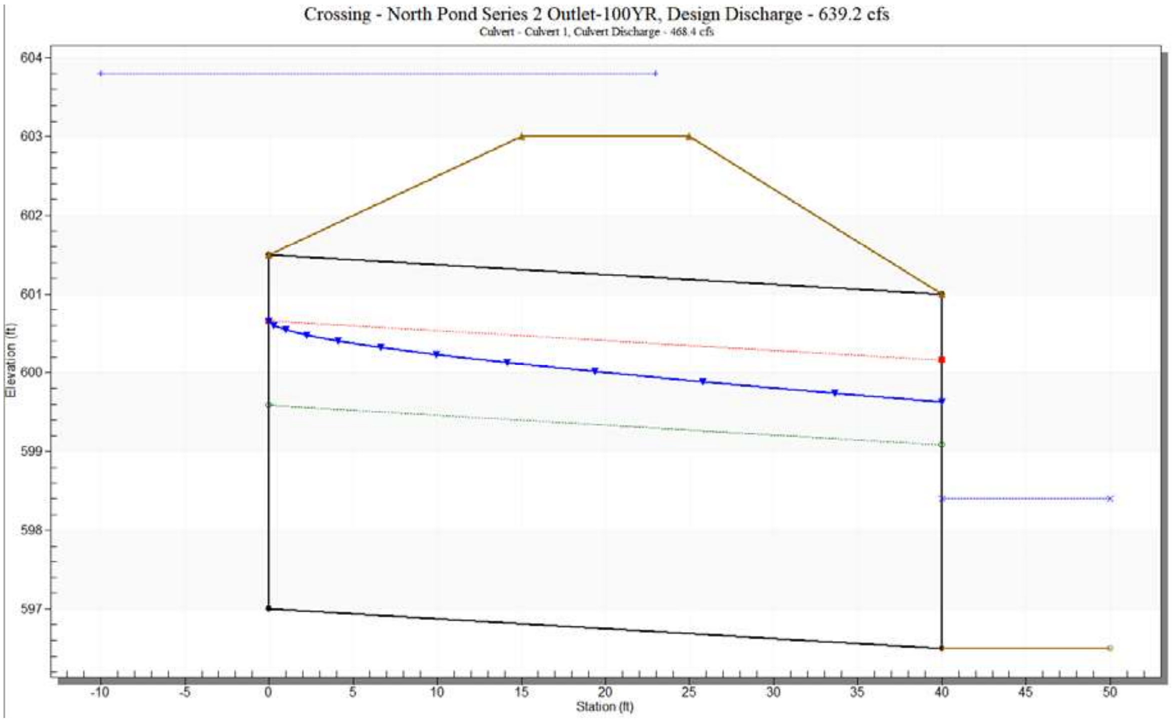


Figure 2C-5. HY-8 Modeling Output for 100-Year Event North Surface Water Pond Series 2 Outlet Pipe

ATTACHMENT 2D

ON-SITE DESIGN – DRAINAGE TERRACES AND DOWNCHUTE CHANNELS

Written by:	O. Bramlet	Date:	01/09/2020	Reviewed and Revised by:	S. Graves	Date:	2/4/2020; 9/15/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

ON-SITE DESIGN – DRAINAGE TERRACES AND DOWNCHUTE CHANNELS FORT WORTH C&D LANDFILL EXPANSION

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SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 22

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TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the design of the top deck drainage terraces, sideslope drainage terraces, and downchute channels for the facility surface water management system for the Fort Worth C&D Landfill. As part of the facility surface water management system design, sheet flow runoff from the final cover system is intercepted by drainage terraces located at the base of the top deck surface and on the 3 horizontal: 1 vertical (3H:1V) final cover sideslopes. Top deck and sideslope drainage terraces convey runoff to downchute channels. These downchute channels subsequently convey the runoff to perimeter drainage channels. The perimeter drainage channels convey surface water runoff to either the midpoint site outfall or the North Surface Water Pond. Design of the surface water pond is presented in Attachment 2C. Design of the perimeter channels is presented in Attachment 2E. The Facility Surface Water Management Plan shows the layout of each of these features and can be found in Drawing 2-1 of the Drainage Report (the drawings are in Attachment 2A of the Drainage Report).

2 METHODOLOGY

The top deck drainage terraces and sideslope drainage terraces are designed as grass-lined v-shaped channels (i.e., trapezoidal channels with bottom width equal to zero) and are sized to convey runoff from the 25-year, 24-hour rainfall event with 0.5 feet of freeboard and to convey the 100-year, 24-hour rainfall event without overtopping. Additionally, the average velocity and the average tractive stress are calculated based on the predicted peak flow for each rainfall event. The top deck drainage terraces are located at the base of the top deck surfaces, while the sideslope drainage terraces are spaced a maximum of 200-feet apart horizontally on the 3H:1V final cover sideslopes (see Drawing 2-1 in Attachment 2A). Typical drainage terrace and downchute cross-sections for the final cover system are shown on the drawings presented in Attachment 2 (the Facility Surface Water Drainage Report) of the Site Development Plan (SDP). The hydraulic design of the terrace and downchute drainage features meets or exceeds the design criteria described herein.

Downchute channels are evaluated as articulated concrete block (ACB) lined trapezoidal channels in this calculation package. Other equivalent downchute channel lining materials meeting the design performance criteria addressed in this calculation package may be used. The downchute channels are designed to convey the 25-year, 24-hour rainfall event with 0.5 feet of freeboard (and to convey the 100-year, 24-hour rainfall event without overtopping) down the 3H:1V final cover sideslopes and into the perimeter drainage channels. The peak 25-year, 24-hour rainfall event discharge and resulting calculated average tractive stresses are used to design the lining system of the downchute channels.

The capacity of each downchute channel and drainage terrace is calculated by solving Manning's equation for the depth of flow within each channel or terrace. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad (1)$$

where:

- Q = discharge (cfs),
- n = Manning's roughness coefficient,
- A = area of cross-section of flow (ft^2),
- P = wetted perimeter (ft),
- R = hydraulic radius = A/P (ft), and
- S = longitudinal slope (ft/ft).

The average tractive stresses in the downchute or drainage terrace for various flows are estimated by Equation (2) (Chow, 1959).

$$\tau_o = \gamma_w RS \tag{2}$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Each top deck drainage area and sideslope drainage area was modeled as a separate sub-basin in the HEC-HMS model as discussed in Attachment 2B. However, the hydraulic performance of the top deck drainage terraces and sideslope drainage terraces were not directly modeled in the HEC-HMS model. The travel time through these drainage features is minimal and would not significantly impact the results; therefore, the hydraulic performance was modeled using Manning's equation as described above. Furthermore, it is conservative to not explicitly model the drainage terraces because this removes the lag effect in the peak flow rates. The peak flow rate for each top deck and sideslope drainage terrace was assumed to be equal to that of the corresponding drainage area. The drainage downchutes were modeled explicitly in the HEC-HMS model. Each sub-basin was routed to a downchute within the HEC-HMS model to compute the peak discharges within each downchute channel. The locations and contributing areas of the top deck drainage terraces and downchute channels are shown on Drawing 2-3 of Attachment 2A. The resulting peak flow rates from the HEC-HMS model output were used in the Manning's equation to calculate the resulting flow depths and tractive stresses in the drainage features to demonstrate that the design parameters of the drainage features are adequate.

The downchute channel design evaluation is for an articulated concrete block (ACB) channel lining to resist erosive forces. As noted, other equivalent downchute channel lining materials meeting the design performance criteria addressed in this calculation package may be used. For this ACB design, the method relates the tested critical shear stress of an ACB system on a horizontal plane to the design conditions and then accounts for slope by checking that the resistance is adequate to prevent failure. The maximum allowable tractive stress is calculated using the following equation:

$$\tau_0 = \frac{\tau_\theta \chi_2}{\chi_2 \cos\theta - \chi_1 \sin\theta} \qquad (3)$$

where: τ_0 = maximum allowable tractive stress at 0° (psf);
τ_θ = maximum allowable tractive stress at θ° (psf); and
χ_2 and χ_1 = extrapolation variables (inches).

ACB-type channel lining is suitable for use on 3H:1V slopes. In fact, the methodology presented in Equation (3) was developed using laboratory flume testing data the ACB Channel Lock 450 system that was conducted on a 3H:1V sideslope bedded on a compacted soil embankment with conditions representative of those expected for this site, for a range of flow rates until failure of the ACB occurred (Ayers, 2001a). This value was used to extend the tested results to a horizontal bed (0° slope) using the moment-balance Equation (3) above to allow the results to be applied to different slope angles. Test data was also extrapolated to ACB systems of different sizes using an overturning moment-balance approach accounting for stabilizing and destabilizing forces. As further described in the subsequent paragraph, there is minimal chance of failure due to sliding of the lining along the plane of the subgrade. The loss of contact is primarily due to the overturning of a block in which failure occurs. The best method for determining failure is in terms of tractive stress, derived in Equation (3) to extrapolate from laboratory settings to hypothetical situations.

According to the ACB design manual (Ayers, 2001b), typical applications of ACBs are on slopes of 2H:1V or flatter. This shows that the design conditions for this site (on 3H:1V slopes) are a typical ACB application condition. The design manual notes that "*the probability of failure due to slipping or sliding of the system matrix along the plane of the subgrade is remote. The loss of intimate contact is most often the result of overturning of a block or group of blocks, in which incipient failure occurs when the overturning moments equal the retaining moments about the downstream contact point of an individual block.*" From the design manual and the flume tests conducted on ACB inclined on a 3H:1V with similar subgrade conditions to that expected for this site, it is apparent that the critical mode of failure for ACB systems on slopes at 2H:1V or flatter is overturning. By using this methodology and confirming that the design conditions can adequately resist an overturning-mode of failure, the design would be expected to adequately resist the less-critical sliding mode of failure.

3 DESIGN PARAMETERS

The design parameters, including channel geometry, Manning's roughness coefficient, and calculated peak discharges for the 25-year and 100-year rainfall events (Attachment 2B), are summarized for each downchute channel and top deck drainage terrace in Table 2D-1 and Table 2D-2, respectively.

The sideslope drainage terraces are designed as a v-shaped tack-on berms constructed on the 3H:1V sideslopes of the final cover system with design parameters summarized in Table 2D-3. Thus, the sideslopes of the terrace are 3H:1V on the final cover side and 2.5H:1V on the berm side and each terrace has a depth of 2.50 ft. The nominal longitudinal slope of each sideslope drainage terrace is approximately 2% and most terraces are laid out to this longitudinal slope. Each of these site-specific conditions was analyzed to confirm that the sideslope drainage terrace design is adequate for the contributing drainage area and terrace slope. Drawing 2-3 shows the location of each sideslope drainage terrace, top deck drainage terrace, and drainage downchute structures on the final cover system.

Each drainage structure is designed to maintain a minimum of 0.5 feet of freeboard during the 25-year, 24-hour rainfall event. Additionally, each terrace and downchute channel is designed to convey the peak flow during the 100-year, 24-hour rainfall event without overtopping. The calculated 25-year average tractive stress is used to design the lining system of each drainage feature.

The downchute channel design evaluation is for an ACB-lined channel to resist erosive forces. As mentioned, other equivalent downchute channel lining materials meeting the design performance criteria addressed in this calculation package may be used. The maximum allowable tractive stress is calculating using Equation (3) above. The critical shear stress for a horizontal bottom width surface for various ACB types is shown in Table 2D-4 (Ayres, 2001a). ACB Channel Lock 800 is proposed for the downchutes. The maximum allowable tractive stress, or shear stress, for the ACB 800 is 12.8 psf as shown in Table 2D-4 (Ayres, 2001a).

As mentioned, the extrapolation variables were developed based on testing of the ACB Channel Lock 450 system on a 3H:1V sideslope. The Ayres (2001a) report indicates that the "performance extrapolation method… is overly conservative when used to estimate the performance of thicker blocks based on tests of thinner blocks." This suggests that the maximum allowable tractive stress for the ACB 800 system is potentially greater than the calculated value of 12.8 psf. The basis for this claim was additional testing conducted on the ACB Channel Lock 800 system on a 2H:1V sideslope until failure. The proposed ACB system is expected to be overly conservative in terms of maximum allowable tractive stress based on testing data conducted on steep slopes. Furthermore, the proposed ACB system will be anchored into the final cover system along the edges of the downchute drainage channel, thus providing additional strength of the system and resistance to erosive forces.

The peak flows applied to the design of each downchute channel are based on the flows from the entire contributing top deck and sideslope areas for the 25-year, 24-hour rainfall event as provided in Attachment 2B. This is considered conservative as the sum of these flows will only influence the performance of the lining materials at the down gradient end of each downchute channel as opposed to the entire length of the downchute channel.

The allowable tractive stress for the ACB-lined downchutes is documented in published research data (e.g., Ayres, 2001a) and selected for design. The ACB-lined downchute is designed to accommodate the design storm event without shifting of the blocks or any loss of embankment soil beneath the ACB system.

Permissible tractive stresses for grass-lined channels range from 0.35 psf to 3.70 psf depending on the retardation class of vegetation. Retardation Class C (which includes Bermuda and Crab grasses among others) is selected for the design of grass lined channels (as shown in Table 2D-5) and has a maximum permissible tractive stress of 1.0 psf (as shown in Table 2D-6 from TxDOT, 2019).

A range of Manning's roughness coefficients for a variety of channel linings are selected from TxDOT (2019) provided in Table 2D-7. For the grass lined channels a roughness value of n = 0.027 was selected. As previously mentioned, the roughness for ACB lined channels was selected as n = 0.036 (Ayers, 2001a).

4 RESULTS

The depth of flow, velocity, and average tractive stress for the peak discharges into each downchute channel, top deck drainage terrace, and each sideslope drainage terrace were calculated using Equations (1) and (2). These calculations for the downchute channels, top deck drainage terraces, and sideslope drainage terraces are summarized in Table 2D-8, Table 2D-9, and Table 2D-10, respectively. Appendix 2D-1 provides spreadsheets used for calculating the results tables for the downchute channel, top deck drainage terrace, and sideslope drainage terrace with the greatest flow rates (i.e., the critical design cases). Drawing 2-3 provides location and layout of each drainage structure discussed within this calculation package.

- Each downchute channel and drainage terrace was calculated to contain the capacity to convey the flows from the 25-year, 24-hour and the 100-year, 24-hour rainfall events.
- Each downchute channel and drainage terrace was designed to maintain at least 0.5 feet of freeboard for the 25-year, 24-hour rainfall event.
- For each downchute channel, the average tractive stresses were calculated to remain below 12.8 psf during the 25-year, 24-hour rainfall event. The average tractive stress for each drainage terrace was calculated to remain below 1.0 psf during the 25-year, 24-hour rainfall event. The selected channel lining materials can adequately resist these tractive stresses.

5 REFERENCES

Ayres Associates (2001a). "*Hydraulic Stability of the Channel-Lock 450 Concrete Block Revetment System*", Ayres Associates, August, 2001.

Ayres Associates (2001b). "*Design Manual for Articulating Concrete Block Systems*", Ayres Associates, September, 2001.

Chow, V.T. (1959). *Open Channel-Hydraulics,* McGraw-Hill.

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TABLES

Table 2D-1. Design Parameter Summary for Downchute Channels

Downchute Channel Segment	Channel Shape	Longitudinal Channel Slope (%)	Manning's n	Bottom Width (ft)	Depth (ft)	Side Slopes (H:V)	25-year Flow Rate[1] Q_{25} (cfs)	100-year Flow Rate[1] Q_{100} (cfs)
Downchute A	Trapezoidal	33.3	0.036	12.0	2.0	3:1	167.70	226.20
Downchute B	Trapezoidal	33.3	0.036	4.0	2.0	3:1	96.00	129.50
Downchute C	Trapezoidal	33.3	0.036	10.0	2.0	3:1	156.20	210.70
Downchute D	Trapezoidal	33.3	0.036	2.0	2.0	3:1	76.60	103.20
Downchute E	Trapezoidal	33.3	0.036	8.0	2.0	3:1	133.40	179.90

Notes:

1. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-2. Design Parameter Summary for Top Deck Drainage Terraces

Top Deck Channel Segment	Channel Shape	Longitudinal Channel Slope (ft/ft)	Manning's n	Bottom Width (ft)	Depth (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	25-year Flow Rate[1] Q_{25} (cfs)	100-year Flow Rate[1] Q_{100} (cfs)
A-1	V-shaped	0.0322	0.027	0.0	2.0	20:1	3:1	66.20	89.30
C-1	V-shaped	0.0100	0.027	0.0	2.0	20:1	3:1	61.90	83.60

Notes:

1. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-3. Design Parameter Summary for Sideslope Drainage Terraces

Sideslope Channel Segment	Channel Shape	Longitudinal Channel Slope (%)	Manning's n	Bottom Width (ft)	Depth (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	25-year Flow Rate[1] Q_{25} (cfs)	100-year Flow Rate[1] Q_{100} (cfs)
A-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	44.0	62.3
A-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	10.2	13.8
A-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	14.3	19.3
A-5	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	23.8	32.2
A-6	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	20.8	28.0
A-7	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	34.3	46.3
B-1	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	19.6	26.5
B-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	18.5	24.9
B-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	25.4	34.3
B-4	V-shaped	2.50%	0.027	0.0	2.5	2.5:1	3:1	33.0	44.5
C-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	36.1	48.7
C-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	14.3	19.3
C-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	26.4	35.7
D-1	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	3.2	4.3
D-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	6.4	8.7
D-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	5.9	8.0
D-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	43.7	58.9
D-5	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	7.3	9.8
D-6	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	10.1	13.7
E-1	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	15.6	21.1
E-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	47.8	64.5
E-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	17.7	23.8
E-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	52.4	70.7

Notes:

1. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-4. Channel Lock ACB Performance Variables

(from Ayres, 2001a)

Block Type	Weight in Air (typ.)[2] (lbs.)	Buoyant Weight W_s (lbs.)	χ^1 (in)	χ^2 (in)	χ^3 (in)	χ^4 (in)	b (in)	τ_c at 0° (lb/ft^2)
450[1]	52	27.0	2.25	7.25	3.60	7.25	14.5	11.6
550	64	33.3	2.75	7.25	4.40	7.25	14.5	13.3
800	93	48.4	4.00	7.25	6.40	7.25	14.5	16.5

Notes: 1. Tested block
2. Based on block volume and assuming concrete density of 130 lb/ft^3

3. Maximum allowable tractive stress for Block Types 550 and 800 was calculated using Equation 3 (from Ayres, 2001a) based on conversion for different slope angles.

Table 2D-5. Retardation Class for Lining Materials

(from TxDOT, 2019)

Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30 in. or 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in. or 915 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12 in. or 305 mm)
	Native grass mixture little bluestem, bluestem, blue gamma, other short and long stem midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good Stand, tall (average 24 in. or 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in. or 480 mm)
	Alfalfa	Good stand, uncut (average 11 in or 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 13 in. or 330 mm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13 in. or 330 mm)
C	Crabgrass	Fair stand, uncut (10-to-48 in. or 55-to-1220 mm)
	Bermuda grass	Good stand, mowed (average 6 in. or 150 mm)
	Common lespedeza	Good stand, uncut (average 11 in. or 280 mm)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6-8 in. or 150-200 mm)
	Centipedegrass	Very dense cover (average 6 in. or 150 mm)
	Kentucky bluegrass	Good stand, headed (6-12 in. or 150-305 mm)
D	Bermuda grass	Good stand, cut to 2.5 in. or 65 mm
	Common lespedeza	Excellent stand, uncut (average 4.5 in. or 115 mm)
	Buffalo grass	Good stand, uncut (3-6 in. or 75-150 mm)
	Grass-legume mixture: fall, spring (orchard grass Italian ryegrass, and common lespedeza)	Good Stand, uncut (4-5 in. or 100-125 mm)
	Lespedeza sericea	After cutting to 2 in. or 50 mm (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5 in. or 40 mm
	Bermuda grass	Burned stubble

Table 2D-6. Permissible Shear Stresses for Various Linings

(from TxDOT, 2019)

Protective Cover	(lb./sq.ft.)	t_p (N/m^2)
Retardance Class A Vegetation (See the "Retardation Class for Lining Materials" table above)	3.70	177
Retardance Class B Vegetation (See the "Retardation Class for Lining Materials" table above)	2.10	101
Retardance Class C Vegetation (See the "Retardation Class for Lining Materials" table above)	1.00	48
Retardance Class D Vegetation (See the "Retardation Class for Lining Materials" table above)	0.60	29
Retardance Class E Vegetation (See the "Retardation Class for Lining Materials" table above)	0.35	17
Woven Paper	0.15	7
Jute Net	0.45	22
Single Fiberglass	0.60	29
Double Fiberglass	0.85	41
Straw W/Net	1.45	69
Curled Wood Mat	1.55	74
Synthetic Mat	2.00	96

Table 2D-7. Manning's Roughness Coefficients (from TxDOT, 2019)

B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2D-8. Summary of Calculated Results for Downchute Channels

Downchute Channel Segment	25-Year Design Rainfall Event					100-Year Design Rainfall Event			
	Peak Flow Rate Q_{25} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)	Minimum Permissible ACB Type[1]	Peak Flow Rate Q_{100} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)
Downchute A	167.70	0.70	17.0	12.5	ACB 800	226.20	0.83	18.8	14.5
Downchute B	96.00	0.86	17.0	12.4	ACB 800	129.50	1.00	18.5	14.1
Downchute C	156.20	0.74	17.3	12.8	ACB 800	210.70	0.87	19.0	14.8
Downchute D	76.60	0.95	16.5	12.0	ACB 800	103.20	1.09	17.9	13.5
Downchute E	133.40	0.76	17.1	12.6	ACB 800	179.90	0.89	18.8	14.5

Notes:

1. ACB 800 indicates ACB Channel Lock 800.

Table 2D-9. Summary of Calculated Results for Top Deck Drainage Terraces

	25-Year Design Rainfall Event				100-Year Design Rainfall Event			
Top Deck Channel Segment	**Peak Flow Rate Q_{25} (cfs)**	**Peak Depth of Flow (ft)**	**Peak Average Velocity (ft/s)**	**Peak Average Tractive Stress (psf)**	**Peak Flow Rate Q_{100} (cfs)**	**Peak Depth of Flow (ft)**	**Peak Average Velocity (ft/s)**	**Peak Average Tractive Stress (psf)**
A-1	66.20	0.97	6.07	0.96	89.30	1.09	6.54	1.08
C-1	61.90	1.18	3.86	0.36	83.60	1.32	4.16	0.41

Table 2D-10. Summary of Calculated Results for Sideslope Drainage Terraces

	25-Year, 24-Hour Rainfall Event				100-Year, 24-Hour Rainfall Event			
Sideslope Channel Segment	Peak Flow Rate Q_{25} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)	Peak Flow Rate Q_{100} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)
A-2	44.00	1.58	6.39	0.93	62.30	1.80	6.98	1.05
A-3	10.20	0.91	4.43	0.53	13.80	1.02	4.78	0.60
A-4	14.30	1.04	4.82	0.61	19.30	1.16	5.20	0.68
A-5	23.80	1.26	5.49	0.74	32.20	1.40	5.91	0.82
B-1	19.60	1.17	5.22	0.68	26.50	1.31	5.63	0.76
B-2	18.50	1.14	5.15	0.67	24.90	1.28	5.55	0.75
B-3	25.40	1.28	5.57	0.75	34.30	1.44	6.01	0.84
B-4	33.00	1.42	5.95	0.83	44.50	1.59	6.41	0.93
C-2	36.10	1.47	6.09	0.86	48.70	1.64	6.56	0.96
C-3	14.30	1.04	4.82	0.61	19.30	1.16	5.20	0.68
C-4	26.40	1.30	5.63	0.76	35.70	1.46	6.07	0.86
C-5	19.00	1.15	5.18	0.68	25.60	1.29	5.58	0.76
D-1	3.20	0.59	3.30	0.34	4.30	0.66	3.57	0.39
D-2	6.40	0.77	3.95	0.45	8.70	0.86	4.26	0.50
D-3	5.90	0.74	3.87	0.44	8.00	0.83	4.17	0.49
D-4	43.70	1.58	6.38	0.92	58.90	1.76	6.88	1.03
D-5	7.30	0.80	4.07	0.47	9.80	0.90	4.39	0.53
D-6	10.10	0.91	4.42	0.53	13.70	1.02	4.78	0.60
E-1	15.60	1.07	4.93	0.63	21.10	1.20	5.32	0.70
E-2	47.80	1.63	6.53	0.96	64.50	1.82	7.04	1.07
E-3	17.70	1.12	5.09	0.66	23.80	1.26	5.49	0.74
E-4	52.40	1.69	6.62	0.97	70.70	1.90	7.14	1.08

Appendix 2D-1
Drainage Feature Calculations

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

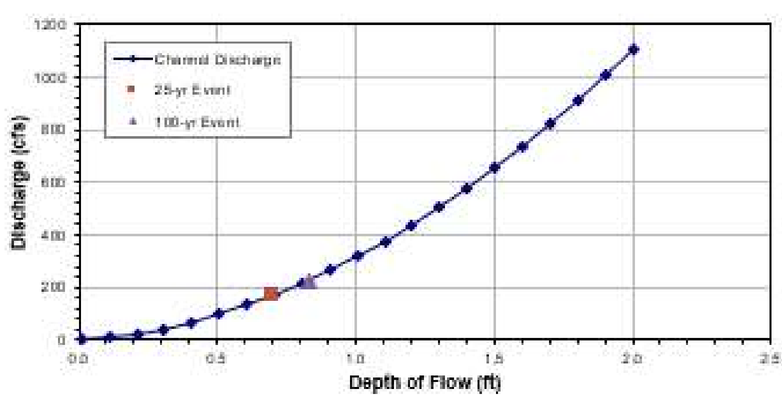
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Downchute A Design**

Peak Discharge, Q_{25} =	167.70	cfs (25-yr Event)
Peak Discharge, Q_{100} =	226.20	cfs (100-yr Event)
Bottom Width, B =	12.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	2.00	ft
Top Width, T =	24.0	ft
Manning's Roughness Coeff., n =	0.04	
Longitudinal Channel Slope, S_o =	0.33	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.12	12.06	0.01	1.11	0.1	0.21	
0.11	1.35	12.69	0.11	5.36	7.2	2.21	
0.21	2.64	13.32	0.20	8.12	21.4	4.12	
0.31	3.99	13.95	0.29	10.36	41.3	5.95	
0.41	5.40	14.58	0.37	12.31	66.4	7.70	
0.51	6.86	15.21	0.45	14.05	96.4	9.39	
0.61	8.39	15.84	0.53	15.64	131.2	11.02	
0.71	9.98	16.47	0.61	17.10	170.6	12.60	
0.81	11.62	17.10	0.68	18.47	214.6	14.14	
0.91	13.33	17.73	0.75	19.75	263.2	15.64	
1.01	15.09	18.36	0.82	20.97	316.4	17.10	
1.10	16.91	18.99	0.89	22.12	374.2	18.53	
1.20	18.80	19.61	0.96	23.23	436.6	19.93	
1.30	20.74	20.24	1.02	24.28	503.6	21.31	
1.40	22.74	20.87	1.09	25.30	575.4	22.66	
1.50	24.80	21.50	1.15	26.28	651.9	23.99	
1.60	26.92	22.13	1.22	27.23	733.2	25.30	
1.70	29.10	22.76	1.28	28.15	819.3	26.60	
1.80	31.34	23.39	1.34	29.05	910.4	27.87	
1.90	33.64	24.02	1.40	29.92	1006.4	29.13	
2.00	36.00	24.65	1.46	30.76	1107.5	30.38	
0.70	9.86	16.42	0.60	17.00	167.54	12.48	Q (25-yr Event)
0.83	12.02	17.25	0.70	18.78	225.79	14.50	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

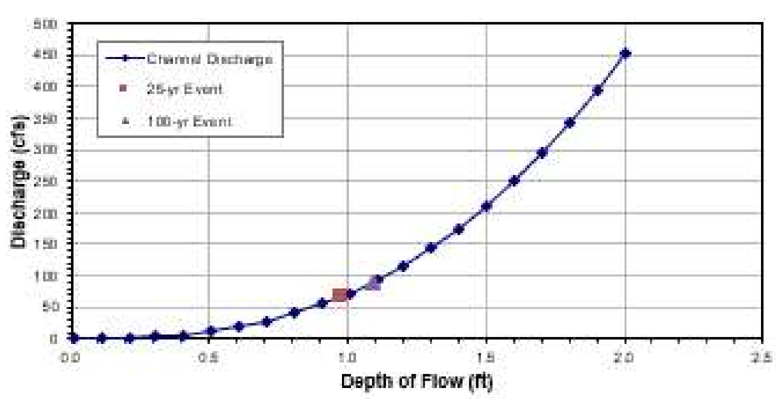
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **A-1 Top Deck Drainage Terrace Design**

Peak Discharge, Q_{25} =	66.20	cfs (25-yr Event)
Peak Discharge, Q_{100} =	89.30	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	20.0	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.00	ft
Top Width, T =	46.0	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0320	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.23	0.00	0.29	0.0	0.01	
0.11	0.14	2.54	0.05	1.41	0.2	0.11	
0.21	0.50	4.85	0.10	2.18	1.1	0.21	
0.31	1.09	7.15	0.15	2.82	3.1	0.31	
0.41	1.91	9.46	0.20	3.40	6.5	0.40	
0.51	2.96	11.77	0.25	3.93	11.7	0.50	
0.61	4.24	14.07	0.30	4.43	18.8	0.60	
0.71	5.74	16.38	0.35	4.90	28.2	0.70	
0.81	7.47	18.69	0.40	5.36	40.0	0.80	
0.91	9.43	21.00	0.45	5.79	54.6	0.90	
1.01	11.62	23.30	0.50	6.20	72.1	1.00	
1.10	14.03	25.61	0.55	6.61	92.7	1.09	
1.20	16.67	27.92	0.60	7.00	116.7	1.19	
1.30	19.54	30.22	0.65	7.38	144.2	1.29	
1.40	22.64	32.53	0.70	7.75	175.5	1.39	
1.50	25.96	34.84	0.75	8.11	210.6	1.49	
1.60	29.51	37.15	0.79	8.47	249.9	1.59	
1.70	33.29	39.45	0.84	8.82	293.5	1.69	
1.80	37.30	41.76	0.89	9.16	341.5	1.78	
1.90	41.54	44.07	0.94	9.49	394.2	1.88	
2.00	46.00	46.37	0.99	9.82	451.7	1.98	
0.97	10.86	22.53	0.48	6.07	65.86	0.96	Q (25-yr Event)
1.09	13.62	25.23	0.54	6.54	89.08	1.08	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

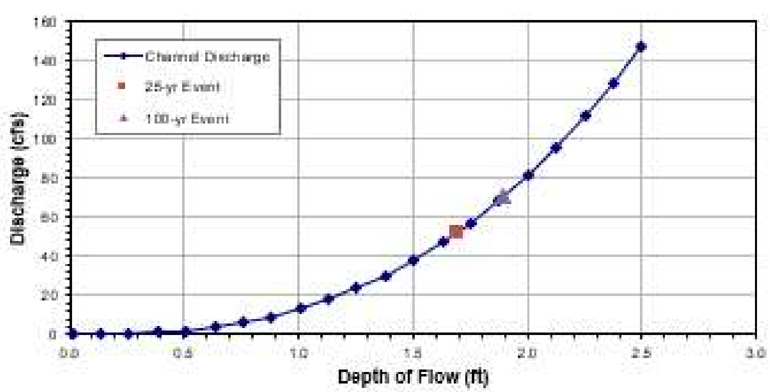
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **E-4 Mid-Slope Drainage Berm Design**

Peak Discharge, Q_{25} =	52.40	cfs (25-yr Event)
Peak Discharge, Q_{100} =	70.70	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.50	ft
Top Width, T =	13.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.020	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.13	0.05	0.79	0.06	1.22	0.1	0.08	
0.26	0.18	1.52	0.12	1.89	0.3	0.15	
0.38	0.40	2.25	0.18	2.46	1.0	0.22	
0.51	0.71	2.97	0.24	2.96	2.1	0.29	
0.63	1.10	3.70	0.30	3.43	3.8	0.36	
0.76	1.58	4.43	0.36	3.87	6.1	0.43	
0.88	2.14	5.16	0.41	4.28	9.1	0.50	
1.01	2.78	5.89	0.47	4.67	13.0	0.57	
1.13	3.51	6.62	0.53	5.05	17.8	0.65	
1.26	4.33	7.35	0.59	5.42	23.5	0.72	
1.38	5.23	8.08	0.65	5.77	30.2	0.79	
1.50	6.22	8.81	0.71	6.11	38.0	0.86	
1.63	7.29	9.53	0.76	6.44	47.0	0.93	
1.75	8.45	10.26	0.82	6.77	57.2	1.00	
1.88	9.69	10.99	0.88	7.09	68.7	1.07	
2.00	11.02	11.72	0.94	7.40	81.5	1.14	
2.13	12.44	12.45	1.00	7.70	95.8	1.22	
2.25	13.93	13.18	1.06	8.00	111.4	1.29	
2.38	15.52	13.91	1.12	8.29	128.7	1.36	
2.50	17.19	14.64	1.17	8.58	147.4	1.43	
1.69	7.89	9.92	0.80	6.62	52.24	0.97	Q (25-yr Event)
1.90	9.90	11.11	0.89	7.14	70.61	1.08	Q (100-yr Event)

Discharge versus Depth Relationship



ATTACHMENT 2E

ON-SITE DESIGN – CULVERTS AND PERIMETER DRAINAGE CHANNELS

Written by:	**O. Bramlet**	Date:	**01/09/2020**	Reviewed by:	**S. Graves**	Date:	**2/4/2020**
Client:	**TRLC**	Project:	**Fort Worth C&D Expansion**	Project No.:	**GW6953**	Phase No.:	**04**

ON-SITE DESIGN – CULVERTS AND PERIMETER DRAINAGE CHANNELS
FORT WORTH C&D LANDFILL EXPANSION

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

5/7/2020

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 28

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the design of the perimeter drainage channels and roadway culverts for the proposed facility surface water management system for the Fort Worth C&D Landfill (site). Riprap aprons located at the outlet of culverts and the outlet of perimeter drainage channels into surface water ponds are also designed within this calculation package. However, surface water pond outlet pipe design analyses including the design of appurtenances (which refers to anti-seep collars and riprap aprons) are evaluated separately within Attachment 2C of the Facility Surface Water Drainage Report (Drainage Report).

Top deck and sideslope drainage terraces convey runoff from the final cover to downchute channels. Perimeter drainage channels will be located at the base of the downchute channels around the north, east, and south sides of the landfill.

The south perimeter drainage channel, designated as Storm Water Channel A, conveys surface water from the southern areas of the final cover system and off-site southern drainage areas through a series of reaches (designated as A1, A2, A3, A4, and A5) to the midpoint site outfall. A reach is defined as a segment of a drainage channel with a specific slope, width, depth, and flow rate. The north perimeter drainage channel, designated as Storm Water Channel C, conveys surface water from the northern areas of the final cover and off-site eastern and northern drainage areas to the North Surface Water Pond through a series of reaches (designated as C1, C2, C3, and C4) and a proposed culvert (designated as

Culvert 1). It is noted that Reach C4 conveys surface water off-site from the North Surface Water Pond to the overall site outfall. Storm Water Channel B is an existing roadside ditch located along the eastern site perimeter adjacent to Dick Price Road. Storm Water Channel B conveys surface water to Storm Water Channel C and only has one reach (designated as B1).

Storm Water Channel A and Storm Water Channel B are separated by a local high point near the southeastern corner of the final cover system. Surface water from the eastern areas of the final cover is conveyed directly into Storm Water Channel C through downchute channels, which are discussed in Attachment 2D of the Drainage Report. Also, Drawing 2-1 in Attachment 2A of the Drainage Report shows a plan view of the facility surface water management system.

2 METHODOLOGY

Perimeter Channels

Storm Water Channel A will be a geomembrane-lined trapezoidal channel conveying flows to the midpoint site outfall. Storm Water Channel B is an existing grass-lined v-ditch (i.e., trapezoidal channel with zero bottom width) which conveys flows to the Storm Water Channel C. Storm Water Channel C is an existing geomembrane-lined trapezoidal channel which conveys flows to the North Surface Water Pond. Final cover areas contributing to each perimeter channel reach are modeled in the computer program HEC-HMS for the post-development site conditions, and peak discharges are subsequently computed for each reach. The details including the methodology and design parameters of this analysis are provided in the *On-Site Drainage Analysis – Hydrology* calculations located in Attachment 2B of the Drainage Report. Each reach is designed to convey the peak surface water runoff corresponding the 24-hour rainfall event with a 4% annual chance of occurrence (referred to herein as the “25-year, 24-hour rainfall event”) flowing to the channel segment, while maintaining a minimum of 0.5 feet of freeboard in the channel during this rainfall event. In addition, each reach was designed with the sufficient capacity to convey the peak discharge from the 24 hour rainfall event with a 1% annual chance of occurrence (refer to herein as the “100-year, 24-hour rainfall event”) without overtopping. Calculations supporting the peak volumes of surface water runoff during these rainfall events are provided in Attachment 2B of the Drainage Report.

Drawing 2-4 in Attachment 2A of the Drainage Report shows the perimeter drainage channel plan and includes reach designations for each perimeter channel segment. Drawings 2-5 and 2-6 provide perimeter drainage profiles for the Storm Water Channels A, B, and C. The typical cross-section and a channel schedule for the perimeter drainage channels are provided in Drawing 2-10. The channel geometry and peak discharge during the design rainfall events are used to calculate the peak velocity and the peak tractive stress during the design rainfall event on the lining of the channel.

It should be noted that channel reaches located along the eastern and northern portions of the currently permitted landfill have already been constructed. The design associated with this lateral expansion for the facility considers the existing channel profile (i.e., design slopes and elevations) from the currently permitted surface water plan for the site.

The capacity of each reach (i.e., drainage channel segment) is calculated and assessed by solving Manning's equation. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad (1)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The peak average tractive stresses on the channel lining for various depths of flow are estimated using the following equation (Chow, 1959):

$$\tau_o = \gamma_w R S \qquad (2)$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Culvert 1

Culvert 1 is designed by utilizing the HY-8 Culvert Analysis Program v.7.5 (HY-8). HY-8 was originally developed by the Federal Highway Administration (FHWA) and has since been updated and revised to its current version (version 7.5). The performance of a culvert is modeled and evaluated based on boundary conditions, culvert configuration, and peak flow criteria. HY-8 is applied for the surface water drainage system to model the box culvert (Culvert 1) conveying the peak discharge from Reach C2 (Storm Water Channel C) beneath a roadway into Reach C3. The performance of Culvert 1 is assessed under two tailwater conditions for the computed water surface elevation within Reach C3 which coincide with the peak discharge during 25-year, 24-hour rainfall event and the 100-year, 24-hour rainfall event. The HEC-HMS model developed in Attachment 2 of this Drainage Report was utilized to compute the peak inflows and tailwater conditions in order to model Culvert 1. Results from the HY-8 model are reviewed to demonstrate that the computed headwater elevation does not overtop the entry driveway at the culvert inlet during the peak discharge.

Riprap Apron Design

The riprap aprons at the outlet of Culvert 1 and at the outlet of Reach C3 into the North Surface Water Pond are designed to protect against erosion and scour from the peak surface water runoff. Each riprap apron is sized from the outflow based on the 25-year, 24-hour rainfall event. The selected design guidance from the Federal Highway Administration (FHWA) provides a methodology for calculating the required length of apron (L_a) and d_{50} of the riprap based on the culvert diameter and flow rate. The d_{50} is the stone size of the riprap for which to 50% of the riprap stones are smaller than d_{50} by mass. The riprap size is calculated using the following equation (FHWA, 2006):

$$d_{50} = 0.2D\left(\frac{Q}{D^{2.5}\sqrt{g}}\right)^{4/3}\frac{D}{TW} \quad (4)$$

where: d_{50} = riprap size (ft),

Q = design discharge (cfs),

D = culvert diameter (ft),

TW = tailwater depth (ft), and

g = gravitational constant.

The tailwater depth should be limited to between 0.4*D* and *D*. FHWA (2006) recommends the use of a tailwater depth equal to 0.4*D* if the tailwater conditions are unknown.

The required length and depth of the riprap apron can be estimated based on the culvert rise and riprap size as provided in Table 2E-1. The width of the riprap apron at the outlet was selected as 3D as recommended by the FHWA (2006) detail for riprap aprons. The apron width will also widen from the outlet along the required length at a rate of 1 ft width per 3 ft length at each edge. Figure 2E-1 provides the typical geometry for the riprap apron.

3 DESIGN PARAMETERS

The design parameters for each channel reach and culvert, including channel geometry and calculated peak discharges as computed by the HEC-HMS model described in Attachment 2B to the Drainage Report for the 25-year and 100-year rainfall events, are summarized in Table 2E-2.

<u>Perimeter Channels</u>

The majority of the perimeter channel reaches are lined with a geomembrane. Manning's roughness values are not specifically available from literature or manufacturers for textured High Density Polyethylene (HDPE) geomembrane. Smooth HDPE Manning's roughness values are approximately 0.01, so it was considered reasonable that a textured geomembrane would be slightly greater. Therefore, a Manning's roughness value of 0.015 for float finish concrete lining was assumed to be representative of the textured HDPE geomembrane channel lining (Table 2E-3 from TxDOT, 2019). This was used for channel sizing design, since a larger roughness value would produce a greater flow depth.

Permissible peak tractive stresses for grass-lined channels range from 0.35 psf to 3.70 psf depending on the retardation class of vegetation. Retardation Class C (which includes Bermuda and Crab grasses among others) was selected for the design of grass lined channels (as shown in Table 2E-4). Grass channels under Retardation Class C have a maximum permissible tractive stress of 1.0 psf (as shown in Table 2E-5 from TxDOT, 2019).

Permissible peak tractive stresses for geomembrane-lined channels are not available from literature or manufacturers for textured or smooth HDPE geomembrane. Therefore, a conservative approach was considered. Table 2E-6 (from Fischenich, 2001) presents the permissible tractive (shear) stress and permissible velocity for a variety of lining materials. Geomembranes are expected to have a large permissible tractive stress (comparable to concrete) due to its smooth and relatively frictionless surface (with minimal roughness for the force of flowing water to act upon), continuous coverage of the channel bed, anchoring at the top of the channel cross-section, and welds between geomembrane panels. Furthermore, geomembranes are less susceptible to erosion or displacement (unlike with many erosion control products). A conservative permissible tractive stress corresponding to unvegetated non-degradable rolled erosion control products (RECPs) of 3.0 psf was selected for geomembrane-lined channels. This permissible tractive stress is expected to significantly underestimate the actual permissible tractive stress of geomembrane-lined channels. The selection of this value is applicable to this design package only to demonstrate adequacy of the design, since, as previously discussed, this approach is likely quite conservative.

Culvert 1

The concrete box Culvert 1 is designed using the following parameters to convey both the peak 25-year, 24-hour rainfall event discharge and the peak 100-year, 24-hour rainfall event discharge. The inlet invert and outlet invert elevations are 639.46 ft MSL and 638.81 ft MSL, respectively, with a culvert slope of 0.51%. A Manning's roughness coefficient is selected as 0.012 for concrete box culverts, based on guidance in Table 2E-8 from TxDOT (2019). The peak inflow into the culvert is computed by HEC-HMS for both rainfall events, as discussed in Attachment 2B. The peak inflow from Reach C2 into Culvert 1 is calculated as 275.20 cfs and 375.40 cfs for the 25-year, 24-hour and 100-year, 24-hour rainfall events, respectively.

The inflow structure into the culvert influences the conveyance of surface water through the culvert. The box culvert inflow structure was modeled with a beveled 45 degree wingwall. The culvert headwall is to be installed according to the TxDOT standard detail

FW-0 for concrete wingwalls with flared wings. A TxDOT standard detail for wingwalls is available in Figure 2E-2.

For the purposes of the outlet riprap apron design, Culvert 1 was considered as three 4.5-ft diameter culverts, with the peak inflow from Reach C2 evenly divided between each culvert barrel. Also for the purposes of riprap apron design, the tailwater depth was considered to be the depth in the downstream channel reach (Reach C3). The peak tailwater depth during the 25-year, 24-hour rainfall event is 2.77 ft.

Riprap Apron Design

Riprap aprons are sized for: (i) the outflow of Culvert 1 and (ii) the outflow of Reach C3 into the North Surface Water Pond. The design parameters describing the conditions for riprap apron design for Culvert 1 are described above. Meanwhile, the peak discharge of Reach C3 into the North Surface Water Pond Series 4 during the 25-year, 24-hour rainfall event is 465.10 cfs. The 8 ft (base width) by 3.5 ft (channel depth) trapezoidal channel was considered as two representative 3.79 ft circular culverts (corresponding to the area of the peak depth of flow within the channel). Each representative culvert is assumed to convey half the peak 25-year, 24-hour rainfall event discharge, solely for the purposes of riprap apron design. Since the invert elevation of Reach C3 is above the peak pond elevation for the 25-year, 24-hour rainfall event, the tailwater depth was taken as the peak depth within Reach C3.

4 RESULTS

The depth of flow, velocity, and average tractive stress for the calculated discharge for each perimeter drainage channel reach during the design rainfall event were calculated using Equations (1) and (2). Calculations for each perimeter channel reach were performed using spreadsheets with results that are summarized in Table 2E-9. Spreadsheet results for the channel reach with the largest peak flow rate for each perimeter channel are presented in Appendix 2E-1. For both rainfall events, the performance of Culvert 1 from HY-8 modeling is presented in Table 2E-9 and shown on Figures 2E-3 and 2E-4.

- The available freeboard in all perimeter channel reaches is calculated to be greater than 0.5 feet during the 25-year, 24-hour rainfall event.
- Each perimeter channel reach was designed to be able to convey the 100-year, 24-hour rainfall event without overtopping as presented in Table 2E-9.

- The average tractive stress during the 25-year, 24-hour rainfall event within each of the perimeter channel reaches is calculated to remain below the maximum one (1) psf (acceptable for grass-lined channels) or below 3.0 psf (acceptable as conservatively applied for geomembrane-lined channels).
- Culvert 1 contains the capacity to convey the flow from Reach C2 to C3 without overtopping the roadway at the culvert inlet wingwall.
- The minimum d_{50} size of the riprap apron was computed by Equation (3) for the outflow of each necessary discharge structure as summarized in Table 2E-10. In addition, the selected riprap class, apron depths and lengths are provided within the table for each riprap apron.

FHWA (2006) recommends an apron width of 3 times the outlet diameter at the up gradient end of the apron near the culvert outlet and a 3:1 rate of expansion at each edge along the length of the apron. However, since each structure is discharging into a stabilized geomembrane-lined trapezoidal channel or surface water pond, the dimensions of the riprap aprons are restricted by the channel dimensions. Therefore, the entire width of the channel (8 feet) should be lined with riprap for Culvert 1. The full apron width will be provided at the outlet of each perimeter channel into the North Surface Water Pond.

5 REFERENCES

Chow, V.T (1959). *Open Channel-Hydraulics,* McGraw-Hill.

FHWA (2006). *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Federal Highway Administration, US Department of Transportation, Hydraulic Engineering Circular No. 14, Third Edition.

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TABLES

Table 2E-1. Riprap Classes and Apron Dimensions

(from FHWA, 2006)

Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1]D is the culvert rise.

Table 2E-2. Design Parameter Summary for Perimeter Drainage Channels and Culverts

Perimeter Channel/ Culvert	Channel Shape	Longitudinal Channel Slope (ft/ft)	Manning's n	Bottom Width (ft)	Depth (ft)	Side Slopes (H:V)	Channel Lining	25-year, 24-hour Flow Rate Q_{25} (cfs)	100-year, 24-hour Flow Rate Q_{100} (cfs)
Perimeter Reach A1	Trapezoid	0.005	0.015	3.0	3.0	3:1	Geomembrane	36.00	48.60
Perimeter Reach A2	Trapezoid	0.005	0.015	8.0	3.0	3:1	Geomembrane	196.10	270.00
Perimeter Reach A3	Trapezoid	0.076	0.015	13.0	1.5	3:1	Geomembrane	217.70	298.40
Perimeter Reach A4	Trapezoid	0.022	0.015	8.0	3.5	3:2	Geomembrane	216.90	298.20
Perimeter Reach A5	Trapezoid	0.008	0.015	8.0	3.5	3:3	Geomembrane	405.90	553.90
Perimeter Reach B1	Triangular	0.025	0.027	0.0	1.8	3:1	Native Vegetation	30.80	41.50
Perimeter Reach C1	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	275.60	376.60
Perimeter Reach C2	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	275.20	375.40
Perimeter Reach C3	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	465.10	639.10
Perimeter Reach C4	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	358.60	577.40
Culvert 1	Box	0.005	0.012	4.0	4.5	-	Concrete	275.20	375.40

Table 2E-3. Manning's n Values for Open Channels

(from TxDOT, 2019)

Type of channel	Manning's n
B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
3. Dragline-excavated or dredged	
a. No vegetation	0.025-0.033
b. Light brush on banks	0.035-0.060
4. Rock cuts	
a. Smooth and uniform	0.025-0.040
b. Jagged and irregular	0.035-0.050
5. Unmaintained channels	
a. Dense weeds, high as flow depth	0.050-0.120
b. Clean bottom, brush on sides	0.040-0.080
c. Clean bottom, brush on sides, highest stage	0.045-0.110
d. Dense brush, high stage	0.080-0.140
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2E-4. Retardation Class for Lining Materials

(from TxDOT, 2019)

Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30 in. or 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in. or 915 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12 in. or 305 mm)
	Native grass mixture little bluestem, bluestem, blue gamma, other short and long stem midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good Stand, tall (average 24 in. or 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in. or 480 mm)
	Alfalfa	Good stand, uncut (average 11 in or 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 13 in. or 330 mm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13 in. or 330 mm)
C	Crabgrass	Fair stand, uncut (10-to-48 in. or 55-to-1220 mm)
	Bermuda grass	Good stand, mowed (average 6 in. or 150 mm)
	Common lespedeza	Good stand, uncut (average 11 in. or 280 mm)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6-8 in. or 150-200 mm)
	Centipedegrass	Very dense cover (average 6 in. or 150 mm)
	Kentucky bluegrass	Good stand, headed (6-12 in. or 150-305 mm)
D	Bermuda grass	Good stand, cut to 2.5 in. or 65 mm
	Common lespedeza	Excellent stand, uncut (average 4.5 in. or 115 mm)
	Buffalo grass	Good stand, uncut (3-6 in. or 75-150 mm)
	Grass-legume mixture: fall, spring (orchard grass Italian ryegrass, and common lespedeza)	Good Stand, uncut (4-5 in. or 100-125 mm)
	Lespedeza sericea	After cutting to 2 in. or 50 mm (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5 in. or 40 mm
	Bermuda grass	Burned stubble

Table 2E-5. Permissible Shear Stress for Various Linings

(from TxDOT, 2019)

Protective Cover	(lb./sq.ft.)	t_p (N/m^2)
Retardance Class A Vegetation (See the "Retardation Class for Lining Materials" table above)	3.70	177
Retardance Class B Vegetation (See the "Retardation Class for Lining Materials" table above)	2.10	101
Retardance Class C Vegetation (See the "Retardation Class for Lining Materials" table above)	1.00	48
Retardance Class D Vegetation (See the "Retardation Class for Lining Materials" table above)	0.60	29
Retardance Class E Vegetation (See the "Retardation Class for Lining Materials" table above)	0.35	17
Woven Paper	0.15	7
Jute Net	0.45	22
Single Fiberglass	0.60	29
Double Fiberglass	0.85	41
Straw W/Net	1.45	69
Curled Wood Mat	1.55	74
Synthetic Mat	2.00	96

Table 2E-6. Permissible Shear Stresses for Various Linings

(from Fischenich, 2001)

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
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E. Gray, D.H., and Sotir, R.B. (1996).
F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
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I. Schiechtl, H. M. and R. Stern. (1996).
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K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

Table 2E-7. Manning's n Values for Closed Conduits

(from TxDOT, 2019)

Material	Manning's n
Asbestos-cement pipe	0.011-0.015
Brick	0.013-0.017
Cast iron pipe	
Cement-lined & seal coated	0.011-0.015
Concrete (monolithic)	
Smooth forms	0.012-0.014
Rough forms	0.015-0.017
Concrete pipe	0.011-0.015
Box (smooth)	0.012-0.015
Corrugated-metal pipe -- (2-1/2 in. x 1/2 in. corrugations)	
Plain	0.022-0.026
Paved invert	0.018-0.022
Spun asphalt lined	0.011-0.015
Plastic pipe (smooth)	0.011-0.015
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. annular)	0.022-0.027
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. helical)	0.011-0.023
Corrugated-metal pipe -- (6 in. by 1 in. helical)	0.022-0.025
Corrugated-metal pipe -- (5 in. by 1 in. helical)	0.025–0.026
Corrugated-metal pipe -- (3 in. by 1 in. helical)	0.027–0.028
Corrugated-metal pipe -- (6 in. by 2 in. structural plate)	0.033–0.035
Corrugated-metal pipe -- (9 in. by 2-1/2 in. structural plate)	0.033–0.037
Corrugated polyethylene	0.010–0.013
Smooth	0.009-0.015
Corrugated	0.018–0.025
Spiral rib metal pipe (smooth)	0.012-0.013
Vitrified clay	
Pipes	0.011-0.015

Table 2E-8. Channel Capacity Calculation Results

Perimeter Channel Segment	25-year Flow Rate Q_{25} (cfs)	Depth of Flow (ft)	Average Velocity (ft/s)	Average Tractive Stress (psf)	25-year Freeboard (ft)	100-year Flow Rate Q_{100} (cfs)	Depth of Flow (ft)	Average Velocity (ft/s)	Average Tractive Stress (psf)
Perimeter Reach A1	36.00	1.07	5.43	0.21	1.93	48.60	1.23	5.87	0.24
Perimeter Reach A2	196.10	1.80	8.13	0.39	1.20	270.00	2.12	8.88	0.44
Perimeter Reach A3	217.70	0.72	19.90	2.93	0.78	298.40	0.86	22.13	3.44
Perimeter Reach A4	216.90	1.28	14.28	1.32	2.22	298.20	1.51	15.65	1.51
Perimeter Reach A5	405.90	2.34	11.55	0.73	1.16	553.90	2.72	12.56	0.83
Perimeter Reach B1	30.80	1.28	6.24	0.94	0.52	41.50	1.43	6.73	1.05
Perimeter Reach C1	275.60	2.14	8.93	0.45	1.36	376.60	2.50	9.72	0.51
Perimeter Reach C2	275.20	2.14	8.92	0.45	1.36	375.40	2.49	9.71	0.51
Perimeter Reach C3	465.10	2.77	10.28	0.55	0.73	639.10	3.23	11.19	0.63
Perimeter Reach C4	358.60	2.42	9.73	0.51	1.08	577.40	3.05	11.05	0.62

Table 2E-9. Culvert 1 Capacity Analysis Results

Design Case	Total Flow Rate Q (cfs)	Pipe Flow (cfs)	Pipe Velocity (fps)	Roadway Flow (cfs)	Tailwater Elev (ft)	Headwater Elev (ft)
25-year, 24-hour	275.20	275.20	9.42	0.0	640.95	643.42
100-year, 24-hour	375.40	375.40	10.10	0.0	641.31	644.46

Table 2E-10. Riprap Apron Design Summary

Riprap Apron Structure	Riprap Size d_{50} (ft)	Riprap Class	Apron Depth (ft)	Apron Length (ft)
Culvert 1	0.40	1	1.0	18.0
Perimeter Reach C3	1.72	6	3.4	30.4

FIGURES

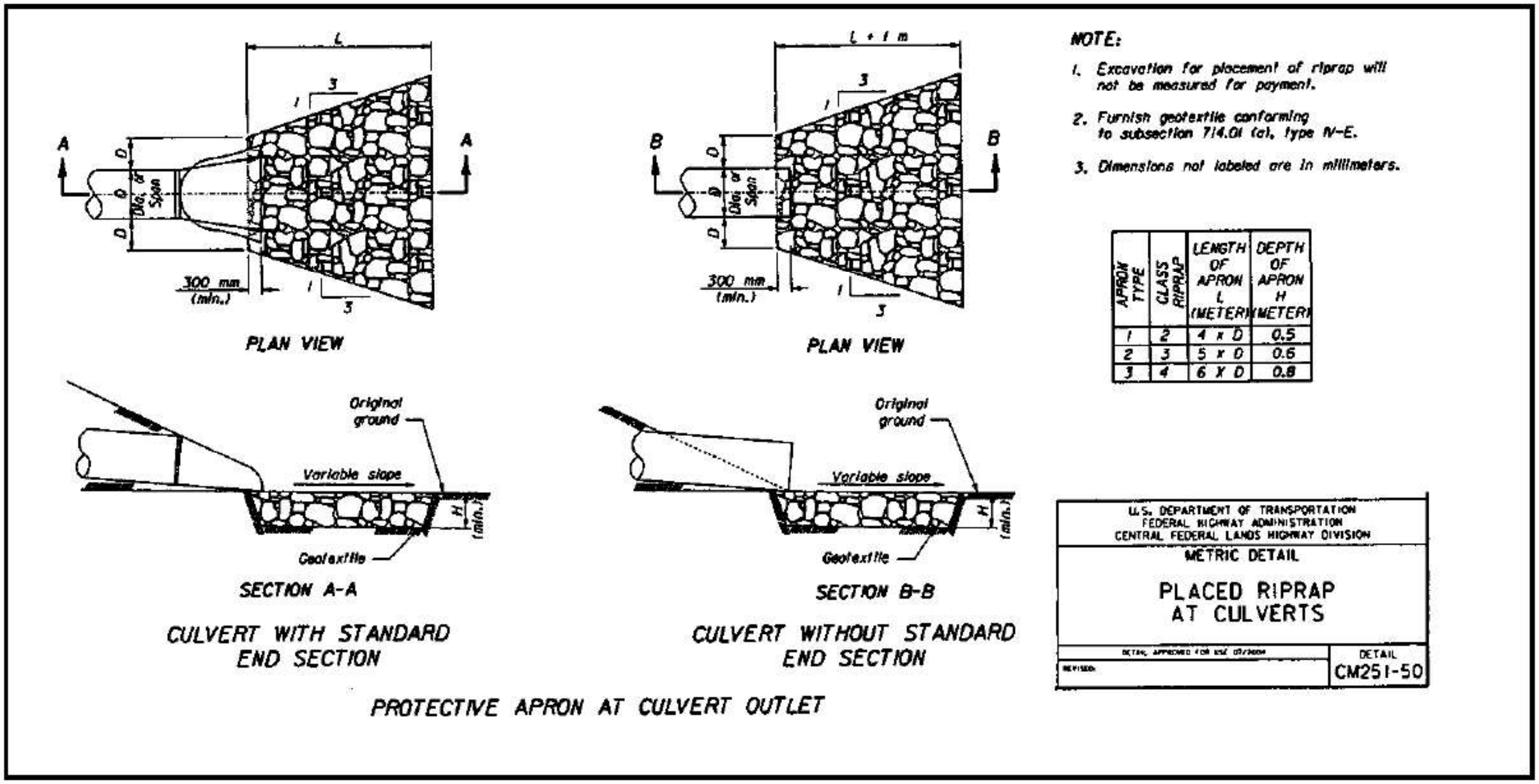


Figure 2E-1. Typical Geometry of Riprap Aprons at Culverts

(from FHWA, 2006)

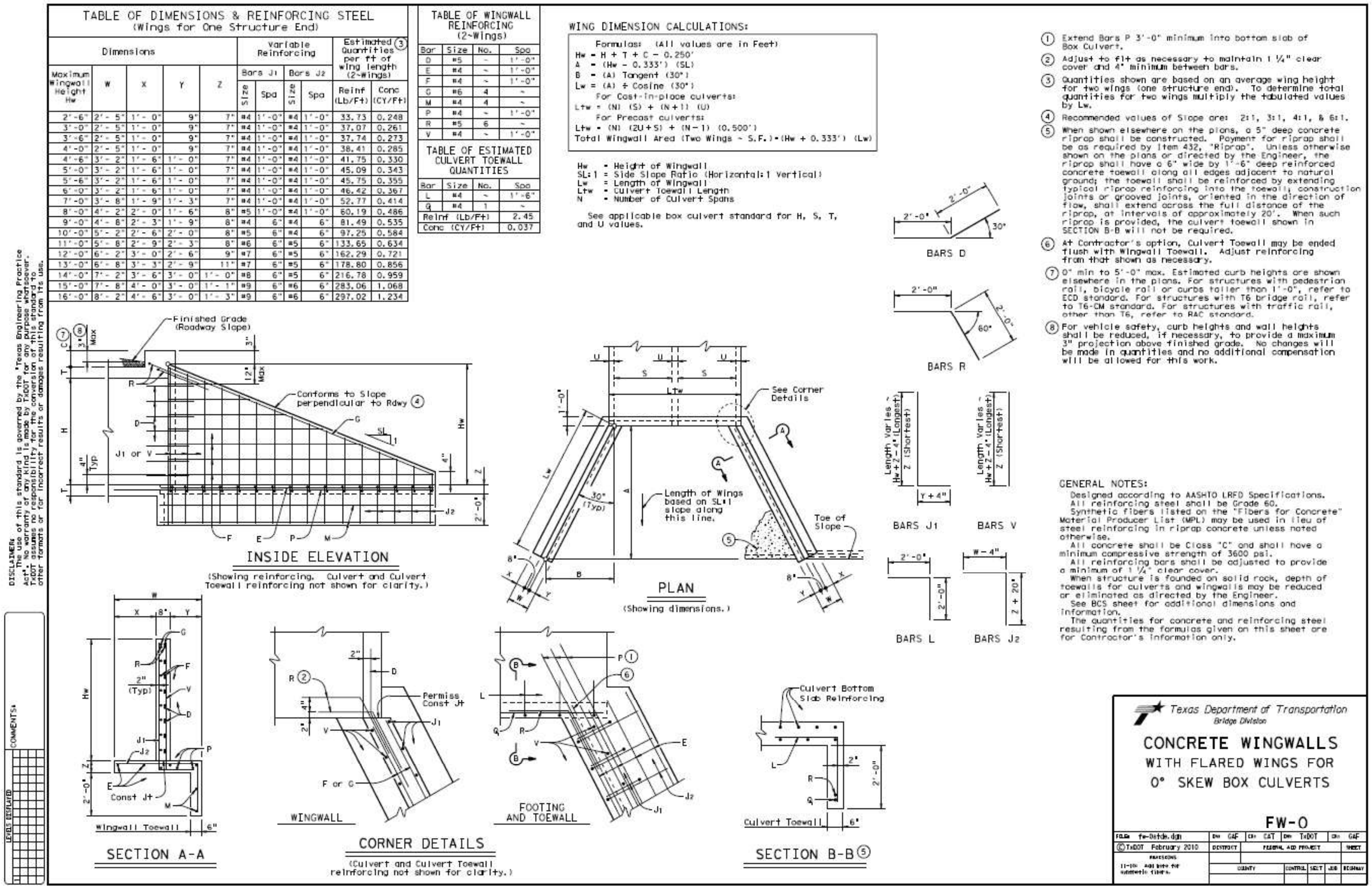


Figure 2E-2. TxDOT Standard Detail FW-0 for Concrete Wingwalls

Source: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/bridge/fw-0stde.pdf (Date Accessed: 12/4/2019)

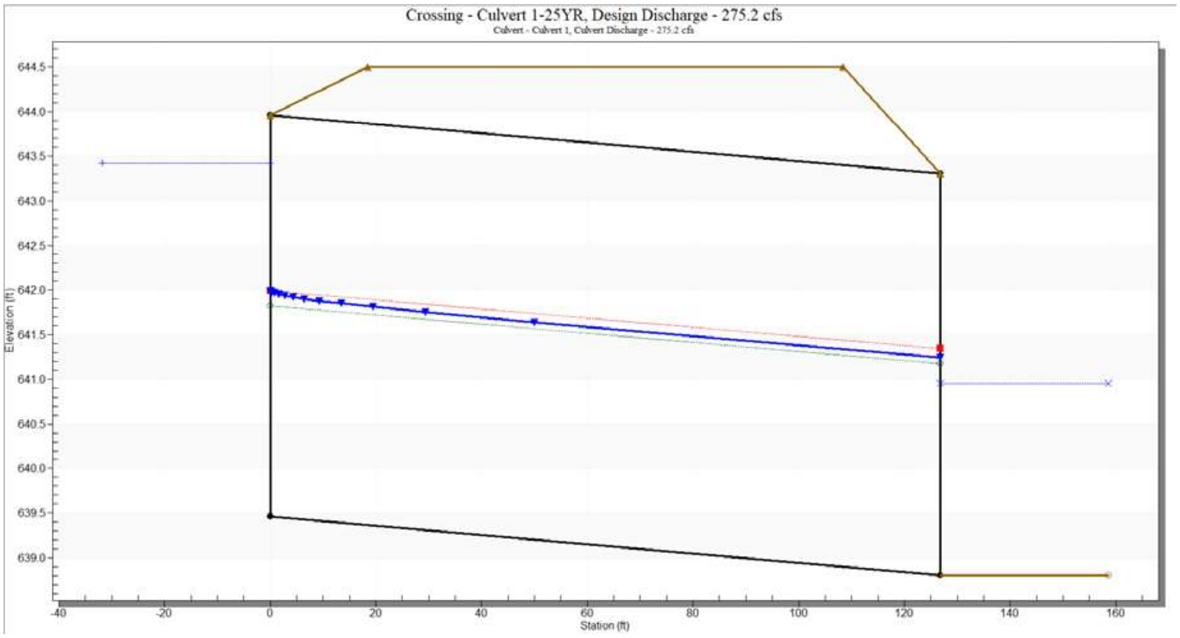


Figure 2E-3. HY-8 Modeling Output for 100-Year Event Culvert 1

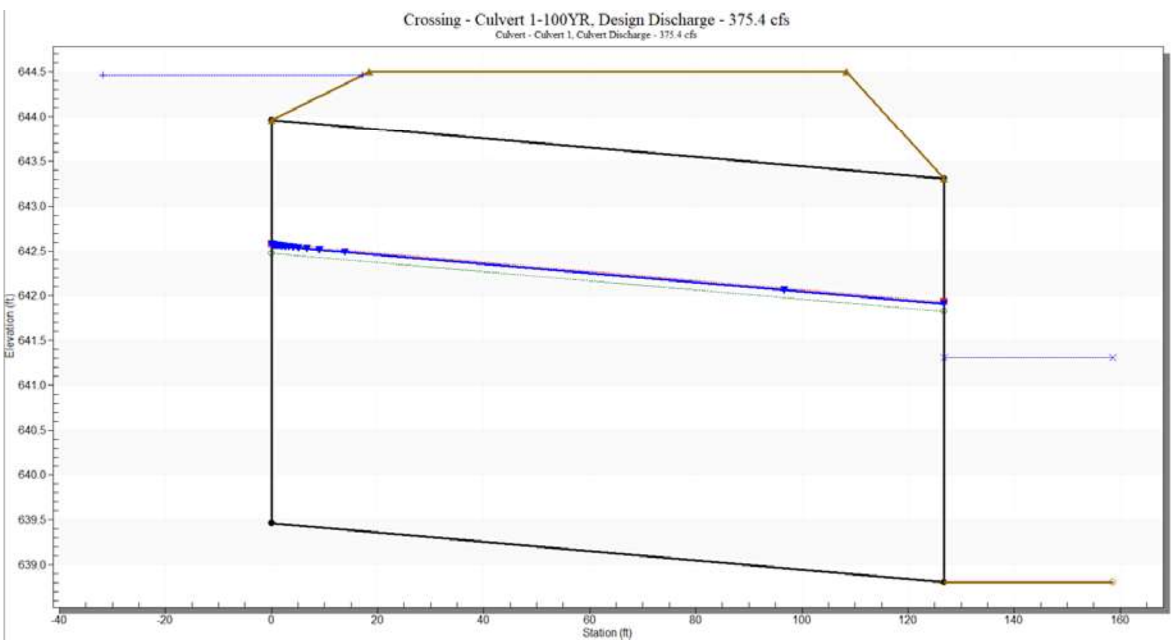


Figure 2E-4. HY-8 Modeling Output for 25-Year Event Culvert 1

Appendix 2E-1
Perimeter Channel Calculations

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

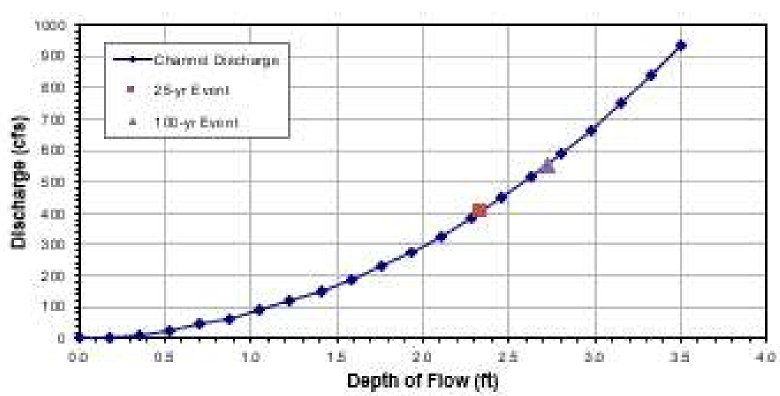
Project: Fort Worth C&D Landfill Expansion

Ditch ID: Perimeter Reach A5 **Design**

Peak Discharge, Q_{25} =	405.90	cfs (25-yr Event)
Peak Discharge, Q_{100} =	553.90	cfs (100-yr Event)
Bottom Width, B =	8.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	3.50	ft
Top Width, T =	29.0	ft
Manning's Roughness Coeff., n =	0.015	
Longitudinal Channel Slope, S_o =	0.008	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.08	8.06	0.01	0.40	0.0	0.00	
0.18	1.58	9.17	0.17	2.68	4.2	0.08	
0.36	3.26	10.27	0.32	4.03	13.1	0.15	
0.53	5.12	11.37	0.45	5.09	26.1	0.21	
0.71	7.17	12.48	0.57	5.98	42.9	0.27	
0.88	9.40	13.58	0.69	6.77	63.6	0.33	
1.06	11.81	14.69	0.80	7.49	88.4	0.38	
1.23	14.40	15.79	0.91	8.14	117.3	0.43	
1.41	17.18	16.89	1.02	8.76	150.4	0.48	
1.58	20.14	18.00	1.12	9.33	188.0	0.53	
1.76	23.28	19.10	1.22	9.88	230.0	0.58	
1.93	26.60	20.20	1.32	10.40	276.8	0.62	
2.10	30.11	21.31	1.41	10.91	328.4	0.67	
2.28	33.80	22.41	1.51	11.39	385.0	0.72	
2.45	37.68	23.51	1.60	11.86	446.8	0.76	
2.63	41.73	24.62	1.70	12.31	513.9	0.80	
2.80	45.97	25.72	1.79	12.76	586.4	0.85	
2.98	50.39	26.83	1.88	13.19	664.5	0.89	
3.15	54.99	27.93	1.97	13.61	748.3	0.93	
3.33	59.78	29.03	2.06	14.02	838.1	0.98	
3.50	64.75	30.14	2.15	14.42	933.9	1.02	
2.34	35.09	22.78	1.54	11.55	405.32	0.73	Q (25-yr Event)
2.72	44.05	25.23	1.75	12.56	553.22	0.83	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

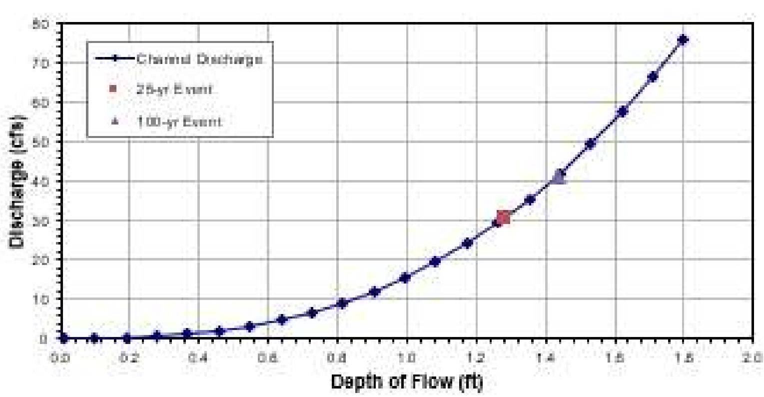
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Perimeter Reach B1** **Design**

Peak Discharge, Q_{25} =	30.80	cfs (25-yr Event)
Peak Discharge, Q_{100} =	41.50	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	1.80	ft
Top Width, T =	10.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.025	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.25	0.0	0.01	
0.10	0.03	0.63	0.05	1.13	0.0	0.07	
0.19	0.11	1.20	0.09	1.74	0.2	0.14	
0.28	0.23	1.76	0.13	2.25	0.5	0.20	
0.37	0.41	2.33	0.17	2.72	1.1	0.27	
0.46	0.63	2.89	0.22	3.14	2.0	0.34	
0.55	0.90	3.46	0.26	3.54	3.2	0.40	
0.64	1.22	4.03	0.30	3.91	4.8	0.47	
0.73	1.58	4.59	0.34	4.27	6.8	0.53	
0.82	2.00	5.16	0.39	4.62	9.2	0.60	
0.91	2.46	5.72	0.43	4.95	12.2	0.67	
0.99	2.97	6.29	0.47	5.27	15.6	0.73	
1.08	3.53	6.86	0.51	5.58	19.7	0.80	
1.17	4.13	7.42	0.56	5.88	24.3	0.86	
1.26	4.79	7.99	0.60	6.18	29.6	0.93	
1.35	5.49	8.55	0.64	6.47	35.5	0.99	
1.44	6.24	9.12	0.68	6.75	42.1	1.06	
1.53	7.04	9.69	0.73	7.03	49.5	1.13	
1.62	7.88	10.25	0.77	7.30	57.5	1.19	
1.71	8.78	10.82	0.81	7.57	66.4	1.26	
1.80	9.72	11.38	0.85	7.83	76.1	1.32	
1.28	4.93	8.10	0.61	6.24	30.74	0.94	Q (25-yr Event)
1.43	6.17	9.07	0.68	6.73	41.47	1.05	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

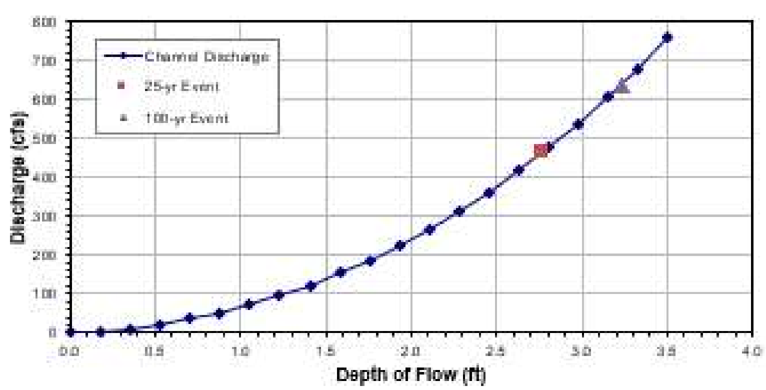
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Perimeter Reach C3** **Design**

Peak Discharge, Q_{25} =	465.10	cfs (25-yr Event)
Peak Discharge, Q_{100} =	639.10	cfs (100-yr Event)
Bottom Width, B =	8.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	3.50	ft
Top Width, T =	29.0	ft
Manning's Roughness Coeff., n =	0.015	
Longitudinal Channel Slope, S_o =	0.005	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.08	8.06	0.01	0.32	0.0	0.00	
0.18	1.58	9.17	0.17	2.17	3.4	0.05	
0.36	3.26	10.27	0.32	3.27	10.6	0.10	
0.53	5.12	11.37	0.45	4.13	21.1	0.14	
0.71	7.17	12.48	0.57	4.85	34.8	0.18	
0.88	9.40	13.58	0.69	5.49	51.6	0.22	
1.06	11.81	14.69	0.80	6.07	71.7	0.25	
1.23	14.40	15.79	0.91	6.61	95.1	0.28	
1.41	17.18	16.89	1.02	7.10	122.0	0.32	
1.58	20.14	18.00	1.12	7.57	152.5	0.35	
1.76	23.28	19.10	1.22	8.02	186.6	0.38	
1.93	26.60	20.20	1.32	8.44	224.5	0.41	
2.10	30.11	21.31	1.41	8.85	266.4	0.44	
2.28	33.80	22.41	1.51	9.24	312.3	0.47	
2.45	37.68	23.51	1.60	9.62	362.4	0.50	
2.63	41.73	24.62	1.70	9.99	416.8	0.53	
2.80	45.97	25.72	1.79	10.35	475.6	0.56	
2.98	50.39	26.83	1.88	10.70	539.0	0.59	
3.15	54.99	27.93	1.97	11.04	607.0	0.61	
3.33	59.78	29.03	2.06	11.37	679.8	0.64	
3.50	64.75	30.14	2.15	11.70	757.5	0.67	
2.77	45.20	25.52	1.77	10.28	464.77	0.55	Q (25-yr Event)
3.23	57.08	28.42	2.01	11.19	638.50	0.63	Q (100-yr Event)

Discharge versus Depth Relationship



ATTACHMENT 2F

ON-SITE DESIGN – ACTIVE FACE SURFACE WATER CONTROLS

Written by:	**O. Bramlet**	Date:	**01/03/2020**	Reviewed and Revised by:	**S. Graves**	Date:	**2/4/2020; 09/15/2020**
Client:	**TRLC**	Project:	**Fort Worth C&D Landfill**	Project No.:	**GW6953**	Phase No.:	**04**

ON-SITE DESIGN – ACTIVE FACE SURFACE WATER CONTROLS
FORT WORTH C&D LANDFILL EXPANSION

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

9/15/2020

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 17

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the analysis for the sizing of the diversion, containment, and run-on berms to be utilized at the active face (i.e., areas of exposed waste) during development of the Fort Worth C&D Landfill (Figure 2F-1). The diversion containment and run-on berms will be utilized to keep clean surface water separate from potentially contaminated water, to minimize the generation of contaminated water, prevent runoff/discharge of contaminated water, and prevent migration of contaminated water to the surface run-on water. Contaminated water will be managed in a timely manner and in accordance with the Contaminated Water Management Plan presented in Appendix IVA of the Site Operating Plan (SOP).

Diversion berms are temporary soil berms constructed up-gradient from the active working face to intercept flow before it comes in contact with waste. These temporary diversion berms will be used to route the clean runoff around active areas into the surface water management system and away from the active face. Meanwhile, temporary containment and run-on berms (down-gradient from, and generally at the base of the active working face), constructed with soil, will be used to contain contaminated water and prevent the migration of contaminated water from the active face, as well as to prevent the run-on of clean surface water draining from adjacent areas onto the active face. The specific objectives of the analysis include (i) calculating the maximum up-gradient drainage area which can be managed by each diversion berm for the 25-year rainfall event; and (ii) calculating the required height of each temporary containment and run-on berm to contain the contaminated runoff and prevent surface run-on resulting from the 25-year rainfall event.

2 ASSUMPTIONS AND PROCEDURES

The following sections discuss the assumptions and procedures for the design of the temporary diversion berms and temporary containment and run-on berms.

2.1 Diversion Berm

It is assumed that temporary diversion berms will be installed with flow line (longitudinal) slopes ranging from 0.5% to 2%. Temporary diversion berms will be placed up-gradient from the active working face. The temporary diversion berms are assumed to be "tack-on" berms with a 2.5:1 side slope (see Figure 2F-1 of this calculation package) to form a v-shaped channel. A channel depth of 2.5 feet was assumed (i.e., this is a fixed parameter of these calculations). The Rational Method described in the Texas Department of Transportation *Hydraulic Design Manual* (TxDOT, 2019) is used to calculate the peak surface water discharge (since the drainage area will be less than 200 acres). A given diversion berm is anticipated to temporarily manage drainage areas on the order of 30 acres or more and is designed accordingly as presented herein. The channels were sized assuming they are flowing full, considered adequate since they are interior and temporary site features, and given other conservative selections of parameters as documented herein. The following steps were utilized to calculate the drainage areas that each diversion berm can accommodate.

1. Compute the discharge capacity of diversion berms with 0.5%, 1%, 1.5%, and 2% slopes using Manning's Equation for open channel flow.

2. Apply the Rational Method to compute the up-gradient drainage area that would produce the discharge capacity calculated in Step 1.

Manning's equation was used to estimate the peak discharge capacity of the v-shaped channel created by a temporary diversion berm. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad (1)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The peak discharge from the contributing drainage area by the Rational Method can be computed by:

$$Q = C \times I \times A \tag{2}$$

where:

Q = peak design discharge (cfs),

C = runoff coefficient (dimensionless),

I = design rainfall intensity (in/hr), and

A = drainage area (acres).

The design rainfall intensity in Equation (2) is calculated using guidance in the TxDOT *Hydraulic Design Manual* (TxDOT, 2019*)*. In September 2018, the National Oceanic and Atmospheric Administration (NOAA) released updated "Atlas 14" precipitation frequency estimates for Texas. This new rainfall data is currently considered by TxDOT (2019) to be the best available data for calculating design rainfall intensity. TxDOT (2019) also recommends 10 minutes as the minimum time of concentration for the Rational Method because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high. The rainfall intensity for the 25-year, 10-minute duration rainfall event is 7.92 inches per hour (in/hr) for the site, as shown in Table 2F-1 (NOAA, 2018).

Equation (2) is rearranged, and the watershed drainage area was back-calculated for each potential flow line slope of a temporary diversion berm.

2.2 Containment and Run-On Berms

It is assumed that temporary containment and run-on berms (which may be a shared berm, provided that the berm height is the larger of the two required heights) will be constructed with 3H:1V side slopes and will be constructed to varying heights, depending on the geometry of the working face, storage area, and resulting calculated volume of contaminated water and surface run-on water to be stored on each respective side of the berm(s). These containment and run-on berms are designed to have one foot (1-ft) of freeboard. The required height of the containment berms is calculated for drainage areas ranging from 0.5 to 4.0 acres (to encompass a range of potential active area sizes in and around the working face itself) and contaminated water storage areas ranging from 0.1 to 1.0 acres. The required height of the run-on berms is calculated for drainage areas ranging from 2.0 to 30.0 acres (to account for a range of potential up-gradient excavation area sizes adjacent to an active Sector/working face) and surface run-on water storage areas ranging from 0.25 to 5.0 acres. The following steps were utilized to calculate the height required for each of the containment and run-on berm scenarios.

1. Calculate the 25-year, 24-hour rainfall volume to be captured behind the containment and run-on berm.

2. Calculate the height of the containment and run-on berm required to hold the volume of water calculated in Step 1, and then add 1-ft of freeboard to calculate the resulting total berm height (i.e., the required minimum berm height).

The total required storage volume of surface water is calculated by:

$$V = A_D \times R \tag{3}$$

where:

V = total storage volume (ft^3),

A_D = drainage area (ft^2), and

R = 25-year, 24-hour rainfall depth (ft).

For these calculations, 100% of the precipitation over the drainage area is considered surface water runoff that requires containment (i.e., no infiltration). This is a conservative assumption for sizing of these berms because it is likely that some infiltration will occur. The 25-year, 24-hour rainfall depth is provided in Table 2F-2.

The required height for each of the containment and run-on berm scenarios is computed by Equation (4):

$$H = V/A_S + 1.0 \text{ ft freeboard} \quad (4)$$

where:

V = total storage volume (ft^3),

H = total height of containment or run-on berm (ft), and

A_S = storage area (ft^2).

3 DESIGN PARAMETERS

The following sections discuss the justification behind the selected design parameters for the temporary diversion berms and temporary containment and run-on berms.

3.1 Diversion Berm

The Manning's Roughness Coefficient (*n*) for the diversion berm was selected as 0.02 for clean, recently completed earth channels that are straight and uniform, as shown in Table 2F-3 (TxDOT, 2019). The peak discharge flowing to the channel is calculated using the Rational Method.

A runoff coefficient (C) was selected based on information provided by TxDOT (2019) for rural watersheds, as shown in Table 2F-4. The runoff coefficients provided apply to storms of up to a 10-year frequency. The total runoff coefficient is based on the sum of the four runoff components in Table 2F-4. The 25-year runoff coefficient is calculated using the following equation:

$$C = C_r + C_i + C_v + C_s \quad (5)$$

The following runoff coefficient is estimated for the steep 3H:1V side slope drainage areas:

$$C = 0.35 + 0.16 + 0.08 + 0.12 = 0.71$$

For a conservative design approach, a minimum time of concentration of 10 minutes was used to calculate the rainfall intensity from Table 2F-1. TxDOT (2019) recommends 10 minutes for the minimum time of concentration because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high, as discussed above.

3.2 Containment and Run-On Berm

The temporary containment and run-on berms were sized by determining the rainfall depth from NOAA Atlas 14 precipitation frequency estimates for Texas (TxDOT, 2019). The rainfall depth for the 25-year, 24-hour rainfall event is listed as 7.17 inches (0.60 feet).

4 RESULTS

The results of the temporary diversion berms calculation are summarized in Table 2F-5 for each assumed flow line slope. The drainage areas calculated represent the maximum drainage area that each temporary diversion berm configuration can accommodate for the 25-year, 24-hour design rainfall event. It should be noted that multiple diversion berms may be constructed if, during operations, a larger area than those calculated in Table 2F-5 will be draining towards the active face, in order to comply with the drainage area requirements presented herein for the given berm height and the selected flow line slope.

The results of the temporary containment and run-on berms calculations are summarized in Table 2F-6 and Table 2F-7, respectively. It is noted that the results presented in Table 2F-6 and Table 2F-7 cover various combinations of drainage areas and water storage areas, to allow for flexibility of site operations. The facility will use this information to select the required berm height based on the corresponding dimensions of the drainage area and storage area. It is noted that a licensed professional engineer is required to size the containment and run-on berms if conditions are not consistent or otherwise addressed by the current design presented in the tables. As mentioned, for most cases, it is expected that a temporary berm will act as both containment and run-on berm, provided that it must have the larger of the two required heights in order to serve the dual-purpose of acting as a containment berm and a run-on berm. However, it should be noted that separate containment and run-on berms meeting the requirements presented herein for a given drainage situation may be constructed at the facility's discretion.

Additionally, if the working face is built directly on top of the protective cover of the liner system (i.e., for the first lift of waste placed in a newly lined sector), the containment and run-on berm shall be installed within the lined area of the cell or phase.

5 REFERENCES

Chow, V.T. (1959). *Open Channel-Hydraulics,* McGraw-Hill.

NOAA (2018). Point Precipitation Frequency Estimates, National Oceanic and Atmospheric Administration, Atlas 14, Volume 11, Version 2.0. Available online: https://hdsc.nws.noaa.gov/hdsc/pfds/, accessed November 2019, site latitude: 32.6326°, longitude: -97.2375°.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.

USDA (1961). *Technical Paper No. 40: Rainfall Frequency Atlas of the United States*, U.S. Department of Agriculture, May 1961

USGS (2004). *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas,* U.S. Geological Survey, June 2004

TABLES

Written by:	O. Bramlet	Date:	01/03/2020	Reviewed by:	S. Graves	Date:	2/4/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

Table 2F-1. NOAA Atlas 14 Point Precipitation Frequency Estimates for Rainfall Intensity (from NOAA, 2018)

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	4.90 (3.71-6.47)	5.75 (4.39-7.51)	7.13 (5.42-9.36)	8.28 (6.22-11.0)	9.86 (7.18-13.5)	11.1 (7.85-15.6)	12.3 (8.52-17.8)	13.7 (9.19-20.2)	15.5 (10.1-23.6)	16.9 (10.7-26.4)
10-min	3.92 (2.97-5.18)	4.61 (3.52-6.02)	5.71 (4.35-7.51)	6.64 (4.98-8.84)	7.92 (5.76-10.9)	8.92 (6.31-12.5)	9.92 (6.84-14.3)	10.9 (7.36-16.2)	12.3 (8.00-18.8)	13.4 (8.46-20.9)
15-min	3.26 (2.47-4.30)	3.82 (2.92-4.99)	4.72 (3.60-6.21)	5.48 (4.12-7.30)	6.53 (4.74-8.94)	7.34 (5.19-10.3)	8.16 (5.63-11.8)	9.03 (6.07-13.3)	10.2 (6.64-15.6)	11.1 (7.05-17.4)
30-min	2.27 (1.72-2.99)	2.65 (2.02-3.47)	3.27 (2.49-4.30)	3.79 (2.85-5.05)	4.51 (3.28-6.17)	5.06 (3.58-7.10)	5.62 (3.88-8.10)	6.23 (4.19-9.20)	7.06 (4.59-10.8)	7.72 (4.89-12.1)
60-min	1.47 (1.11-1.94)	1.73 (1.32-2.26)	2.14 (1.63-2.81)	2.48 (1.87-3.31)	2.96 (2.15-4.05)	3.33 (2.35-4.67)	3.71 (2.56-5.34)	4.12 (2.77-6.08)	4.69 (3.05-7.16)	5.15 (3.26-8.05)
2-hr	0.900 (0.686-1.18)	1.07 (0.818-1.38)	1.34 (1.02-1.74)	1.56 (1.18-2.06)	1.88 (1.38-2.55)	2.13 (1.52-2.97)	2.40 (1.66-3.42)	2.68 (1.81-3.92)	3.09 (2.02-4.65)	3.41 (2.17-5.26)
3-hr	0.664 (0.508-0.866)	0.794 (0.609-1.02)	0.998 (0.767-1.29)	1.17 (0.890-1.54)	1.43 (1.05-1.92)	1.62 (1.16-2.25)	1.83 (1.27-2.60)	2.06 (1.40-2.99)	2.39 (1.56-3.57)	2.65 (1.69-4.05)
6-hr	0.393 (0.303-0.509)	0.474 (0.366-0.602)	0.600 (0.464-0.771)	0.710 (0.542-0.926)	0.867 (0.641-1.16)	0.993 (0.714-1.36)	1.13 (0.789-1.58)	1.27 (0.867-1.83)	1.48 (0.973-2.19)	1.65 (1.06-2.49)
12-hr	0.230 (0.178-0.295)	0.278 (0.216-0.350)	0.353 (0.275-0.450)	0.418 (0.321-0.540)	0.510 (0.379-0.677)	0.584 (0.422-0.792)	0.663 (0.466-0.918)	0.748 (0.512-1.06)	0.869 (0.574-1.27)	0.966 (0.621-1.44)
24-hr	0.135 (0.105-0.172)	0.163 (0.127-0.204)	0.207 (0.162-0.262)	0.245 (0.189-0.314)	0.299 (0.223-0.392)	0.342 (0.248-0.458)	0.387 (0.273-0.530)	0.436 (0.300-0.610)	0.506 (0.336-0.727)	0.562 (0.363-0.824)
2-day	0.078 (0.061-0.099)	0.094 (0.074-0.117)	0.119 (0.094-0.150)	0.141 (0.110-0.179)	0.172 (0.129-0.223)	0.196 (0.143-0.260)	0.222 (0.158-0.301)	0.250 (0.173-0.346)	0.290 (0.194-0.412)	0.323 (0.209-0.466)
3-day	0.057 (0.045-0.072)	0.068 (0.054-0.085)	0.087 (0.069-0.108)	0.102 (0.080-0.129)	0.124 (0.094-0.161)	0.142 (0.104-0.187)	0.160 (0.114-0.216)	0.181 (0.125-0.248)	0.210 (0.140-0.295)	0.233 (0.152-0.334)
4-day	0.045 (0.036-0.057)	0.054 (0.043-0.067)	0.069 (0.055-0.086)	0.081 (0.064-0.102)	0.099 (0.075-0.127)	0.113 (0.083-0.148)	0.128 (0.091-0.171)	0.144 (0.100-0.196)	0.167 (0.112-0.233)	0.185 (0.121-0.264)
7-day	0.029 (0.023-0.036)	0.035 (0.028-0.043)	0.044 (0.035-0.054)	0.052 (0.041-0.065)	0.063 (0.048-0.081)	0.072 (0.053-0.094)	0.082 (0.059-0.109)	0.092 (0.064-0.125)	0.107 (0.072-0.148)	0.119 (0.078-0.167)
10-day	0.022 (0.018-0.028)	0.027 (0.021-0.033)	0.034 (0.027-0.041)	0.040 (0.031-0.049)	0.048 (0.037-0.061)	0.055 (0.041-0.071)	0.062 (0.045-0.082)	0.070 (0.049-0.094)	0.081 (0.054-0.111)	0.089 (0.059-0.125)
20-day	0.014 (0.012-0.018)	0.017 (0.014-0.021)	0.021 (0.017-0.026)	0.024 (0.019-0.030)	0.029 (0.022-0.037)	0.033 (0.024-0.042)	0.037 (0.026-0.048)	0.041 (0.029-0.054)	0.047 (0.032-0.063)	0.052 (0.034-0.071)
30-day	0.011 (0.009-0.014)	0.013 (0.011-0.016)	0.016 (0.013-0.020)	0.019 (0.015-0.023)	0.022 (0.017-0.028)	0.025 (0.019-0.032)	0.028 (0.020-0.036)	0.031 (0.022-0.040)	0.035 (0.024-0.047)	0.038 (0.025-0.052)
45-day	0.009 (0.007-0.011)	0.011 (0.009-0.013)	0.013 (0.011-0.016)	0.015 (0.012-0.019)	0.018 (0.014-0.022)	0.020 (0.015-0.025)	0.022 (0.016-0.029)	0.025 (0.017-0.032)	0.028 (0.019-0.037)	0.030 (0.020-0.041)
60-day	0.008 (0.007-0.010)	0.009 (0.008-0.011)	0.011 (0.009-0.014)	0.013 (0.011-0.016)	0.016 (0.012-0.019)	0.018 (0.013-0.022)	0.019 (0.014-0.025)	0.021 (0.015-0.028)	0.024 (0.017-0.032)	0.026 (0.018-0.035)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Table 2F-2. NOAA Atlas 14 Point Precipitation Frequency Estimates for Rainfall Depth (from NOAA, 2018)

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.408** (0.309-0.539)	**0.479** (0.366-0.626)	**0.594** (0.452-0.780)	**0.690** (0.518-0.919)	**0.822** (0.598-1.13)	**0.925** (0.654-1.30)	**1.03** (0.710-1.48)	**1.14** (0.766-1.68)	**1.29** (0.838-1.97)	**1.41** (0.891-2.20)
10-min	**0.654** (0.495-0.864)	**0.768** (0.586-1.00)	**0.952** (0.725-1.25)	**1.11** (0.830-1.47)	**1.32** (0.960-1.81)	**1.49** (1.05-2.09)	**1.65** (1.14-2.38)	**1.82** (1.23-2.69)	**2.05** (1.33-3.13)	**2.23** (1.41-3.48)
15-min	**0.815** (0.617-1.08)	**0.955** (0.729-1.25)	**1.18** (0.900-1.55)	**1.37** (1.03-1.83)	**1.63** (1.19-2.23)	**1.83** (1.30-2.58)	**2.04** (1.41-2.94)	**2.26** (1.52-3.33)	**2.55** (1.66-3.90)	**2.78** (1.76-4.35)
30-min	**1.13** (0.858-1.50)	**1.32** (1.01-1.73)	**1.64** (1.25-2.15)	**1.90** (1.42-2.53)	**2.26** (1.64-3.09)	**2.53** (1.79-3.55)	**2.81** (1.94-4.05)	**3.11** (2.09-4.60)	**3.53** (2.29-5.39)	**3.86** (2.44-6.03)
60-min	**1.47** (1.11-1.94)	**1.73** (1.32-2.26)	**2.14** (1.63-2.81)	**2.48** (1.87-3.31)	**2.96** (2.15-4.05)	**3.33** (2.35-4.67)	**3.71** (2.56-5.34)	**4.12** (2.77-6.08)	**4.69** (3.05-7.16)	**5.15** (3.26-8.05)
2-hr	**1.80** (1.37-2.36)	**2.13** (1.64-2.76)	**2.67** (2.05-3.48)	**3.13** (2.36-4.13)	**3.77** (2.75-5.11)	**4.27** (3.04-5.93)	**4.79** (3.32-6.83)	**5.37** (3.63-7.84)	**6.17** (4.03-9.31)	**6.82** (4.34-10.5)
3-hr	**1.99** (1.53-2.60)	**2.38** (1.83-3.06)	**3.00** (2.30-3.88)	**3.53** (2.67-4.64)	**4.28** (3.14-5.78)	**4.88** (3.48-6.75)	**5.51** (3.83-7.80)	**6.20** (4.20-8.98)	**7.17** (4.69-10.7)	**7.95** (5.07-12.2)
6-hr	**2.35** (1.81-3.05)	**2.84** (2.19-3.61)	**3.60** (2.78-4.62)	**4.25** (3.25-5.55)	**5.19** (3.84-6.95)	**5.95** (4.28-8.15)	**6.75** (4.72-9.46)	**7.63** (5.19-10.9)	**8.87** (5.83-13.1)	**9.86** (6.32-14.9)
12-hr	**2.77** (2.15-3.56)	**3.35** (2.60-4.22)	**4.25** (3.31-5.42)	**5.03** (3.87-6.51)	**6.15** (4.57-8.15)	**7.04** (5.09-9.55)	**7.99** (5.62-11.1)	**9.02** (6.17-12.8)	**10.5** (6.91-15.3)	**11.6** (7.49-17.3)
24-hr	**3.24** (2.52-4.12)	**3.91** (3.06-4.90)	**4.97** (3.90-6.29)	**5.88** (4.55-7.54)	**7.17** (5.36-9.41)	**8.20** (5.96-11.0)	**9.28** (6.56-12.7)	**10.5** (7.20-14.6)	**12.1** (8.05-17.5)	**13.5** (8.71-19.8)
2-day	**3.76** (2.95-4.75)	**4.52** (3.56-5.62)	**5.72** (4.52-7.19)	**6.76** (5.26-8.60)	**8.24** (6.20-10.7)	**9.41** (6.88-12.5)	**10.7** (7.58-14.4)	**12.0** (8.31-16.6)	**13.9** (9.29-19.8)	**15.5** (10.0-22.4)
3-day	**4.10** (3.23-5.15)	**4.92** (3.90-6.10)	**6.23** (4.94-7.79)	**7.35** (5.75-9.30)	**8.95** (6.75-11.6)	**10.2** (7.49-13.5)	**11.6** (8.24-15.5)	**13.0** (9.03-17.9)	**15.1** (10.1-21.3)	**16.8** (10.9-24.1)
4-day	**4.34** (3.44-5.45)	**5.22** (4.14-6.44)	**6.60** (5.25-8.22)	**7.79** (6.10-9.82)	**9.48** (7.18-12.2)	**10.8** (7.96-14.2)	**12.2** (8.76-16.4)	**13.8** (9.60-18.8)	**16.0** (10.7-22.4)	**17.8** (11.6-25.3)
7-day	**4.88** (3.88-6.07)	**5.86** (4.67-7.18)	**7.40** (5.91-9.15)	**8.73** (6.88-10.9)	**10.6** (8.09-13.6)	**12.1** (8.97-15.8)	**13.7** (9.87-18.2)	**15.5** (10.8-20.9)	**17.9** (12.1-24.8)	**19.9** (13.0-28.1)
10-day	**5.34** (4.26-6.62)	**6.39** (5.12-7.81)	**8.06** (6.46-9.93)	**9.49** (7.51-11.8)	**11.5** (8.81-14.7)	**13.2** (9.76-17.1)	**14.9** (10.7-19.6)	**16.7** (11.7-22.5)	**19.4** (13.1-26.6)	**21.5** (14.1-30.0)
20-day	**6.91** (5.55-8.49)	**8.11** (6.57-9.89)	**10.0** (8.13-12.3)	**11.7** (9.30-14.4)	**14.0** (10.7-17.5)	**15.7** (11.7-20.1)	**17.5** (12.7-22.9)	**19.6** (13.8-25.9)	**22.4** (15.2-30.4)	**24.8** (16.3-34.1)
30-day	**8.21** (6.63-10.1)	**9.55** (7.79-11.6)	**11.7** (9.53-14.3)	**13.5** (10.8-16.6)	**16.0** (12.3-20.0)	**17.9** (13.3-22.7)	**19.8** (14.4-25.7)	**22.0** (15.5-28.9)	**25.1** (17.1-33.7)	**27.6** (18.2-37.6)
45-day	**9.98** (8.09-12.2)	**11.6** (9.50-14.0)	**14.2** (11.6-17.3)	**16.4** (13.2-20.1)	**19.4** (15.0-24.1)	**21.7** (16.2-27.4)	**24.0** (17.5-30.8)	**26.5** (18.8-34.6)	**30.0** (20.5-40.0)	**32.9** (21.8-44.4)
60-day	**11.5** (9.38-14.0)	**13.4** (11.0-16.2)	**16.5** (13.5-20.0)	**19.1** (15.4-23.3)	**22.6** (17.5-28.0)	**25.3** (19.0-31.8)	**28.0** (20.5-35.8)	**30.9** (22.0-40.2)	**34.9** (23.9-46.2)	**38.0** (25.2-51.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Table 2F-3. Manning's Roughness Coefficients for Open Channels (from TxDOT, 2019)

Type of channel	Manning's n
c. Cultivated areas, no crop	0.020-0.040
d. Cultivated areas, mature row crops	0.025-0.045
e. Cultivated areas, mature field crops	0.030-0.050
f. Scattered brush, heavy weeds	0.035-0.070
g. Light brush and trees in winter	0.035-0.060
h. Light brush and trees in summer	0.040-0.080
i. Medium to dense brush in winter	0.045-0.110
j. Medium to dense brush in summer	0.070-0.160
k. Trees, dense willows summer, straight	0.110-0.200
l. Trees, cleared land with tree stumps, no sprouts	0.030-0.050
m. Trees, cleared land with tree stumps, with sprouts	0.050-0.080
n. Trees, heavy stand of timber, few down trees, flood stage below branches	0.080-0.120
o. Trees, heavy stand of timber, few down trees, flood stage reaching branches	0.100-0.160
3. Major streams (top width at flood stage > 100 ft)	
a. Regular section with no boulders or brush	0.025-0.060
b. Irregular rough section	0.035-0.100
B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050

Written by:	O. Bramlet	Date:	01/03/2020	Reviewed by:	S. Graves	Date:	2/4/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

Table 2F-4. Runoff Coefficients for Rural Watersheds (from TxDOT, 2019)

Watershed characteristic	Extreme	High	Normal	Low
Relief - C_r	0.28-0.35 Steep, rugged terrain with average slopes above 30%	0.20-0.28 Hilly, with average slopes of 10-30%	0.14-0.20 Rolling, with average slopes of 5-10%	0.08-0.14 Relatively flat land, with average slopes of 0-5%
Soil infiltration - C_i	0.12-0.16 No effective soil cover; either rock or thin soil mantle of negligible infiltration capacity	0.08-0.12 Slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 Normal; well drained light or medium textured soils, sandy loams	0.04-0.06 Deep sand or other soil that takes up water readily; very light, well-drained soils
Vegetal cover - C_v	0.12-0.16 No effective plant cover, bare or very sparse cover	0.08-0.12 Poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area has good cover	0.06-0.08 Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in cultivated crops	0.04-0.06 Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface Storage - C_s	0.10-0.12 Negligible; surface depressions few and shallow, drainageways steep and small, no marshes	0.08-0.10 Well-defined system of small drainageways, no ponds or marshes	0.06-0.08 Normal; considerable surface depression, e.g., storage lakes and ponds and marshes	0.04-0.06 Much surface storage, drainage system not sharply defined; large floodplain storage, large number of ponds or marshes

Table 4-11 note: The total runoff coefficient based on the 4 runoff components is $C = C_r + C_i + C_v + C_s$

Table 2F-5. Diversion Berm Drainage Area Sizing

Depth of Channel (ft)	Diversion Berm Flow Line Slope (%)	Maximum Predicted Flow Velocity (ft/s)	Maximum Predicted Flow Rate (cfs)	Maximum Drainage Area (ac)
2.5	0.5%	5.9	100.8	17.9
	1.0%	8.3	142.5	25.3
	1.5%	10.2	174.6	31.0
	2.0%	11.7	201.6	35.8

Note:

1. The back-calculated maximum allowable drainage area for the channel dimensions (geometry and slope) given above, as calculated by the Rational Method, assumes that the channel created by the diversion berm is flowing full when conveying the peak discharge during the 25-year rainfall event and to the maximum contributing drainage area.

Table 2F-6. Containment Berm Heights for Various Drainage and Storage Areas

Containment Berm Drainage Area (ac)	Containment Berm Storage Volume (ac-ft)	Contaminated Water Storage Area (ac)	Minimum Required Berm Height (ft)
0.5	0.30	0.10	4.0
		0.25	2.2
		0.50	1.6
1.0	0.60	0.10	7.0
		0.25	3.4
		0.50	2.2
1.5	0.90	0.25	4.6
		0.50	2.8
		0.75	2.2
2.0	1.20	0.25	5.8
		0.50	3.4
		0.75	2.6
3.0	1.79	0.40	5.5
		0.75	3.4
		1.00	2.8
4.0	2.39	0.50	5.8
		0.75	4.2
		1.00	3.4

Notes:

1. The calculated required berm height includes 1-ft of freeboard for the containment berm.
2. Table is intended as a guide for the landfill operator, as during operation, the active working face location will change as filling progresses, and new containment berms will be constructed accordingly. The containment storage areas and corresponding berm heights are based on flat (horizontal) storage areas. Containment berm storage volumes are provided as a guide for design of areas that are not horizontal and flat (see Note 3).
3. A licensed professional engineer is required to size the containment berms if conditions are not consistent or otherwise covered by the current design presented.

Table 2F-7. Run-On Berm Heights for Various Drainage and Storage Areas

Run-On Berm Drainage Area (ac)	Run-On Berm Storage Volume (ac-ft)	Run-On Water Storage Area (ac)	Minimum Required Berm Height (ft)
2.0	1.20	0.25	5.8
		0.50	3.4
		0.75	2.6
4.0	2.39	0.50	5.8
		0.75	4.2
		1.00	3.4
10.0	5.98	1.00	7.0
		2.00	4.0
		3.00	3.0
15.0	8.96	2.00	5.5
		3.00	4.0
		4.00	3.2
20.0	11.95	2.00	7.0
		3.00	5.0
		4.00	4.0
25.0	14.94	3.00	6.0
		4.00	4.7
		5.00	4.0
30.0	17.93	3.00	7.0
		4.00	5.5
		5.00	4.6

Notes:

1. The calculated required berm height includes 1-ft of freeboard for the containment berm.
2. Table is intended as a guide for the landfill operator, as during operation, the excavation areas contributing run-on towards the berm next to the active area will change as filling progresses, and new run-on berms will be constructed accordingly. The run-on storage areas and corresponding berm heights are based on flat (horizontal) storage areas. The Run-on berm storage volumes are provided as a guide for design of areas that are not horizontal and flat (see Note 3).
3. A licensed professional engineer is required to size the run-on berms if conditions are not consistent or otherwise covered by the current design presented.

FIGURES

- Figure 2F-1. Typical/Schematic of Active Fill Area Section (Not to Scale (NTS))

Written by: **O. Bramlet** Date: **01/03/2020** Reviewed & Revised by: **S. Graves** Date: **2/4/2020**

Client: **TRLC** Project: **Fort Worth C&D Landfill** Project No.: **GW6953** Phase No.: **04**

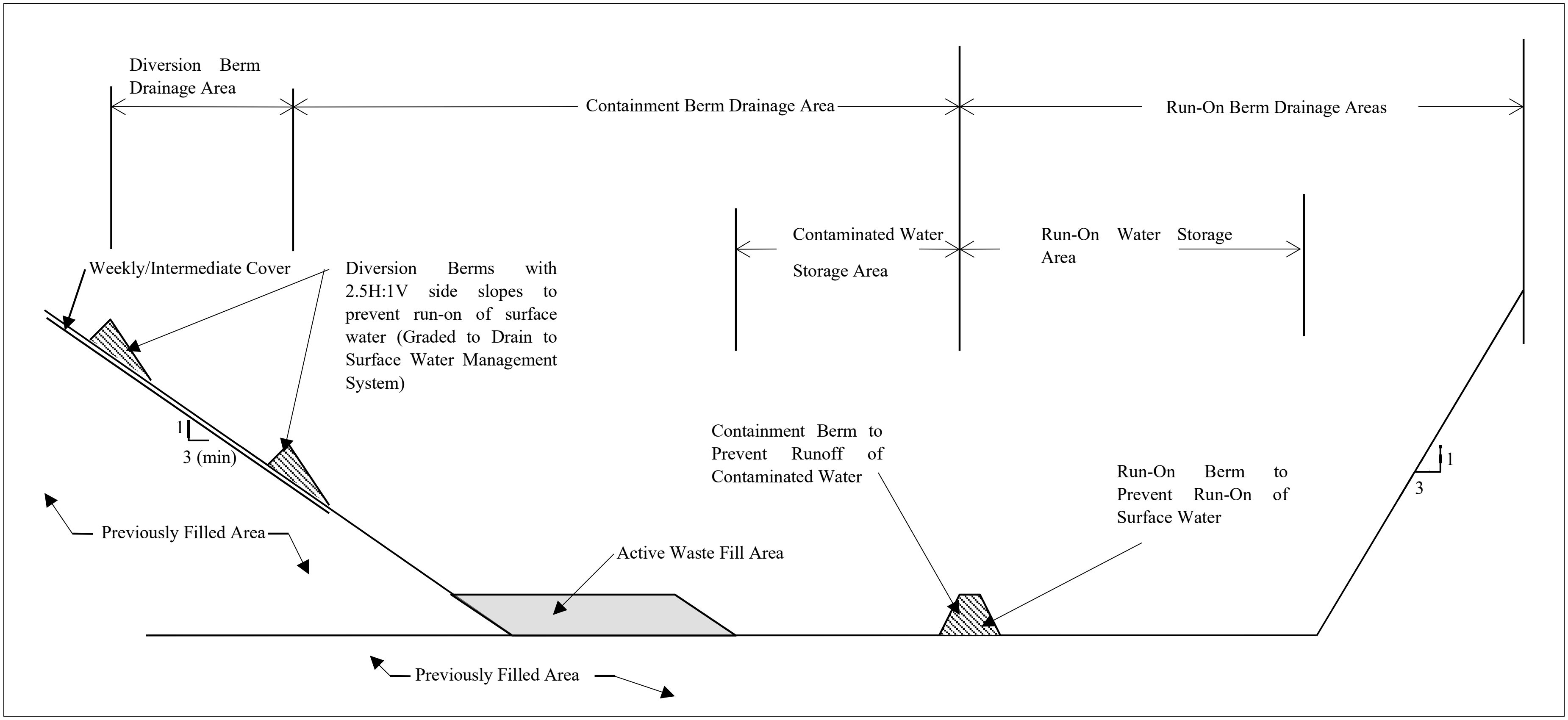


Figure 2F-1. Typical/Schematic of Active Fill Area Section (Not to Scale (NTS))

Note: If the working face is built directly on top of the protective cover of the liner system (i.e., during the first waste lift in a new lined sector), the containment and run-on berm shall be constructed within the lined area.

ATTACHMENT 2G

INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

Prepared for:
Texas Regional Landfill Company, LP

PERMIT AMENDMENT APPLICATION
PART III – SITE DEVELOPMENT PLAN
ATTACHMENT 2G

INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

FORT WORTH C&D LANDFILL
MSW PERMIT NO. 1983D
FORT WORTH, TARRANT COUNTY, TEXAS

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LICENSED
PROFESSIONAL ENGINEER
5/7/2020

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May 2020

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INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

STATE OF TEXAS
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LICENSED PROFESSIONAL ENGINEER
5/7/2020
FOR PERMIT PURPOSES ONLY
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM
REGISTRATION NO. F-1182

DRAWINGS

APPENDICES

1. INTRODUCTION

The purpose of this document is to provide a plan for controlling erosion and sediment on intermediate cover for the Fort Worth C&D Landfill (the landfill). Erosion control is necessary to maintain the integrity of the intermediate cover and to prevent off-site discharge of sediments. This Intermediate Cover Erosion and Sediment Control Plan (ICESCP) has been developed to address the requirements identified in Title 30 Texas Administrative Code (30 TAC) §330.305.

As required by 30 TAC §330.305(d), the landfill has been designed to provide effective erosional stability to top deck surfaces and external side slopes during all phases of landfill operation, closure, and post-closure care. Top deck surfaces and external side slopes are:

- those above grade slopes that directly drain to the facility surface water management system (i.e., areas where the surface water directly flows to a perimeter channel or surface water pond);
- those slopes that have received intermediate or final cover; and
- those surfaces that have either reached their permitted elevation, or will subsequently remain inactive for longer than 180 days.

Slopes that drain to areas of ongoing waste placement, pre-excavated areas, areas that have received only weekly cover, or areas under construction which have not received waste are not considered external side slopes.

The top deck surfaces and external side slopes will be covered with weekly cover, intermediate cover, or final cover. The definitions of each of these cover systems and their respective erosion and sediment control practices are provided below.

1.1 Weekly Cover

Weekly cover is defined in 30 TAC §330.165(b) for Type IV landfills. Weekly cover consists of six inches of well-compacted earthen material (or approved alternative) not previously mixed with garbage, rubbish, or other solid waste. The rate of cover must be no less than weekly, unless the Texas Commission on Environmental Quality (TCEQ) Executive Director approves another schedule. The placement and erosion control practices for weekly cover areas are addressed in the Site Operating Plan (SOP).

1.2 Intermediate Cover

Intermediate cover is defined in 30 TAC §330.165(c). Intermediate cover consists of at least 12 inches of suitable earthen material and is graded and maintained to prevent erosion and ponding of water. All areas that have received waste but will be inactive for longer than 180 days will be provided with intermediate cover. Information regarding the erosion and sediment control practices for intermediate cover is provided in Section 3 of this ICESCP. Additional information regarding placement, maintenance, and repair of intermediate cover is located in Section 5 of this ICESCP and Section 24 of the SOP.

1.3 Final Cover

1.3.1 Reference to Closure Plan

Final cover is defined in 30 TAC §330, Subchapter K. The final cover system for the landfill is described in the Closure Plan located in Attachment 7 of the Site Development Plan (SDP). As areas of the landfill reach final grade, the final cover system and the permanent surface water management system will be installed, which includes vegetated top deck and side slopes, drainage terraces, and downchute channels.

1.3.2 Erosional Stability of the Final Cover

The long-term erosional stability of the final cover slopes is demonstrated using the Revised Universal Soil Loss Equation (RUSLE) and is presented in Attachment 3E of the SDP. As shown in Attachment 3E and further described in the Closure Plan (Attachment 7), the calculated long-term annual soil loss is less than the long-term permissible value, indicating that the final cover system is designed with adequate resistance to erosion. Refer to these aforementioned attachments for additional discussion to clarify the ground coverage percentage and other assumptions that factor in to the calculated long-term annual soil loss. In particular, the "Conclusions and Recommendations" section of Attachment 3E discusses usage of soil loss results including how they relate to ground coverage. Additionally, the erosional stability of the side slope drainage terraces, top deck drainage terraces, and downchutes is demonstrated based on calculated flow velocity and is presented in Attachment 2D.

1.3.3 Final Cover Maintenance

Maintenance requirements for areas with final cover during operations and after closure are addressed, respectively, in Section 24 of the SOP and Section 3 of the Post-Closure Plan Attachment 8 of the SDP).

1.4 Landfill Perimeter Areas

The permanent surface water management system design includes features in the landfill perimeter areas outside the footprint of the disposal area. Runoff will be conveyed from the landfill to perimeter drainage channels and culverts and ultimately routed to the on-site surface water pond or midpoint site outfall. These features provide for non-erosive drainage of runoff from the landfill and surrounding site areas. Perimeter drainage channels will be utilized during development and operation of the landfill and will ultimately convey surface water runoff from the final cover or intermediate cover slopes. The erosional stability of the permanent drainage channels is demonstrated based on calculated flow velocity and is presented in Attachment 2E. Maintenance requirements for perimeter drainage features are addressed in Section 3 in the Post-Closure Plan located in Attachment 8 of the SDP.

2. INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DESIGN

As required by 30 TAC §330.305(d), the landfill design must provide effective erosional stability to top deck surfaces and external side slopes. An Intermediate Cover Erosion Analysis was performed and is included in Appendix 2G-1 of this ICESCP.

2.1 Permissible Soil Loss and Non-Erodible Velocity

A permissible soil loss of 50 tons/acre/year is used as the design criteria to which the calculated soil loss for intermediate cover is compared (TCEQ, 2018). For the purposes of the site-specific erosion and sediment control design, the permissible soil loss is the "permissible soil loss for comparable soil-slope lengths and soil-cover conditions" referred to by 30 TAC §330.305(d)(2). For comparison purposes, 50 tons/acre is equivalent to a soil thickness of 0.25 in. (six mm) for a soil with a typical bulk density of 110 pcf.

The permissible non-erodible velocity of five (5) ft/sec is used as the design criteria to which the estimated flow velocities are compared. *Storm Water Management Guidelines for Construction Activities* (TxDOT, 2002) indicates that flow velocities should not exceed four (4) ft/sec in sandy soils or five (5) ft/sec in more cohesive soils. Five (5) ft/sec is appropriate for this facility because it is anticipated that intermediate cover will be constructed of cohesive soils that are readily available at the site.

2.2 Intermediate Cover Erosion Analysis Results

The Intermediate Cover Erosion Analysis is presented in Appendix 2G-1 of this ICESCP. The Revised Universal Soil Loss Equation (RUSLE) is used in the Intermediate Cover Erosion Analysis to calculate the annual soil loss. Results from the Intermediate Cover Erosion Analysis indicate that adequate erosional stability of the intermediate cover on the top deck and side slopes can be achieved with stabilized soil surfaces and surface water diversions. To achieve effective erosional stability, the maximum parallel offset (horizontal) of the temporary diversion structures is 550-ft on the top deck. The maximum parallel offset for the external 3H:1V side slopes is dependent on the ground cover attained on the interim cover. For 60%, 70%, and 80% ground cover on the interim cover system, the maximum parallel offset of terraces on the external 3H:1V side slopes is 300-ft, 500-ft, and 680-ft, respectively. These distances are based on a soil stabilization practice method that provides a cropping management factor (C) corresponding to the above options for percentage of ground cover. on the top deck and external side slopes. The C values correspond to ground cover consisting of grass, grass-like plants, mulch, or organic matter at least two inches deep covering the specified percentage of the surface of the intermediate cover.

3. EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES (BMPS)

Based on the Intermediate Cover Erosion Analysis presented in Appendix 2G-1 of this ICESCP, soil stabilization and surface water diversion BMPs are required for erosional stability of the intermediate cover on the top deck surface and external side slopes during landfill operations. Drawing 2G-1 depicts a plan view of the site to show an example configuration of a landfill development phase, showing the areas requiring erosion and sediment controls addressed in this plan. Descriptions of the required soil stabilization and drainage controls are provided below. Optional BMPs that may be used in addition to the required BMPs at the landfill operator's discretion are also described.

3.1 <u>Soil Stabilization</u>

The purpose of soil stabilization is to provide a ground cover that limits the rainfall impact energy, provides a limited amount of water storage through rainfall interception, and limits sheet flow runoff velocity by increasing surface roughness. In the natural condition, soil is stabilized by native vegetation. As previously described, the temporary soil stabilization practice must provide a maximum C value of 0.042 for intermediate cover. These C values correspond to ground cover consisting of grass, grass-like plants, mulch, or organic matter at least two inches deep covering at least 60% of the surface of the intermediate cover. Intermediate cover will be installed in accordance with the requirements of the SOP, will be stabilized with at least 60% ground cover within 180 days following installation, and will be maintained until final cover is installed or waste filling operations resume. Placement of intermediate cover and stabilization activities will be documented in the Site Operating Record. Details of the soil stabilization BMPs that will be implemented are listed below.

- Vegetation – Vegetation, as a BMP, is the sowing or sodding of fast-germinating annual or perennial grasses, grains, or legumes to provide a vegetative stabilization for disturbed areas. With leaves and stems above ground and fibrous roots below ground, vegetation can provide an effective and long-lasting ground cover. Lack of water and lack of or improper use of soil amendments will usually result in poor vegetation establishment. Seed may be applied to the landfill surface by broadcasting, drilling, hydraulic methods such as hydroseeding or hydromulching, or other methods. Vegetation types, rates of application, and other specifications for establishing vegetation are left to the discretion of the landfill operator, but should be in accordance with temporary vegetation BMP standards or guidelines published by relevant State or local agencies, appropriate for the area. An example of a standard vegetation specification is published in TxDOT (2014), the *Texas Department of Transportation (TxDOT) Standard Specification for Construction and Maintenance of Highways, Streets, and Bridges*, Item 162 (sodding) and Item 164 (seeding). Use of this particular standard specification is not required but is provided as an example of a common and widely-used specification that provides vegetation-related BMPs. Intermediate cover must achieve a relatively uniform ground cover of at least 60% within 180 days following placement. If vegetation establishment at the minimum density specified above cannot be achieved (due to drought, temperatures, or other unforeseen conditions), then additional soil stabilization BMPs (e.g., mulch) will be implemented until the required vegetation density is achieved.

- Mulch – Mulching is the application of a layer of organic, biodegradable material which is spread over areas where vegetation is not yet established. Types of mulch include compost, shredded wood, straw, or manufactured products. Mulch may be distributed over the ground surface dry or hydraulically applied as slurry. If applied dry, the mulch must be tracked into the surface to prevent the mulch from being washed away. If mulch is to be used as the only soil stabilization feature (i.e., without vegetation), a two-inch (minimum) thick layer of "primary grind" mulch is required. Note that "primary grind" mulch is mulch obtained from the primary run from an industrial tub grinder. Primary grind mulch is very coarse mulch that mats together and resists washing away. It is noted that this technique has been used successfully in stabilizing intermediate cover side slopes at similar landfill projects within Texas. Types of mulch slurries include hydromulch, bonded fiber matrix (BFM), flexible growth medium (FGM), as well as other commercially available products. Slurry mixtures typically include a tackifier or binder which increases the strength and durability of the mulch. Seed can also be added to the slurry, in which case the ground surface would be stabilized with a mulch/vegetation composite. If mulch is used in lieu of vegetation for intermediate cover, then the mulch will be applied to cover all of the area requiring stabilization within 180 days of intermediate cover installation. If mulch is used in conjunction with vegetation, then the mulch will be applied to areas where the vegetation fails to establish, or the mulch will be used as a supplemental layer to encourage vegetative growth while providing some degree of soil stabilization until vegetation becomes established.

3.2 Surface Water Diversions

The purpose of a surface water diversion structure is to limit the length of slope over which surface water runoff can travel as sheet flow or shallow concentrated flow. The diversion concentrates and laterally conveys surface water in a non-erosive manner to the perimeter ditch or downchute. Surface water diversion BMPs that will be implemented are listed below.

- Side Slope Drainage Terraces – The proposed final grading plan includes tack-on terraces on the external 3H:1V side slopes of the landfill. These terraces will be constructed of intermediate cover overlying waste and will have a flow line (or longitudinal) slope of approximately 2%. The surface of the intermediate cover within the terrace will be stabilized with vegetation or mulch. Rolled erosion control products may also be used for stabilization of the drainage terraces. Details showing the required dimensions and spacing of the built-in terraces are provided on Drawing 2G-2. Design calculations for these side slope drainage terraces on the intermediate cover surface are provided in Appendix 2G-2.

- Top Deck Drainage Terraces – Top deck drainage terraces are open channels used to collect flow from top deck surfaces and convey it to the temporary downchute channels along the side slopes in a non-erosive manner. Top deck drainage terraces are designed as v-shaped channels with 3H:1V and 5% side slopes and a flow line slope of approximately 0.15%. Details showing the required dimensions and layout of the drainage features are provided on Drawing 2G-2. Design calculations for the top deck drainage terraces on the intermediate cover surface are provided in Appendix 2G-2.

- Temporary Downchutes – Temporary downchutes (also known as downdrains or let-downs) are open channels used to collect flow from surface water diversion structures and convey it down the side slope in a non-erosive manner. Downchutes will be constructed using soil berms to create an above-grade channel, or will be excavated to create a depressed channel (in which case a minimum of one foot of intermediate cover will be maintained beneath the downchute). The bottom and side slopes of the temporary downchute channel will be lined with turf reinforcement mat, geomembrane, reno mattress/articulated block, or other alternative lining material to prevent erosion. If an alternative lining material is used, the lining material must have a Manning's n equal to or less than 0.015. The lining material must be able to tolerate the anticipated velocity and tractive stress at the design flow rate and corresponding calculated depth of flow. All equivalency evaluations performed pursuant to these criteria will be placed in the Site Operating Record. A rip rap apron will be installed at the downstream end of the downchutes to provide erosion protection. Details showing the required dimensions and information on these structures are provided on Drawing 2G-2. Design calculations for these temporary structures are provided in Appendix 2G-2.

3.3 <u>Optional Erosion and Sediment Control BMPs</u>

As demonstrated in the Intermediate Cover Erosion Analysis included in Appendix 2G-1, the soil stabilization and surface water diversion BMPs specified above in Sections 3.1 and 3.2 are the only BMPs required to limit soil loss in accordance with 30 TAC §330.305(d). No other BMPs are required. However, other erosion and sediment control BMPs may be implemented during landfill operations at the operator's discretion in order to reduce soil losses even further than required or to provide temporary erosion and sediment controls during the period between installation of intermediate cover and establishment of vegetation or mulch on the top deck and external side slopes. Examples of optional BMPs that may be implemented are listed below.

- Silt Fence – Silt fence consists of filter fabric supported by wire mesh netting or other backing stretched between either wooden or metal posts with the lower edge of the fabric securely embedded in the soil. Silt fence may be located as needed to intercept and filter sheet flow. Typical locations of silt fence include along the toe or crest of external side slopes and should be installed at a fairly level grade. Silt fence may not be used in areas of concentrated flow (e.g., channels and diversions). The maximum drainage area to the silt fence should not exceed the manufacturer's specification, but in no case shall the drainage area be greater than 0.5 acre per 100 ft of fence. A typical silt fence detail is provided on Drawing 2G-3.

- Biodegradable Logs – Biodegradable logs (or filter socks) consist of a biodegradable core material contained in a synthetic mesh sock or tube and are installed above, across, or below slopes to intercept and filter sheet flow. The logs are anchored to the surface using stakes or other methods and should be installed at a fairly level grade. Biodegradable logs may not be used in areas of concentrated flow (e.g., channels and diversions). The maximum drainage area to the biodegradable logs should not exceed 0.5 acre per 100 ft of log. A typical biodegradable log detail is provided on Drawing 2G-3.

- Organic Berms – Organic berms (or organic filter berms) are linear berms constructed of mulch or a mix of mulch and compost. Organic berms may be located as needed to intercept and filter sheet flow. Typical locations of organic berms include along the toe or crest of external side slopes. Organic berms may not be used in areas of concentrated flow (e.g., channels, terraces, and diversions). The maximum drainage area to the organic berms should not exceed 0.5 acre per 100 ft of berm. A typical organic berm detail is provided on Drawing 2G-3.

4. INTERMEDIATE COVER INSTALLATION AND STABILIZATION SCHEDULE

The schedule for installation of intermediate cover and associated erosion and sediment control BMPs is as follows:

- Areas with weekly cover that remain inactive for periods greater than 180 days will receive intermediate cover.

- Intermediate cover diversion structures and downchutes will be installed as soon as practical following placement of intermediate cover, but in no case more than 180 days from when intermediate cover is installed.

- Intermediate cover will be stabilized with vegetation or mulch as soon as practical following placement of intermediate cover. A minimum of 60% land cover (corresponding to a maximum cropping management factor of 0.042) will be established over the intermediate cover areas within 180 days from intermediate cover construction.

- The intermediate cover and temporary erosion control structures will be maintained as detailed in Section 5 below (the Intermediate Cover Erosion and Sediment Control Maintenance Plan).

- Final cover will be constructed incrementally as the site develops. Temporary erosion control features will be removed as permanent erosion control structures are constructed.

5. INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL MAINTENANCE PLAN

The landfill operator will restore and repair the intermediate cover areas and their erosion and sediment control features in the event of washout or failure. Excess silt buildup, weeds and other debris that are adversely affecting flow in diversion structures will be removed to restore their design configuration, followed by re-stabilizing the disturbed areas as appropriate. Site inspections by landfill personnel will be performed weekly in accordance with the facility's Texas Pollutant Discharge Elimination System (TPDES) Multi-Sector General Permit. Written records of these inspections and maintenance activities will be maintained in the Site Operating Record, as further discussed in the Site Operating Plan (SOP).

The following items will be evaluated during the inspections:

- presence of adequate vegetation coverage (grass and/or mulch) to meet the applicable minimum ground cover percentages specified herein;
- adequacy of the spacing between interim diversion structures on side slopes in accordance with the table on Drawing 2G-2;
- erosion of intermediate cover areas, perimeter ditches, diversion channels, downchutes, and other drainage features;
- settlement of intermediate cover areas, diversion channels, downchutes, and other drainage features;
- silt and sediment build-up in diversion channels, perimeter ditches, downchutes, and surface water ponds;
- presence of ponded water on intermediate cover or behind diversion structures;
- obstructions in drainage features;
- presence of erosion or sediment discharge at off-site surface water discharge locations; and
- functionality of temporary erosion and sediment control features.

Maintenance activities will be performed to correct damaged or deficient items noted during the site inspections. These activities will be performed as soon as possible after the inspection. Damaged or deficient items will be corrected within seven days of detection unless access is restricted due to weather, ground conditions, and other site-specific conditions.

Maintenance activities will consist of the following, as needed:

- placement of additional vegetation or mulch on areas with deficient coverage;
- adjustments to, or installation of, interim diversion structures that are found to be spaced inadequately;
- placement, grading, and stabilization of additional soils in eroded areas or in areas which have settled;
- replacement of riprap or other structural armoring;
- removal of obstructions from drainage features;
- removal of silt and sediment build-up from the erosion and sediment controls;
- removal of ponded water on the intermediate cover or behind diversion structures;
- repairs to erosion and sedimentation controls; and
- installation of additional erosion and sedimentation controls, as needed.

Inspection, maintenance, and recordkeeping frequencies and techniques are discussed below.

- Site inspections by landfill personnel will be performed weekly.
- Documentation of the inspection will be included in the Site Operating Record.
- Documentation of maintenance activities that were performed to correct damaged or deficient items noted during the site inspections will be included in the Site Operating Record.
- Landfill personnel will be trained to perform inspections, install, and maintain erosion and sediment control features.

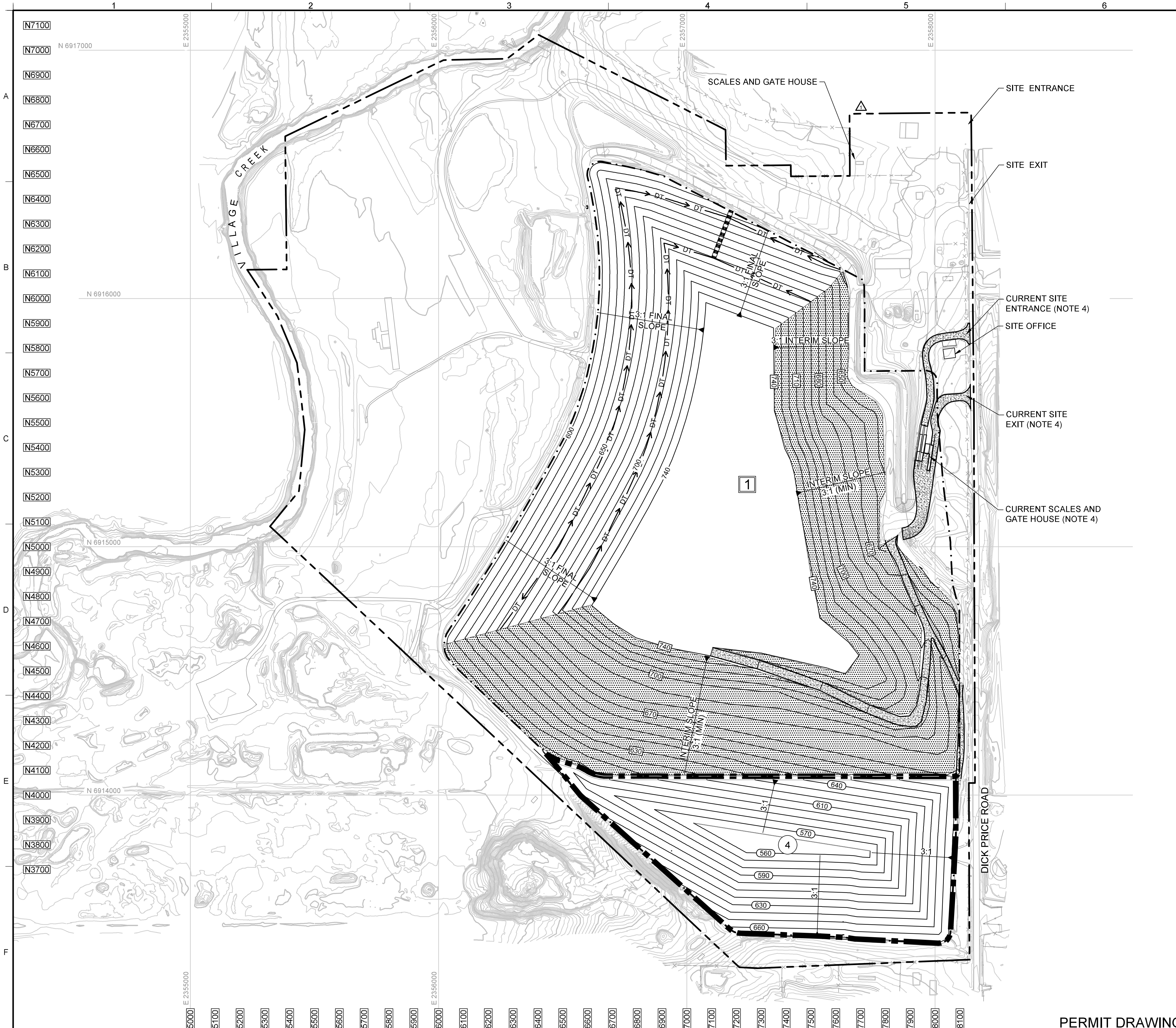
6. REFERENCES

TCEQ (2018). Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill, Regulatory Guidance 417 (RG-417), Texas Commission on Environmental Quality, Waste Permits Division, Revised May 2018.

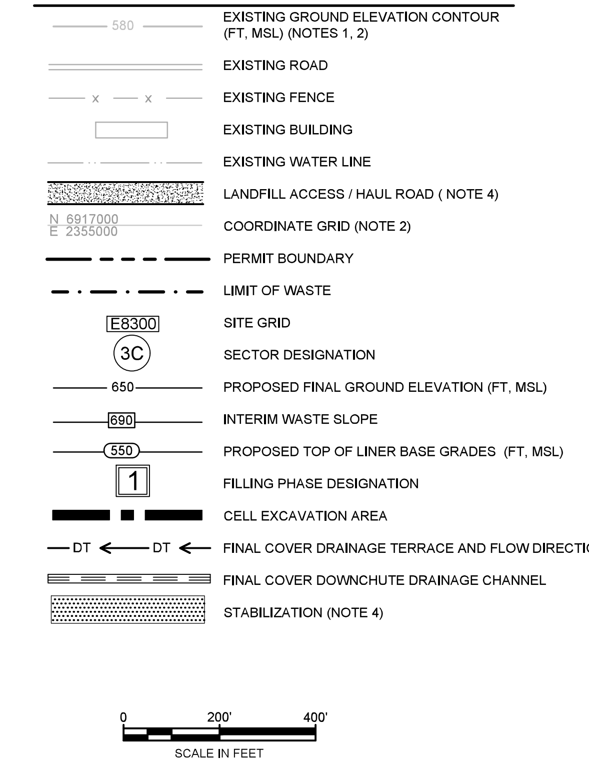
TxDOT (2002). *Storm Water Management Guidelines for Construction*, Texas Department of Transportation.

TxDOT (2014). Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Texas Department of Transportation, 1 November 2014.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.



LEGEND



NOTES:

1. EXISTING TOPOGRAPHIC BASE MAP COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 06 MARCH 2019 BY DALLAS AERIAL SURVEYS, INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED BY THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988. COORDINATE GRID BASED ON TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS NORTH CENTRAL ZONE (4202), NORTH AMERICAN DATUM OF 1983 (NAD-83).
3. THIS PLAN REPRESENTS A "SNAPSHOT" OF GENERAL CONDITIONS FOR INTERMEDIATE COVER EROSION AND SEDIMENT CONTROLS DURING DEVELOPMENT OF PHASE 1 AND MAY NOT REFLECT THE EXACT CONFIGURATION OF THE LANDFILL OR LOCATION OF CONTROLS. ACTUAL EROSION AND SEDIMENT CONTROL FEATURES WILL VARY BASED ON LANDFILL DEVELOPMENT.
4. DETAILS AND INFORMATION ON THE REQUIRED SPACING OF INTERIM DRAINAGE TERRACES IS PROVIDED ON DRAWING 2G-2. THE DESIGN CALCULATIONS ARE PRESENTED IN APPENDIX 2G-2.
5. DIVERSION STRUCTURES MUST BE INSTALLED AND STABILIZED WITHIN 180 DAYS FOLLOWING PLACEMENT INTERMEDIATE COVER.
6. STABILIZATION MAY CONSIST OF VEGETATION, MULCH, OR COMBINATION OF BOTH. THE STABILIZATION MUST OBTAIN AT LEAST 60% COVERAGE WITHIN 180 DAYS FOLLOWING PLACEMENT OF INTERMEDIATE COVER. IF MULCH IS USED AS THE ONLY STABILIZATION FEATURE, A MINIMUM LAYER THICKNESS OF 2 INCHES IS REQUIRED AND AT LEAST 50% (BY BULK VOLUME) MUST CONSIST OF PARTICLES WITH DIMENSIONS EQUIVALENT TO THAT OBTAINED FROM THE PRIMARY RUN FROM AN INDUSTRIAL TUB GRINDER.

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12/14/2020

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REV	DATE	DESCRIPTION	DRN	APP
1	DEC 2020	RESPONSE TO NOD 2	JJV	SMG
-	MAY 2020	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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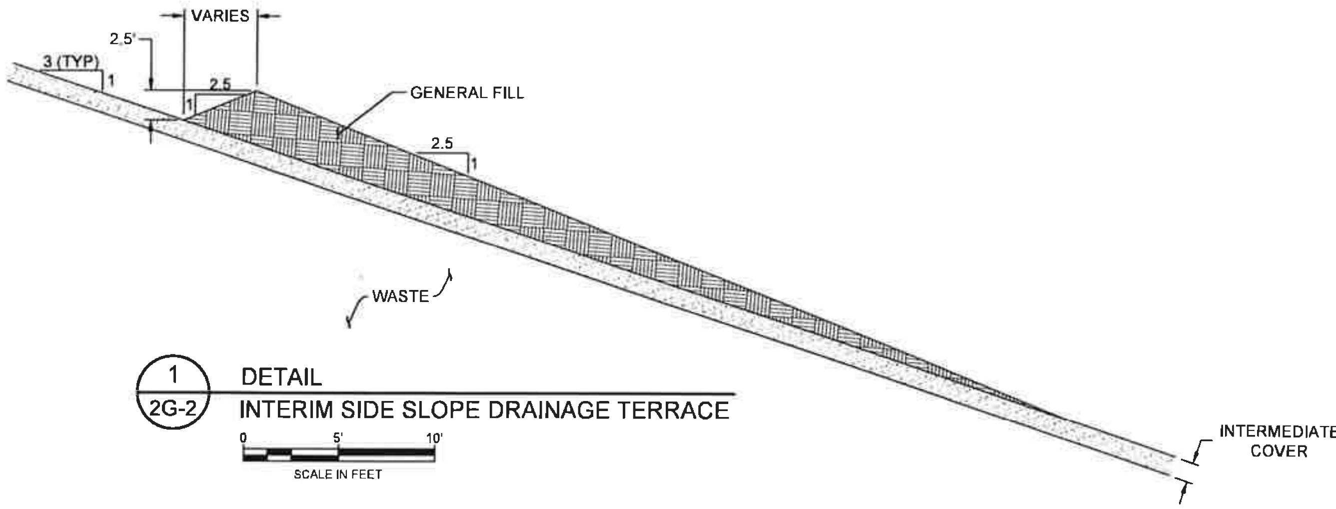
TITLE: EXAMPLE INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

PROJECT: FORT WORTH C&D LANDFILL EXPANSION
PERMIT AMENDMENT APPLICATION - PERMIT NO. MSW-1983D

PERMIT DRAWING

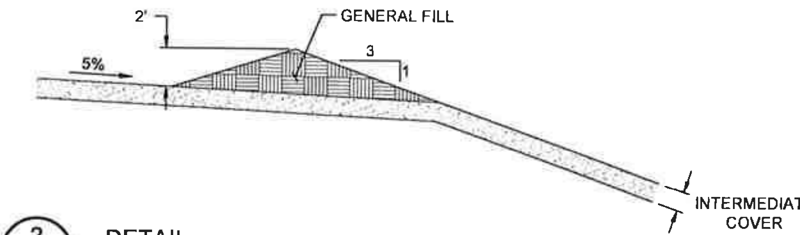
PROJECT NO.:	GW6953	DESIGN BY:	SMG	REVIEWED BY:	BG	PART NO.:	DRAWING:
FILE:	GW6953P2G1	DRAWN BY:	JJV / KH	APPROVED BY:	SMG	III	2G-1

DRAWING: Austin P:\CADD\Projects\Fort worth c&d landfill expansion (gw6953)\DRAWINGS\GW6953P2G1.dwg PLOTTED: Dec 07, 2020 - 2:38pm



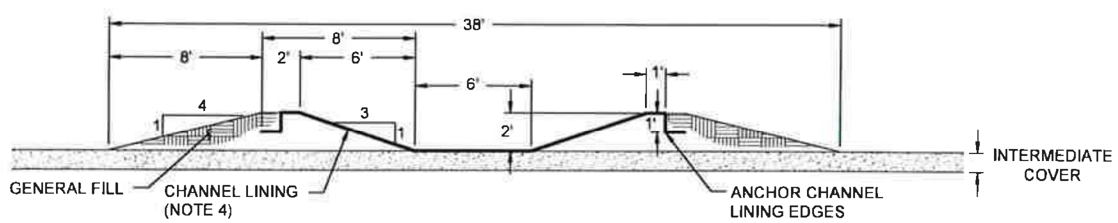
1 / 2G-2 DETAIL
INTERIM SIDE SLOPE DRAINAGE TERRACE

0 5' 10'
SCALE IN FEET



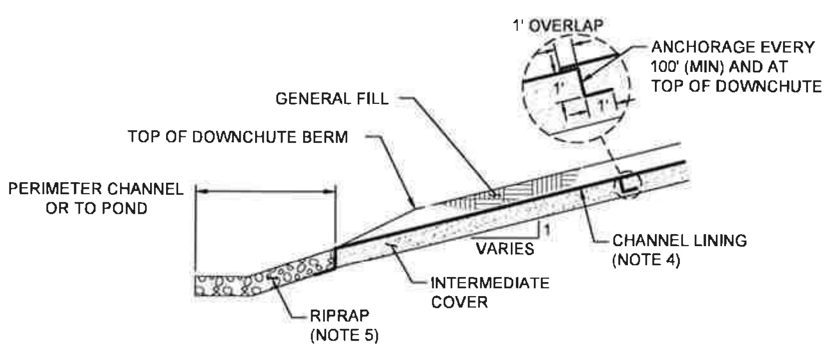
2 / 2G-2 DETAIL
INTERIM TOP DECK DRAINAGE TERRACE (NOTE 2)

0 5' 10'
SCALE IN FEET



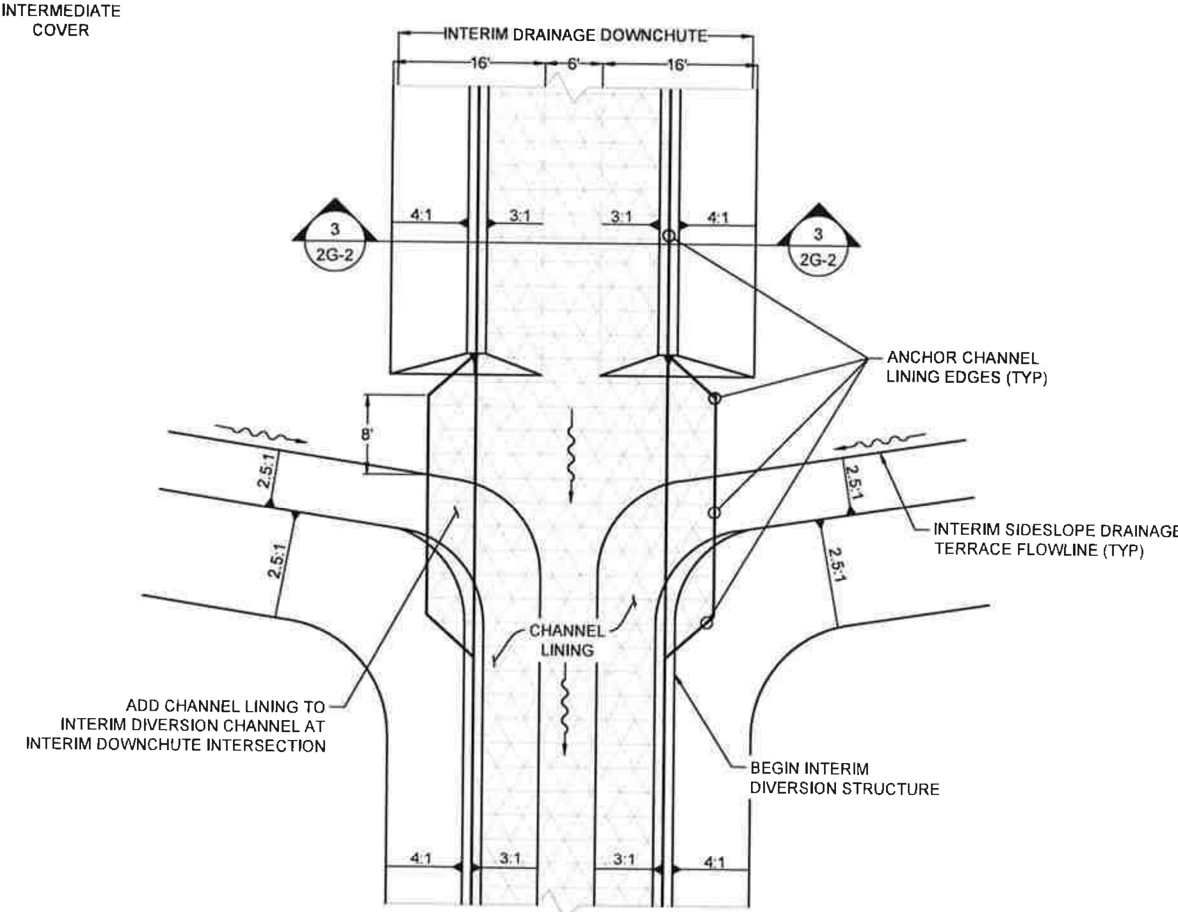
3 / 2G-2 DETAIL
TYPICAL INTERIM DRAINAGE DOWNCHUTE CROSS SECTION

0 5' 10'
SCALE IN FEET



4 / 2G-2 DETAIL
TYPICAL INTERIM DRAINAGE DOWNCHUTE

0 5' 10'
SCALE IN FEET



5 / 2G-2 DETAIL
TYPICAL INTERIM DRAINAGE DIVERSION STRUCTURE AND DOWNCHUTE INTERSECTION

0 10' 20'
SCALE IN FEET

NOTES:

1. THE INTERIM DIVERSION STRUCTURES CONSTRUCTED ON SIDE SLOPES SHALL BE SPACED ACCORDING TO THE MAXIMUM ALLOWABLE DRAINAGE TERRACE SPACING TABLE (SEE BELOW) AND INTERIM COVER STABILIZATION METHOD. THE FLOWLINE SLOPE OF THE CHANNEL SHALL BE APPROXIMATELY 2%.
2. THE DIVERSION STRUCTURES CONSTRUCTED ON 5% TOP DECK SURFACES SHALL BE SPACED A MAXIMUM OF 675 FT HORIZONTALLY. THE FLOWLINE SLOPE OF THE CHANNEL SHALL BE APPROXIMATELY 0.15%.
3. ROLLED EROSION CONTROL PRODUCTS IF USED WITHIN THE DIVERSION CHANNELS MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
4. THE BOTTOM AND SIDESLOPES OF THE DOWNCHUTE CHANNEL WILL BE LINED WITH TURF REINFORCEMENT MAT, GEOMEMBRANE, RENO MATTRESS, OR OTHER ALTERNATIVE LINING MATERIAL TO PREVENT EROSION. IF AN ALTERNATIVE LINING MATERIAL IS USED, THE LINING MATERIAL MUST HAVE A MANNING'S N LESS THAN 0.015. THE LINING MATERIAL MUST BE ABLE TO TOLERATE THE ANTICIPATED VELOCITY AND TRACTIVE STRESS AT THE DESIGN FLOW RATE AND CORRESPONDING CALCULATED DEPTH OF FLOW. ALL EQUIVALENCY EVALUATIONS PERFORMED PURSUANT TO THESE CRITERIA WILL BE PLACED IN THE FACILITY OPERATING RECORD.
5. RIPRAP APRON SHALL BE A MINIMUM OF 2' THICK AND SHALL HAVE D_{50} = 12" AND D_{MAX} = 24"; APRON WIDTH = 24' MIN.

MAXIMUM ALLOWABLE DRAINAGE TERRACE SPACING				
		MAXIMUM ALLOWABLE TERRACE SPACING		
INTERIM COVER STABILIZATION METHOD	REQUIRED MINIMUM GROUND COVER	5% TOP DECK	33% SIDE SLOPES	CHANNEL DEPTH (FT)
GRASS	60%	675-FT	250-FT	2.5
GRASS & MULCH	70%	675-FT	450-FT	2.5
MULCH	80%	675-FT	600-FT	2.5

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-	MAY 2020	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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TITLE: INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DETAILS I

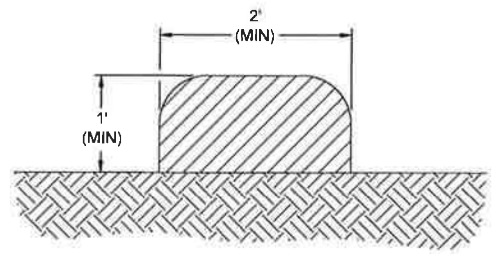
PROJECT: FORT WORTH C&D LANDFILL EXPANSION
PERMIT AMENDMENT APPLICATION - PERMIT NO. MSW-1983D

PROJECT NO.: GW6953	DESIGN BY: SMG	REVIEWED BY: BG	PART NO.: III	DRAWING: 2G-2
FILE: GW6953P2G2	DRAWN BY: JJV / KH	APPROVED BY: SMG		

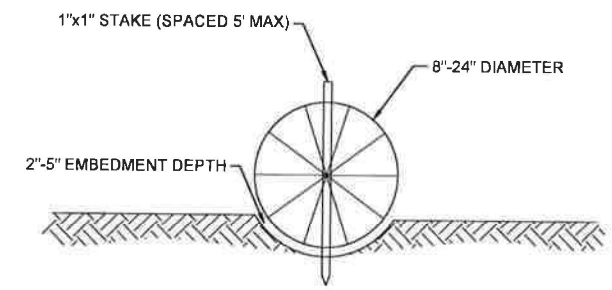
PERMIT DRAWING

IIIF-E-305

DRAWING: Austin P:\CAD\Projects\ft worth c&d landfill expansion (gw6953)\DRAWINGS\GW6953P2G2.dwg PLOTTED: May 05, 2020 - 2:32pm



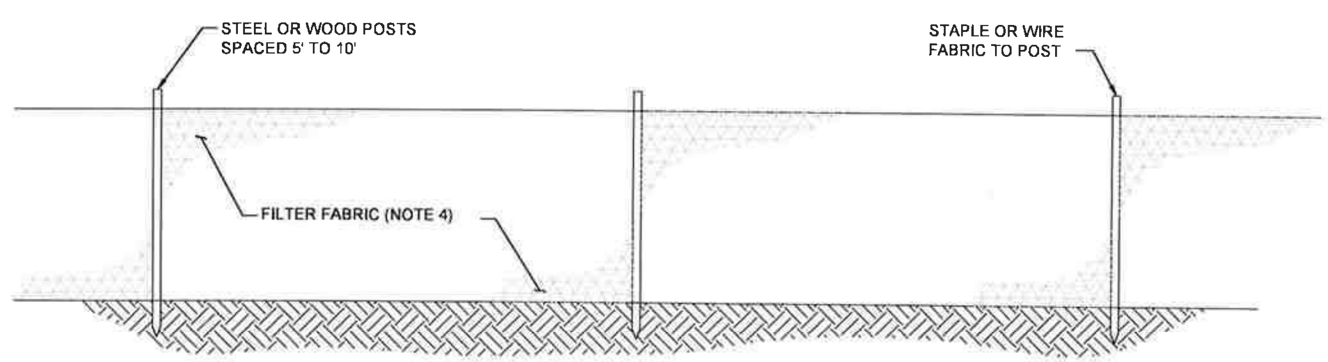
6
2G-3
DETAIL
ORGANIC BERM
SCALE: NTS



7
2G-3
DETAIL
BIODEGRADABLE LOG
SCALE: NTS

NOTES:

1. THE EROSION AND SEDIMENT CONTROL FEATURES SHOWN ON THIS FIGURE ARE OPTIONAL AND MAY BE IMPLEMENTED DURING LANDFILL OPERATIONS AT THE OPERATOR'S DISCRETION IN ORDER TO REDUCE SOIL LOSSES EVEN FURTHER THAN REQUIRED OR TO PROVIDE TEMPORARY EROSION AND SEDIMENT CONTROLS DURING THE PERIOD BETWEEN INSTALLATION OF THE INTERMEDIATE COVER AND ESTABLISHMENT OF VEGETATION OR MULCH ON THE EXTERNAL SLOPES.
2. IF USED, THE OPTIONAL EROSION AND SEDIMENT CONTROL FEATURES MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS, THE DETAILS SHOWN ON THIS FIGURE, OR OTHER PUBLISHED SOURCE (E.G., TXDOT OR MUNICIPAL OR COUNTY GOVERNMENT AGENCY).
3. THE MAXIMUM DRAINAGE AREA TO THE SILT FENCE, ORGANIC BERM, AND BIODEGRADABLE LOG SHALL NOT EXCEED THE MANUFACTURER'S RECOMMENDATION, BUT IN NO CASE SHALL THE DRAINAGE AREA BE GREATER THAN 0.5 ACRE PER 100 FT. THESE OPTIONAL FEATURES MAY NOT BE USED IN AREAS OF CONCENTRATED FLOW (FOR EXAMPLE, DITCHES, CHANNELS, AND TERRACES).
4. THE LOWER EDGE OF THE SILT FENCE FILTER FABRIC SHALL BE SECURELY EMBEDDED IN THE SOIL.
5. ORGANIC BERMS MAY BE CONSTRUCTED OF MULCH, WOODCHIPS, BRUSH, COMPOST, OR SHREDDED WOODWASTE.
6. BIODEGRADABLE LOGS MAY CONSIST OF MUSH SOCKS FILLED WITH MULCH, WOODCHIPS, BRUSH, COMPOST, OR SHREDDED WOODWASTE.



8
2H-3
DETAIL
SILT FENCE
SCALE: NTS

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER
5/7/2020

FOR PERMIT PURPOSES ONLY

REV	DATE	DESCRIPTION	DRN	APP
-	MAY 2020	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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TITLE: INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DETAILS II

PROJECT: FORT WORTH C&D LANDFILL EXPANSION
PERMIT AMENDMENT APPLICATION - PERMIT NO. MSW-1983D

PROJECT NO.:	GW6953	DESIGN BY:	SMG	REVIEWED BY:	BG	PART NO.:	DRAWING:
FILE:	GW6953P2G3	DRAWN BY:	JJV / KH	APPROVED BY:	SMG	III	2G-3

PERMIT DRAWING

APPENDIX 2G-1

INTERMEDIATE COVER EROSION ANALYSIS

Written by:	**O. Bramlet**	Date:	**01/09/2019**	Reviewed by:	**S. Graves**	Date:	**2/4/2020**
Client:	**TRLC**	Project:	**Fort Worth C&D Landfill**	Project No.:	**GW6953**	Phase No.:	**04**

INTERMEDIATE COVER EROSION ANALYSIS

5/7/2020

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 21

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the intermediate cover erosion analysis for the Fort Worth C&D Landfill. This package provides calculations for the annual soil loss from the external-facing intermediate cover top deck and side slope surfaces under potential interim conditions during operations. In addition, estimates of flow velocities on the previously mentioned slopes are provided for the purpose of assessing whether the surface water velocities will remain below permissible non-erodible velocities.

2 PROJECT BACKGROUND

The landfill intermediate cover system includes a surface water management system. Intermediate cover placement of the landfill is expected to be completed as areas reach final elevations and await the construction of the final cover system. The intermediate cover system is comprised of a top deck surface and side slopes designed with temporary drainage features until the final cover system is constructed. The top deck of the landfill will have a surface slope of approximately 5% and flow into top deck drainage terraces. The side slopes of the intermediate cover on external-facing slopes will be constructed with a grade of 3 horizontal to 1 vertical (3H:1V) (i.e., 33.3%). The landfill's surface water management system includes the following permanent and temporary drainage features: top deck drainage terraces, downchute channels, side slope drainage terraces, perimeter drainage channels, and a surface water pond. The proposed top deck drainage terraces will convey flow from the top deck to the downchute channels and into the perimeter drainage channels. The proposed side slope drainage terraces will collect and convey surface water runoff from the side slopes to the downchute channels. The perimeter drainage channels will also convey flow from these diversion structures to the surface water pond located to the north of the landfill and those to the south of the landfill will convey flow to the midpoint site outfall.

A permissible soil loss of 50 tons/acre/year is adopted for the purposes of these calculations (TCEQ, 2018). Also, sheet flow and shallow concentrated flow velocities are evaluated to verify that the predicted velocity of runoff is maintained below the permissible erodible velocity of the intermediate cover soil, which is established as five (5) ft/sec for cohesive soil as recommended by TxDOT (2002).

3 CALCULATION METHODOLOGY

The method to calculate the soil erosion loss over the project area was obtained from the guidance document *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)* (USDA, 1997) as well as previously published information provided by USDA. This document presents the Revised Universal Soil Loss Equation (RUSLE) and guidance for each of the equation's parameters. The RUSLE is described as follows:

$$A = R \times K \times LS \times C \times P$$

where:

A	=	the computed spatial average annual soil loss (tons/acre/year),
R	=	the average annual rainfall runoff erosivity factor,
K	=	the soil erodibility factor,
LS	=	the topographic factor,
C	=	the cover management factor, and
P	=	the erosion control practice factor.

The sheet flow and shallow concentrated flow velocities are estimated using guidance provided in TxDOT (2019) and USDA (2010). TxDOT (2019) indicates that sheet flow velocities (for distances up to 100 ft) may be estimated based on slope and surface conditions using Manning's kinematic solution to estimate sheet flow travel time:

$$T_t = \frac{0.007(nL)^{0.8}}{P_{2-24}{}^{0.5} S^{0.4}}$$

where: T_t = travel time for sheet flow (hr);

n = roughness coefficient;

L = flow length (ft);

$P_{2\text{-}24}$ = 2-year, 24-hour rainfall (in.); and

S = slope of hydraulic grade line (land slope, ft/ft).

The sheet flow velocity is $V = L / T_t$. The 2-year, 24-hour rainfall depth is provided by the National Oceanic Atmospheric Association's (NOAA) Precipitation Frequency Data Server for Atlas 14. The 2-year, 24-hour rainfall depth is 3.91 inches (NOAA, 2018). Roughness coefficient values for sheet flow are provided in Table 2G-1-1.

For shallow concentrated flow, the velocity can be estimated using the equation provided by USDA (2010), as follows:

$$V = K_v \times S^{1/2}$$

where:

V = shallow concentrated flow velocity (ft/s),

K_v = velocity factor (ft/s), and

S = slope (ft/ft).

The velocity factor (K_v) is selected from the description of the surface cover as provided in Table 2G-1-2. The estimates of sheet flow and shallow concentrated flow velocities are compared to the permissible non-erodible velocity of five (5) ft/sec for cohesive soil as recommended by TxDOT (2002).

4 RUSLE PARAMETERS

4.1 Rainfall Runoff Erosivity Factor (R)

The rainfall runoff erosivity factor is defined as the average annual rainfall erosion index specific for the project area. Based on USDA (1997), the value of R was determined to be approximately 275 for Fort Worth, Texas, as shown in Figure 2G-1-1.

4.2 Soil Erodibility Factor (K)

The soil erodibility factor is a function of the physical and chemical properties of the soil and is specific to the source of the cover material. The soil erodibility factor can be thought of as the ease with which soil is detached by splash during rainfall or by surface flow. The soils to be used for the intermediate cover system of the landfill are expected to be based on the native soils available at the project site or from local off-site sources. For soil loss calculation purposes, assessments were made of on-site soils and those nearby, using the Tarrant County soil survey (USDA, 1981). This information shows that the site and nearby area has soils that are a combination of a number of soil classifications, including the following: Frio, Gasil, Birome-Aubrey-Rayex, Arents, and Crosstell. The Frio silty clay, Gasil fine sandy loam, and Gasil sandy clay loam formations constitute the majority of the site and will be used for intermediate cover materials. A soil survey map of the site vicinity was previously provided on Figure 2B-2 that is included in Attachment 2B of the Facility Surface Water Drainage Report – "On-Site Drainage Analysis – Hydrology."

The Web Soil Survey tool operated by the USDA Natural Resources Conservation Service (NRCS) (2019) was consulted for Tarrant County for information on the corresponding soil erodibility factors. The value of K for the project location soils near the surface varies from 0.15 to 0.28, where the estimate considers the erodibility of fine-earth fraction for material less than two mm in size (using the Kf erosion factor provided in Table 2G-1-3). Thus, the use of 0.28 in the calculation is a conservative value of the formations that are most predominant at the site and surrounding areas (i.e., the most likely source of future intermediate cover).

4.3 Topographic Factor (LS)

The slope length factor and slope steepness factor are typically combined into one topographic factor, LS, to facilitate field application of these equation components. USDA (1997) presents values of the LS factor for slope lengths in feet up to 1,000 feet and percent slopes up to 60%, as shown in Table 2G-1-4. To manage surface water runoff from the intermediate surface slopes and terraces, temporary surface water diversion structures will be installed on the intermediate cover system. The surface water diversion features will be placed to limit soil erosion.

The average slope length on the intermediate cover system was used to determine the LS factor. This length provides an estimate of soil loss over the entire intermediate cover system. The top deck surface slope will consist of a 5% grade along a length of approximately 550 ft. The intermediate cover system consists of a 3H:1V (i.e., 33.3%) side slope with periodic "tack-on" side slope drainage terraces. Three options are evaluated for ground coverage scenarios: 60%, 70%, and 80% ground coverage. The reason for evaluating different ground coverage percentages is to provide flexibility to the operator on the resulting required terrace spacing, based on the ground coverage that the facility is able to achieve. The maximum side slope length is approximately 680 ft which is used as a limiting factor on the erosion analysis. The following LS factors are selected from Table 2G-1-4 and apply to the average length along the top deck and side slopes of the intermediate cover system of the landfill:

- Top Deck – 5% slope over a length of 550 ft, LS = 1.81
- Side Slopes (60% Cover) – 33% slope over a length of 300 ft, LS = 14.96
- Side Slopes (70% Cover) – 33% slope over a length of 500 ft, LS = 22.44
- Side Slopes (80% Cover) – 33% slope over a length of 680 ft, LS = 28.76

4.4 Cover Management Factor (C)

The cover management factor is a function of the type of land cover, based on three factors: (i) the vegetative cover in direct contact with the soil surface, (ii) the canopy cover, and (iii) the effects at and beneath the surface. The intermediate cover is categorized as Pasture, Range, and Idle Land, with C values provided in Table 2G-1-5 (USDA, 1977). The land cover is assumed to have no appreciable canopy and a ground cover surface that is grass, mulch, grass-like plants, decaying compacted duff, or litter at least two inches deep. It is noted that the terms "duff" and "litter" are terms used by USDA and refer to types of organic ground cover material, not waste. For these conditions, the "C" values in Table 2G-1-5 vary depending on the percent ground cover.

For 60% ground cover of grass the C value is 0.042. For 70% ground cover of grass/mulch, by interpolating on the table, the C value is 0.0275. For 80% ground cover of mulch, the C value is 0.013. These three ground cover scenarios will be evaluated herein.

4.5 Erosion Control Practice Factor (P)

The erosion control practice factor considers topographical practices that will reduce erosion by altering runoff drainage patterns. This factor generally applies to agricultural cropping practices and is not anticipated for the landfill. Therefore, the P factor is assumed to be equal to one.

5 FLOW VELOCITY PARAMETERS

5.1 Watercourse Slope

The watercourse slopes for estimating the maximum flow velocities are as follows:

- Top Deck – 5% slope;
- Side Slopes – 3H:1V (33.3%) slope

5.2 Surface Condition

For sheet flow velocity calculation purposes, the surface condition of the intermediate cover is assumed to be: (i) minimum percent ground cover 60%; (ii) no appreciable canopy; and (iii) ground cover at surface is grass, grass-like plants, decaying compacted duff, or litter at least two inches deep. Only the 60% ground cover scenario is evaluated, since a 70% (or greater) ground cover will result in lower velocities. For estimating sheet flow velocities for flow distances less than 100 ft using TxDOT (2019), a roughness coefficient of n = 0.05 for fallow surfaces and n = 0.15 for short grass prairies as shown in Table 2G-1-1.

The surface conditions most applicable to the intermediate cover conditions are "nearly bare ground" and "short grass pasture and lawns." To estimate the shallow concentrated flow velocity for 60% ground coverage, a weighted average flow velocity is calculated from the "nearly bare ground" and "short grass pasture and lawns" flow velocities based on the ground coverage of each cover condition. Note that this surface condition is applicable for grass and grass-like plants. For ground cover consisting of decaying compacted duff or litter (e.g., mulch), the most applicable representative surface condition for velocity calculation purposes is "forest with heavy ground litter and hay meadows." While the mulch-covered slopes of the landfill are not situated in a forest, the mulched surface will have a surface condition (or "roughness") that is best compared to "heavy ground litter" found in a forest (i.e., decaying duff and litter, twigs, etc.). However, the "short grass pasture and lawns" cover will result in larger velocities, and therefore, the mulch cover will not be considered in estimating shallow concentrated flow velocities.

For estimating shallow concentrated flow velocities for flow distances more than 100 ft using USDA (2010), a velocity factor (K_v) of 9.965 is selected from Table 2G-1-2 for a "nearly bare and untilled" surface and K_v = 6.962 for "short-grass pasture." The velocity factor is applied with the slope to estimate the velocity of the interim cover condition for shallow concentrated flow (after 100-ft of sheet flow).

6 RESULTS

6.1 RUSLE

Applying the RUSLE with the parameters defined above, the computed soil loss in tons/acre/year is calculated as follows:

$$A = R \times K \times LS \times C \times P$$

Top Deck Slopes, 60% ground cover:

$$A = 275 \times 0.28 \times 1.81 \times 0.042 \times 1 = 5.85 \text{ tons/acre/year}$$

Side Slopes, 60% ground cover, 300-ft slope length between terraces:

$$A = 275 \times 0.28 \times 14.96 \times 0.042 \times 1 = 48.37 \text{ tons/acre/year}$$

Top Deck Slopes, 70% ground cover:

$$A = 275 \times 0.28 \times 1.81 \times 0.0275 \times 1 = 3.83 \text{ tons/acre/year}$$

Side Slopes, 70% ground cover, 500-ft slope length between terraces:

$$A = 275 \times 0.28 \times 22.44 \times 0.0275 \times 1 = 47.52 \text{ tons/acre/year}$$

Top Deck Slopes, 80% ground cover:

$$A = 275 \times 0.28 \times 1.81 \times 0.013 \times 1 = 1.81 \text{ tons/acre/year}$$

Side Slopes, 80% ground cover, 680-ft slope length between terraces:

$$A = 275 \times 0.28 \times 28.76 \times 0.013 \times 1 = 28.79 \text{ tons/acre/year}$$

As shown above, the calculated annual soil loss from the intermediate cover on the top deck and side slope surfaces are less than the 50 tons/acre/year permissible rate of soil loss for interim conditions. These results show that if 60% ground cover is present, the side slope terraces should be placed no greater than 300-ft apart. If 70% ground cover is present, the side slope terraces may be placed up to 500-ft apart. If 80% ground cover is present during interim conditions, the side slope terraces may be placed up to 680-ft apart. It is expected that 60%, 70%, and 80% ground cover can be achieved with grassing, a combination of grassing and mulching, and mulching, respectively. Table 2G-1-6 summarizes allowable side slope terrace spacing under each ground cover option.

6.2 Erodible Velocity

As mentioned previously, sheet flow velocity estimates are performed only for the more conservative condition of having only 60% ground cover. The estimated velocities are as follows:

Top Deck Slopes (5%): For sheet flow (length up to 100 ft)

- $V = L / T_t = 100 / [0.007\times(0.05\times100)^{0.8}/(3.91^{0.5}\times0.05^{0.4})] = 0.7$ ft/s (for bare ground) and
- $V = L / T_t = 100 / [0.007\times(0.15\times100)^{0.8}/(3.91^{0.5}\times0.05^{0.4})] = 0.3$ ft/s (for grass).

The weighted average value for the sheet flow velocity for 60% ground cover is calculated as:

$$\text{Top Deck Sheet Flow Velocity} = 0.7 \times 0.40 + 0.3 \times 0.60 = 0.4 \text{ ft/s}$$

For distances greater than 100-ft on the top deck, where flow becomes shallow concentrated flow, the velocity estimates using the previously mentioned equation are calculated as:

Top Deck Slopes (5%): For shallow concentrated flow (lengths over 100 ft)

- $V = K_v \times S^{1/2} = 9.965 \times 0.05^{1/2} = 2.2$ ft/s (for bare ground) and
- $V = K_v \times S^{1/2} = 6.962 \times 0.05^{1/2} = 1.6$ ft/s (for grass).

The weighted average value for the shallow concentrated flow velocity for 60% ground cover is calculated as:

Top Deck Shallow Concentrated Flow Velocity = 2.2 × 0.40 + 1.6 × 0.60 = 1.8 ft/s

Side Slopes (33%): For sheet flow (length up to 100 ft)

- $V = L \ / \ T_t = 100 \ / \ [0.007 \times (0.05 \times 100)^{0.8} / (3.91^{0.5} \times 0.33^{0.4})] = 1.4$ ft/s (for bare ground) and
- $V = L \ / \ T_t = 100 \ / \ [0.007 \times (0.15 \times 100)^{0.8} / (3.91^{0.5} \times 0.33^{0.4})] = 0.6$ ft/s (for grass).

The weighted average value for the sheet flow velocity for 60% ground cover is calculated as:

Side Slopes Sheet Flow Velocity = 1.4 × 0.40 + 0.6 × 0.60 = 0.9 ft/s

For distances greater than 100-ft on the top deck, where flow becomes shallow concentrated flow, the velocity estimates using the previously mentioned equation are calculated as:

Side Slopes (33%): For shallow concentrated flow (lengths over 100 ft)

- $V = K_v \times S^{1/2} = 9.965 \times 0.33^{1/2} = 5.8$ ft/s (for bare ground) and
- $V = K_v \times S^{1/2} = 6.962 \times 0.05^{1/2} = 4.0$ ft/s (for grass).

The weighted average value for the shallow concentrated flow velocity for 60% ground cover is calculated as:

Side Slopes Shallow Concentrated Flow Velocity = 5.8 × 0.40 + 4.0 × 0.60 = 4.7 ft/s

As shown above, the estimated flow velocities are less than the permissible non-erosive velocity of 5.0 ft/s.

7 CONCLUSIONS

The ground surface cover condition and maximum terrace spacing requirements are computed above and summarized in Table 2G-1-6. Based on the calculations presented herein, the following conclusions are drawn:

- For the conditions analyzed herein, the calculated soil loss from the intermediate cover is less than the permissible soil loss of 50 tons/acre/year, which is acceptable.
- For the conditions analyzed herein, the estimated velocities for the top deck and side slope surfaces were calculated to be less than the permissible non-erosive velocity of five (5) ft/sec, which is acceptable.
- To provide effective erosional stability on the external facing 5% top deck slope surfaces, a horizontal spacing of 550-ft between temporary diversion structures is acceptable for a 60% or greater ground cover of grass/mulch or the like.
- To provide effective erosional stability on the external facing 33% side slopes when there is a 60% ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 300-ft.
- To provide effective erosional stability on the external facing 33% side slopes when there is a 70% or greater ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 500-ft.
- To provide effective erosional stability on the external facing 33% side slopes when there is a 80% or greater ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 680-ft corresponding to the maximum side slope length.

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TABLES

Table 2G-1-1. Sheet Flow Roughness Coefficients for Calculating Sheet Flow Travel Time (from TxDOT, 2019)

Surface description		n_{ol}
Fallow (no residue)		0.05
Cultivated soils:	Residue $cover \leq 20\%$	0.06
	Residue cover > 20%	0.17
Grass:	Short grass prairie	0.15
	Dense grasses	0.24
	Bermuda	0.41
Range (natural):		0.13
Woods:	Light underbrush	0.40
	Dense underbrush	0.80

Table 2G-1-2. Equations and Assumptions Relating Shallow Concentrated Flow Velocity to Surface Slope (from USDA, 2010)

Flow type	Depth (ft)	Manning's *n*	Velocity equation (ft/s)
Pavement and small upland gullies	0.2	0.025	$V = 20.328(s)^{0.5}$
Grassed waterways	0.4	0.050	$V=16.135(s)^{0.5}$
Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions	0.2	0.051	$V=9.965(s)^{0.5}$
Cultivated straight row crops	0.2	0.058	$V=8.762(s)^{0.5}$
Short-grass pasture	0.2	0.073	$V=6.962(s)^{0.5}$
Minimum tillage cultivation, contour or strip-cropped, and woodlands	0.2	0.101	$V=5.032(s)^{0.5}$
Forest with heavy ground litter and hay meadows	0.2	0.202	$V=2.516(s)^{0.5}$

Table 2G-1-3. Soil Erodibility Factor K for Frio and Gasil Soils (from USDA, 2019)

Map Unit Symbol	Map Unit Name	Soil Erodibility Factor, Kf
27	Frio silty clay, frequently flooded	0.24
30	Gasil fine sandy loam, 3 to 8 percent slopes	0.28
31	Gasil sandy clay loam, graded, 1 to 5 percent slopes	0.15

Table 2G-1-4. Values for Topographic Factor, LS, for High Ratio of Rill to Interrill Erosion[1] (from USDA, 1997)

Slope (%)	Horizontal slope length (ft) <3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

[1] Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil)

Table 2G-1-5. C Factor Cover Values for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland[1]

(from USDA, 1977)

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy 2/	Canopy Cover 3/ %	Type 4/	Percent Ground Cover					
			0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

1/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years. Also to be used for burned forest land and forest land that has been harvested less than three years ago.

2/ Average fall height of waterdrops from canopy to soil surface: m = meters.

3/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

4/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface), and/or undecayed residue.

Table 2G-1-6. Summary of Maximum Allowable Drainage Terrace Spacing

Interim Cover Stabilization Method	Required Minimum Ground Cover	Maximum Allowable Terrace Spacing		Calculated Velocity < Permissible Velocity?
		5% Top Deck	33% Side Slopes	
Grass	60%	550-ft	300-ft	Yes
Grass & Mulch	70%	550-ft	500-ft	Yes
Mulch	80%	550-ft	680-ft	Yes

FIGURES

- Figure 2G-1-1. Average Annual Rainfall Runoff Erosivity Factor, R, Isoerodent Map (from USDA, 1997)

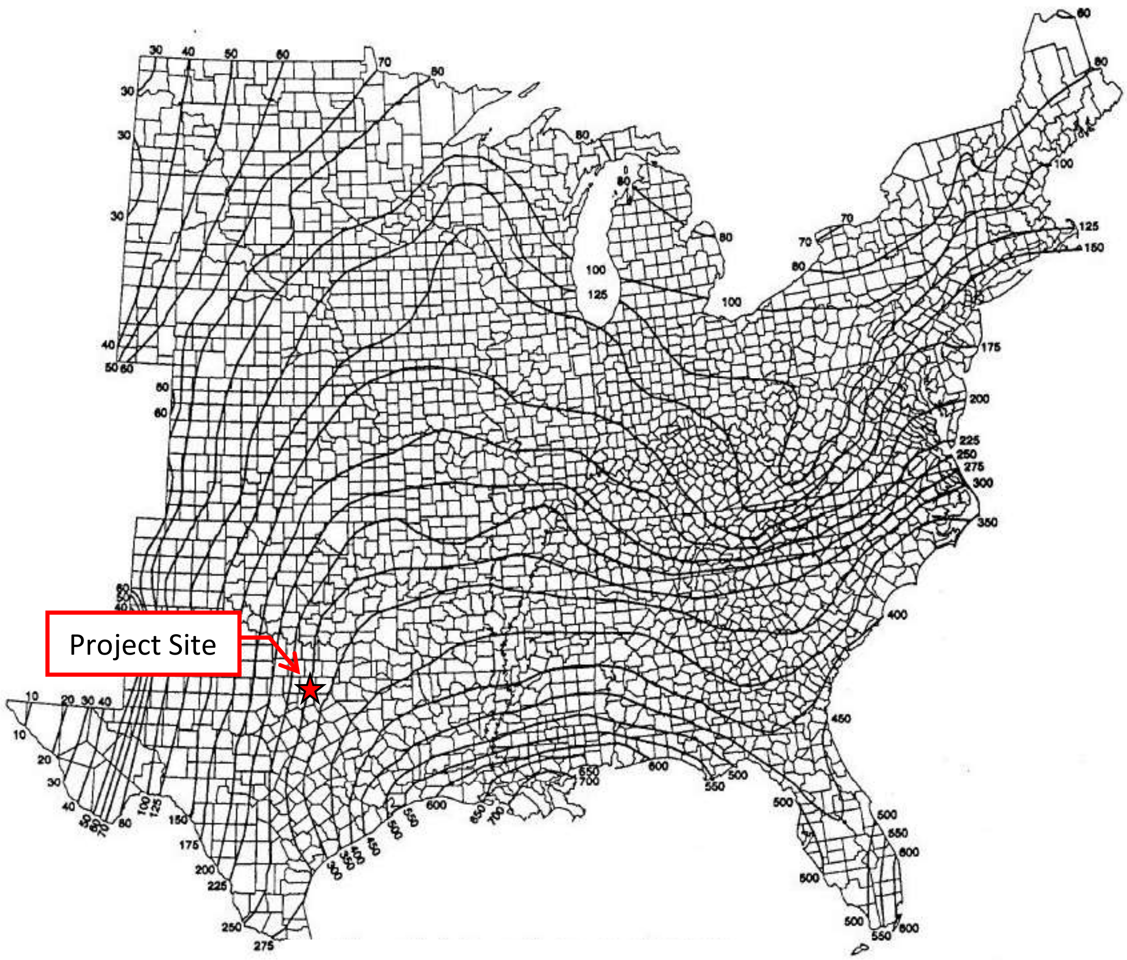


Figure 2G-1-1. Average Annual Rainfall Runoff Erosivity Factor, R, Isoerodent Map (from USDA, 1997)

APPENDIX 2G-2

HYDRAULIC DESIGN OF INTERMEDIATE COVER DIVERSION STRUCTURES

Written by: **O. Bramlet** Date: **01/09/2020** Reviewed by: **S. Graves** Date: **2/4/2020**

Client: **TRLC** Project: **Fort Worth C&D Landfill** Project No.: **GW6953** Phase No.: **04**

HYDRAULIC DESIGN OF INTERMEDIATE COVER DIVERSION STRUCTURES

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

5/7/2020

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 17

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the hydraulic design of the intermediate cover diversion structures for the proposed expansion of the Fort Worth C&D Landfill. This package provides calculations for the peak runoff discharges flowing to diversion structures and the sizing design of intermediate cover surface water diversion structures, including side slope drainage terraces, top deck drainage terraces, and downchute channels.

2 CALCULATION METHODOLOGY

The following sections describe the calculation methodology applied to design the temporary diversion structures for the intermediate cover.

2.1 Hydrology

Per 30 TAC §330.305(f)(1), the peak runoff discharge to each temporary diversion structure is calculated by the Rational Method, as outlined in Texas Department of Transportation (TxDOT) *Hydraulic Design Manual* (TxDOT, 2019). The equation for the Rational Method is applied as follows:

$$Q = C \times I \times A \tag{1}$$

where:

Q = peak runoff discharge (cfs),

C = runoff coefficient,

I = rainfall intensity (in/hr), and

A = drainage area (acres).

In September 2018, the National Oceanic and Atmospheric Administration (NOAA) released updated precipitation frequency estimates for Texas. This rainfall data is currently considered by TxDOT (2019) to be the best available data for calculating design rainfall intensity. TxDOT (2019) also recommends 10 minutes as the minimum time of concentration for the Rational Method because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high. The rainfall intensity for the 25-year, 10-minute duration rainfall event is 7.92 inches per hour (in/hr) for the site (NOAA, 2018).

2.2 Hydraulic Design of Diversion Structures

Manning's equation is applied to the calculate peak discharge rates through each intermediate cover diversion structure. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad (4)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

R = hydraulic radius = A/P (ft),

P = wetted perimeter (ft), and

S = longitudinal slope (ft/ft).

The tractive stresses in the channel for various depths of flow are estimated using the following equation (Chow, 1959):

$$\tau_o = \gamma_w R S \qquad (5)$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Each diversion structure is designed to convey the peak runoff discharge from the 25-year rainfall event as calculated by the Rational Method. The depth of flow, maximum velocity, and tractive stress for the design rainfall event through each channel reach is calculated using Manning's equation and the tractive stress equation.

3 DESIGN PARAMETERS

The following sections describe the selected parameters applied in the calculations of the peak runoff discharge by the Rational Method and the capacity of the drainage structures by Manning's equation.

3.1 Drainage Areas

The diversion structures on the intermediate cover are designed for the runoff from contributing drainage areas during landfill operating conditions. It is envisioned that the temporary side slope drainage terraces, top deck drainage terraces, and temporary downchutes on the intermediate cover system will be installed to approximate the post-development (i.e., final) drainage patterns of the final cover system. Accordingly, the drainage areas contributing to each of these structures during interim conditions are selected based on the largest area that contributes to the type of structure according to the grading plan layout of the final cover grades. The largest top deck area (8.82 acres) that contributes to a single drainage terrace is selected to design the typical top deck drainage terraces on the intermediate cover. The sum of the largest top deck (8.82 acres) and side slope (4.09 acres) areas which combine to a single downchute is selected as the design drainage area (12.91 acres) for the typical downchute channel on the intermediate cover.

Meanwhile, side slope drainage terraces will have a maximum spacing of 300-ft, 500-ft, or 680-ft apart depending on the ground cover applied (and resulting ground cover percentage) to the 3H:1V intermediate cover side slopes. The longest side slope drainage terrace (approximately 1,940-ft in length) is selected for the design of the typical side slope drainage terraces for each spacing. The drainage area selected for the design of side slope drainage terraces is calculated based on the longest length and the maximum spacing for each ground cover scenario for the intermediate cover side slopes.

3.2 Runoff Coefficients

A runoff coefficient (C) was selected based on information provided by TxDOT (2019) for rural watersheds, as shown in Table 2G-2-1. The total runoff coefficient is based on the sum of the four runoff components in Table 2G-2-1. The 25-year runoff coefficient is calculated using the following equation:

$$C = (C_r + C_i + C_v + C_s) \quad (6)$$

The following runoff coefficient is estimated for the steep 3H:1V side slope drainage areas:

$$C = (0.35 + 0.16 + 0.08 + 0.12) = 0.710$$

The following runoff coefficient is estimated for the flatter (5%) top deck drainage areas:

$$C = (0.14+ 0.16 + 0.08 + 0.12) = 0.500$$

The following runoff coefficient is estimated for the drainage areas contributing to the downchute channels using a weighted average of the top deck and side slope runoff coefficients per the drainage areas listed above:

$$C = (8.82 \text{ ac} \times 0.500 + 4.09 \text{ ac} \times 0.710) / (8.82 \text{ ac} + 4.09 \text{ ac}) = 0.567$$

3.3 Manning's Roughness Coefficient

Manning's roughness coefficient (n) is a measure of the surface roughness of a pipe, conduit, channel or other hydraulic structure. As the Manning's roughness coefficient increases, the resistance to flow within a channel increases. As shown in Table 2G-2-2 (TxDOT, 2019), Manning's roughness coefficients were selected based on a grass-lined side slope drainage terrace and top deck drainage terrace and geomembrane lined interim downchute channel. A Manning's roughness coefficient of n = 0.027 was selected for grass-lined channels. A Manning's roughness coefficient of n = 0.015 was selected for geomembrane lined downchute channels based on a representative value for lined channels with similar roughness as a float finished concrete lining. Roughness values are not available for textured HDPE geomembrane; smooth HDPE has a roughness of approximately 0.01, so it is reasonable that textured geomembrane would be slightly greater.

3.4 Hydraulic Design

Each intermediate cover diversion structure is designed to convey the 25-year rainfall event. Additionally for structures that have a flow velocity of greater than five ft/s during the 25-year rainfall event, a channel lining (e.g., geomembrane, riprap, articulated concrete blocks) is required until the final cover system is constructed.

4 CALCULATIONS

The peak runoff discharge to each temporary drainage structure was calculated by the Rational Method. The results from these calculations are presented in Table 2G-2-3.

Based on the calculated runoff discharge, each temporary diversion structure was sized by applying Manning's equation. These calculations were performed using the spreadsheets presented at the end of this calculation package. The design parameters and results of the hydraulic design of each component of the intermediate cover surface water management system are summarized in Table 2G-2-4.

5 CONCLUSIONS

Results from calculations presented in this calculation package indicate that the proposed surface water diversion structures for Fort Worth C&D Landfill intermediate cover will collect and control the runoff resulting from a 25-year rainfall event. These calculations indicate that the temporary downchute channels and drainage terraces should be lined with an erosion resistant channel lining material until the final cover system is constructed.

6 REFERENCES

Chow, V.T. (1959). *Open Channel-Hydraulics,* McGraw-Hill.

NOAA (2018). Point Precipitation Frequency Estimates, National Oceanic and Atmospheric Administration, Atlas 14, Volume 11, Version 2.0. Available online: https://hdsc.nws.noaa.gov/hdsc/pfds/, accessed November 2019, site latitude: 32.6326^o, longitude: -97.2375^o.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.

TABLES

Table 2G-2-1. Runoff Coefficients for Rural Watersheds (from TxDOT, 2019)

	Extreme	High	Normal	Low
Relief - C_f	*0.28-0.35* steep, rugged terrain with average slopes above 30%	0.20-0.28 hilly, with average slopes of 10-30%	0.14-0.20 rolling, with average slopes of 5-10%	0.08-0.14 relatively flat land, with average slopes of 0-5%
Soil Infiltration - C_i	0.12-0.16 no effective soil cover either rock or thin soil mantle of negligble infiltration capacity	0.08-0.12 slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 normal; well drained light or medium textured soils, sandy loams	0.04-0.06 deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover - C_v	0.12-0.16 no effective plan cover, bare or very sparse cover	0.08-0.12 poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area over good cover	0.06-0.08 fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in culitvated crops	0.04-0.06 good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface - C_s	0.10-0.12 negligible; surface depression few and shallow, drainageways steep and small, no marshes	0.08-0.10 well defined system of small drainageways, no ponds or marshes	0.06-0.08 normal; considerable surface depression storage lakes and ponds and marshes	0.04-0.06 much surface storage, drainage system not sharply defined; large floodplain storage of large number of ponds or marshes
NOTE: The total runoff coefficient based on the four runoff components is $C = C_r + C_i + C_v + C_s$				

Table 2G-2-2. Manning's Roughness Coefficients (from TxDOT, 2019)

B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2G-2-3. Intermediate Cover Peak Discharge Calculations for the 25-year Rainfall Event

Diversion Structure	Spacing (ft) [2]	A (acres)	C	I (in/hr)	Q (cfs)
Side Slope Drainage Terraces [1]	300	13.36	0.710	7.92	75.13
Side Slope Drainage Terraces [1]	500	22.27	0.710	7.92	125.22
Side Slope Drainage Terraces [1]	680	30.28	0.710	7.92	170.30
Top Deck Drainage Terraces	-	8.82	0.500	7.92	34.93
Downchutes	-	12.91	0.567	7.92	57.97

Notes:

1. The maximum side slope drainage area is estimated based on the terrace spacing shown above, and a maximum terrace length of 1,940 ft.
2. Spacing of terraces on the side slopes is varied based on the assumed ground cover scenarios, as described in Appendix 2G-1.

Table 2G-2-4. Summary of Intermediate Cover Hydraulic Design Results

Diversion Structure	Spacing (ft)	Bottom Width (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	Channel Depth (ft)	Manning's n	Flowline Slope (ft/ft)	Design Depth of Flow (ft)	Design Velocity (ft/s)	Tractive Stress (psf)	Channel Lining Required?
Side Slope Drainage Terrace	300	0.00	2.5:1	3:1	2.50	0.027	0.020	1.93	7.31	1.13	Yes
Side Slope Drainage Terrace	500	0.00	2.5:1	3:1	2.50	0.027	0.020	2.34	8.31	1.37	Yes
Side Slope Drainage Terrace	680	0.00	2.5:1	3:1	3.00	0.027	0.020	2.61	9.04	1.56	Yes
Top Deck Drainage Terrace	-	0.00	3:1	20:1	2.00	0.027	0.0015	1.36	1.64	0.06	No
Downchute Channel	-	5.00	3:1	3:1	1.00	0.015	0.333	0.33	24.91	5.96	Yes

MANNING'S EQUATION CALCULATIONS

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

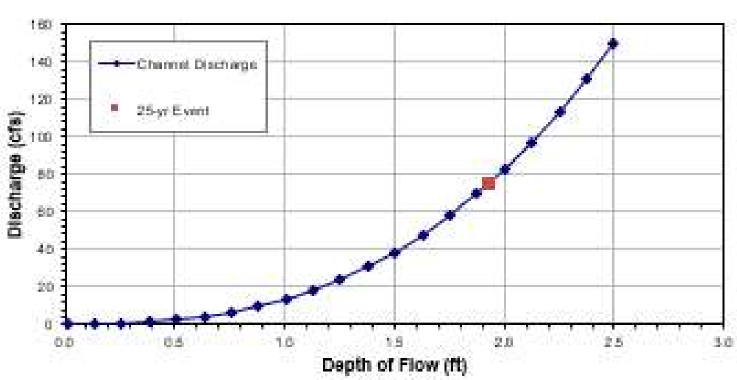
Project: Fort Worth C&D Landfill Expansion

Ditch ID: Interim Side Slope Drainage Terrace, 300-ft Spacing

Runoff Coefficient, C =	0.71	
25-year Rainfall Intensity, I =	7.92	in/hr
Longest Drainage Terrace Length =	1940	ft
Terrace Spacing =	300	ft
Contributing Drainage Area, A =	13.36	acres
Peak Discharge, Q_{25} =	75.13	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.50	ft
Top Width, T =	13.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0200	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.13	0.05	0.79	0.06	1.24	0.1	0.08	
0.26	0.18	1.52	0.12	1.92	0.4	0.15	
0.38	0.40	2.25	0.18	2.49	1.0	0.22	
0.51	0.71	2.97	0.24	3.00	2.1	0.30	
0.63	1.10	3.70	0.30	3.47	3.8	0.37	
0.76	1.58	4.43	0.36	3.92	6.2	0.44	
0.88	2.14	5.16	0.41	4.34	9.3	0.52	
1.01	2.78	5.89	0.47	4.73	13.2	0.59	
1.13	3.51	6.62	0.53	5.12	18.0	0.66	
1.26	4.33	7.35	0.59	5.49	23.8	0.74	
1.38	5.23	8.08	0.65	5.84	30.6	0.81	
1.50	6.22	8.81	0.71	6.19	38.5	0.88	
1.63	7.29	9.53	0.76	6.53	47.6	0.95	
1.75	8.45	10.26	0.82	6.86	57.9	1.03	
1.88	9.69	10.99	0.88	7.18	69.6	1.10	
2.00	11.02	11.72	0.94	7.49	82.6	1.17	
2.13	12.44	12.45	1.00	7.80	97.0	1.25	
2.25	13.93	13.18	1.06	8.10	112.9	1.32	
2.38	15.52	13.91	1.12	8.40	130.3	1.39	
2.50	17.19	14.64	1.17	8.69	149.3	1.47	
1.93	10.25	11.30	0.91	7.31	74.96	1.13	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

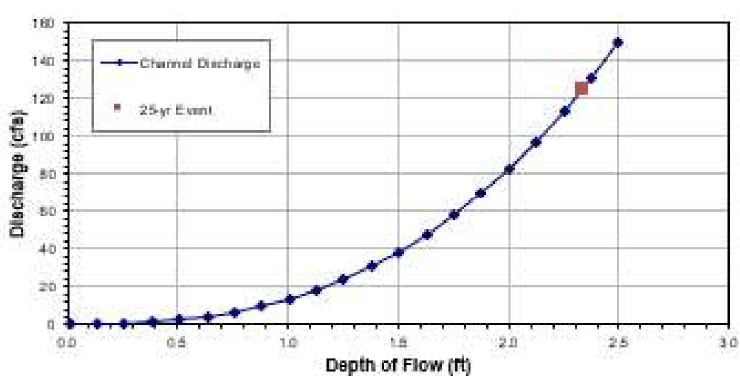
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Interim Side Slope Drainage Terrace, 500-ft Spacing**

Runoff Coefficient, C =	0.71	
25-year Rainfall Intensity, I =	7.92	in/hr
Longest Drainage Terrace Length =	1940	ft
Terrace Spacing =	500	ft
Contributing Drainage Area, A =	22.27	acres
Peak Discharge, Q_{25} =	125.22	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.50	ft
Top Width, T =	13.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0200	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.13	0.05	0.79	0.06	1.24	0.1	0.08	
0.26	0.18	1.52	0.12	1.92	0.4	0.15	
0.38	0.40	2.25	0.18	2.49	1.0	0.22	
0.51	0.71	2.97	0.24	3.00	2.1	0.30	
0.63	1.10	3.70	0.30	3.47	3.8	0.37	
0.76	1.58	4.43	0.36	3.92	6.2	0.44	
0.88	2.14	5.16	0.41	4.34	9.3	0.52	
1.01	2.78	5.89	0.47	4.73	13.2	0.59	
1.13	3.51	6.62	0.53	5.12	18.0	0.66	
1.26	4.33	7.35	0.59	5.49	23.8	0.74	
1.38	5.23	8.08	0.65	5.84	30.6	0.81	
1.50	6.22	8.81	0.71	6.19	38.5	0.88	
1.63	7.29	9.53	0.76	6.53	47.6	0.95	
1.75	8.45	10.26	0.82	6.86	57.9	1.03	
1.88	9.69	10.99	0.88	7.18	69.6	1.10	
2.00	11.02	11.72	0.94	7.49	82.6	1.17	
2.13	12.44	12.45	1.00	7.80	97.0	1.25	
2.25	13.93	13.18	1.06	8.10	112.9	1.32	
2.38	15.52	13.91	1.12	8.40	130.3	1.39	
2.50	17.19	14.64	1.17	8.69	149.3	1.47	
2.34	15.05	13.70	1.10	8.31	125.06	1.37	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

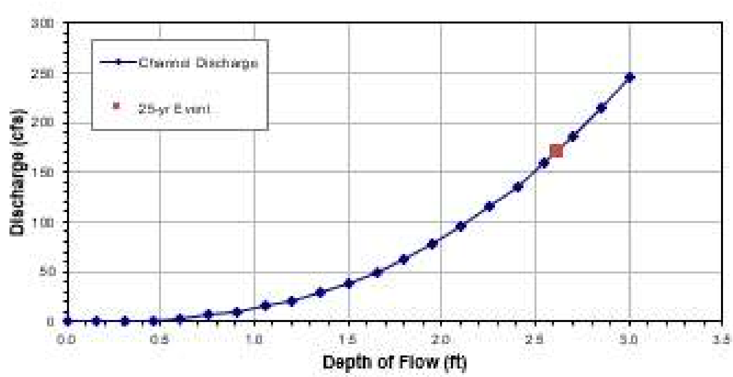
Project: Fort Worth C&D Landfill Expansion

Ditch ID: Interim Side Slope Drainage Terrace, 680-ft Spacing

Runoff Coefficient, C =	0.71	
25-year Rainfall Intensity, I =	7.92	in/hr
Longest Drainage Terrace Length =	1940	ft
Terrace Spacing =	680	ft
Contributing Drainage Area, A =	30.28	acres
Peak Discharge, Q_{25} =	170.30	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	3.00	ft
Top Width, T =	16.5	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0204	ft/ft

Depth of Flow Y ft	Area of Flow A ft²	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft³/s	Avg. Tractive Stress τ_0 lb/ft²	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.16	0.07	0.93	0.07	1.40	0.1	0.10	
0.31	0.26	1.81	0.15	2.18	0.6	0.18	
0.46	0.58	2.68	0.22	2.83	1.6	0.27	
0.61	1.02	3.56	0.29	3.42	3.5	0.36	
0.76	1.58	4.44	0.36	3.96	6.2	0.45	
0.91	2.26	5.31	0.43	4.46	10.1	0.54	
1.06	3.07	6.19	0.50	4.94	15.2	0.63	
1.21	4.00	7.06	0.57	5.40	21.6	0.72	
1.36	5.05	7.94	0.64	5.83	29.5	0.81	
1.51	6.23	8.81	0.71	6.25	39.0	0.90	
1.65	7.53	9.69	0.78	6.66	50.2	0.99	
1.80	8.95	10.56	0.85	7.06	63.2	1.08	
1.95	10.49	11.44	0.92	7.44	78.1	1.17	
2.10	12.16	12.31	0.99	7.82	95.1	1.26	
2.25	13.95	13.19	1.06	8.18	114.2	1.35	
2.40	15.87	14.06	1.13	8.54	135.5	1.44	
2.55	17.90	14.94	1.20	8.89	159.2	1.53	
2.70	20.06	15.81	1.27	9.24	185.3	1.61	
2.85	22.34	16.69	1.34	9.57	213.9	1.70	
3.00	24.75	17.56	1.41	9.91	245.2	1.79	
2.61	18.80	15.31	1.23	9.04	169.99	1.56	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

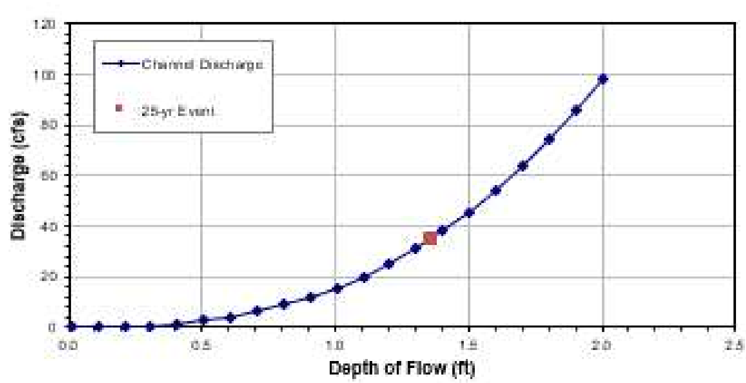
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Interim Top Deck Drainage Terrace**

Runoff Coefficient, C =	0.500	
25-year Rainfall Intensity, I =	7.92	in/hr
Contributing Drainage Area, A =	8.82	acres
Peak Discharge, Q_{25} =	34.93	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.0	horizontal :1 vertical
Right Side Slope, Z_2 =	20.0	horizontal :1 vertical
Channel Depth, Y =	2.00	ft
Top Width, T =	46.0	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0015	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.23	0.00	0.06	0.0	0.00	
0.11	0.14	2.54	0.05	0.31	0.0	0.01	
0.21	0.50	4.85	0.10	0.47	0.2	0.01	
0.31	1.09	7.15	0.15	0.61	0.7	0.01	
0.41	1.91	9.46	0.20	0.74	1.4	0.02	
0.51	2.96	11.77	0.25	0.85	2.5	0.02	
0.61	4.24	14.07	0.30	0.96	4.1	0.03	
0.71	5.74	16.38	0.35	1.06	6.1	0.03	
0.81	7.47	18.69	0.40	1.16	8.7	0.04	
0.91	9.43	21.00	0.45	1.25	11.8	0.04	
1.01	11.62	23.30	0.50	1.34	15.6	0.05	
1.10	14.03	25.61	0.55	1.43	20.1	0.05	
1.20	16.67	27.92	0.60	1.52	25.3	0.06	
1.30	19.54	30.22	0.65	1.60	31.2	0.06	
1.40	22.64	32.53	0.70	1.68	38.0	0.07	
1.50	25.96	34.84	0.75	1.76	45.6	0.07	
1.60	29.51	37.15	0.79	1.83	54.1	0.07	
1.70	33.29	39.45	0.84	1.91	63.5	0.08	
1.80	37.30	41.76	0.89	1.98	73.9	0.08	
1.90	41.54	44.07	0.94	2.05	85.3	0.09	
2.00	46.00	46.37	0.99	2.13	97.8	0.09	
1.36	21.21	31.43	0.67	1.64	34.82	0.06	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

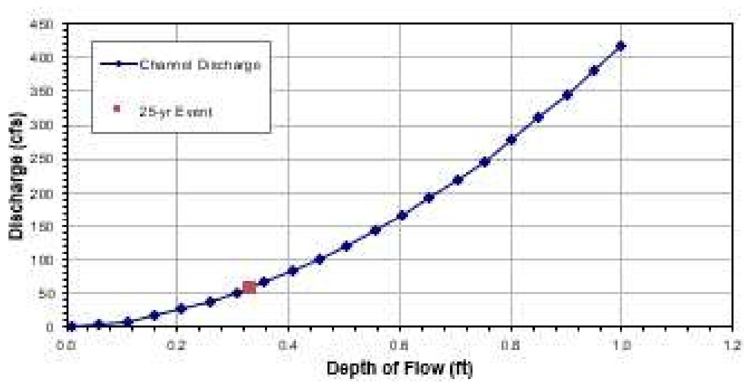
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Interim Downchute Channel, 3:1 Slope**

Runoff Coefficient, C =	0.567	
25-year Rainfall Intensity, I =	7.92	in/hr
Contributing Drainage Area, A =	12.91	acres
Peak Discharge, Q_{25} =	57.97	cfs (25-yr Event)
Bottom Width, B =	6.00	ft
Left Side Slope, Z_1 =	3.0	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	1.00	ft
Top Width, T =	12.0	ft
Manning's Roughness Coeff., n =	0.015	
Longitudinal Channel Slope, S_o =	0.3333	ft/ft

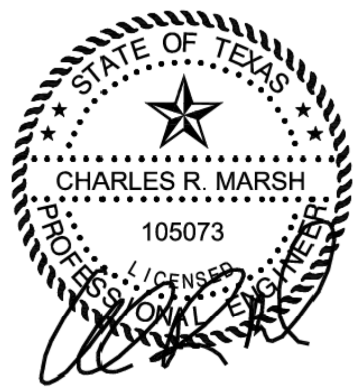
Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.06	6.06	0.01	2.65	0.2	0.21	
0.06	0.37	6.38	0.06	8.56	3.1	1.20	
0.11	0.69	6.69	0.10	12.61	8.7	2.14	
0.16	1.03	7.00	0.15	15.94	16.4	3.05	
0.21	1.38	7.32	0.19	18.84	26.0	3.92	
0.26	1.74	7.63	0.23	21.44	37.4	4.75	
0.31	2.12	7.94	0.27	23.81	50.6	5.56	
0.36	2.52	8.25	0.31	26.00	65.5	6.35	
0.41	2.93	8.57	0.34	28.05	82.2	7.11	
0.46	3.36	8.88	0.38	29.97	100.6	7.86	
0.51	3.80	9.19	0.41	31.79	120.7	8.59	
0.55	4.25	9.51	0.45	33.53	142.5	9.30	
0.60	4.72	9.82	0.48	35.18	166.0	9.99	
0.65	5.20	10.13	0.51	36.77	191.3	10.68	
0.70	5.70	10.45	0.55	38.30	218.3	11.35	
0.75	6.21	10.76	0.58	39.77	247.1	12.01	
0.80	6.74	11.07	0.61	41.20	277.7	12.66	
0.85	7.28	11.39	0.64	42.58	310.2	13.31	
0.90	7.84	11.70	0.67	43.93	344.4	13.94	
0.95	8.41	12.01	0.70	45.23	380.6	14.57	
1.00	9.00	12.32	0.73	46.51	418.6	15.19	
0.33	2.32	8.10	0.29	24.91	57.76	5.96	Q (25-yr Event)

Discharge versus Depth Relationship



APPENDIX IIIF-G-A

EXCERPTS FROM THE APPROVED CLOMR APPLICATION



08/10/2023

APPENDIX B

FEMA CERTIFICATION FORMS

U.S. DEPARTMENT OF HOMELAND SECURITY
FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 1660-0016
Expires February 28, 2014

PAPERWORK BURDEN DISCLOSURE NOTICE

Public reporting burden for this form is estimated to average 1 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless it displays a valid OMB control number. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Department of Homeland Security, Federal Emergency Management Agency, 1800 South Bell Street, Arlington, VA 20958-3005, Paperwork Reduction Project (1660-0016). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

PRIVACY ACT STATEMENT

AUTHORITY: The National Flood Insurance Act of 1968, Public Law 90-448, as amended by the Flood Disaster Protection Act of 1973, Public Law 93-234.

PRINCIPAL PURPOSE(S): This information is being collected for the purpose of determining an applicant's eligibility to request changes to National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRM).

ROUTINE USE(S): The information on this form may be disclosed as generally permitted under 5 U.S.C § 552a(b) of the Privacy Act of 1974, as amended. This includes using this information as necessary and authorized by the routine uses published in DHS/FEMA/NFIP/LOMA-1 National Flood Insurance Program (NFIP); Letter of Map Amendment (LOMA) February 15, 2006, 71 FR 7990.

DISCLOSURE: The disclosure of information on this form is voluntary; however, failure to provide the information requested may delay or prevent FEMA from processing a determination regarding a requested change to a (NFIP) Flood Insurance Rate Maps (FIRM).

A. REQUESTED RESPONSE FROM DHS-FEMA

This request is for a (check one):

☒ CLOMR: A letter from DHS-FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

☐ LOMR: A letter from DHS-FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See 44 CFR Ch. 1, Parts 60, 65 & 72)

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Example: 480301 480287	City of Katy Harris County	TX TX	48473C 48201C	0005D 0220G	02/08/83 09/28/90
480582	Tarrant County	TX	48439C	0340K	09/25/09

2. a. Flooding Source: Village Creek

   b. Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH)
   ☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

3. Project Name/Identifier: Fort Worth C&D Landfill

4. FEMA zone designations affected: AE and X (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

5. Basis for Request and Type of Revision:

   a. The basis for this revision request is (check all that apply)

☒ Physical Change	☒ Improved Methodology/Data	☒ Regulatory Floodway Revision	☐ Base Map Changes
☐ Coastal Analysis	☒ Hydraulic Analysis	☐ Hydrologic Analysis	☐ Corrections
☐ Weir-Dam Changes	☐ Levee Certification	☐ Alluvial Fan Analysis	☐ Natural Changes
☒ New Topographic Data	☐ Other (Attach Description)		

Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

IIIF-G-A-41

b. The area of revision encompasses the following structures (check all that apply)

Structures: ☐ Channelization ☐ Levee/Floodwall ☐ Bridge/Culvert

☐ Dam ☒ Fill ☐ Other (Attach Description)

6. ☒ Documentation of ESA compliance is submitted (required to initiate CLOMR review). Please refer to the instructions for more information.

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☒ Yes Fee amount: $6,500

☐ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm for Fee Amounts and Exemptions.

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Gary Bartels	Company: Texas Regional Landfill, LP	
Mailing Address: 9100 South I-35W Alvarado, Tx 75009	Daytime Telephone No.: 817-705-6072	Fax No.:
	E-Mail Address: gary.bartels@wasteconnections.com	
Signature of Requester (required): Gary J Bartels	Date: 5-25-2022	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirements for when fill is placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. For Conditional LOMR requests, the applicant has documented Endangered Species Act (ESA) compliance to FEMA prior to FEMA's review of the Conditional LOMR application. For LOMR requests, I acknowledge that compliance with Sections 9 and 10 of the ESA has been achieved independently of FEMA's process. For actions authorized, funded, or being carried out by Federal or State agencies, documentation from the agency showing its compliance with Section 7(a)(2) of the ESA will be submitted. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Clair Davis, P.E., C.F.M., Floodplain Administrator	Community Name: City of Fort Worth	
Mailing Address: 200 Texas Street Fort Worth, TX 76102	Daytime Telephone No.: 817-392-5981	Fax No.:
	E-Mail Address: clair.davis@fortworthtexas.gov	
Community Official's Signature (required): [signature]	Date: 5/31/2022	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Charles R. Marsh	License No.: 105073	Expiration Date: 09/30/2022
Company Name: Weaver Consultants Group, LLC	Telephone No.: 817-735-9770	Fax No.: 817-735-9775
Signature: [signature]	Date: 5.25.22	E-Mail Address: cmarsh@wcgrp.com

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☒ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

Seal (Optional)

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

IIIF-G-A-43

U.S. DEPARTMENT OF HOMELAND SECURITY
FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 1660-0016
Expires February 28, 2014

PAPERWORK BURDEN DISCLOSURE NOTICE

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PRIVACY ACT STATEMENT

AUTHORITY: The National Flood Insurance Act of 1968, Public Law 90-448, as amended by the Flood Disaster Protection Act of 1973, Public Law 93-234.

PRINCIPAL PURPOSE(S): This information is being collected for the purpose of determining an applicant's eligibility to request changes to National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRM).

ROUTINE USE(S): The information on this form may be disclosed as generally permitted under 5 U.S.C § 552a(b) of the Privacy Act of 1974, as amended. This includes using this information as necessary and authorized by the routine uses published in DHS/FEMA/NFIP/LOMA-1 National Flood Insurance Program (NFIP); Letter of Map Amendment (LOMA) February 15, 2006, 71 FR 7990.

DISCLOSURE: The disclosure of information on this form is voluntary; however, failure to provide the information requested may delay or prevent FEMA from processing a determination regarding a requested change to a (NFIP) Flood Insurance Rate Maps (FIRM).

A. REQUESTED RESPONSE FROM DHS-FEMA

This request is for a (check one):

☒ CLOMR: A letter from DHS-FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

☐ LOMR: A letter from DHS-FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See 44 CFR Ch. 1, Parts 60, 65 & 72)

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Example: 480301 480287	City of Katy Harris County	TX TX	48473C 48201C	0005D 0220G	02/08/83 09/28/90
480582	Tarrant County	TX	48439C	0340K	09/25/09

2. a. Flooding Source: Village Creek

   b. Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH)
   ☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

3. Project Name/Identifier: Fort Worth C&D Landfill

4. FEMA zone designations affected: AE and X (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

5. Basis for Request and Type of Revision:

   a. The basis for this revision request is (check all that apply)

   ☒ Physical Change ☒ Improved Methodology/Data ☒ Regulatory Floodway Revision ☐ Base Map Changes
   ☐ Coastal Analysis ☒ Hydraulic Analysis ☐ Hydrologic Analysis ☐ Corrections
   ☐ Weir-Dam Changes ☐ Levee Certification ☐ Alluvial Fan Analysis ☐ Natural Changes
   ☒ New Topographic Data ☐ Other (Attach Description)

   Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

IIIF-G-A-44

b. The area of revision encompasses the following structures (check all that apply)

Structures: ☐ Channelization ☐ Levee/Floodwall ☐ Bridge/Culvert

☐ Dam ☒ Fill ☐ Other (Attach Description)

6. ☒ Documentation of ESA compliance is submitted (required to initiate CLOMR review). Please refer to the instructions for more information.

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☒ Yes Fee amount: $6,500

☐ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm for Fee Amounts and Exemptions.

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Gary Bartels	Company: Texas Regional Landfill, LP	
Mailing Address: 9100 South I-35W Alvarado, Tx 75009	Daytime Telephone No.: 817-705-6072	Fax No.:
	E-Mail Address: gary.bartels@wasteconnections.com	
Signature of Requester (required): Gary J Bartels	Date: 5-25-2022	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirements for when fill is placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. For Conditional LOMR requests, the applicant has documented Endangered Species Act (ESA) compliance to FEMA prior to FEMA's review of the Conditional LOMR application. For LOMR requests, I acknowledge that compliance with Sections 9 and 10 of the ESA has been achieved independently of FEMA's process. For actions authorized, funded, or being carried out by Federal or State agencies, documentation from the agency showing its compliance with Section 7(a)(2) of the ESA will be submitted. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Clair Davis, P.E., C.F.M., Floodplain Administrator	Community Name: City of Fort Worth	
Mailing Address: 200 Texas Street Fort Worth, TX 76102	Daytime Telephone No.: 817-392-5981	Fax No.:
	E-Mail Address: clair.davis@fortworthtexas.gov	
Community Official's Signature (required): [signature]	Date: 5/31/2022	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Charles R. Marsh	License No.: 105073	Expiration Date: 09/30/2022
Company Name: Weaver Consultants Group, LLC	Telephone No.: 817-735-9770	Fax No.: 817-735-9775
Signature: [signature]	Date: 5.25.22	E-Mail Address: cmarsh@wcgrp.com

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☒ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

Seal (Optional)

IIIF-G-A-46

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

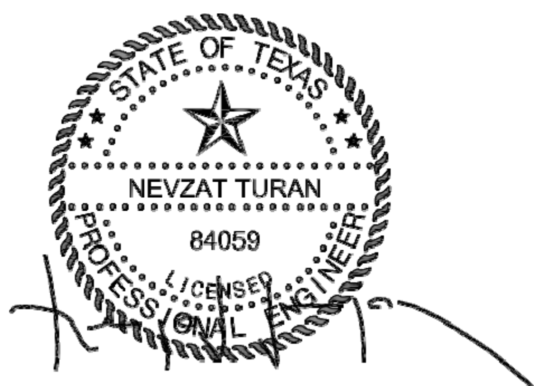
VOLUME 3 OF 4

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023



08/10/2023

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

This document is intended for permitting purposes only.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIG
GEOLOGY REPORT

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

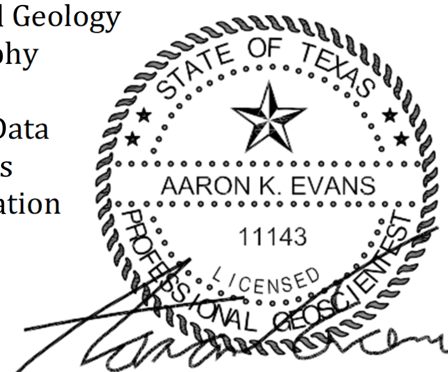
08/10/2023

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11

CONTENTS



08/10/2023

GEOLOGY REPORT CERTIFICATION

Site Information

Site: Fort Worth C&D Landfill

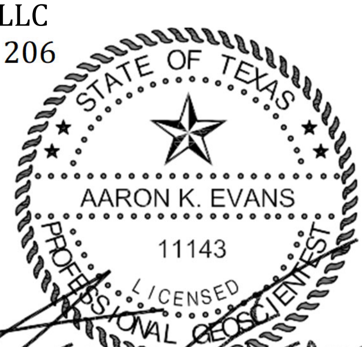
Site Location: Tarrant County

MSW Permit No.: 1983E

Qualified Groundwater Scientist Statement

I, Aaron K. Evans, am a Texas-licensed professional geoscientist and a qualified groundwater scientist as defined in Title 30 TAC §330.3(120). I have prepared the Geology Report which constitutes Appendix IIIG of this permit application. In my professional opinion, the Geology Report is in compliance with the requirements specified in Title 30 TAC §330.63(e). This report has been completed specifically for the Fort Worth C&D Landfill. The only warranty made by me in connection with this report is that I have used that degree of care and skill ordinarily exercised under similar conditions by reputable members of my profession, practicing in the same or similar locality. No other warranty, expressed or implied, is intended.

Firm/Address: Weaver Consultants Group, LLC
6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109



Signature: 08/10/2023

Aaron K. Evans, P.G., Texas License No. 11143

Date: 08/10/2023

3.1.5 Main Street Limestone

Underlying the Grayson Shale, the Main Street Limestone consists of hard, dry limestone interbedded with dry, calcareous, clayey shale that ranges in thickness from about 28 to 31 feet across the site. It is noted that the BEG (1987) regional geologic formation taxonomy categorized the Grayson Shale and Main Street Limestone as a single undivided formation. Laboratory permeability testing indicates a vertical hydraulic conductivity ranging from 2.06×10^{-8} to 9.83×10^{-8} cm/sec.

3.1.6 Pawpaw Formation

The Pawpaw Formation underlies the Main Street Limestone and consists predominately of hard, dry, calcareous shale. None of the existing boreholes have penetrated the vertical extent of the Pawpaw beneath the site. The uppermost contact of Pawpaw to overlying Main Street Limestone sediments is below elevation 525 ft-msl as observed in onsite borings. No site-specific hydrogeological data exists for this deep-bedded dry shale formation.

3.1.7 Stratigraphic Interpretation

The existing subsurface characterization delineates Alluvium and Woodbine outcrop based on general sedimentary composition and taking into consideration regional geology as depicted by the Bureau of Economic Geology in the Geologic Atlas of Texas, Dallas Sheet (BEG, 1987).

Figures IIIG-A-1 (Regional Geologic Map) and IIIG-C-33 (Surface Geology Map) show the site location and regional formational outcrop areas. As indicated, Quaternary Alluvium (Qal) is isolated to the westernmost facility permit boundary proximal to Village Creek, the Woodbine Formation (Kwb) is isolated in the eastern permit boundary, and the Grayson Formation (Kgm) is interpreted to outcrop in a limited area within the central portion of the permit boundary. These outcrop areas appear to be generally consistent with site-specific subsurface investigation findings.

Alluvium sediments are typically observed to include a basal layer of coarse-grained sands and/or gravel as described in lithologic logs for monitor wells MW-2, MW-5, MW-6, MW-7, and MW-8. Alternatively, Woodbine sediments are generally comprised of sand and clay without the presence of basal gravels or with lithologic descriptions for gravelly soils that suggest a makeup of ironstone or calcareous nodules. The lithologic logs for the borings advanced in 1989 by Freeze and Nichols and 1991 by Baker-Shifflet include formational associations with some logged site-specific strata. These include notable Woodbine Formation sediment designations logged in borings B-16/16A and B-22/22A. In the central portion of the site, the residual weathering of Grayson Formation shale sediments is indicated by the more prevalent occurrence of clay and shaly clay above indurated unweathered

Grayson shale sediments. Figure IIIG-C-34 in Appendix IIG-C (Woodbine Formation Thickness Isopach Map) illustrates the general estimated thickness of Woodbine sediments as interpreted from previously advanced borings and based on pre-development surface grades. As indicated, Woodbine sediment thickness increases toward the east commensurate with the regional dip of the formation.

Delineating precise surficial formational contacts among the Alluvium, Woodbine, and Grayson sediments can be difficult given some of the similarities in sedimentary composition. For this reason, the hydrogeologic characterization is conservatively interpreted to include both an Alluvium and Woodbine groundwater monitoring system network. The facility's groundwater monitoring systems are further discussed in Attachment IIIH.

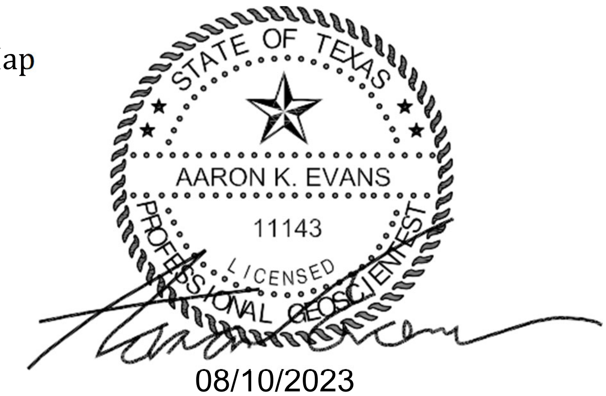
APPENDIX IIIG-C

SITE GEOLOGIC DATA

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

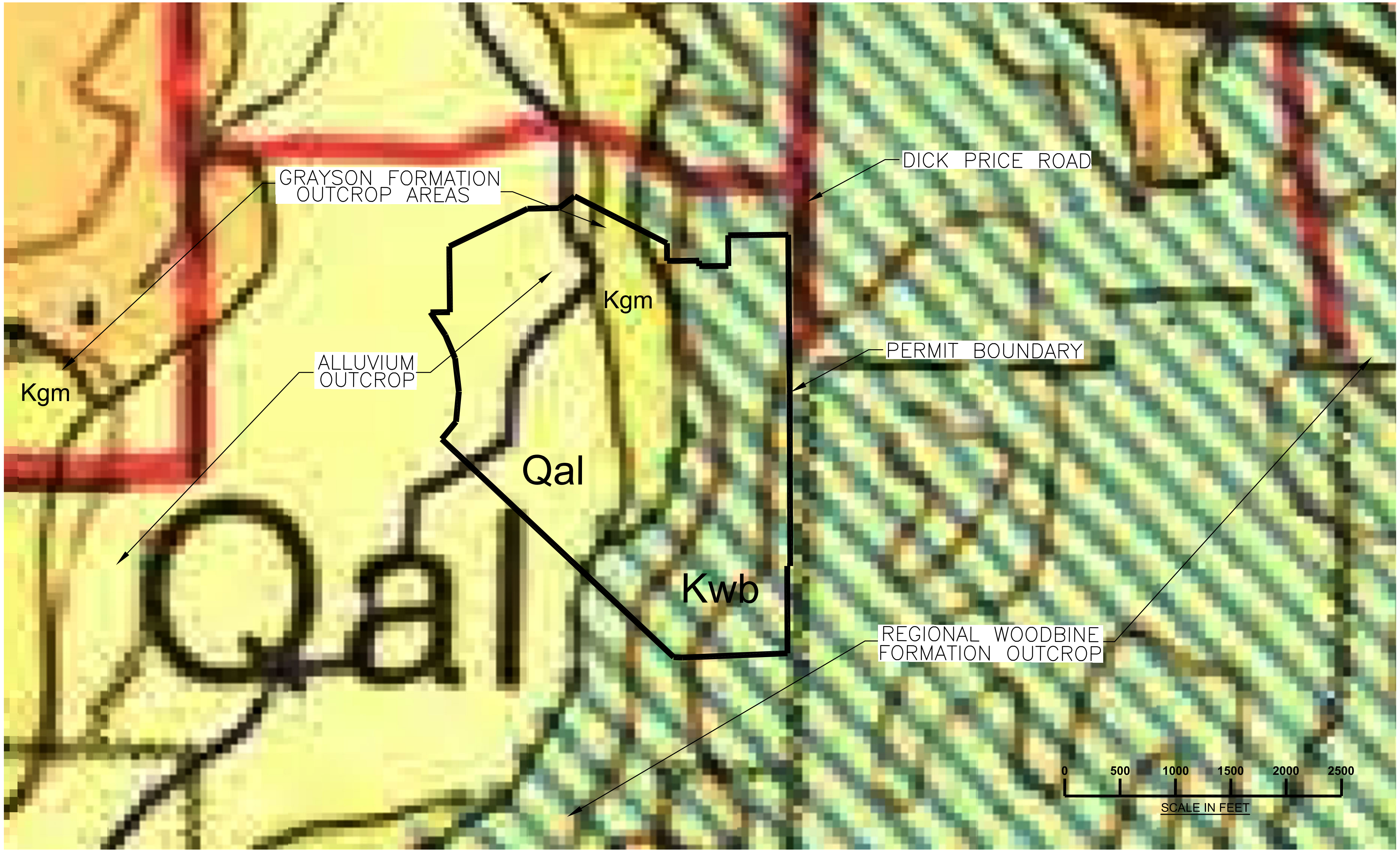
08/10/2023

CONTENTS



STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST
08/10/2023

ADDITIONAL GEOLOGY FIGURES



N

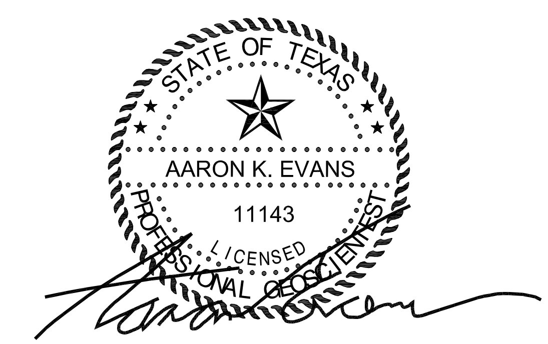
LEGEND

▬▬	PERMIT BOUNDARY (APPROXIMATE)
Qal	QUATERNARY ALLUVIUM OUTCROP
Kwb	WOODBINE FORMATION OUTCROP
Kgm	GRAYSON FORMATION OUTCROP

GEOLOGIC ATLAS OF TEXAS, DALLAS SHEET

GAYLE SCOTT MEMORIAL EDITION

REVISED 1987



08/10/2023

NOTES:

1. SURFACE GEOLOGY MODIFIED FROM BUREAU OF ECONOMIC GEOLOGY REGIONAL GEOLOGIC MAP OF TEXAS, DALLAS SHEET, 1987.
2. LOCALIZED FORMATIONAL OUTCROP AREAS MAY VARY FROM THOSE DEPICTED BY THE REGIONAL GEOLOGIC MAP.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2023
FILE: 0771-356-11
CAD: IIIG-C-33_SURFACE GEO. MAP.DWG

DRAWN BY: JDW
DESIGN BY: AKE
REVIEWED BY: NT

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
TEXAS REGIONAL LANDFILL COMPANY, LP

REVISIONS

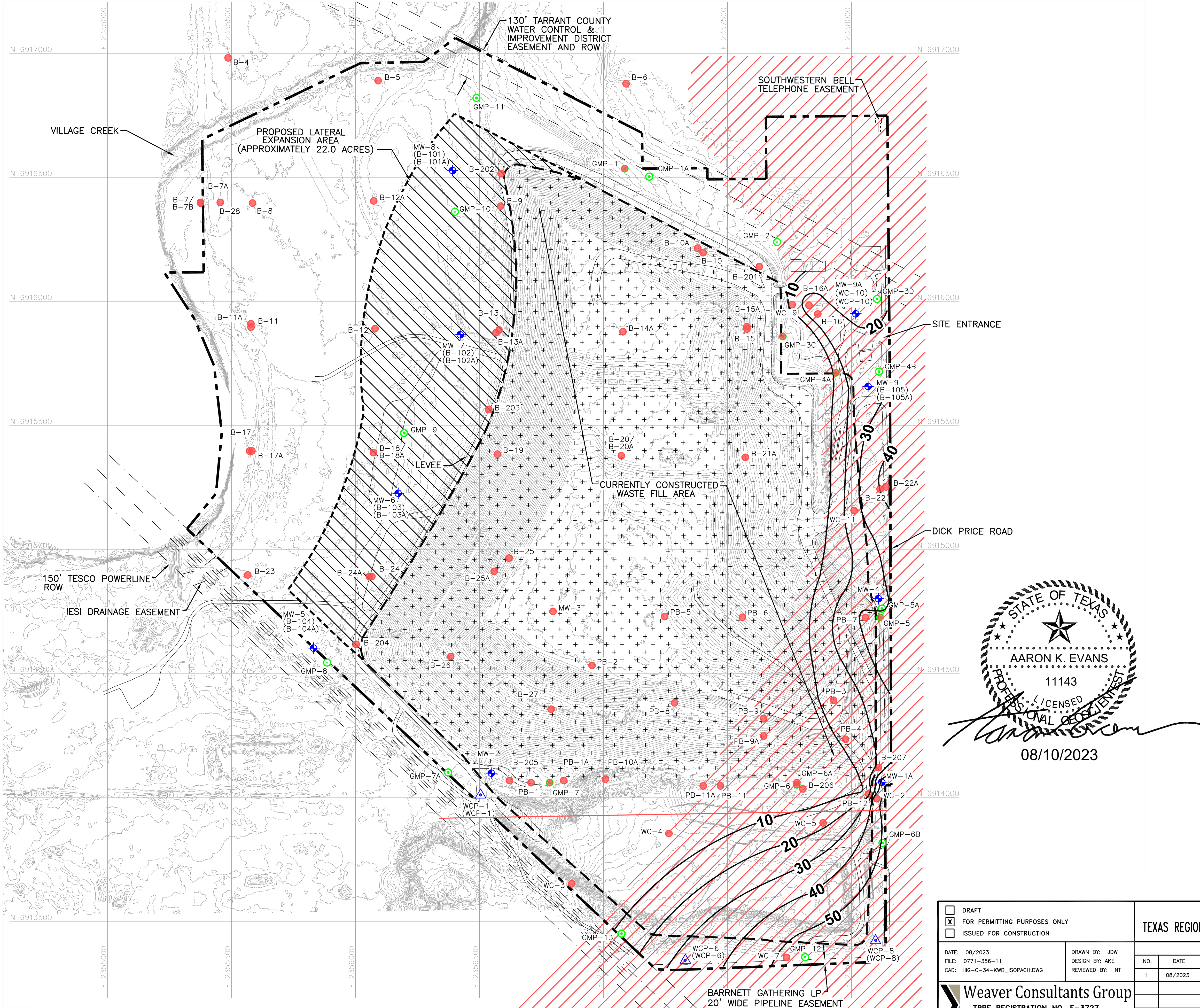
NO.	DATE	DESCRIPTION
1	08/2023	NEW FIGURE IIIG-C-33 ADDED

MAJOR PERMIT AMENDMENT
SURFACE GEOLOGY MAP

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS

WWW.WCGRP.COM

FIGURE IIIG-C-33



LEGEND

(line)	PERMIT BOUNDARY
(line)	PERMITTED LIMITS OF WASTE
(line)	PROPOSED LIMITS OF WASTE
630	EXISTING CONTOUR
N 6915000	STATE PLANE COORDINATE
(line)	EASEMENT
(pattern)	CURRENTLY CONSTRUCTED WASTE FILL AREA
(pattern)	PROPOSED LATERAL EXPANSION AREA
MW-7	EXISTING GROUNDWATER MONITORING WELL
GMP-1	EXISTING LANDFILL GAS MONITORING PROBE
B-16	PREVIOUSLY DRILLED BOREHOLE LOCATION
WCP-1 (WP-1)	EXISTING GROUNDWATER PIEZOMETER LOCATION
40	WOODBINE THICKNESS CONTOUR IN FEET (SEE NOTE 5)
(pattern)	APPROXIMATE WOODBINE FORMATION OUTCROP (SEE NOTE 6)

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY FIRMATEK, FROM AERIAL PHOTOGRAPHY FLOWN 02-17-2022. GRID COORDINATES BASED ON TEXAS STATE PLANE COORDINATE SYSTEM NAD 83.
2. THE EXISTING PERMIT BOUNDARY REPRODUCED FROM THE CURRENTLY APPROVED SITE DEVELOPMENT PLAN BY GEOSYNTEC CONSULTANTS, INC., DATED DECEMBER 2020.
3. BOREHOLE AND FORMER GROUNDWATER MONITOR WELL COORDINATES OBTAINED FROM APPENDIX 4 (GEOLOGY REPORT) OF THE CURRENTLY APPROVED SITE DEVELOPMENT PLAN PREPARED BY GEOSYNTEC CONSULTANTS, INC., DATED DECEMBER 2020. EXISTING GROUNDWATER MONITOR WELL COORDINATES FROM MAY 2023 ASBUILT SURVEY BY WCG.
4. GAS MONITORING PROBE LOCATION COORDINATES OBTAINED FROM ATTACHMENT 6 (LANDFILL GAS MANAGEMENT PLAN) OF THE CURRENTLY APPROVED SITE DEVELOPMENT PLAN PREPARED BY GEOSYNTEC CONSULTANTS, INC., DATED DECEMBER 2020, AND THE GAS PROBE INSTALLATION REPORT BY SCS ENGINEERS DATED JANUARY 2022.
5. WOODBINE FORMATION THICKNESS ESTIMATED FROM SITE-SPECIFIC BORING SEDIMENTARY COMPOSITION AND PREDEVELOPMENT SURFACE TOPOGRAPHY.
6. WOODBINE FORMATION OUTCROP ESTIMATED FROM REGIONAL GEOLOGIC MAP (BEG, 1987) AND SEDIMENTARY COMPOSITION OF SITE-SPECIFIC BORINGS.

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☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2023
FILE: 0771-356-11
CAD: IIIG-C-34-KWB_ISOPACH.DWG

DRAWN BY: JDW
DESIGN BY: AKE
REVIEWED BY: NT

PREPARED FOR
TEXAS REGIONAL LANDFILL COMPANY, LP

REVISIONS

NO.	DATE	DESCRIPTION
1	08/2023	NEW FIGURE IIIG-C-34 ADDED

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT
WOODBINE FORMATION THICKNESS ISOPACH MAP
FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS

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FIGURE IIIG-C-34

O:\0771\356\EXPANSION 2022\PART III\IIIG\IIIG-C-34-WOODBINE ISOPACH MAP.dwg, sford, 1:2

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIH
GROUNDWATER SAMPLING AND ANALYSIS PLAN

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

08/10/2023

Prepared by

Weaver Consultants Group, LLC
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6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

data. These data are summarized in Figure IIIH-A-2 (Groundwater Monitoring Well Details) in Appendix IIH-A. Typical groundwater monitoring well specifications are depicted in Figure IIIH-A-3 in Appendix IIIH-A. Review of monitoring well installation records indicate that the facility's existing monitoring wells were constructed in accordance with the requirements of Title 30 TAC §330.421.

All parts of the groundwater monitoring system will be operated and maintained so that they perform to design specifications throughout the life of the monitoring program. Any monitoring well that is damaged to the extent that it is no longer suitable for sampling will be reported to the TCEQ who may make a determination about whether to repair or replace the well. Well plugging and abandonment will be performed by a Texas-licensed monitoring well driller in accordance with TCEQ and any other applicable regulatory requirements. One monitoring well was plugged and abandoned prior to 2023 (MW-3) and the State of Texas Plugging Report is provided in Appendix IIIH-A. No monitoring well will be plugged and abandoned without prior written authorization from TCEQ. Any replacement monitoring well installation will be performed in accordance with Title 30 TAC §330.421 by a Texas-licensed monitoring well driller. Monitoring well construction will provide for the maintenance of the integrity of the borehole, collection of representative groundwater samples from the uppermost aquifer, and prevention of migration of groundwater and surface water within the borehole in accordance with Title 30 TAC §330.421(a).

New or replacement monitoring well installations will be surveyed for horizontal and vertical control by a Texas-licensed Registered Professional Land Surveyor prior to initiation of groundwater sampling in accordance with Title 30 TAC §330.421(d).

2.3 Groundwater Monitoring Program

Facility detection monitoring wells will be sampled annually for the detection monitoring parameters listed in 40 Code of Federal Regulations (CFR), Part 258, Appendix I, which are also listed in Table 5-1 in Section 5.1. Details regarding groundwater sampling, analyses, and statistical comparison procedures are discussed in the following sections of Appendix IIIH.

In accordance with Title 30 TAC §403(e)(3), the facility will promptly notify the executive director, and any local pollution agency with jurisdiction that has requested to be notified, in writing of changes in facility construction or operation or changes in adjacent property that affect or are likely to affect the direction and rate of groundwater flow and the potential for detecting groundwater contamination and that may require the installation of additional monitoring wells or sampling points. Such additional wells or sampling points require a modification of the site development plan which will be requested in accordance with Title 30 TAC §305.70(j).

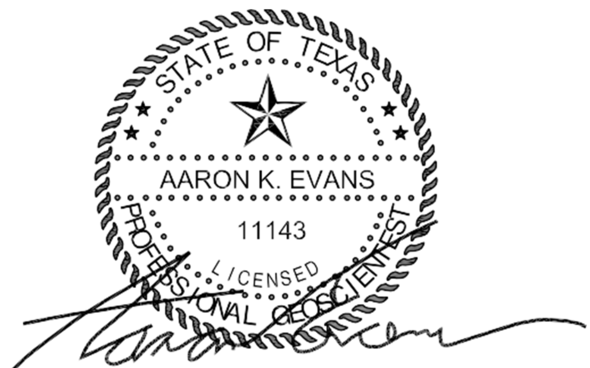
APPENDIX IIIH-A

GROUNDWATER MONITORING SYSTEM

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

08/10/2023

CONTENTS



08/10/2023

STATE OF TEXAS PLUGGING REPORT for Tracking #11086

Owner:	**Ft. Worth C & D Landfill**	Owner Well #:	**MW3**
Address:	**4144 Dick Price Rd. Ft. Worth, TX 76060**	Grid #:	**32-23-7**
Well Location:	**4144 Dick Price Rd. Ft. Worth, TX 76060**	Latitude:	**32° 37' 51" N**
		Longitude:	**097° 14' 19" W**
Well County:	**Tarrant**	Elevation:	**No Data**

Well Type: **Monitor**

Drilling Information

Company: **No Data**

Date Drilled: **No Data**

Driller: **No Data**

License Number: **No Data**

Borehole:

Diameter (in.)	*Top Depth (ft.)*	*Bottom Depth (ft.)*
4		**23**

Plugging Information

Date Plugged: **3/11/2003**

Plugger: **Brian Kern**

Plug Method: **Pour in 3/8 bentonite chips when standing water in well is less than 100 feet depth, cement top 2 feet**

Casing Left in Well:

No Data

Plug(s) Placed in Well:

No Data

Certification Data: The driller certified that the driller plugged this well (or the well was plugged under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the reports(s) being returned for completion and resubmittal.

Company Information: **Total Support Services**

P.O. Box 81621
Austin, TX 78708

Driller Name: **Brian Kern**

License Number: **54611**

Comments: **No Data**

ATTACHMENT 3

REPLACEMENT PAGES
(CLEAN)

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

VOLUME 1 OF 4

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER

Prepared by

08/10/2023

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817-735-9770

WCG Project No. 0771-356-11-35

This document intended for permitting purposes only.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

TCEQ PART I APPLICATION FORM, PART II APPLICATION FORM, CORE DATA FORM, WASTE ACCEPTANCE PLAN FORM, AND MAILING LABELS

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER

08/10/2023

Prepared by
Weaver Consultants Group, LLC
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6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

This document intended for permitting purposes only

Signature Page

Site Operator or Authorized Signatory

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: Gary Bartels Title: Southern Region Engineer

Email Address: gary.bartels@wasteconnections.com

Signature: [signature] Date: 08/10/2023

Operator or Principal Executive Officer Designation of Authorized Signatory

To be completed by the operator if the application is signed by an authorized representative for the operator.

I hereby designate ________________________ as my representative and hereby authorize said representative to sign any application, submit additional information as may be requested by the Commission; and/or appear for me at any hearing or before the Texas Commission on Environmental Quality in conjunction with this request for a Texas Water Code or Texas Solid Waste Disposal Act permit. I further understand that I am responsible for the contents of this application, for oral statements given by my authorized representative in support of the application, and for compliance with the terms and conditions of any permit which might be issued based upon this application.

Operator or Principal Executive Officer Name: ________________________

Email Address: ________________________

Signature: ________________________ Date: ____________

Notary

SUBSCRIBED AND SWORN to before me by the said Gary Bartels

On this 10th day of August, 2023

My commission expires on the 11th day of August, 2026

Stacy M. Wilson

Notary Public in and for

TARRANT County, Texas

STACY M. WILSON
Notary Public, State of Texas
Comm. Expires 08-11-2026
Notary ID 133903285

Note: Application Must Bear Signature & Seal of Notary Public

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT

APPENDIX I/IIC
LOCATION RESTRICTION DEMONSTRATIONS

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER
08/10/2023

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/10/2023

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817-735-9770

WCG Project No. 0771-356-11-35

This document is intended for permitting purposes only.

11 COASTAL AREAS

The coastal areas location restriction within Title 30 TAC §330.561 requires that a new landfill cell or expansion of an existing cell of a landfill managing Class 1 Industrial Solid Waste not be located on a barrier island or peninsula, or within 1,000 feet of an active coastal shoreline erosion.

The Fort Worth C&D Landfill does not accept Class 1 Industrial Solid Waste and is not located in a coastal area. Therefore, the site is in compliance with the coastal areas location restriction.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

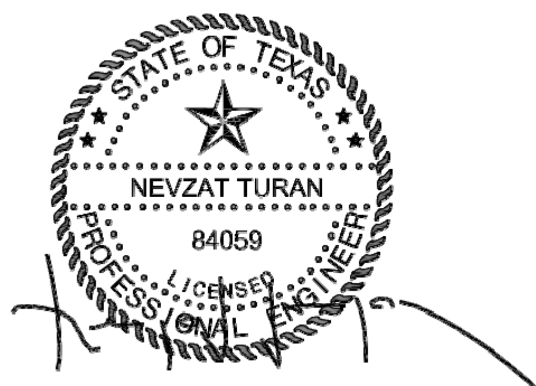
VOLUME 2 OF 4

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023



Prepared by

08/10/2023

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817-735-9770

WCG Project No. 0771-356-11-35

This document intended for permitting purposes only.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIF
SURFACE WATER DRAINAGE PLAN

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

08/10/2023

Prepared by

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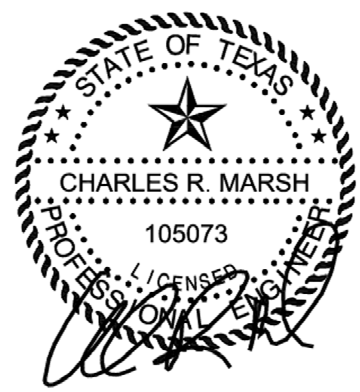
817-735-9770

WCG Project No. 0771-356-11-35

This document is intended for permitting purposes only.

APPENDIX IIIF-E

PERMITTED LANDFILL CONDITION HYDROLOGIC CALCULATIONS



08/10/2023

Includes pages IIIF-E-1 through IIIF-E-346

ATTACHMENT 2B

ON-SITE DRAINAGE ANALYSIS – HYDROLOGY

Written by:	O. Bramlet	Date:	01/08/2020	Reviewed and Revised by:	S. Graves	Date:	01/19/2020; 09/15/2020
Client:	TRLC	Project:	Fort Worth C&D Expansion	Project No.:	GW6953	Phase No.:	04

ON-SITE DRAINAGE ANALYSIS – HYDROLOGY
FORT WORTH C&D LANDFILL EXPANSION

9/15/2020

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

SEALED FOR PERMITTING PURPOSES;
CALCULATION PAGES 1 TO 76

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the hydrology analysis for the estimation of surface water runoff as a part of the permit amendment application for the proposed lateral expansion of the Fort Worth C&D Landfill (site) in Fort Worth, Texas. The specific objectives of the hydrologic analysis include calculating peak discharges and total runoff volumes from the site for the: (i) pre-development conditions and (ii) post-development conditions. The calculated values of peak discharge and runoff volume of the proposed surface water system for lateral expansion presented in this calculation package are compared against currently permitted pre-development conditions in order to demonstrate that lateral expansion design does not adversely alter, to any significant degree, the drainage patterns of the watershed in the vicinity of the site.

The following definitions pertain to the two conditions analyzed in this package:

- Pre-Development Conditions – represent the currently permitted drainage conditions of the landfill facility. The currently permitted surface water management system is analyzed, while incorporating additional off-site run-on drainage areas.
- Post-Development Conditions – represent conditions of the site once the expansion design has been fully developed, with the final cover and permanent surface water management system installed, while incorporating additional off-site run-on drainage areas.

2 METHODOLOGY

2.1 HEC-HMS Computer Model

Surface water discharges for the pre-development and post-development conditions are estimated using the Hydrologic Modeling System (HEC-HMS) version 4.3 computer program developed through the Hydraulic Engineering Center (HEC) of the United States Army Corps of Engineers (USACE). The program simulates natural and controlled precipitation-runoff and routing processes of a watershed. HEC-HMS is the successor to and replacement for the HEC-1 program (USACE, 2000). For precipitation-runoff-routing simulation, HEC-HMS provides the following components:

- Precipitation-specification options can describe an historical precipitation event, a frequency-based hypothetical precipitation event (i.e., design rainfall or storm event), or an event that represents the upper limit of precipitation possible at a given location. For this analysis, the 25-year (4% annual chance), 24-hour duration hypothetical precipitation event (herein referred to as the 25-year, 24-hour event) was used to compare pre-development and post-development conditions. Additionally, the analysis is repeated for the 100-year (1% annual chance), 24-hour duration hypothetical precipitation event (herein referred to as the 100-year, 24-hour event) to obtain the design information needed for surface water pond sizing and discharge structure sizing to route the runoff without overtopping the pond crest for that hypothetical 100-year event.

- Water loss models can estimate the volume of runoff given the precipitation and properties of the watershed. For this analysis, the Soil Conservation Service (SCS) Curve Number Loss Model was used (USDA, 1986).

- Direct runoff transform models can account for overland flow, storage, and energy losses as surface water runs off a watershed and into the drainage channels. For this analysis, the SCS Unit Hydrograph Model was selected.

- Hydraulic routing models account for storage and energy flux as surface water flows through drainage channels. The Kinematic Wave Model was selected for these analyses.

- Hydraulic models of water-control measures such as surface water pond outfall structures (i.e., outlet control structures).

HEC-HMS was used to model the pre-development conditions and the post-development conditions. More specifically, HEC-HMS modeling calculates surface water runoff volumes, peak flow rates, and flow characteristics for the perimeter channels and the surface water ponds.

2.2 Pre-Development Condition

Drawing 2-2 in Attachment 2A of the Facility Surface Water Drainage Report (Drainage Report) presents the final configuration of the currently permitted landfill and surface water management system design including the natural conditions for the off-site areas adjacent to the landfill. Existing topographic information was compiled from photogrammetric methods based on aerial photography performed on 06 March 2019 by Dallas Aerial Surveys, Inc. The topographic information for the general site vicinity was used to model the natural conditions adjacent to the currently permitted landfill boundary. The pre-development drainage area of 207.14 acres includes the currently permitted surface water management system within the facility permit boundary area, as well as off-site areas. The consideration of off-site areas for the pre-development condition allows for direct comparison between the pre-development and post-development analysis since the total drainage areas are equivalent. The currently permitted surface water management system design utilizes drainage terraces, downchute channels, perimeter drainage channels, and storm water (detention) ponds to control surface water runoff from the site.

The currently permitted surface water management system maintains similar drainage patterns to the natural (or undeveloped) conditions. The currently permitted surface water management system discharges surface water at two locations (outfalls). The overall site outfall is located at the storm water pond outlet pipe in the northern portion of the site and discharges to Village Creek, which flows along the west boundary of the site. The midpoint site outfall is located where the permit boundary deviates from Village Creek near the midpoint along the western permit boundary. Both outfall locations are used for evaluation of the pre-development conditions. The entire drainage area of 207.14 acres drains to the overall site outfall, whereas 95.7 acres drain to the midpoint site outfall for pre-development conditions.

2.3 Post-Development Condition

Drawing 2-1 in Attachment 2A shows the final configuration of the lateral expansion and the proposed surface water management system design. Like the currently permitted facility, the proposed surface water management system will utilize drainage terraces, downchute channels, and perimeter drainage channels to control surface water runoff from the site. The drainage areas flowing to each of the drainage features are delineated on Drawing 2-3 in Attachment 2A.

The proposed surface water management system will maintain similar drainage patterns to the pre-development condition. The proposed surface water management system will discharge at the currently permitted outfalls described in the pre-development condition section above. The overall site outfall is located at the surface water pond outlet area in the northern portion of the site and discharges to Village Creek, which flows along the west boundary of the site. The midpoint site outfall is located where the permit boundary deviates from Village Creek near the midpoint along the western permit boundary. The midpoint site outfall and the overall site outfall locations used for evaluation of the post-development conditions coincide with the 207.14-acre drainage area for pre-development conditions. The entire drainage area of 207.14 acres drains to the overall site outfall, whereas 83.5 acres drain to the midpoint site outfall for post-development conditions. The proposed grading of the final cover system results in a slightly smaller area draining to the midpoint site outfall, but is the same where runoff leaves the overall site at the north end (i.e., 207.14 acres). As mentioned, the post-development drainage area includes the entire proposed facility permit boundary area.

3 DESIGN PARAMETERS

The following data and assumptions were utilized in selecting engineering parameters to estimate surface water runoff.

3.1 Rainfall

- Rainfall Return Periods, Durations, and Depths – The Texas Department of Transportation (TxDOT) *Hydraulic Design Manual* (2019) provides guidance for rainfall frequency and duration depths. The site is located in the Village Creek watershed, and outflow from the site drains into Village Creek. The rainfall depths corresponding to 24-hour duration hypothetical precipitation event and 25-year and 100-year frequency return periods for the site are 7.17 inches and 9.27 inches, respectively, using the latest available "Atlas 14" data (NOAA, 2018). The design rainfall hyetograph is defined using a SCS Type II rainfall distribution, which is selected based on Figure 2B-1 (USDA, 1986). The design rainfall depths in the hydrologic model were consistent with TxDOT (2019) methods and procedures; however, the design rainfall hyetograph was defined with a SCS Type II distribution in order to be consistent with the method utilized in the previous permit application. This rainfall intensity method for determining rainfall distribution was retained in the hydrologic model for this application for a more conservative approach, as it resulted in higher peak intensity values than the latest TxDOT (2019) Hydraulic Design Manual.

3.2 Drainage Areas and Reaches

- Drainage Areas – The contributing watershed areas for each basin (drainage area) or reach (perimeter channel) in the pre-development and post-development models are divided into multiple subbasins (subareas). Subbasins are modeled based on the receiving surface water drainage feature, and are delineated for the following areas: top deck surfaces draining to the top deck drainage terraces and the drainage downchutes; sideslope surfaces draining to the sideslope drainage terraces and the drainage downchutes and perimeter channel; off-site run-on areas; and surface water pond areas. The SCS Curve Number Loss Model was used to estimate the volume of runoff from a given subbasin. The SCS Unit Hydrograph Model was used to estimate the direct runoff flow rates from each subbasin. Each subbasin is assigned a curve number representing the type of ground cover for a given soil for the area. The subbasin area, curve number, and SCS Unit Hydrograph lag time input parameters are included in the HEC-HMS output in Appendix 2B-1.

- Hydrologic Soil Groups (HSGs) – Figure 2B-2 shows the approximate footprint of the landfill superimposed on a soil map from the Web Soil Survey tool operated by the USDA Natural Resources Conservation Service (USDA, 2019) for Tarrant County. The predominate soil types at the site include a combination of Frio silty clay, Gasil fine sandy loam, and Gasil sandy clay loam formations. The on-site soil types have a range of HSG designations as shown in Table 2B-1. To be conservative, the HSG within the landfill permit area is assumed to be a type D soil, which generally provides the highest calculated runoff volumes. Off-site natural areas are assumed to have an HSG of type C, corresponding to the Frio silty clay soil found adjacent to the expansion area.

- Curve Number (CN) – Curve numbers are obtained from the TR-55 (USDA, 1986) and are based on the predominant HSG of the drainage area. The curve number for the proposed final cover of the landfill was selected as 85 based on TCEQ's guidelines as described in Regulatory Guidance 417 (TCEQ, 2018). Table 2B-2 summarizes the CNs chosen for all off-site areas within the analyses detailed in this calculation package. Off-site natural conditions (HSG type C) are assumed to be meadow cover conditions (CN = 71). Off-site areas currently developed with buildings and driveways are assumed to represent farmstead conditions (CN = 82).

- Manning's Roughness Coefficients – Values of Manning's roughness coefficients used in the reach routing calculations were obtained from the TxDOT *Hydraulic Design Manual* (2019). Table 2B-3 summarizes the Manning's coefficients used in this calculation package. It should be noted that for design purposes, the culverts assume a Manning's coefficient for a reinforced concrete pipe (RCP). Any culvert material type may be used provided that the Manning's coefficient is equal to or less than that for RCP.

- Perimeter Channel Reaches – Reaches in the HEC-HMS program represent perimeter channels that route surface water from upstream subbasins to downstream subbasins through a junction. Reaches also may route surface water from upstream reaches. The Kinematic Wave Model is used to model the surface water flow in each of the reaches in the HEC-HMS program. The Kinematic Wave Model accounts for storage and energy flux as surface water moves through stream channels. Average geometric characteristics of the stream channel measured from the existing and proposed topography are input into HEC-HMS.

3.3 Surface Water Ponds

The pre-development analysis incorporated the currently permitted surface water ponds, the North Surface Water Pond and the South Surface Water Pond. The surface water ponds temporarily retain surface water runoff and reduce discharge flow rates from the upstream areas. The post-development analysis incorporates only the North Surface Water Pond which is comprised of a series of four connected sub-ponds. The existing North Surface Water Pond will be modified and portions of the drainage area to the south are diverted to the North Surface Water Pond to maintain post-development discharge flow rates at or below pre-development discharge flow rates for a 24-hour duration hypothetical precipitation event occurring at a 25-year frequency. Surface water ponds are accounted for in the HEC-HMS program as "reservoir" nodes. The elevation-area relationship is input for each surface water pond to describe the volume of storage provided by the surface water pond, which is computed based on the proposed surface water pond geometry. Specifically, the surface area at various elevations throughout the ponds was used to compute the elevation-area relationship. Design characteristics of the outflow structures include pond outflow pipe diameter and emergency spillway depth and breadth. Input and output files for the surface water ponds design are provided in Appendix 2B-1. The North Surface Water Pond discharges to a drainage channel and ultimately to Village Creek at the overall site outfall for both pre-development and post-development conditions. The South Surface Water Pond (only present under pre-development conditions) discharges to a drainage channel and ultimately to Village Channel at the midpoint outfall.

3.4 Nodal Network Diagrams

Nodal network diagrams used in HEC-HMS for the pre-development and post-development analyses are provided and correspond to the output files included in Appendix 2B-1.

- Pre-Development Nodal Network – Figure 2B-3 of this calculation package presents the nodal network drawing for the pre-development conditions. The pre-development nodal network diagram shows the subbasins, permitted storm water ponds, and discharge locations. The nodal network diagram represents the existing permitted surface water management system and discharge point shown on Drawing 2-2 in Attachment 2A
- Post-Development Nodal Network – Figure 2B-4 of this calculation package presents the nodal network drawing for the post-development conditions. The post-development nodal network diagram shows the subbasins, reaches, surface water ponds, and discharge locations. The nodal network diagram represents the proposed surface water management system and discharge point shown on

Drawing 2-3 in Attachment 2A.

4 RESULTS

Modeling results from calculations presented in this calculation package indicate that post-development peak discharges from the facility are less than the pre-development peak discharge rates at both the overall site outfall and midpoint discharge locations for the 25-year, 24-hour precipitation event. Thus, the lateral expansion is not anticipated to adversely affect or significantly alter the drainage patterns in the vicinity of the site. Table 2B-4 summarizes analysis results for the pre- and post-development peak discharges and total discharge runoff volumes from the site. The calculation results described in Table 2B-4 are provided in Appendix 2B-1.

5 REFERENCES

Chow, V.T. (1959). *Open-Channel Hydraulics*, McGraw-Hill Book Company, Inc., New York, NY.

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TCEQ (2018). Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill, Regulatory Guidance 417 (RG-417), Texas Commission on Environmental Quality, Waste Permits Division, Revised May 2018.

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TABLES

Table 2B-1. Hydrologic Soil Groups for On-Site Soils
(from USDA, 2019)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
7	Arents, frequently flooded	A	19.8	9.3%
8	Arents, loamy	B	11.2	5.3%
12	Birome-Aubrey-Rayex complex, 5 to 15 percent slopes	D	34.7	16.3%
22	Crosstell fine sandy loam, 3 to 8 percent slopes	D	9.2	4.3%
27	Frio silty clay, frequently flooded	C	60.2	28.2%
30	Gasil fine sandy loam, 3 to 8 percent slopes	B	50.8	23.8%
31	Gasil sandy clay loam, graded, 1 to 5 percent slopes	B	25.2	11.8%
71	Silstid loamy fine sand, 1 to 5 percent slopes	B	0.1	0.0%
83	Whitesboro loam, frequently flooded	B	1.9	0.9%
Totals for Area of Interest			**213.1**	**100.0%**

Table 2B-2. Summary of Curve Numbers used in Analysis[1] (from USDA, 1986)

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. 2/	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. 3/	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 4/	48	65	73
Woods—grass combination (orchard or tree farm). 5/	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. 6/	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 4/	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Note that the curve number for the proposed final cover of the landfill was selected as 85 based on TCEQ's guidelines as described in Regulatory Guidance 417 (TCEQ, 2018). This is a conservative assumption since the information in this table would support the selection of a smaller CN for the expected soil types and cover types/conditions of the landfill final cover.

**Table 2B-3. Manning's n Values
(from TxDOT, 2019)**

Type of channel	Manning's n
B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
3. Dragline-excavated or dredged	
a. No vegetation	0.025-0.033
b. Light brush on banks	0.035-0.060
4. Rock cuts	
a. Smooth and uniform	0.025-0.040
b. Jagged and irregular	0.035-0.050
5. Unmaintained channels	
a. Dense weeds, high as flow depth	0.050-0.120
b. Clean bottom, brush on sides	0.040-0.080
c. Clean bottom, brush on sides, highest stage	0.045-0.110
d. Dense brush, high stage	0.080-0.140
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2B-4. Summary of Peak Discharge and Total Discharge Volumes at Site Outfalls

Location	Item	Pre-Development (25-year)	Post-Development (25-year)
Midpoint Site Outfall	Peak Discharge (cfs)	515.4	515.4
	Total Runoff Volume (ac-ft)	36.3	33.6
Overall Site Outfall	Peak Discharge (cfs)	802.6	797.1
	Total Runoff Volume (ac-ft)	78.7	82.0

FIGURES

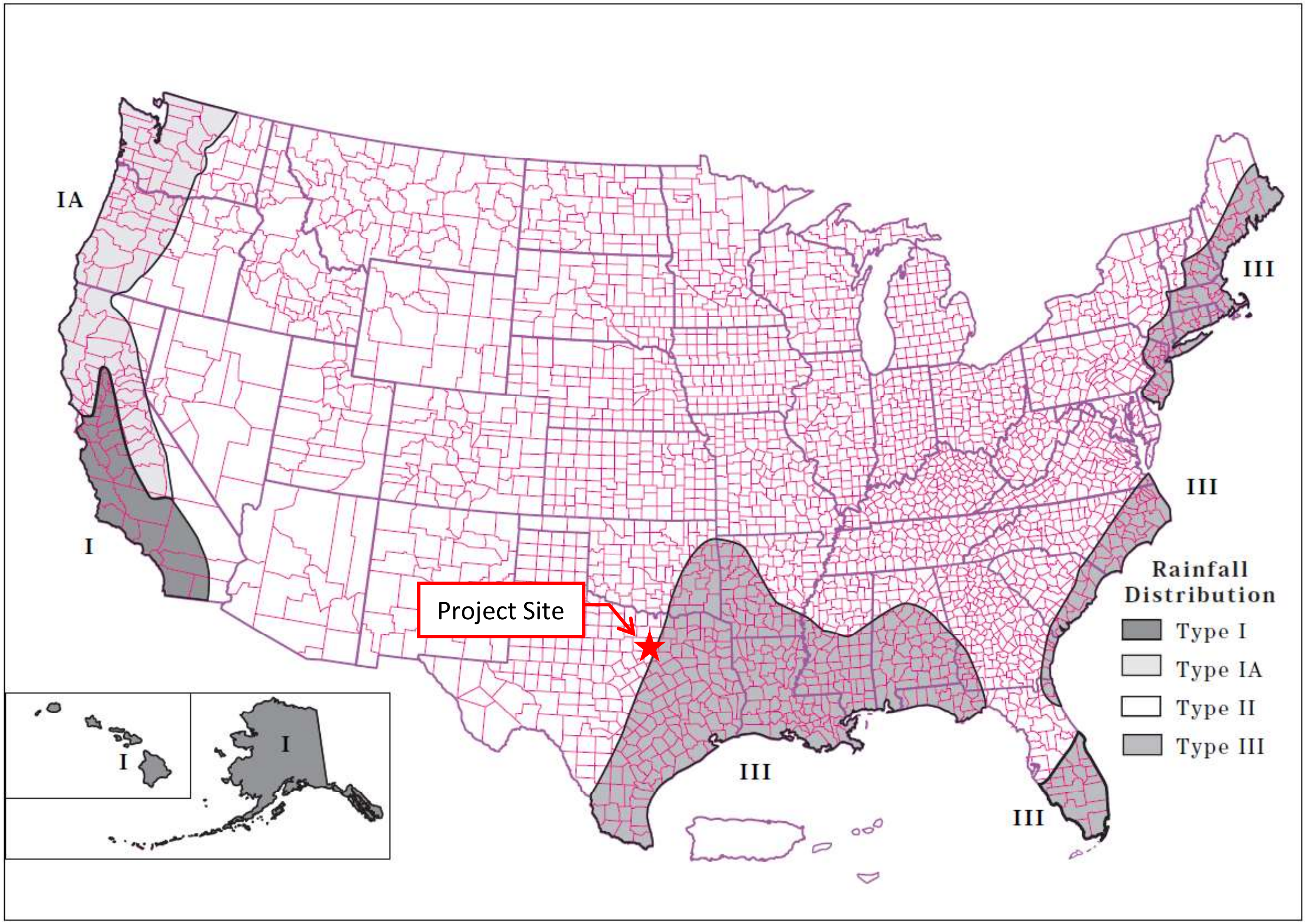

Figure 2B-1. SCS Rainfall Distributions (from USDA, 1986)

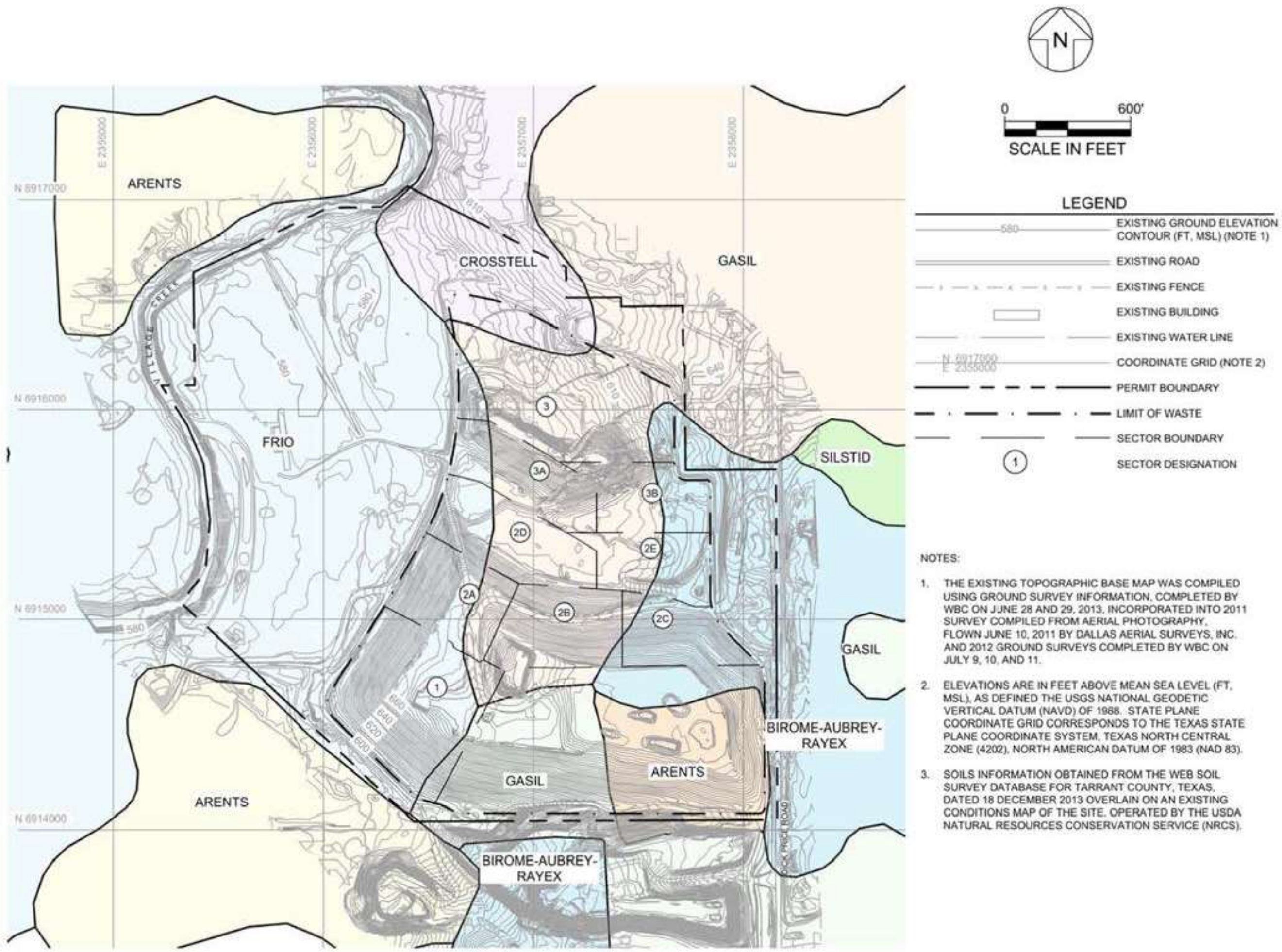

Figure 2B-2. Soil Survey Map

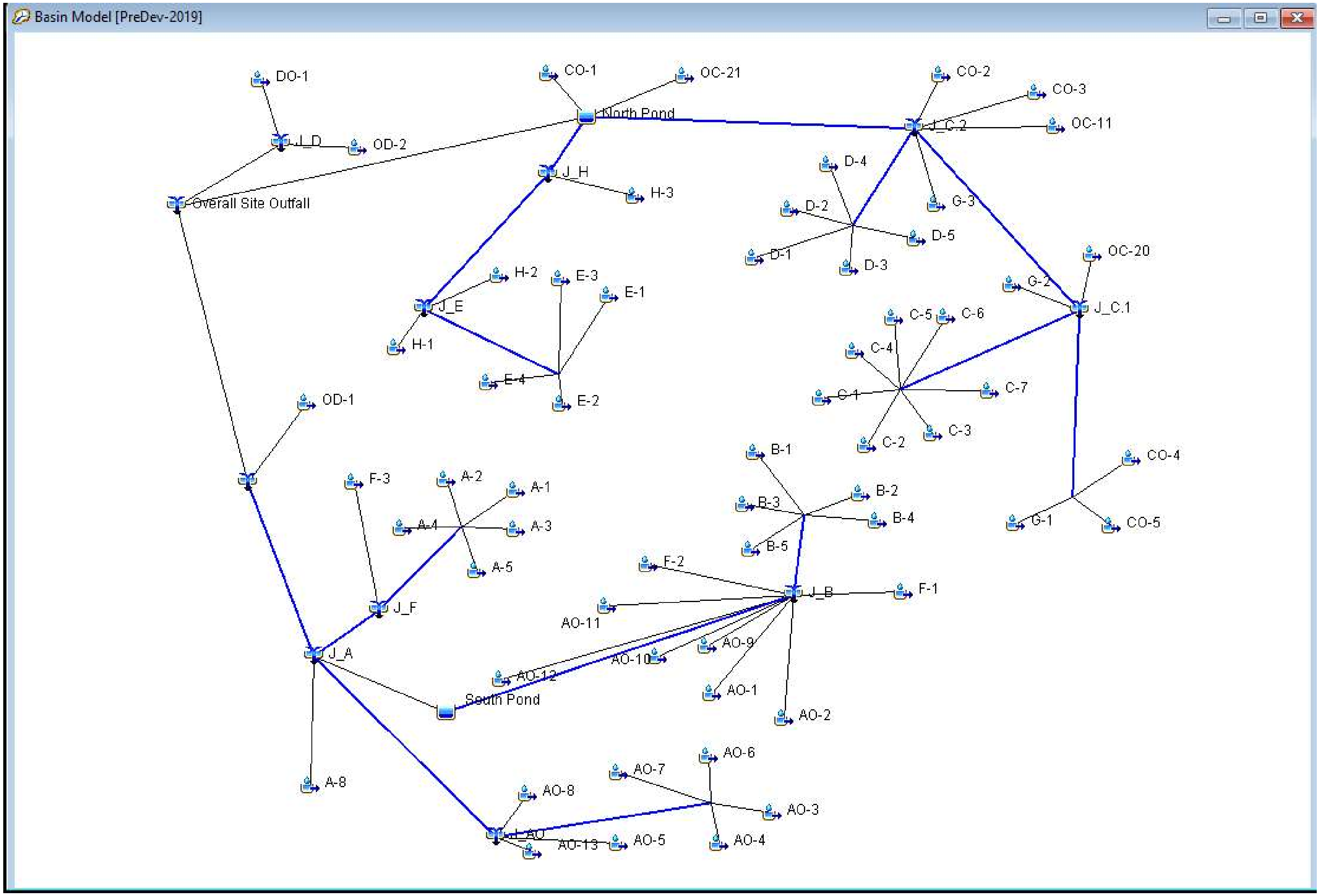

Figure 2B-3. Pre-Development HEC-HMS Nodal Network

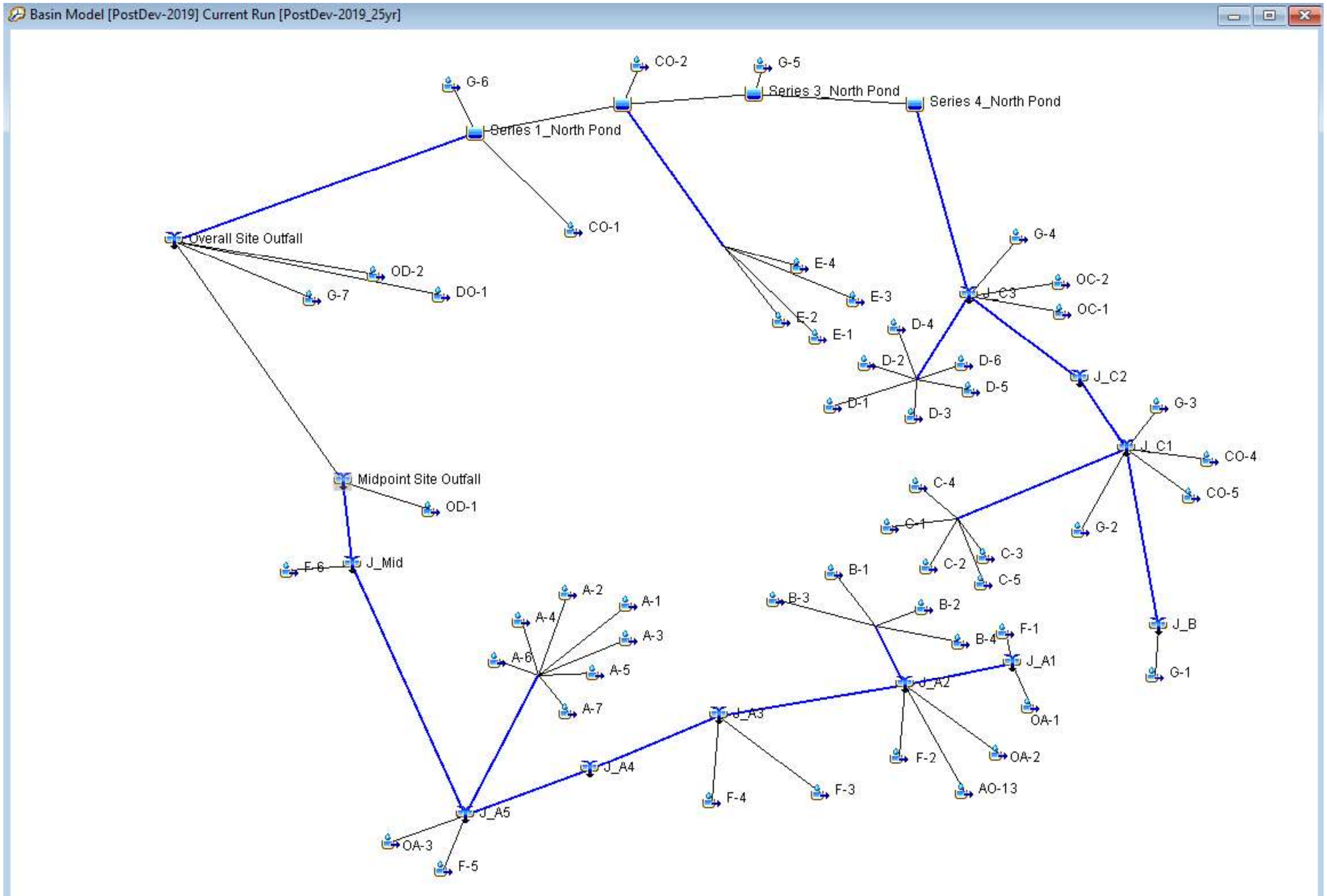

Figure 2B-4. Post-Development HEC-HMS Nodal Network

APPENDIX 2B-1
HEC-HMS HYDROLOGIC MODEL PARAMETERS

Table 2B-1-1. Pre-Development Permitted North Surface Water Pond Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
588.0	0.7703
588.5	0.8016
589.0	0.8331
589.5	0.8650
590.0	0.8971
590.5	0.9296
591.0	0.9623
591.5	0.9954
592.0	1.0287
592.5	1.0623
593.0	1.0963
593.5	1.1305
594.0	1.1650
594.5	1.1998
595.0	1.2350
595.5	1.2704
596.0	1.3061
596.5	1.3421
597.0	1.3784
597.5	1.4150
598.0	1.4519
598.5	1.4891
600.0	1.4891

Table 2B-1-2. Pre-Development South Surface Water Pond Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
591.0	0.0847
591.5	0.0961
592.0	0.1079
592.5	0.1200
593.0	0.1327
593.5	0.1458
594.0	0.1592
594.5	0.1731
595.0	0.1874
595.5	0.2021
596.0	0.2172
596.5	0.2327
597.0	0.2485
597.5	0.2648
598.0	0.2813
598.5	0.2981
599.0	0.3153
599.5	0.3328
600.0	0.3507

Table 2B-1-3. Pre-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PreDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PreDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PreDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 10:29:31 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
AO-1	0.01045	41.8	01Jan2019, 11:57	3.87
AO-10	0.00055	2.2	01Jan2019, 11:57	3.87
AO-11	0.00114	4.6	01Jan2019, 11:57	3.87
AO-12	0.00133	5.3	01Jan2019, 11:57	3.87
AO-13	0.01602	59.9	01Jan2019, 11:59	3.87
AO-2	0.00483	19.4	01Jan2019, 11:57	3.87
AO-3	0.00306	12.3	01Jan2019, 11:57	3.87
AO-4	0.00272	10.9	01Jan2019, 11:57	3.87
AO-5	0.00250	10.0	01Jan2019, 11:57	3.87
AO-6	0.00017	0.7	01Jan2019, 11:57	3.87
AO-7	0.00072	2.9	01Jan2019, 11:57	3.87
AO-8	0.00216	8.7	01Jan2019, 11:57	3.87
AO-9	0.00027	1.1	01Jan2019, 11:57	3.87
A-1	0.00880	42.7	01Jan2019, 11:59	5.42
A-2	0.00377	20.2	01Jan2019, 11:57	5.42
A-3	0.00330	17.7	01Jan2019, 11:57	5.42
A-4	0.00703	37.6	01Jan2019, 11:57	5.42
A-5	0.00453	24.3	01Jan2019, 11:57	5.42
A-8	0.00238	12.7	01Jan2019, 11:57	5.42
B-1	0.00345	16.8	01Jan2019, 11:59	5.42
B-2	0.00105	5.6	01Jan2019, 11:57	5.42
B-3	0.00291	15.6	01Jan2019, 11:57	5.42
B-4	0.00353	18.9	01Jan2019, 11:57	5.42
B-5	0.00353	18.9	01Jan2019, 11:57	5.42
Channel AO	0.02735	103.6	01Jan2019, 12:00	3.86
Channel A.1	0.04313	202.1	01Jan2019, 11:58	4.75
Channel A.2	0.11168	438.2	01Jan2019, 12:02	4.78
Channel North 1	0.01517	65.8	01Jan2019, 11:58	4.35
Channel North 2	0.04492	215.2	01Jan2019, 11:59	4.98
Channel North 3	0.07893	359.7	01Jan2019, 12:00	4.86
CO-1	0.00472	17.3	01Jan2019, 11:59	3.87
CO-2	0.01319	45.8	01Jan2019, 12:01	3.87
CO-3	0.01038	49.0	01Jan2019, 11:59	5.08
CO-4	0.00895	34.9	01Jan2019, 11:58	3.87
CO-5	0.00147	5.9	01Jan2019, 11:57	3.87
C-1	0.00417	21.4	01Jan2019, 11:58	5.42
C-2	0.00205	11.0	01Jan2019, 11:57	5.42
C-3	0.00358	19.2	01Jan2019, 11:57	5.42
C-4	0.00189	10.1	01Jan2019, 11:57	5.42
C-5	0.00273	14.6	01Jan2019, 11:57	5.42
C-6	0.00120	6.4	01Jan2019, 11:57	5.42
C-7	0.00217	11.6	01Jan2019, 11:57	5.42
Downchute A	0.02743	139.5	01Jan2019, 11:58	5.42
Downchute AO	0.00667	26.7	01Jan2019, 11:57	3.87
Downchute B	0.01447	74.6	01Jan2019, 11:57	5.42
Downchute C	0.01779	94.0	01Jan2019, 11:57	5.42

Table 2B-1-3 (continued). Pre-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PreDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PreDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PreDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 10:29:31 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Downchute A	0.02743	139.5	01Jan2019, 11:58	5.42
Downchute AO	0.00667	26.7	01Jan2019, 11:57	3.87
Downchute B	0.01447	74.6	01Jan2019, 11:57	5.42
Downchute C	0.01779	94.0	01Jan2019, 11:57	5.42
Downchute D	0.00822	44.0	01Jan2019, 11:57	5.42
Downchute E	0.01144	61.2	01Jan2019, 11:57	5.41
DO-1	0.00272	9.9	01Jan2019, 12:00	3.87
Drop North	0.02895	154.2	01Jan2019, 11:57	5.41
Drop South	0.03882	199.8	01Jan2019, 11:57	5.42
D-1	0.00319	17.1	01Jan2019, 11:57	5.42
D-2	0.00211	11.3	01Jan2019, 11:57	5.42
D-3	0.00053	2.8	01Jan2019, 11:57	5.42
D-4	0.00181	9.7	01Jan2019, 11:57	5.42
D-5	0.00058	3.1	01Jan2019, 11:57	5.42
E-1	0.00086	4.6	01Jan2019, 11:57	5.42
E-2	0.00327	17.5	01Jan2019, 11:57	5.42
E-3	0.00320	17.1	01Jan2019, 11:57	5.42
E-4	0.00411	22.0	01Jan2019, 11:57	5.42
F-1	0.00173	9.3	01Jan2019, 11:57	5.42
F-2	0.00836	44.8	01Jan2019, 11:57	5.42
F-3	0.01139	60.5	01Jan2019, 11:57	5.42
G-1	0.00475	25.4	01Jan2019, 11:57	5.42
G-2	0.00230	12.3	01Jan2019, 11:57	5.42
G-3	0.00195	10.4	01Jan2019, 11:57	5.42
H-1	0.00503	26.9	01Jan2019, 11:57	5.42
H-2	0.00339	18.1	01Jan2019, 11:57	5.42
H-3	0.00909	48.7	01Jan2019, 11:57	5.42
J_A	0.11168	440.5	01Jan2019, 12:01	4.78
J_AO	0.02735	104.2	01Jan2019, 11:58	3.87
J_B	0.02456	128.6	01Jan2019, 11:57	5.42
J_C.1	0.04492	215.4	01Jan2019, 11:58	4.98
J_C.2	0.07893	361.1	01Jan2019, 11:59	4.86
J_D	0.05006	156.9	01Jan2019, 12:03	3.87
J_E	0.01986	106.3	01Jan2019, 11:57	5.41
J_F	0.03882	199.8	01Jan2019, 11:57	5.42
J_H	0.02895	154.3	01Jan2019, 11:57	5.41
Midpoint Site Outfall	0.14957	515.4	01Jan2019, 12:02	4.55
MSE North	0.01986	105.7	01Jan2019, 11:58	5.41
North Pond	0.12405	268.6	01Jan2019, 12:08	4.86
OC-11	0.00027	1.4	01Jan2019, 11:57	5.42
OC-20	0.00966	45.3	01Jan2019, 11:59	5.08
OC-21	0.01145	40.7	01Jan2019, 12:00	3.87
OD-1	0.03789	94.7	01Jan2019, 12:08	3.87
OD-2	0.04734	148.2	01Jan2019, 12:03	3.87
Overall Site Outfall	0.32368	802.6	01Jan2019, 12:05	4.56
South Pond	0.04313	168.0	01Jan2019, 12:02	4.75

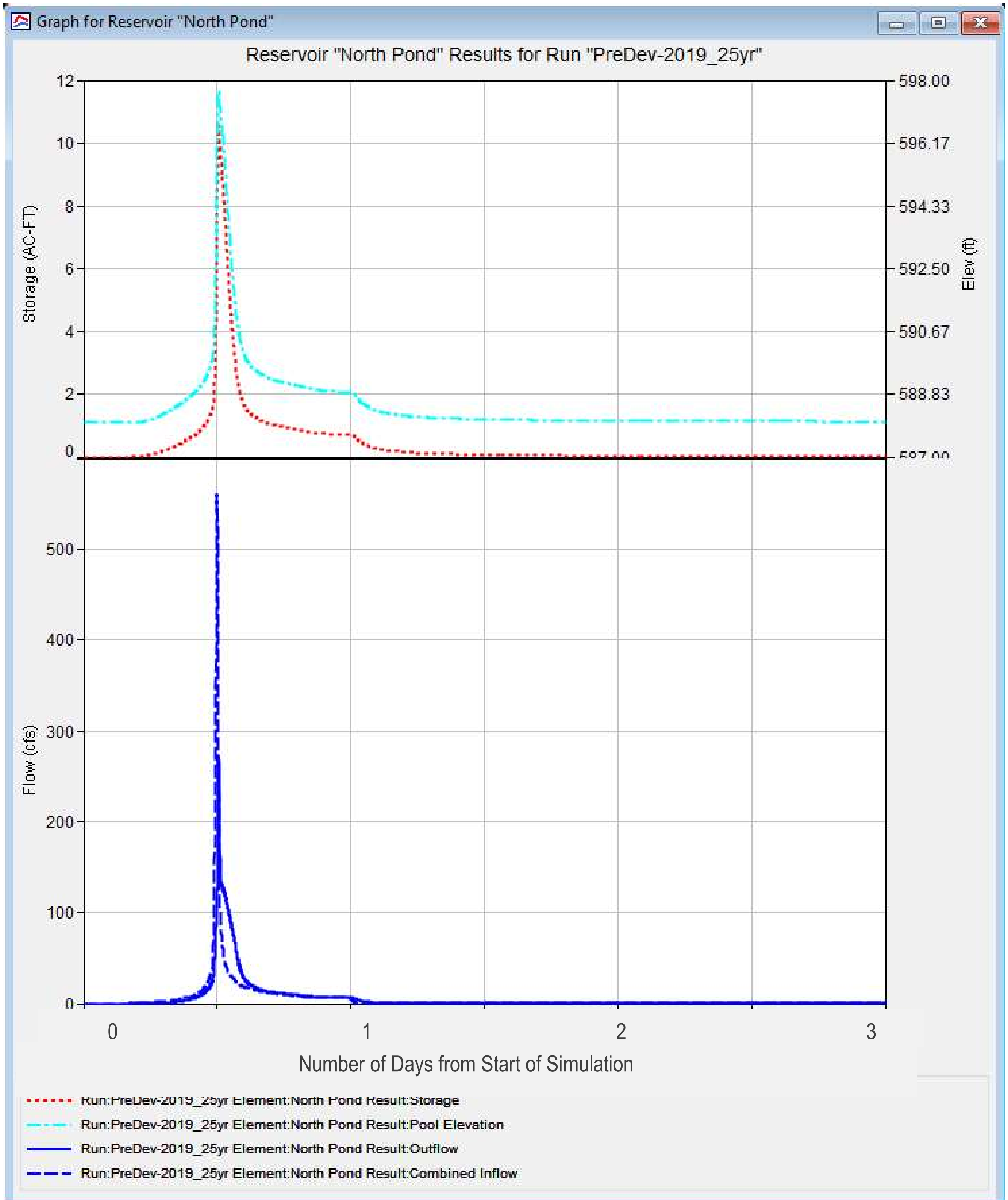

Figure 2B-1-1. Pre-Development 25-year, 24-hour Precipitation Event Permitted North Surface Water Pond Hydrograph and Elevation/Storage Relationships

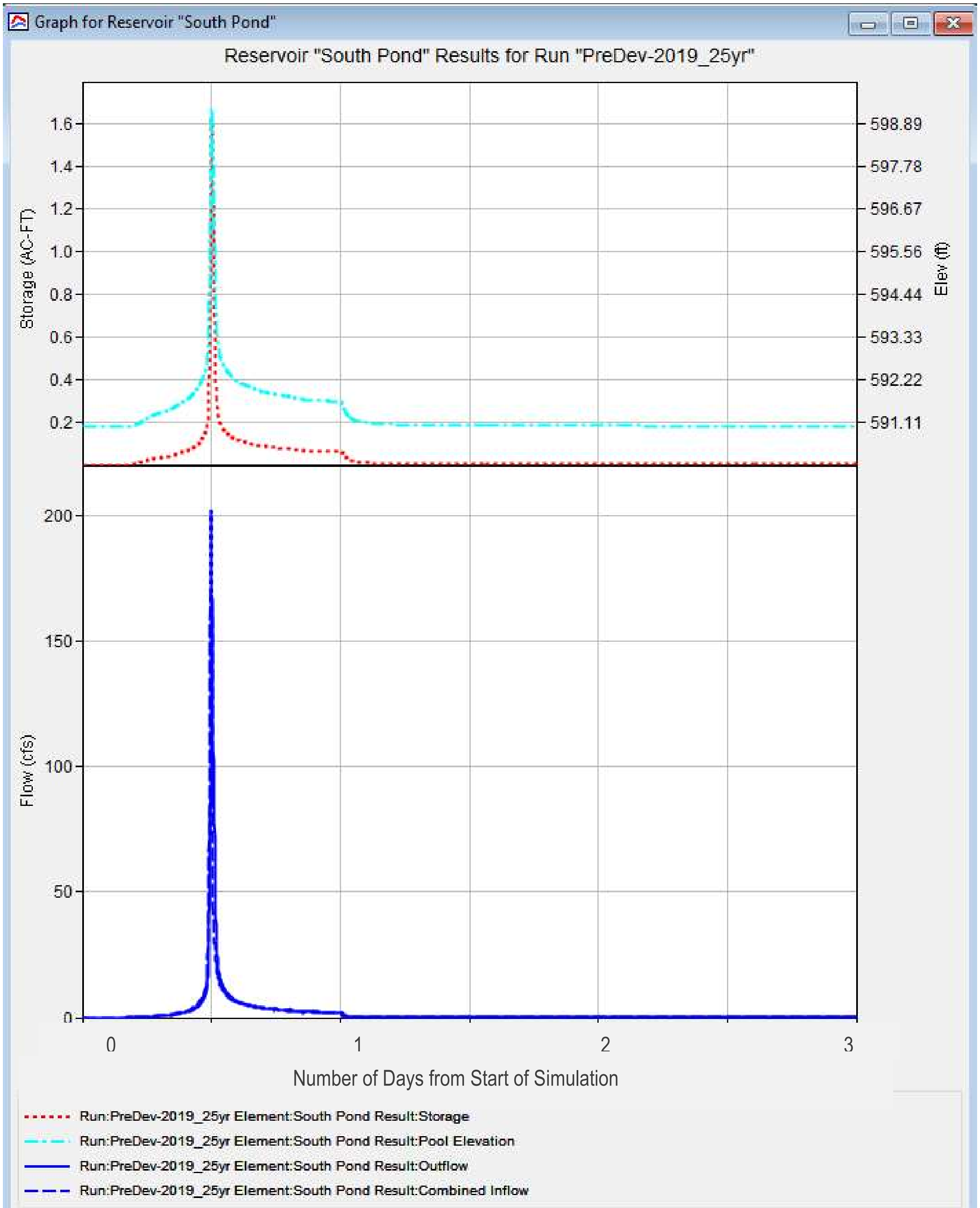

Figure 2B-1-2. Pre-Development 25-year, 24-hour Precipitation Event Permitted South Surface Water Pond Hydrograph and Elevation/Storage Relationships

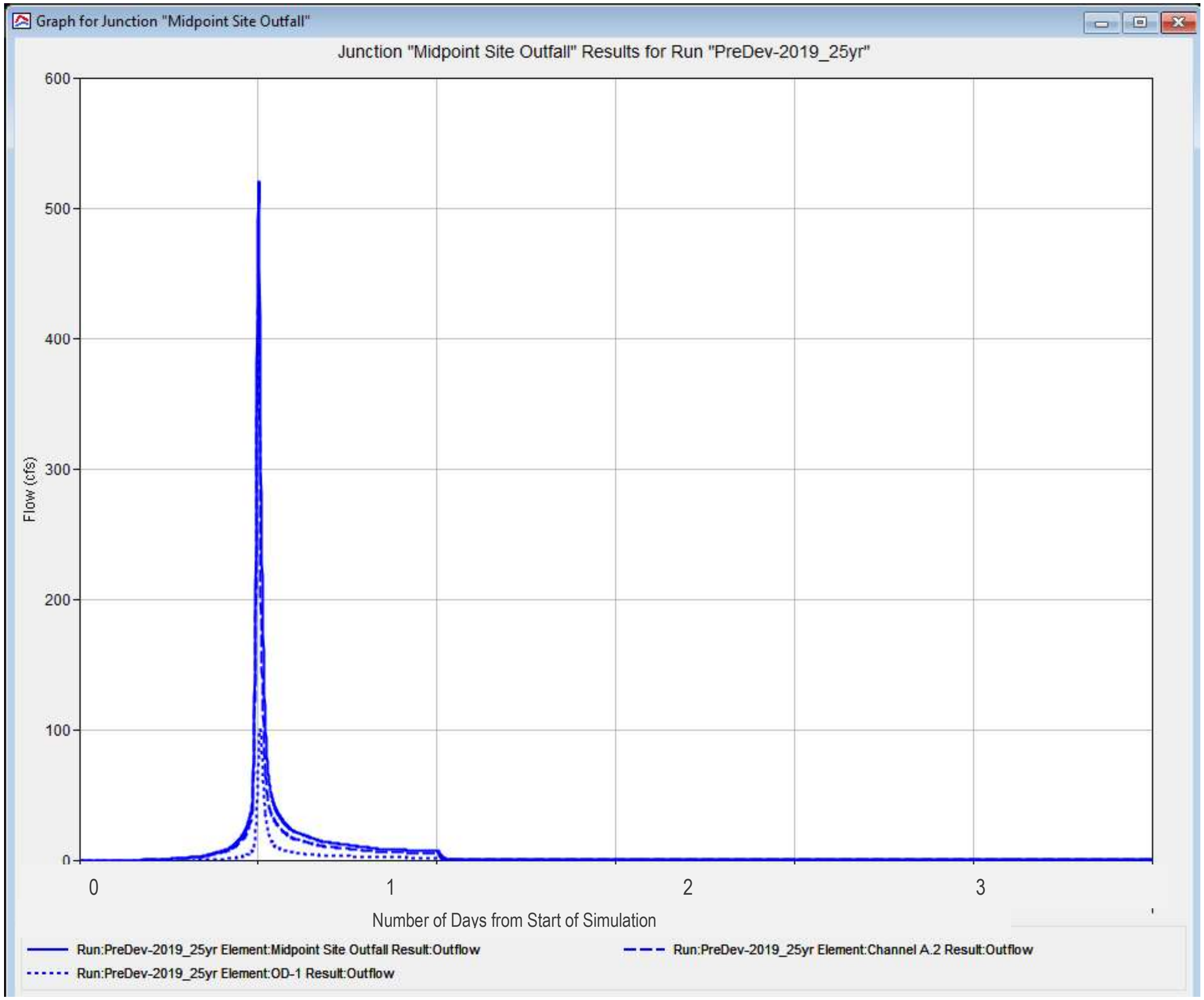

Figure 2B-1-3. Pre-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Midpoint Site Outfall

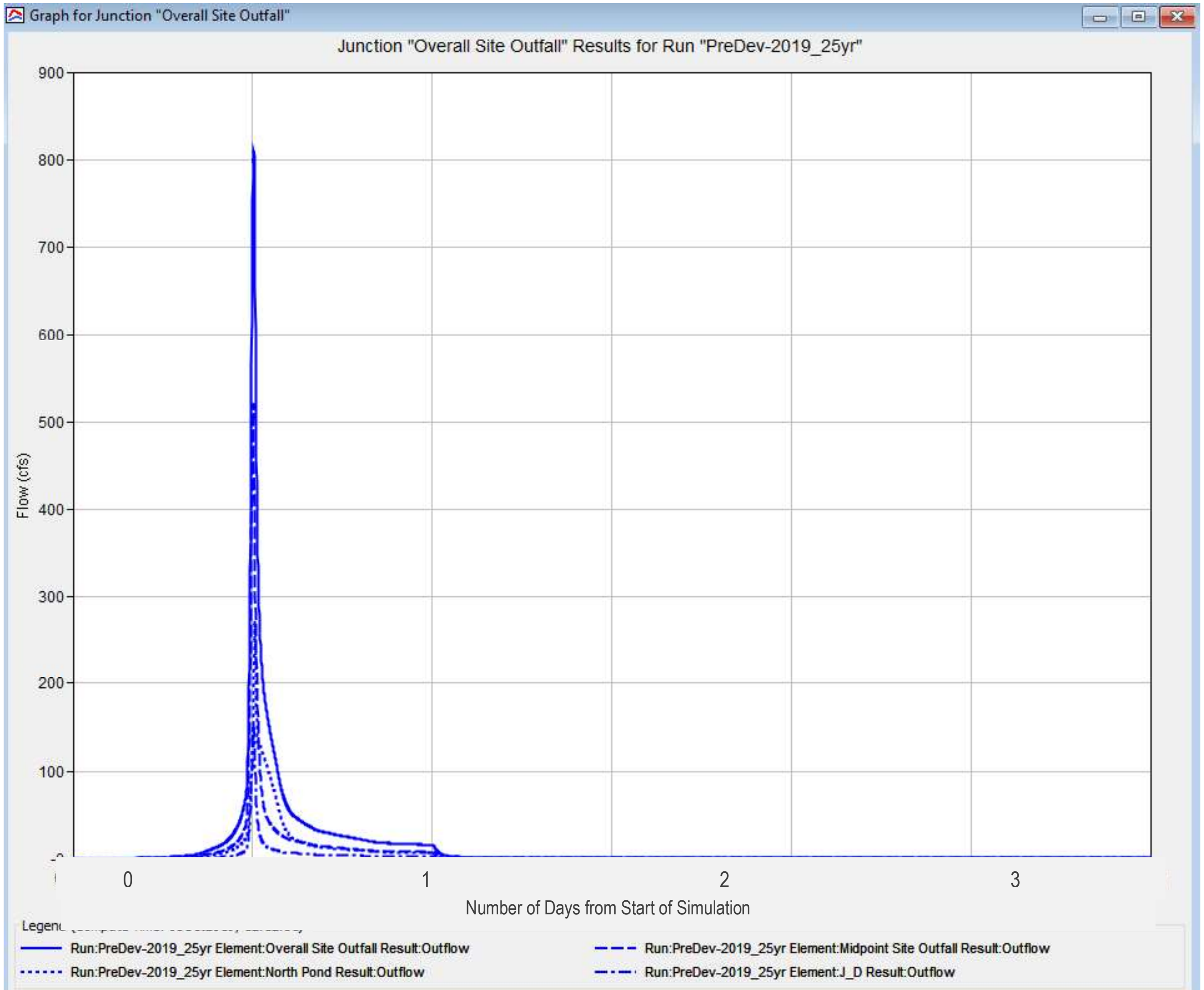

Figure 2B-1-4. Pre-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Overall Site Outfall

Table 2B-1-4a. Post-Development North Surface Water Pond Series 1 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
588.000	0.58107
589.000	0.67440
590.000	0.76805
591.000	0.86336
592.000	0.96296
593.000	1.06660
594.000	1.17050
595.000	1.27370
596.000	1.39090
597.000	1.48980
598.500	1.48980

Table 2B-1-4b. Post-Development North Surface Water Pond Series 2 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
597.000	0.0000000
598.000	0.0370574
599.000	0.1279600
600.000	0.1829600
601.000	0.2499000
602.000	0.3242600
603.000	0.3671600
604.200	0.4000000

Table 2B-1-4c. Post-Development North Surface Water Pond Series 3 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
603.000	0.0000000
604.000	0.0097720
605.000	0.0612539
606.000	0.1220700
607.000	0.1855800
608.000	0.2432300
609.000	0.2940500
610.000	0.3486000
611.000	0.4074200
612.000	0.4525400
613.000	0.4970200
614.200	0.5300000

Table 2B-1-4d. Post-Development North Surface Water Pond Series 4 Elevation-Area Relationship

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
613.000	0.0000000
615.000	0.0212961
616.000	0.0567124
617.000	0.0964187
618.000	0.1217600
619.000	0.1509500
620.000	0.1831400
621.000	0.2177300
622.000	0.2547100
623.000	0.2940900
624.000	0.3359000
625.000	0.3600000

Table 2B-1-5. Post-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PostDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PostDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PostDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 09:07:20 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
AO-13	0.0106400	39.8	01Jan2019, 11:59	3.87
A-1	0.0137800	66.2	01Jan2019, 12:00	5.42
A-2	.00039063	2.1	01Jan2019, 11:57	5.42
A-3	0.0019100	10.2	01Jan2019, 11:57	5.42
A-4	0.0026719	14.3	01Jan2019, 11:57	5.42
A-5	0.0044500	23.8	01Jan2019, 11:57	5.42
A-6	0.0038906	20.8	01Jan2019, 11:57	5.42
A-7	0.0064100	34.3	01Jan2019, 11:57	5.42
B-1	0.0038600	19.6	01Jan2019, 11:58	5.42
B-2	0.0034500	18.5	01Jan2019, 11:57	5.42
B-3	0.0047500	25.4	01Jan2019, 11:57	5.42
B-4	0.0061600	33.0	01Jan2019, 11:57	5.42
Channel A	0.0918631	446.9	01Jan2019, 12:00	5.23
CO-1	0.0047200	17.3	01Jan2019, 11:59	3.87
CO-2	0.0075800	26.7	01Jan2019, 12:00	3.87
CO-4	0.0089500	34.9	01Jan2019, 11:58	3.87
CO-5	0.0014700	5.9	01Jan2019, 11:57	3.87
C-1	0.0121400	61.9	01Jan2019, 11:58	5.42
C-2	0.0072200	36.1	01Jan2019, 11:59	5.42
C-3	0.0026700	14.3	01Jan2019, 11:57	5.42
C-4	0.0049400	26.4	01Jan2019, 11:57	5.42
C-5	0.0035500	19.0	01Jan2019, 11:57	5.42
Downchute A	0.0335031	167.7	01Jan2019, 11:58	5.42
Downchute B	0.0182200	96.0	01Jan2019, 11:57	5.42
Downchute C	0.0305200	156.2	01Jan2019, 11:58	5.42
Downchute D	0.0143062	76.6	01Jan2019, 11:57	5.42
Downchute E	0.0249231	133.4	01Jan2019, 11:57	5.41
DO-1	0.0027200	9.9	01Jan2019, 12:00	3.87
D-1	.00059	3.2	01Jan2019, 11:57	5.42
D-2	0.0012000	6.4	01Jan2019, 11:57	5.42
D-3	0.0011100	5.9	01Jan2019, 11:57	5.42
D-4	0.0081563	43.7	01Jan2019, 11:57	5.42
D-5	0.0013600	7.3	01Jan2019, 11:57	5.42
D-6	0.0018900	10.1	01Jan2019, 11:57	5.42
E-1	0.0029200	15.6	01Jan2019, 11:57	5.42
E-2	0.0089219	47.8	01Jan2019, 11:57	5.42
E-3	0.0033000	17.7	01Jan2019, 11:57	5.42
E-4	0.0097813	52.4	01Jan2019, 11:57	5.42
F-1	0.0032300	17.3	01Jan2019, 11:57	5.42
F-2	0.0011900	6.4	01Jan2019, 11:57	5.42
F-3	0.0015600	8.4	01Jan2019, 11:57	5.42
F-4	0.0026900	14.4	01Jan2019, 11:57	5.42
F-5	0.0024200	13.0	01Jan2019, 11:57	5.42
F-6	0.0083600	44.8	01Jan2019, 11:57	5.42
G-1	0.0057500	30.8	01Jan2019, 11:57	5.42
G-2	0.0079700	42.7	01Jan2019, 11:57	5.42

Table 2B-1-5 (continued). Post-Development 25-year, 24-hour Precipitation Event Nodal Areas, Peak Flow Rates, and Runoff Volumes

Global Summary Results for Run "PostDev-2019_25yr"

Project: FtWorth_Expansion_191213 Simulation Run: PostDev-2019_25yr

Start of Run: 01Jan2019, 00:00 Basin Model: PostDev-2019
End of Run: 04Jan2019, 00:00 Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Jan2020, 09:07:20 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN / AC-FT Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
F-1	0.0032300	17.3	01Jan2019, 11:57	5.42
F-2	0.0011900	6.4	01Jan2019, 11:57	5.42
F-3	0.0015600	8.4	01Jan2019, 11:57	5.42
F-4	0.0026900	14.4	01Jan2019, 11:57	5.42
F-5	0.0024200	13.0	01Jan2019, 11:57	5.42
F-6	0.0083600	44.8	01Jan2019, 11:57	5.42
G-1	0.0057500	30.8	01Jan2019, 11:57	5.42
G-2	0.0079700	42.7	01Jan2019, 11:57	5.42
G-3	0.0011900	6.4	01Jan2019, 11:57	5.42
G-4	0.0016300	8.7	01Jan2019, 11:57	5.42
G-5	.00041	2.2	01Jan2019, 11:57	5.42
G-6	0.0014700	7.9	01Jan2019, 11:57	5.42
G-7	0.0034800	18.6	01Jan2019, 11:57	5.42
J_A1	0.0067300	36.0	01Jan2019, 11:57	5.42
J_A2	0.0409400	197.2	01Jan2019, 11:58	5.01
J_A3	0.0451900	218.1	01Jan2019, 11:58	5.05
J_A4	0.0451900	217.7	01Jan2019, 11:59	5.05
J_A5	0.0835031	406.0	01Jan2019, 11:59	5.22
J_B	0.0057500	30.8	01Jan2019, 11:57	5.42
J_C1	0.0558500	275.6	01Jan2019, 11:57	5.13
J_C2	0.0558500	275.6	01Jan2019, 11:58	5.12
J_C3	0.10014	466.8	01Jan2019, 11:59	5.01
J_Mid	0.0918631	447.4	01Jan2019, 11:59	5.23
Midpoint Site Outfall	0.13049	515.4	01Jan2019, 12:01	4.83
OA-1	0.0035000	18.7	01Jan2019, 11:57	5.42
OA-2	0.0041600	22.1	01Jan2019, 11:57	5.42
OA-3	0.0023900	12.8	01Jan2019, 11:57	5.42
OC-1	0.0164400	71.8	01Jan2019, 12:01	5.08
OC-2	0.0119100	42.3	01Jan2019, 12:00	3.87
OD-1	0.0386300	96.6	01Jan2019, 12:08	3.87
OD-2	0.0477500	149.5	01Jan2019, 12:03	3.87
Overall Site Outfall	0.32368	797.1	01Jan2019, 12:01	4.75
Peri A1	0.0067300	36.0	01Jan2019, 12:00	5.42
Peri A2	0.0409400	196.1	01Jan2019, 11:59	5.01
Peri A3	0.0451900	217.7	01Jan2019, 11:59	5.05
Peri A4	0.0451900	216.9	01Jan2019, 11:59	5.05
Peri A5	0.0835031	405.9	01Jan2019, 11:59	5.22
Peri B1	0.0057500	30.8	01Jan2019, 11:58	5.41
Peri C1	0.0558500	275.6	01Jan2019, 11:58	5.12
Peri C2	0.0558500	275.2	01Jan2019, 11:59	5.12
Peri C3	0.10014	465.1	01Jan2019, 11:59	5.01
Peri C4	0.13924	358.6	01Jan2019, 12:14	4.99
Series 1_North Pond	0.13924	360.3	01Jan2019, 12:13	4.99
Series 2_North Pond	0.13305	467.4	01Jan2019, 12:02	5.03
Series 3_North Pond	0.10055	369.4	01Jan2019, 12:07	5.02
Series 4_North Pond	0.10014	412.8	01Jan2019, 12:03	5.02

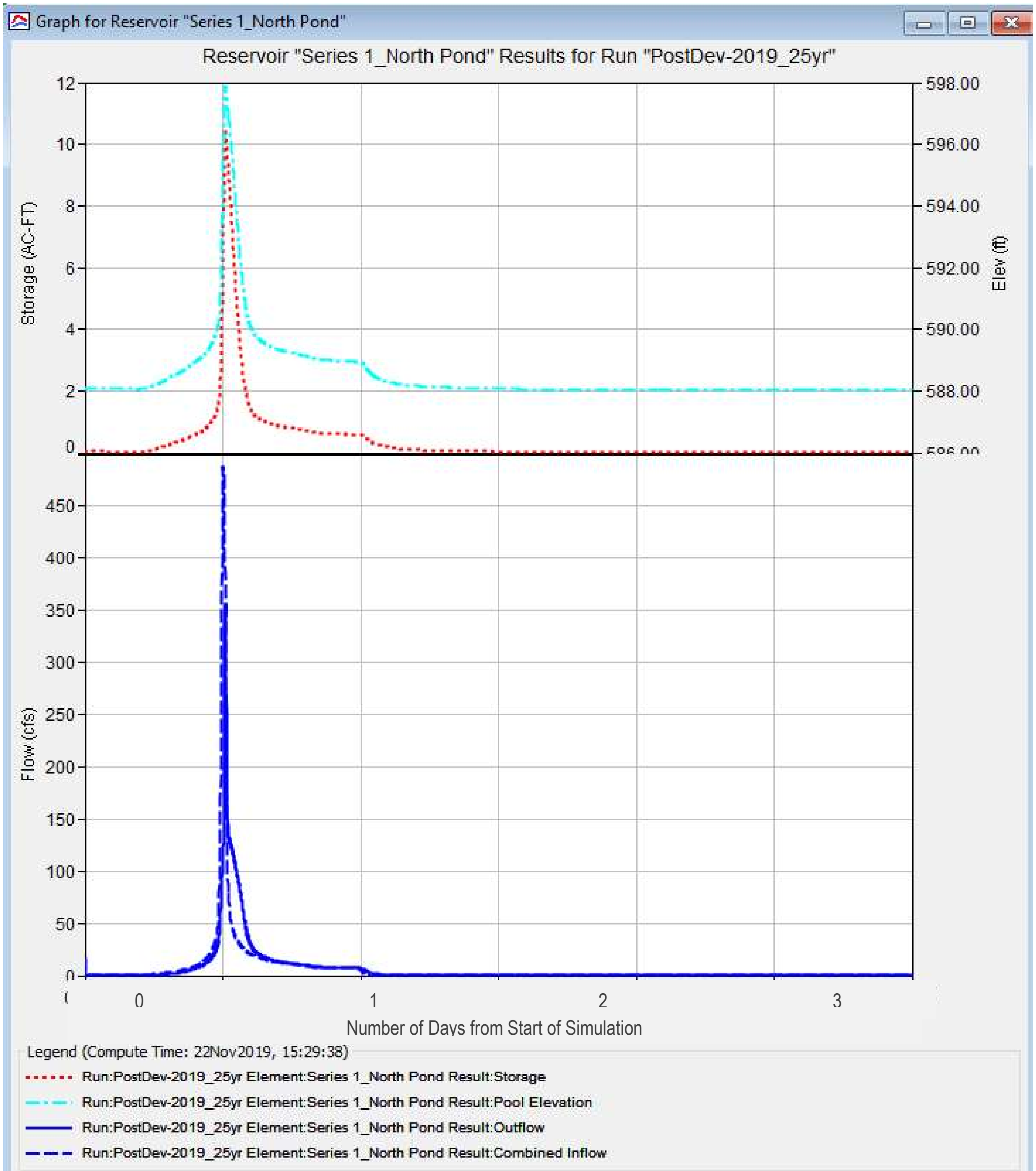

Figure 2B-1-5a. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 1 Hydrograph and Elevation/Storage Relationships

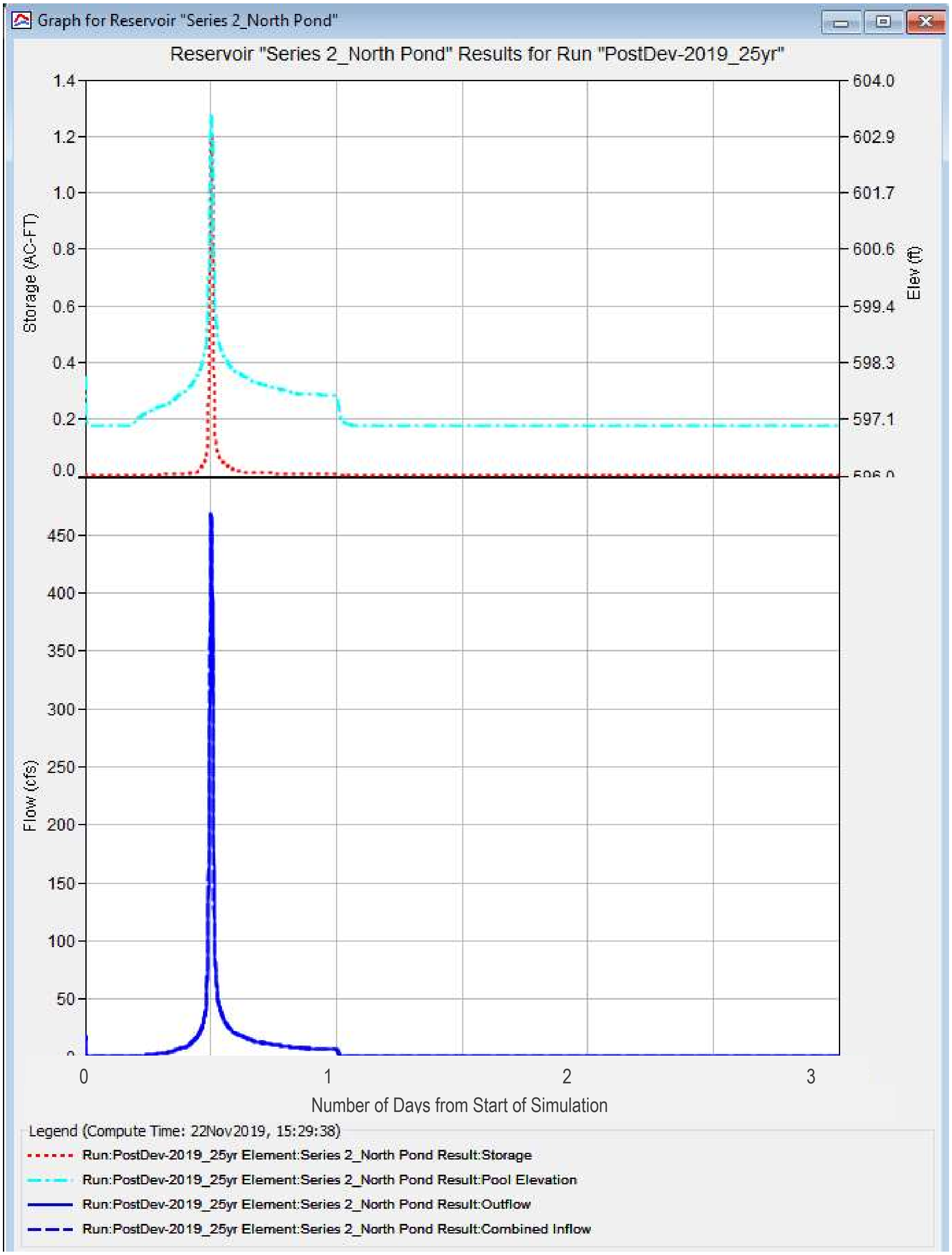

Figure 2B-1-5b. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 2 Hydrograph and Elevation/Storage Relationships

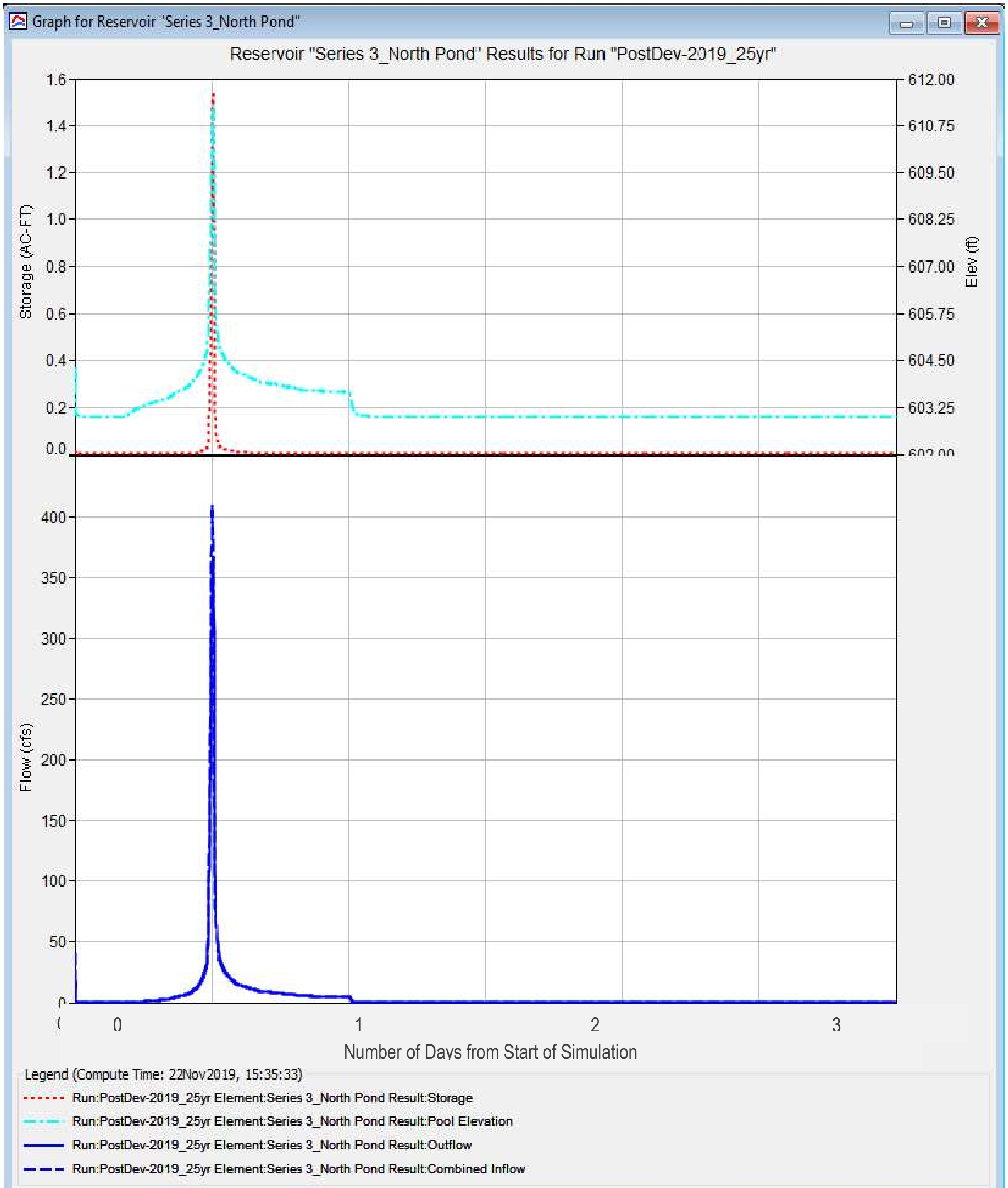

Figure 2B-1-5c. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 3 Hydrograph and Elevation/Storage Relationships

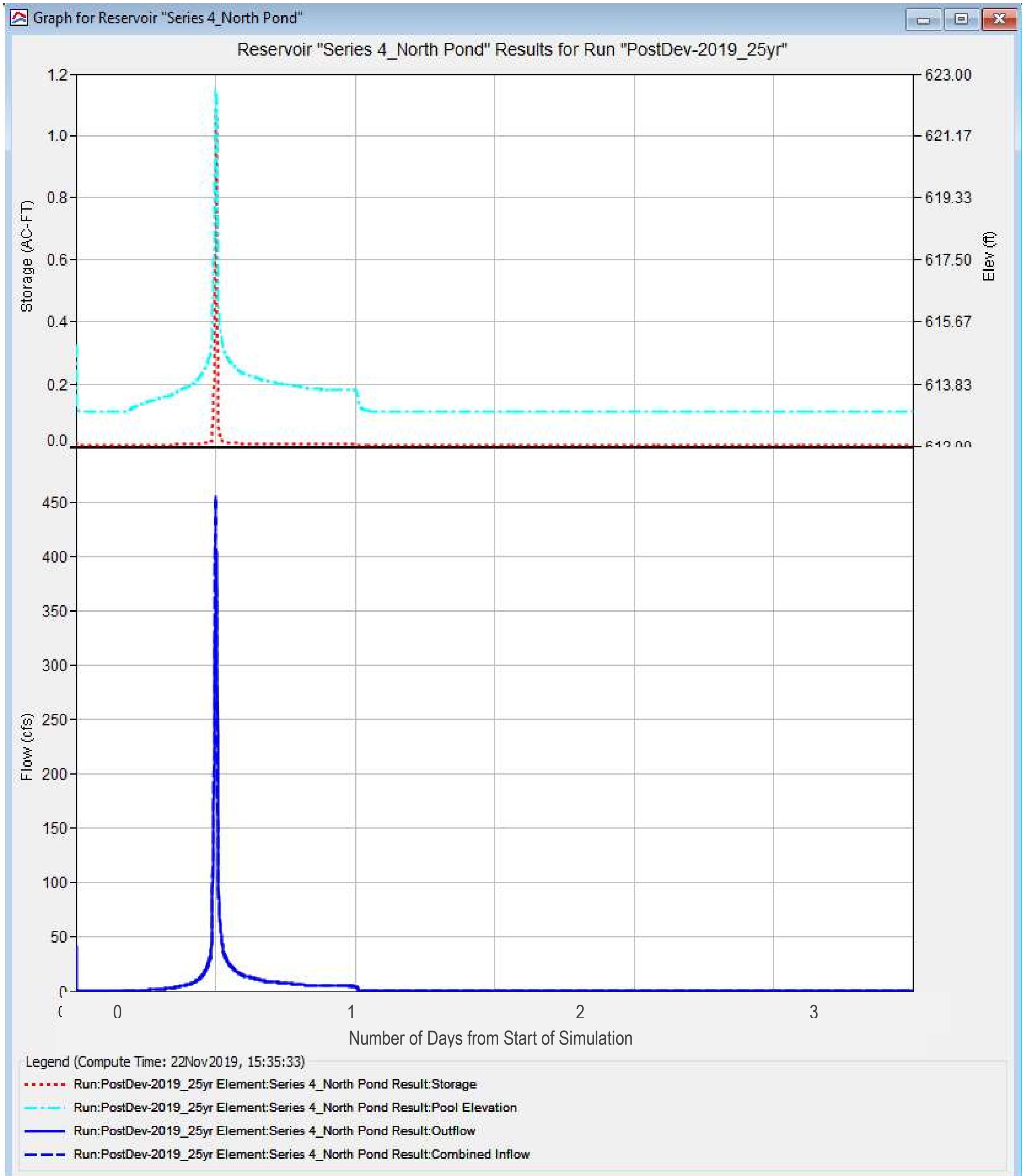

Figure 2B-1-5d. Post-Development 24-year, 24-hour Precipitation Event North Surface Water Pond Series 4 Hydrograph and Elevation/Storage Relationships

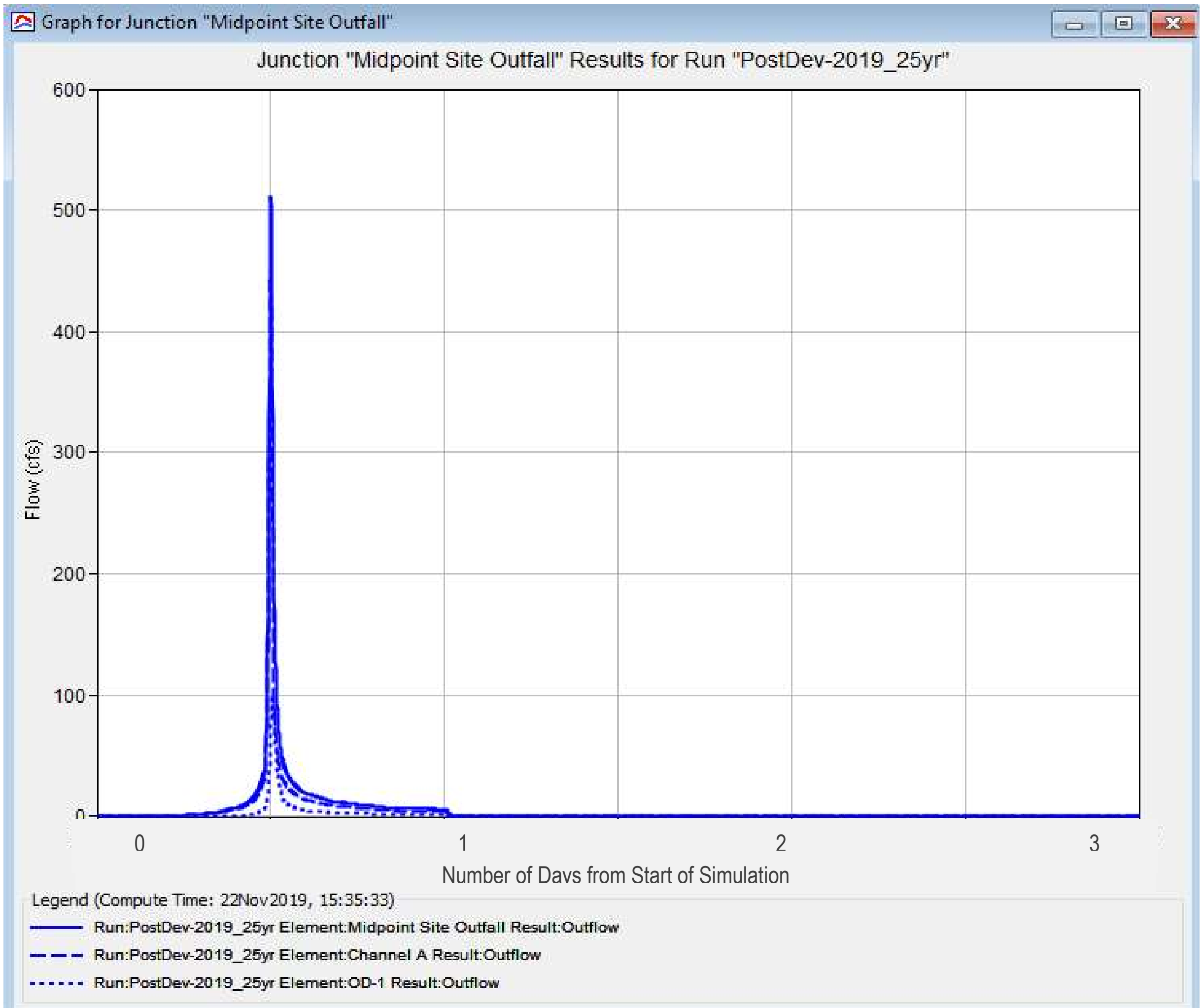

Figure 2B-1-6. Post-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Midpoint Site Outfall

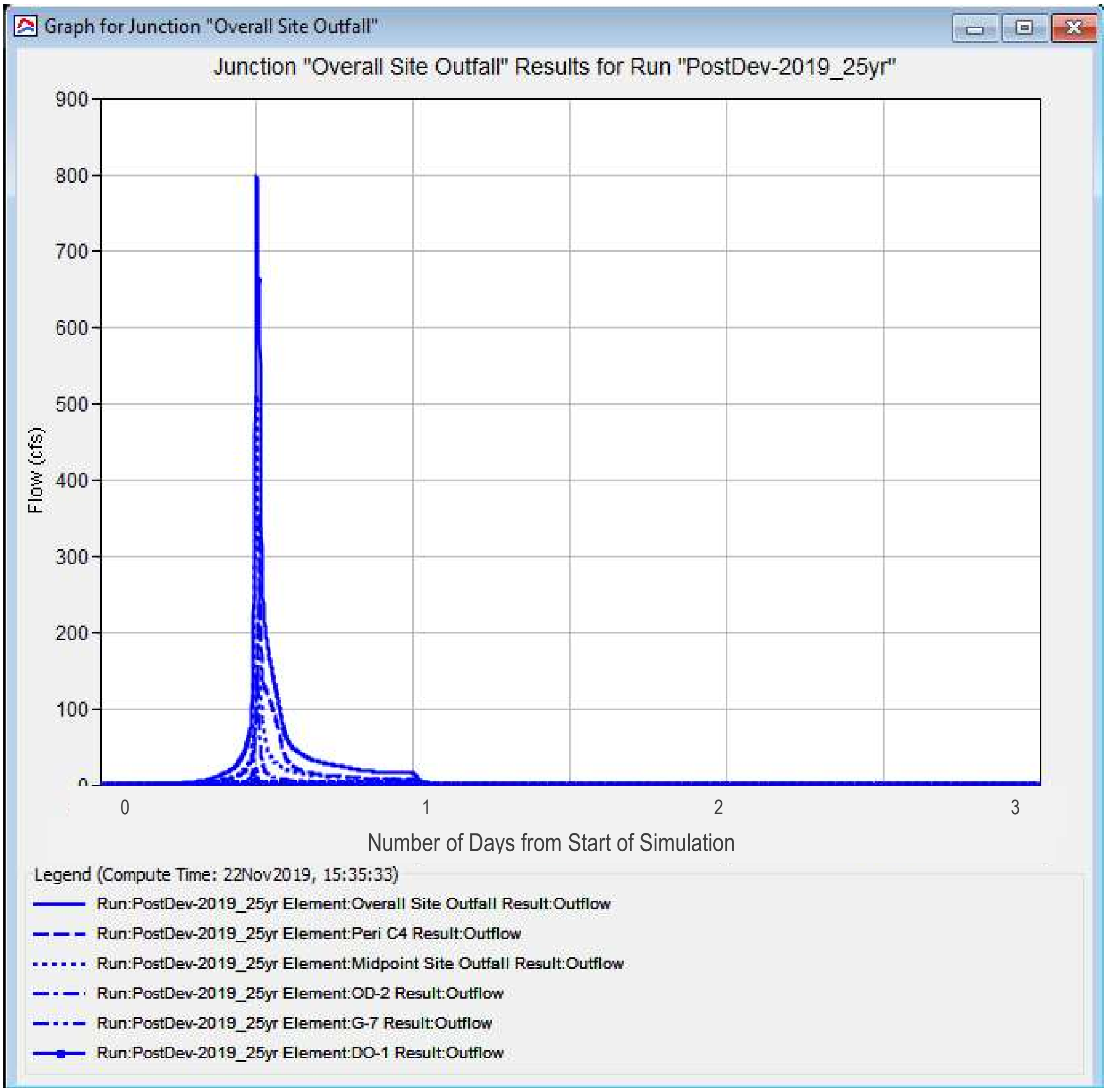

Figure 2B-1-7. Post-Development 25-year, 24-hour Precipitation Event Runoff Hydrograph at Overall Site Outfall

HEC-HMS PRE-DEVELOPMENT HYDROLOGIC MODEL INPUT PARAMETERS

Pre-Development HEC-HMS Basin Input Parameters for Kinematic Wave Model

PRE-DEVELOPMENT CONDITIONS			Watershed Characterization			Sheet Flow				Shallow Concentrated Flow					Open Channel Flow												
Subcatchment Designation	Area A (mi²)	Area A (acres)	Initial Abstraction (in)	Curve Number	Impervious Cover (%)	Flow Length (ft)	Manning's n	Slope (ft/ft)	Time T_t (min)	Flow Length (ft)	Velocity Factor (ft/s)	Slope (ft/ft)	Average Velocity (ft/s)	Time T_t (min)	Flow Length (ft)	Depth d (ft)	Area A (ft²)	Wetted P (ft)	Hydraulic Radius (ft)	Manning's n	Slope (ft/ft)	Velocity (ft/s)	Time T_t (min)	Design T_c (min)	SCS Lag Time (min)	HMS 25-yr Flow (cfs)	HMS 100-yr Flow (cfs)
A-1	0.00880	5.63	0.35	85	0.00	100	0.15	0.050	6.15	400	7.00	0.050	1.57	4.26								0.00	0.00	10.41	6.25	42.70	57.60
A-2	0.00377	2.41	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	900	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.00	6.00	3.60	20.20	27.20
A-3	0.00330	2.11	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	17.70	23.80
A-4	0.00703	4.5	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	1150	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.56	6.00	3.60	37.60	50.80
A-5	0.00453	2.9	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	800	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.78	6.00	3.60	24.30	32.70
A-8	0.00238	1.52	0.35	85	0.00	75	0.15	0.133	3.30						800	3.0	51.00	25.56	1.99	0.027	0.020	12.37	1.08	6.00	3.60	12.70	17.20
B-1	0.00345	2.21	0.35	85	0.00	100	0.15	0.050	6.15	350	7.00	0.050	1.57	3.73	150	1.0	11.50	23.19	0.50	0.027	0.020	4.89	0.51	10.39	6.23	16.80	22.70
B-2	0.00105	0.67	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	5.60	7.60
B-3	0.00291	1.86	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	15.60	21.00
B-4	0.00353	2.26	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	850	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.89	6.00	3.60	18.90	25.50
B-5	0.00353	2.26	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	18.90	25.50
C-1	0.00417	2.67	0.35	85	0.00	100	0.15	0.050	6.15	180	7.00	0.050	1.57	1.92								0.00	0.00	8.07	4.84	21.40	28.80
C-2	0.00205	1.31	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	150	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.33	6.00	3.60	11.00	14.80
C-3	0.00358	2.29	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	200	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.45	6.00	3.60	19.20	25.90
C-4	0.00189	1.21	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	400	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.89	6.00	3.60	10.10	13.70
C-5	0.00273	1.75	0.35	85	0.00	100	0.15	0.333	2.88	25	7.00	0.333	4.04	0.10	450	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.00	6.00	3.60	14.60	19.70
C-6	0.00120	0.77	0.35	85	0.00	100	0.15	0.333	2.88						350	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.78	6.00	3.60	6.40	8.70
C-7	0.00217	1.39	0.35	85	0.00	100	0.15	0.333	2.88						500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	11.60	15.70
D-1	0.00319	2.04	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.67	6.00	3.60	17.10	23.00
D-2	0.00211	1.35	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.67	6.00	3.60	11.30	15.20
D-3	0.00053	0.34	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	100	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.22	6.00	3.60	2.80	3.80
D-4	0.00181	1.16	0.35	85	0.00	100	0.15	0.333	2.88	30	7.00	0.333	4.04	0.12	300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.67	6.00	3.60	9.70	13.10
D-5	0.00058	0.37	0.35	85	0.00	100	0.15	0.333	2.88	30	7.00	0.333	4.04	0.12	100	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.22	6.00	3.60	3.10	4.20
E-1	0.00086	0.55	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	250	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.56	6.00	3.60	4.60	6.20
E-2	0.00327	2.09	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16	650	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.45	6.00	3.60	17.50	23.60
E-3	0.00320	2.05	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	750	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.67	6.00	3.60	17.10	23.10
E-4	0.00411	2.63	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	600	2.0	11.00	11.71	0.94	0.027	0.020	7.39	1.35	6.00	3.60	22.00	29.70
F-1	0.00173	1.11	0.35	85	0.00	80	0.15	0.333	2.41						350	3.0	36.00	20.56	1.75	0.027	0.010	8.02	0.73	6.00	3.60	9.30	12.50
F-2	0.00836	5.35	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	800	3.0	36.00	20.56	1.75	0.027	0.010	8.02	1.66	6.00	3.60	44.80	60.40
F-3	0.01139	7.29	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	1550	3.0	36.00	20.56	1.75	0.027	0.010	8.02	3.22	6.52	3.91	60.50	81.50
G-1	0.00475	3.04	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	600	3.0	27.00	18.97	1.42	0.027	0.010	6.98	1.43	6.00	3.60	25.40	34.30
G-2	0.00230	1.47	0.35	85	0.00	80	0.15	0.333	2.41						600	3.5	64.75	28.49	2.27	0.027	0.010	9.54	1.05	6.00	3.60	12.30	16.60
G-3	0.00195	1.25	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16	400	3.5	64.75	28.49	2.27	0.027	0.010	9.54	0.70	6.00	3.60	10.40	14.10
H-1	0.00503	3.22	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	600	3.0	36.00	20.56	1.75	0.027	0.010	8.02	1.25	6.00	3.60	26.90	36.30
H-2	0.00339	2.17	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41	500	3.0	36.00	20.56	1.75	0.027	0.010	8.02	1.04	6.00	3.60	18.10	24.50
H-3	0.00909	5.82	0.35	85	0.00	100	0.15	0.333	2.88	150	7.00	0.333	4.04	0.62	1000	3.0	36.00	20.56	1.75	0.027	0.010	8.02	2.08	6.00	3.60	48.70	65.70
OD-1	0.03789	24.25	0.82	71	0.00	100	0.15	0.033	7.23	600	7.00	0.01	0.70	14.29	1000	2.0	40.00	40.20	1.00	0.027	0.006	4.26	3.91	25.43	15.26	94.70	139.60
OD-2	0.04734	30.3	0.82	71	0.00	100	0.15	0.033	7.23	475	7.00	0.02	1.03	7.66	900	6.0	444.00	99.48	4.46	0.027	0.007	12.21	1.23	16.12	9.67	148.20	217.30
AO-1	0.01045	6.69	0.82	71	0.00	100	0.15	0.167	3.80	200	7.00	0.040	1.40	2.38								0.00	0.00	6.18	3.71	41.80	61.00
AO-2	0.00483	3.09	0.82	71	0.00	100	0.15	0.333	2.88	150	7.00	0.040	1.40	1.79								0.00	0.00	6.00	3.60	19.40	28.30
AO-3	0.00306	1.96	0.82	71	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60	500	3.0	22.50	16.16	1.39	0.027	0.010	6.88	1.21	6.00	3.60	12.30	17.90
AO-4	0.00272	1.74	0.82	71	0.00	100	0.15	0.333	2.88						700	3.0	22.50	16.16	1.39	0.027	0.010	6.88	1.70	6.00	3.60	10.90	15.90
AO-5	0.00250	1.6	0.82	71	0.00	100	0.15	0.333	2.88						800	3.0	22.50	16.16	1.39	0.027	0.010	6.88	1.94	6.00	3.60	10.00	14.60
AO-6	0.00017	0.11	0.82	71	0.00	100	0.15	0.333	2.88													0.00	0.00	6.00	3.60	0.70	1.00
AO-7	0.00072	0.46	0.82	71	0.00	100	0.15	0.333	2.88						150	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.36	6.00	3.60	2.90	4.20
AO-8	0.00216	1.38	0.82	71	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60	150	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.36	6.00	3.60	8.70	12.70
AO-9	0.00027	0.17	0.82	71	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60	100	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.24	6.00	3.60	1.10	1.60
AO-10	0.00055	0.35	0.82	71	0.00	100	0.15	0.333	2.88						200	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.48	6.00	3.60	2.20	3.20
AO-11	0.00114	0.73	0.82	71	0.00	100	0.15	0.333	2.88						300	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.73	6.00	3.60	4.60	6.70
AO-12	0.00133	0.85	0.82	71	0.00	100	0.15	0.333	2.88						300	3.0	22.50	16.16	1.39	0.027	0.010	6.88	0.73	6.00	3.60	5.30	7.80
AO-13	0.01602	10.25	0.82	71	0.00	100	0.15	0.104	4.59	150	7.00	0.040	1.40	1.79	1100	3.0	22.50	16.16	1.39	0.027	0.010	6.88	2.66	9.04	5.42	59.90	87.50
CO-1	0.00472	3.02	0.82	71	0.00	100	0.15	0.087	4.34	400	7.00	0.040	1.40	4.76								0.00	0.00	9.70	5.82	17.30	25.40
CO-2	0.01319	8.44	0.82	71	0.00	100	0.15	0.100	4.66	650	7.00	0.044	1.48	7.34								0.00	0.00	12.00	7.20	45.80	66.30
CO-3	0.01038	6.64	0.44	82	0.00	100	0.15	0.050	6.15	350	7.00	0.064	1.77	3.29								0.00	0.00	9.45	5.67	49.00	67.10
CO-4	0.00895	5.73	0.82	71	0.00	100	0.15	0.160	3.86	200	7.00	0.040	1.40	2.38	500	3.0	46.50	24.16	1.93	0.027	0.010	8.54	0.98	7.22	4.33	34.90	50.90
CO-5	0.00147	0.94	0.82	71	0.00	50	0.15	0.160	2.22						700	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.37	6.00	3.60	5.90	8.60
OC-11	0.00027	0.17	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.040	1.40	0.60								0.00	0.00	6.00	3.60	1.40	2.00
OC-20	0.00966	6.18	0.44	82	0.00	100	0.15	0.053	6.00	200	7.00	0.040	1.40	2.38	700	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.37	9.74	5.85	45.30	62.00
OC-21	0.01145	7.33	0.82	71	0.00	100	0.15	0.040	6.73	200	7.00	0.040	1.40	2.38	1000	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.95	11.06	6.64	40.70	59.50
DO-1	0.00272	1.74	0.82	71	0.00	100	0.15	0.067	5.48	500	7.00	0.06667	1.81	4.61								0.00	0.00	10.09	6.06	9.90	14.50
		207.14																									

2-year, 24-hour Design Rainfall Depth = 3.90 inches

Bench Left Side Slope = 2.5 H:V
Bench Right Side Slope = 3.0 H:V

Notes:

1) *Curve number = 85 landfill final cover surface in accordance with TCEQ RG-417 guidance (TCEQ, 2018).*
2) *Curve number = 71 represents meadow with continuous grass for hydrologic soil group C (USDA, 1986).*
3) *Curve number = 82 represents farmsteads of buildings, lanes, driveways, and surrounding lots for hydrologic soil group C (USDA, 1986).*
4) *Manning's roughness coefficient: n = 0.15 represents short grass prairie for sheet flow (USDA, 1984).*
5) *Manning's roughness coefficient: n = 0.027 represents an excavated earth channel that is straight and uniform with short grass and few weeds (Chow, 1959).*
6) *Travel Time (T_t) is calculated using Manning's kinematic solutions for sheet flow (USDA, 1986).*

$$T_t = 0.007(nL)^{0.8} / (P_{2\text{-}24})^{0.5} S^{0.4}$$

7) *Velocity factor of 7.0 ft/s corresponds to short grass pasture from the Upland Method as reported by HydroCAD v.8 Owner's Manual.*
8) *Open channel flow velocity is calculated using Manning's equation (USDA, 1986).*

$$V = (1.49 r^{2/3} S^{1/2}) / n$$ *where: r = hydraulic radius (ft) and is equal to A/P [area (ft²)/wetted perimeter (ft)]*

9) *Design rainfall depth taken from NOAA Atlas 14, Volume 11, Version 2.*

Basin: PreDev-2019
Last Modified Date: 9 September 2019
Last Modified Time: 18:31:47
Version: 4.3
Filepath Separator: \
Unit System: English
Missing Flow To Zero: No
Enable Flow Ratio: No
Compute Local Flow At Junctions: No

Enable Sediment Routing: No

Enable Quality Routing: No
End:

Subbasin: B-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1662.3588258448644
Canvas Y: -471.9875563540154
Area: 0.00353
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 244.1077441077441
Canvas Y: -791.2457912457912
Area: 0.00353
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-1
Last Modified Date: 9 September 2019
Last Modified Time: 22:20:27
Canvas X: 294.61279461279446
Canvas Y: 286.1952861952859
Area: 0.00345
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 6.15
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 176.76767676767668
Canvas Y: -286.1952861952859
Label X: -2.0
Label Y: -1.0
Area: 0.00291
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1473.0639730639732
Canvas Y: -168.35016835016813
Area: 0.00105
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute B
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 715.4882154882152
Canvas Y: -1313.1313131313127
From Canvas X: 834.0466727105622
From Canvas Y: -408.14049818109606
Downstream: J_B

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 380
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -900.6734006734005
Canvas Y: -959.5959595959594
Area: 0.00836
Downstream: J_B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1944.4444444444443
Canvas Y: -1262.6262626262624
Area: 0.00173
Downstream: J_B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_B
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: 715.4882154882152
Canvas Y: -1313.1313131313127
Downstream: Channel A.1
End:

Subbasin: AO-1
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:37
Canvas X: 996.2663676564744
Canvas Y: -2531.711135770982
Area: 0.01045
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.71
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-2
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:36
Canvas X: 1731.322500553625
Canvas Y: -2439.829119158838
Area: 0.00483
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60

Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-12
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:43
Canvas X: -1978.4139201616827
Canvas Y: -1831.1107591033851
Area: 0.00133
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-11
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1364.709605095608
Canvas Y: -1430.8400124873501
Label X: -51.0
Label Y: -17.0
Area: 0.00114
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-10
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:40
Canvas X: -577.2131668264892
Canvas Y: -2095.2715568632984
Label X: -52.0
Label Y: -5.0
Area: 0.00055
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-9
Last Modified Date: 26 December 2019
Last Modified Time: 17:19:39
Canvas X: 123.38720984110842
Canvas Y: -2141.2125651693705
Area: 0.00027
Downstream: Channel A.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Channel A.1
Last Modified Date: 3 October 2019
Last Modified Time: 17:10:17
Canvas X: -3142.4154250057254
Canvas Y: -2587.809713810464
From Canvas X: 715.4882154882152
From Canvas Y: -1313.1313131313127
Downstream: South Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1000
Energy Slope: 0.02
Mannings n: 0.027
Shape: Triangular
Number of Subreaches: 2
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reservoir: South Pond
Last Modified Date: 3 October 2019

Last Modified Time: 17:10:17
Canvas X: -3142.4154250057254
Canvas Y: -2587.809713810464
Label X: 3.0
Label Y: 8.0
Downstream: J_A

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 591
Elevation-Area Table: Pond_South_Pre-Dev-2019
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 3.5
Number Barrels: 1
Culvert Length: 58.5
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 591
Outlet Invert Elevation: 590
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 50
Spillway Crest Elevation: 598.8
Spillway Coefficient: 3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: A-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2382.154882154882
Canvas Y: -134.68013468013487
Area: 0.00880
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 6.25
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -3644.781144781145
Canvas Y: -555.5555555555557
Area: 0.00703
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2819.86531986532
Canvas Y: -1026.9360269360268
Area: 0.00453
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -3156.5656565656564
Canvas Y: -16.835016835017086
Area: 0.00377
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2382.154882154882
Canvas Y: -572.3905723905718
Area: 0.00330
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute A
Last Modified Date: 9 July 2019
Last Modified Time: 14:15:50
Canvas X: -3914.1414141414143
Canvas Y: -1481.4814814814818
From Canvas X: -2993.1005899385354
From Canvas Y: -543.0818241872967
Label X: -26.0
Label Y: 17.0
Downstream: J_F

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 370
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-3
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4187.685949171736
Canvas Y: -47.25801621843857
Area: 0.01139
Downstream: J_F

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.91
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_F
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -3914.1414141414143
Canvas Y: -1481.4814814814818
Downstream: Drop South
End:

Reach: Drop South
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4629.810222140172
Canvas Y: -1992.38891005
From Canvas X: -3914.1414141414143
From Canvas Y: -1481.4814814814818
Downstream: J_A

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 100
Energy Slope: 0.333
Mannings n: 0.012
Shape: Circular
Number of Subreaches: 2
Width: 2
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: AO-13
Last Modified Date: 10 September 2019
Last Modified Time: 14:35:07
Canvas X: -2199.935105183882
Canvas Y: -4174.1021827130535
Label X: 9.0
Label Y: 3.0
Area: 0.01602
Downstream: J_AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.42
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 479.7979797979797
Canvas Y: -3737.3737373737367
Area: 0.00306
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -109.42760942760924
Canvas Y: -4074.074074074073
Area: 0.00272
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-7
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1237.3737373737376
Canvas Y: -3282.8282828282827
Area: 0.00072
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-6
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -227.27272727272793
Canvas Y: -3097.6430976430975
Area: 0.00017
Downstream: Downchute AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute AO
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -2598.7503998533884
Canvas Y: -4016.6546416546407
From Canvas X: -204.96464241452122
From Canvas Y: -3629.2192170299622
Label X: 1.0
Label Y: 0.0
Downstream: J_AO

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 180
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: AO-5
Last Modified Date: 4 September 2019

Last Modified Time: 21:33:46
Canvas X: -1237.3737373737376
Canvas Y: -4074.074074074073
Area: 0.00250
Downstream: J_AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-8
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2247.4747474747473
Canvas Y: -3518.5185185185182
Area: 0.00216
Downstream: J_AO

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_AO
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -2598.7503998533884
Canvas Y: -4016.6546416546407
Downstream: Channel AO
End:

Reach: Channel AO
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4629.810222140172
Canvas Y: -1992.38891005
From Canvas X: -2598.7503998533884
From Canvas Y: -4016.6546416546407
Downstream: J_A

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1100
Energy Slope: 0.010
Mannings n: 0.027
Shape: Triangular
Number of Subreaches: 2
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: A-8
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -4679.962010455659
Canvas Y: -3432.873026874046
Area: 0.00238
Downstream: J_A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_A
Last Modified Date: 19 September 2019
Last Modified Time: 14:15:54
Canvas X: -4629.810222140172
Canvas Y: -1992.38891005
Downstream: Channel A.2
End:

Reach: Channel A.2
Last Modified Date: 2 October 2019
Last Modified Time: 20:29:17
Canvas X: -5360.92723353286
Canvas Y: -120.86952857206597
From Canvas X: -4629.810222140172
From Canvas Y: -1992.38891005
Downstream: Midpoint Site Outfall

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 600
Energy Slope: 0.02
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None

End:

Subbasin: OD-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:17:00
Canvas X: -4720.250832037668
Canvas Y: 840.6577778645565
Area: 0.03789
Downstream: Midpoint Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 15.26
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: Midpoint Site Outfall
Last Modified Date: 2 October 2019
Last Modified Time: 20:29:17
Canvas X: -5360.92723353286
Canvas Y: -120.86952857206597
Downstream: Overall Site Outfall
End:

Subbasin: C-1
Last Modified Date: 9 September 2019
Last Modified Time: 22:20:27
Canvas X: 1035.3535353535344
Canvas Y: 892.2558922558919
Area: 0.00417
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 4.84
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2281.8909353676954
Canvas Y: 502.0809022661042
Area: 0.00358
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1839.5918238944487
Canvas Y: 1792.8721867696622
Area: 0.00273
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-7
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2913.746808900907
Canvas Y: 980.4860636555345
Area: 0.00217
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1532.6903996068904
Canvas Y: 366.6832150804162
Area: 0.00205
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1406.3192249002477
Canvas Y: 1422.7851751287817
Area: 0.00189
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-6
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2417.288622553384
Canvas Y: 1810.9252117277538
Area: 0.00120
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute C
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 3914.1414141414143
Canvas Y: 1868.6868686868688
From Canvas X: 1905.995085080246
From Canvas Y: 990.3198726987312
Label X: -12.0
Label Y: -12.0
Downstream: J_C.1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: CO-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 4498.424361875559
Canvas Y: 222.9024133227049
Area: 0.00895
Downstream: Channel North 1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 4.33
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 3197.537994489234
Canvas Y: -505.46398417894306
Area: 0.00475
Downstream: Channel North 1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 4270.023332175082
Canvas Y: -534.0635931838988
Area: 0.00147
Downstream: Channel North 1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Channel North 1
Last Modified Date: 18 November 2019
Last Modified Time: 22:35:43
Canvas X: 3914.1414141414143
Canvas Y: 1868.6868686868688
From Canvas X: 3920.080986953666
From Canvas Y: 422.0224808591647
Downstream: J_C.1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 400
Energy Slope: 0.05
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OC-20
Last Modified Date: 9 September 2019
Last Modified Time: 18:43:45
Canvas X: 4053.2349742144634
Canvas Y: 2505.934055570371
Area: 0.00966
Downstream: J_C.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 82

Transform: SCS
Lag: 5.85
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 3156.5656565656564
Canvas Y: 2154.8821548821547
Area: 0.00230
Downstream: J_C.1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C.1
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: 3914.1414141414143
Canvas Y: 1868.6868686868688
Downstream: Channel North 2
End:

Reach: Channel North 2
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 3914.1414141414143
From Canvas Y: 1868.6868686868688
Downstream: J_C.2

Route: Kinematic Wave

Channel: Kinematic Wave
Length: 800
Energy Slope: 0.01
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: CO-2
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: 2363.7124639404365
Canvas Y: 4506.206566449147
Area: 0.01319
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 7.20
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-3
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: 3442.760942760943
Canvas Y: 4309.7643097643095
Area: 0.01038
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 82

Transform: SCS
Lag: 5.67
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 289.6228803903232
Canvas Y: 2463.842885230684
Area: 0.00319
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 677.6034236804571
Canvas Y: 3002.8530670470755
Area: 0.00211
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1119.5286195286199
Canvas Y: 3501.6835016835016
Area: 0.00181
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60

Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-5
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2095.9595959595963
Canvas Y: 2676.7676767676767
Area: 0.00058
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 1338.3838383838383
Canvas Y: 2340.06734006734
Area: 0.00053
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute D
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 1380.3723569916438
From Canvas Y: 2814.7465042631334
Downstream: J_C.2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.236
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: G-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 2314.814814814815
Canvas Y: 3063.973063973064
Area: 0.00195
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OC-11
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: 3649.4075759431453
Canvas Y: 3927.280120004649
Area: 0.00027
Downstream: J_C.2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C.2
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
Downstream: Channel North 3

End:

Reach: Channel North 3
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -1589.7849110216812
Canvas Y: 4030.647141124137
From Canvas X: 2062.289562289562
From Canvas Y: 3905.723905723906
Downstream: North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1300
Energy Slope: 0.023
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: E-4
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2685.185185185185
Canvas Y: 1060.6060606060605
Area: 0.00411
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:24:07
Canvas X: -1860.2693602693607
Canvas Y: 824.9158249158254
Label X: -58.0
Label Y: -8.0
Area: 0.00327
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1877.104377104377
Canvas Y: 2222.222222222222
Area: 0.00320
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1338.3838383838383
Canvas Y: 2037.037037037037
Area: 0.00086
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute E
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -3409.090909090909
Canvas Y: 1885.5218855218855
From Canvas X: -1911.1462629730354

From Canvas Y: 1164.4265473514447
Downstream: J_E

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 460
Energy Slope: 0.16
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: H-1
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -3712.1212121212125
Canvas Y: 1464.6464646464647
Area: 0.00503
Downstream: J_E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: H-2
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -2567.3400673400674
Canvas Y: 2272.727272727273
Area: 0.00339
Downstream: J_E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_E
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -3409.090909090909
Canvas Y: 1885.5218855218855
Downstream: MSE North
End:

Reach: MSE North
Last Modified Date: 9 July 2019
Last Modified Time: 14:16:39
Canvas X: -2028.6195286195289
Canvas Y: 3383.838383838384
From Canvas X: -3409.090909090909
From Canvas Y: 1885.5218855218855
Downstream: J_H

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 500
Energy Slope: 0.01
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 3
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: H-3
Last Modified Date: 4 September 2019
Last Modified Time: 21:33:46
Canvas X: -1052.1885521885524
Canvas Y: 3148.1481481481483
Area: 0.00909
Downstream: J_H

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_H
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -2028.6195286195289
Canvas Y: 3383.838383838384
Downstream: Drop North
End:

Reach: Drop North
Last Modified Date: 9 July 2019

Last Modified Time: 14:16:39
Canvas X: -1589.7849110216812
Canvas Y: 4030.647141124137
From Canvas X: -2028.6195286195289
From Canvas Y: 3383.838383838384
Downstream: North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 100
Energy Slope: 0.333
Mannings n: 0.012
Shape: Circular
Number of Subreaches: 2
Width: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OC-21
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -497.8103794894987
Canvas Y: 4492.179493687236
Area: 0.01145
Downstream: North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.64
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-1
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -2012.7342377759342
Canvas Y: 4520.233639211058
Area: 0.00472
Downstream: North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.82
Unitgraph Type: STANDARD

Baseflow: None
End:

Reservoir: North Pond
Last Modified Date: 10 September 2019
Last Modified Time: 14:52:30
Canvas X: -1589.7849110216812
Canvas Y: 4030.647141124137
Downstream: Overall Site Outfall

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 588
Elevation-Area Table: Pond_North_Pre-Dev-2019
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 2.5
Number Barrels: 2
Culvert Length: 64.5
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1.0
Top Manning's n: 0.011
Inlet Invert Elevation: 588
Outlet Invert Elevation: 587.4
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 80
Spillway Crest Elevation: 597
Spillway Coefficient: 3
End Spillway:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 420
Spillway Crest Elevation: 598.5
Spillway Coefficient: 3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: OD-2
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -4149.83164983165
Canvas Y: 3686.868686868687
Area: 0.04734
Downstream: J_D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 9.67
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: DO-1
Last Modified Date: 23 December 2019
Last Modified Time: 15:16:45
Canvas X: -5227.272727272728
Canvas Y: 4461.279461279461
From Canvas X: -841.654778887304
From Canvas Y: -142.65335235378052
Area: 0.00272
Downstream: J_D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.06
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_D
Last Modified Date: 9 September 2019
Last Modified Time: 18:31:45
Canvas X: -4999.380073210335
Canvas Y: 3725.3760549215094
Downstream: Overall Site Outfall
End:

Junction: Overall Site Outfall
Last Modified Date: 9 July 2019
Last Modified Time: 13:59:42
Canvas X: -6169.687038971845
Canvas Y: 3035.1950238313875
End:

Basin Layer Properties:
Element Layer:
Name: Icons
Layer shown: Yes
End Layer:
End:

Basin Spatial Properties:
End:

Basin Schematic Properties:
Last View N: 5493.85041812838
Last View S: -5494.996284046745
Last View W: -7557.92807960787
Last View E: 6581.220047344323
Maximum View N: 4520.233639211058
Maximum View S: -4273.324274832017
Maximum View W: -16812.32574325535
Maximum View E: 4498.424361875559
Extent Method: Elements
Buffer: 0
Draw Icons: Yes
Draw Icon Labels: Name
Draw Map Objects: No
Draw Gridlines: No
Draw Flow Direction: No
Draw HillShade Layer: Yes
Draw Elevation Layer: Yes
Elevation Layer Color Palette: Default
Ignore Elevation Color Ramp Scale: No
Use Interpolated Color Ramp for Elevation Layer: Yes
Color Ramp Opacity Level for Elevation Layer: 33.0
Fix Element Locations: No
Fix Hydrologic Order: No
End:

HEC-HMS POST-DEVELOPMENT HYDROLOGIC MODEL INPUT PARAMETERS

Post-Development HEC-HMS Basin Input Parameters for Kinematic Wave Model

POST-DEVELOPMENT CONDITIONS			Watershed Characterization			Sheet Flow				Shallow Concentrated Flow					Open Channel Flow												
Subcatchment Designation	Area A (mi²)	Area A (acres)	Initial Abstraction (in)	Curve Number	Impervious Cover (%)	Flow Length (ft)	Manning's n	Slope (ft/ft)	Time T_t (min)	Flow Length (ft)	Velocity Factor (ft/s)	Slope (ft/ft)	Average Velocity (ft/s)	Time T_t (min)	Flow Length (ft)	Depth d (ft)	Area A (ft²)	Wetted P (ft)	Hydraulic Radius (ft)	Manning's n	Slope (ft/ft)	Velocity (ft/s)	Time T_t (min)	Design T_c (min)	SCS Lag Time (min)	HMS 25-yr Flow (cfs)	HMS 100-yr Flow (cfs)
A-1	0.01378	8.82	0.35	85	0.00	100	0.15	0.050	6.15	435	7.00	0.050	1.57	4.63										10.78	6.47	66.20	89.30
A-2	0.00039063	0.25	0.35	85	0.00	90	0.15	0.333	2.65						775	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.73	6.00	3.60	2.10	2.80
A-3	0.00190625	1.22	0.35	85	0.00	100	0.15	0.333	2.88						600	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.34	6.00	3.60	10.20	13.80
A-4	0.00267188	1.71	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	1000	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.23	6.00	3.60	14.30	19.30
A-5	0.00445313	2.85	0.35	85	0.00	100	0.15	0.333	2.88	75	7.00	0.333	4.04	0.31	550	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.22	6.00	3.60	23.80	32.20
A-6	0.00389063	2.49	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	1300	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.89	6.10	3.66	20.80	28.00
A-7	0.00641	4.10	0.35	85	0.00	100	0.15	0.333	2.88	85	7.00	0.333	4.04	0.35	650	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.45	6.00	3.60	34.30	46.30
B-1	0.00386	2.47	0.35	85	0.00	100	0.15	0.050	6.15	200	7.00	0.160	2.80	1.19	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	8.45	5.07	19.60	26.50
B-2	0.00345	2.21	0.35	85	0.00	100	0.15	0.333	2.88	45	7.00	0.333	4.04	0.19	750	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.67	6.00	3.60	18.50	24.90
B-3	0.00475	3.04	0.35	85	0.00	100	0.15	0.333	2.88	75	7.00	0.333	4.04	0.31	900	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.00	6.00	3.60	25.40	34.30
B-4	0.00616	3.94	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	945	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.10	6.00	3.60	33.00	44.50
C-1	0.01214	7.77	0.35	85	0.00	100	0.15	0.050	6.15	200	7.00	0.050	1.57	2.13										8.28	4.97	61.90	83.60
C-2	0.00722	4.62	0.35	85	0.00	100	0.15	0.050	6.15	200	7.00	0.160	2.80	1.19	780	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.74	9.08	5.45	36.10	48.70
C-3	0.00267	1.71	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	400	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.89	6.00	3.60	14.30	19.30
C-4	0.00494	3.16	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	800	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.78	6.00	3.60	26.40	35.70
C-5	0.00355	2.27	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	19.00	25.60
D-1	0.00059	0.38	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	200	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.45	6.00	3.60	3.20	4.30
D-2	0.00120	0.77	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16	900	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.00	6.00	3.60	6.40	8.70
D-3	0.00111	0.71	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	150	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.33	6.00	3.60	5.90	8.00
D-4	0.00815625	5.22	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	250	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.56	6.00	3.60	43.70	58.90
D-5	0.00135938	0.87	0.35	85	0.00	100	0.15	0.333	2.88	20	7.00	0.333	4.04	0.08	200	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.45	6.00	3.60	7.30	9.80
D-6	0.00189063	1.21	0.35	85	0.00	100	0.15	0.333	2.88	20	7.00	0.333	4.04	0.08	250	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.56	6.00	3.60	10.10	13.70
E-1	0.00292188	1.87	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	400	2.0	11.00	11.71	0.94	0.027	0.020	7.49	0.89	6.00	3.60	15.60	21.10
E-2	0.00892188	5.71	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33	870	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.94	6.00	3.60	47.80	64.50
E-3	0.00329688	2.11	0.35	85	0.00	100	0.15	0.333	2.88	100	8.00	0.333	4.62	0.36	500	2.0	11.00	11.71	0.94	0.027	0.020	7.49	1.11	6.00	3.60	17.70	23.80
E-4	0.00978125	6.26	0.35	85	0.00	100	0.15	0.333	2.88	60	9.00	0.333	5.20	0.19	1290	2.0	11.00	11.71	0.94	0.027	0.020	7.49	2.87	6.00	3.60	52.40	70.70
F-1	0.00323	2.07	0.35	85	0.00	100	0.15	0.333	2.88						1000	3.0	51.00	25.56	1.99	0.027	0.005	6.18	2.70	6.00	3.60	17.30	23.30
F-2	0.00119	0.76	0.35	85	0.00	100	0.15	0.333	2.88															6.00	3.60	6.40	8.60
F-3	0.00156	1.00	0.35	85	0.00	100	0.15	0.333	2.88															6.00	3.60	8.40	11.30
F-4	0.00269	1.72	0.35	85	0.00	100	0.15	0.333	2.88	40	7.00	0.333	4.04	0.16										6.00	3.60	14.40	19.40
F-5	0.00242	1.55	0.35	85	0.00	100	0.15	0.333	2.88	70	7.00	0.333	4.04	0.29	300	3.0	51.00	25.56	1.99	0.027	0.005	6.18	0.81	6.00	3.60	13.00	17.50
F-6	0.00836	5.35	0.35	85	0.00	100	0.15	0.333	2.88	100	7.00	0.333	4.04	0.41										6.00	3.60	44.80	60.40
G-1	0.00575	3.68	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21	800	3.0	51.00	25.56	1.99	0.027	0.005	6.18	2.16	6.00	3.60	30.80	41.50
G-2	0.00797	5.1	0.35	85	0.00	100	0.15	0.333	2.88						500	3.0	51.00	25.56	1.99	0.027	0.005	6.18	1.35	6.00	3.60	42.70	57.60
G-3	0.00119	0.76	0.35	85	0.00	100	0.15	0.333	2.88						230	3.0	51.00	25.56	1.99	0.027	0.005	6.18	0.62	6.00	3.60	6.40	8.60
G-4	0.00163	1.04	0.35	85	0.00	90	0.15	0.333	2.65						300	3.0	51.00	25.56	1.99	0.027	0.005	6.18	0.81	6.00	3.60	8.70	11.80
G-5	0.00041	0.26	0.35	85	0.00	70	0.15	0.333	2.17															6.00	3.60	2.20	3.00
G-6	0.00147	0.94	0.35	85	0.00	100	0.15	0.333	2.88	50	7.00	0.333	4.04	0.21										6.00	3.60	7.90	10.60
G-7	0.00348	2.23	0.35	85	0.00	100	0.15	0.333	2.88	80	7.00	0.333	4.04	0.33										6.00	3.60	18.60	25.10
OD-1	0.03863	24.72	0.82	71	0.00	100	0.15	0.033	7.23	600	7.00	0.010	0.70	14.29	1000	2.0	40.00	40.20	1.00	0.027	0.006	4.26	3.91	25.43	15.26	96.60	142.30
OD-2	0.04775	30.56	0.82	71	0.00	100	0.15	0.033	7.23	475	7.00	0.022	1.03	7.66	900	6.0	444.00	99.48	4.46	0.027	0.007	12.21	1.23	16.12	9.67	149.50	219.20
OA-1	0.00350	2.24	0.35	85	0.00	100	0.15	0.167	3.80						500	3.0	51.00	25.56	1.99	0.027	0.005	6.18	1.35	6.00	3.60	18.70	25.30
OA-2	0.00416	2.66	0.35	85	0.00	100	0.15	0.167	3.80						950	3.0	51.00	25.56	1.99	0.027	0.005	6.18	2.56	6.36	3.81	22.10	29.90
OA-3	0.00239	1.53	0.35	85	0.00	50	0.15	0.200	2.03						600	3.0	51.00	25.56	1.99	0.027	0.005	6.18	1.62	6.00	3.60	12.80	17.30
AO-13	0.01064	6.81	0.82	71	0.00	100	0.15	0.104	4.59	150	7.00	0.040	1.40	1.79	1100	3.0	22.50	16.16	1.39	0.027	0.010	6.88	2.66	9.04	5.42	39.80	58.10
OC-1	0.01644	10.52	0.44	82	0.00	100	0.15	0.040	6.73	500	7.00	0.040	1.40	5.95										12.68	7.61	71.80	98.40
OC-2	0.01191	7.62	0.82	71	0.00	100	0.15	0.040	6.73	200	7.00	0.040	1.40	2.38	1000	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.95	11.06	6.64	42.30	61.90
CO-1	0.00472	3.02	0.82	71	0.00	100	0.15	0.087	4.94	400	7.00	0.040	1.40	4.76										9.70	5.82	17.30	25.40
CO-2	0.00758	4.85	0.82	71	0.00	100	0.15	0.100	4.66	600	7.00	0.044	1.48	6.78										11.44	6.86	26.70	39.00
CO-4	0.00895	5.73	0.82	71	0.00	100	0.15	0.160	3.86	200	7.00	0.040	1.40	2.38	500	3.0	46.50	24.16	1.93	0.027	0.010	8.54	0.98	7.22	4.33	34.90	50.90
CO-5	0.00147	0.94	0.82	71	0.00	50	0.15	0.160	2.22	0	0.00	0.000	0.00	0.00	700	3.0	46.50	24.16	1.93	0.027	0.010	8.54	1.37	6.00	3.60	5.90	8.60
DO-1	0.00272	1.74	0.82	71	0.00	100	0.15	0.067	5.48	500	7.00	0.0667	1.81	4.61										10.09	6.06	9.90	14.50
		207.14																									

2-year, 24-hour Design Rainfall Depth = 3.90 inches

Bench Left Side Slope = 2.5 H:V
Bench Right Side Slope = 3.0 H:V

Notes:

1) *Curve number = 85 landfill final cover surface in accordance with TCEQ RG-417 guidance (TCEQ, 2018).*
2) *Curve number = 71 represents meadow with continuous grass for hydrologic soil group C (USDA, 1986).*
3) *Curve number = 82 represents farmsteads of buildings, lanes, driveways, and surrounding lots for hydrologic soil group C (USDA, 1986).*
4) *Manning's roughness coefficient: n = 0.15 represents short grass prairie for sheet flow (USDA, 1984).*
5) *Manning's roughness coefficient: n = 0.027 represents an excavated earth channel that is straight and uniform with short grass and few weeds (Chow, 1959).*
6) *Travel Time (T_t) is calculated using Manning's kinematic solutions for sheet flow (USDA, 1986).*

$$T_t = 0.007(nL)^{0.8} / (P_{2\text{-}24})^{0.5} S^{0.4}$$

7) *Velocity factor of 7.0 ft/s corresponds to short grass pasture from the Upland Method as reported by HydroCAD v.8 Owner's Manual.*
8) *Open channel flow velocity is calculated using Manning's equation (USDA, 1986).*

$$V = (1.49 r^{2/3} S^{1/2}) / n$$ where: r = hydraulic radius (ft) and is equal to A/P [area (ft²)/wetted perimeter (ft)]

9) *Design rainfall depth taken from NOAA Atlas 14, Volume 11, Version 2.*

Basin: PostDev-2019
Last Modified Date: 13 December 2019
Last Modified Time: 16:42:00
Version: 4.3
Filepath Separator: \
Unit System: English
Missing Flow To Zero: No
Enable Flow Ratio: No
Compute Local Flow At Junctions: No

Enable Sediment Routing: No

Enable Quality Routing: No
End:

Reservoir: Series 3_North Pond
Description: Third basin of the North Pond Series
Last Modified Date: 4 December 2019
Last Modified Time: 14:50:44
Canvas X: -738.8990558096202
Canvas Y: 6539.7288686574675
From Canvas X: -2686.2212969881784
From Canvas Y: 5196.47027005563
Downstream: Series 2_North Pond

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 604
Elevation-Area Table: Pond_North_Series3_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 4.5
Number Barrels: 2
Culvert Length: 10
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 603
Outlet Invert Elevation: 602.5
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 60
Spillway Crest Elevation: 613
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Junction: J_C3
Last Modified Date: 19 November 2019
Last Modified Time: 16:54:18
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
Downstream: Peri C3
End:

Subbasin: E-4
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -143.73704479314074
Canvas Y: 4284.420573576127
From Canvas X: -143.73704479314074
From Canvas Y: 4284.420573576127
Area: 0.0097813
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-2
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -380.6904669830892
Canvas Y: 3589.357201818946
Area: 0.0089219
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-3

Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 582.9201165893664
Canvas Y: 3857.9044136342204
From Canvas X: 582.9201165893664
From Canvas Y: 3857.9044136342204
Area: 0.00330
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: E-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 85.96448372417399
Canvas Y: 3366.5102757543623
Area: 0.00292
Downstream: Downchute E

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute E
Last Modified Date: 16 December 2019
Last Modified Time: 19:36:17
Canvas X: -2474.1427739564424
Canvas Y: 6417.821941121796
From Canvas X: -1142.1200473700083
From Canvas Y: 4560.254810942866
Downstream: Series 2_North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 460
Energy Slope: 0.16
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: CO-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -2240.9130882934473
Canvas Y: 6934.043847122182
Area: 0.00758
Downstream: Series 2_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.86
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute D
Last Modified Date: 28 August 2019
Last Modified Time: 19:43:04
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 1380.3723569916438
From Canvas Y: 2814.7465042631334
Downstream: J_C3

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.236
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reservoir: Series 4_North Pond
Description: Fourth basin of the North Pond Series
Last Modified Date: 16 December 2019
Last Modified Time: 16:31:11
Canvas X: 1356.876944391328
Canvas Y: 6402.03323920955
From Canvas X: -3659.8441744480297
From Canvas Y: 5295.243605450108
Downstream: Series 3_North Pond

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 615
Elevation-Area Table: Pond_North_Series4_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 4.5
Number Barrels: 2
Culvert Length: 10
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 613
Outlet Invert Elevation: 612.5
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 60
Spillway Crest Elevation: 624
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Reach: Peri C3
Last Modified Date: 16 December 2019
Last Modified Time: 16:31:11
Canvas X: 1356.876944391328
Canvas Y: 6402.03323920955
From Canvas X: 2062.289562289562
From Canvas Y: 3905.723905723906
Downstream: Series 4_North Pond

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 339.32
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: D-4
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: 1119.5286195286199
Canvas Y: 3501.6835016835016
Area: 0.0081563
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-6
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 1994.037977450369
Canvas Y: 3023.8939475440548
From Canvas X: 1922.295663466335
From Canvas Y: 3044.3917515394933
Area: 0.00189
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OC-2

Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 3273.4627608045475
Canvas Y: 4082.0409898726684
From Canvas X: 1737.8154275073903
From Canvas Y: 5350.394701026314
Area: 0.01191
Downstream: J_C3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.64
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2095.9595959595963
Canvas Y: 2676.7676767676767
Area: 0.00136
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C1
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:46
Canvas X: 4121.424554625923
Canvas Y: 1899.0894568639842
Downstream: Peri C1
End:

Reach: Peri C1
Last Modified Date: 19 November 2019
Last Modified Time: 17:14:50
Canvas X: 3506.0190584361662
Canvas Y: 2818.1354023946215
From Canvas X: 4121.424554625923
From Canvas Y: 1899.0894568639842
Downstream: J_C2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 522.75
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reach: Peri B1
Last Modified Date: 19 November 2019
Last Modified Time: 17:14:19
Canvas X: 4121.424554625923
Canvas Y: 1899.0894568639842
From Canvas X: 4532.143819755165
From Canvas Y: -423.0540805975061
Downstream: J_C1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 631.25
Energy Slope: 0.025
Mannings n: 0.027
Shape: Triangular
Number of Subreaches: 2
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: C-1
Last Modified Date: 13 December 2019
Last Modified Time: 16:49:57
Canvas X: 1035.3535353535344
Canvas Y: 892.2558922558919
Area: 0.01214
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0

Curve Number: 85

Transform: SCS
Lag: 4.97
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_C2
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:35
Canvas X: 3506.0190584361662
Canvas Y: 2818.1354023946215
From Canvas X: 3506.0190584361662
From Canvas Y: 2818.1354023946215
Downstream: Peri C2
End:

Subbasin: C-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 2281.8909353676954
Canvas Y: 502.0809022661042
Area: 0.00267
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-2
Last Modified Date: 13 December 2019
Last Modified Time: 16:49:57
Canvas X: 1532.6903996068904
Canvas Y: 366.6832150804162
Area: 0.00722
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 5.45
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-1
Last Modified Date: 16 December 2019
Last Modified Time: 16:01:05
Canvas X: 4497.635771417183
Canvas Y: -1049.9496403118637
Area: 0.00575
Downstream: J_B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-5
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 2258.3534371140413
Canvas Y: 150.7523695898717
Area: 0.00355
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: CO-5
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09

Canvas X: 4970.13310982375
Canvas Y: 1288.3064189821735
From Canvas X: 5637.9264566415895
From Canvas Y: -454.64787022283235
Area: 0.00147
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: C-4
Last Modified Date: 13 December 2019
Last Modified Time: 16:49:57
Canvas X: 1406.3192249002477
Canvas Y: 1422.7851751287817
Area: 0.00494
Downstream: Downchute C

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_B
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:46
Canvas X: 4532.143819755165
Canvas Y: -423.0540805975061
From Canvas X: 3510.875473112812
From Canvas Y: -870.6888115892416
Downstream: Peri B1
End:

Subbasin: CO-4
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 5208.551172036108
Canvas Y: 1772.764211828372
From Canvas X: 47.390684437988966
From Canvas Y: 410.71926512924347
Area: 0.00895
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 4.33
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-3
Last Modified Date: 13 December 2019
Last Modified Time: 16:46:35
Canvas X: 4545.703207967837
Canvas Y: 2467.685464480591
Area: 0.00119
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-2
Last Modified Date: 16 December 2019
Last Modified Time: 15:53:37
Canvas X: 3528.410461865249
Canvas Y: 840.0397133144043
Area: 0.00797
Downstream: J_C1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute C
Last Modified Date: 13 December 2019
Last Modified Time: 16:41:59
Canvas X: 4121.424554625923
Canvas Y: 1899.0894568639842
From Canvas X: 1905.995085080246
From Canvas Y: 990.3198726987312
Label X: -12.0
Label Y: -12.0
Downstream: J_C1

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 240
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reach: Peri C2
Last Modified Date: 19 November 2019
Last Modified Time: 17:17:26
Canvas X: 2062.289562289562
Canvas Y: 3905.723905723906
From Canvas X: 3506.0190584361662
From Canvas Y: 2818.1354023946215
Downstream: J_C3

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 545.79
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OC-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 3284.1538569991963
Canvas Y: 3686.4704306706362
From Canvas X: 3254.6529231698314
From Canvas Y: 3843.806107361591
Area: 0.01644
Downstream: J_C3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 82

Transform: SCS
Lag: 7.61
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-2
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 733.2896603298632
Canvas Y: 3016.5309027832345
Area: 0.00120
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 1338.3838383838383
Canvas Y: 2340.06734006734
Area: 0.00111
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: D-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 289.6228803903232
Canvas Y: 2463.842885230684
Area: 0.00059
Downstream: Downchute D

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -632.2364776272752
Canvas Y: 6922.715350750865
From Canvas X: 1081.8856996533614
From Canvas Y: 4202.517677281763
Area: 0.00041
Downstream: Series 3_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-4
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: 2717.525758682771
Canvas Y: 4670.051280578392
From Canvas X: 1532.837387553005
From Canvas Y: 3720.8192833889602
Area: 0.00163
Downstream: J_C3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reservoir: Series 2_North Pond
Description: Secind basin of the north pond series
Last Modified Date: 16 December 2019
Last Modified Time: 19:36:17
Canvas X: -2474.1427739564424
Canvas Y: 6417.821941121796
From Canvas X: -2700.3317734731045
From Canvas Y: 5379.906464359659
Downstream: Series 1_North Pond

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 598
Elevation-Area Table: Pond_North_Series2_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 4.5

Number Barrels: 3
Culvert Length: 10
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1
Top Manning's n: 0.011
Inlet Invert Elevation: 597
Outlet Invert Elevation: 596.5
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 60
Spillway Crest Elevation: 603
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: CO-1
Last Modified Date: 4 November 2019
Last Modified Time: 21:34:19
Canvas X: -3106.1843766466563
Canvas Y: 4773.342403746244
Area: 0.00472
Downstream: Series 1_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.82
Unitgraph Type: STANDARD

Baseflow: None
End:

Reservoir: Series 1_North Pond
Last Modified Date: 16 December 2019
Last Modified Time: 16:19:52
Canvas X: -4383.237509402856
Canvas Y: 6038.025981164064
Downstream: Peri C4

Route: Controlled Outflow
Routing Curve: Elevation-Area
Initial Elevation: 588
Elevation-Area Table: Pond_North_Series1_Post19
Adaptive Control: On
Main Tailwater Condition: None
Auxiliary Tailwater Condition: None

Conduit: Culvert
Conduit Outlet: Main
Culvert Shape: Circular
Chart Number: 1
Scale Number: 1
Solution Control: Automatic
Diameter: 2.5
Number Barrels: 2
Culvert Length: 64.5
Entrance Loss Coefficient: 0.5
Exit Loss Coefficient: 1.0
Top Manning's n: 0.011
Inlet Invert Elevation: 588
Outlet Invert Elevation: 587.4
End Conduit:

Spillway: Broad-Crested Spillway
Spillway Outlet: Main
Spillway Crest Length: 80
Spillway Crest Elevation: 597
Spillway Coefficient: 3.3
End Spillway:

Evaporation Method: Zero Evaporation
End Evaporation:
End:

Subbasin: G-6
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -4694.308916577716
Canvas Y: 6667.773565879497
From Canvas X: -1066.1123501521834
From Canvas Y: 4826.889360949745
Area: 0.00147
Downstream: Series 1_North Pond

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri C4
Last Modified Date: 16 December 2019
Last Modified Time: 16:19:52
Canvas X: -8322.890474947622
Canvas Y: 4620.729306795858
From Canvas X: -4383.237509402856
From Canvas Y: 6038.025981164064
Downstream: Overall Site Outfall

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 300
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Junction: J_A5
Last Modified Date: 19 November 2019
Last Modified Time: 16:42:03
Canvas X: -4520.20202020202
Canvas Y: -2895.622895622895
Downstream: Peri A5
End:

Junction: J_Mid
Last Modified Date: 19 November 2019
Last Modified Time: 16:42:58
Canvas X: -6004.385020291189
Canvas Y: 382.58755484831636
From Canvas X: -6461.306170667974
From Canvas Y: 953.6157440047755
Downstream: Channel A
End:

Reach: Downchute A
Last Modified Date: 28 August 2019
Last Modified Time: 19:22:07
Canvas X: -4520.20202020202
Canvas Y: -2895.622895622895
From Canvas X: -3561.915769552974
From Canvas Y: -1050.7338501924505
Label X: -26.0
Label Y: 17.0
Downstream: J_A5

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 370
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Reach: Channel A
Last Modified Date: 19 November 2019
Last Modified Time: 16:43:14
Canvas X: -6121.783716957593
Canvas Y: 1463.9154354050097
From Canvas X: -6004.385020291189
From Canvas Y: 382.58755484831636
Downstream: Midpoint Site Outfall

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1000
Energy Slope: 0.02
Mannings n: 0.027
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -4811.960947673597
Canvas Y: -3594.1660778856867
From Canvas X: -5282.682440930265
From Canvas Y: -3156.1939570806235
Area: 0.00242
Downstream: J_A5

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OA-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -5488.145209808417
Canvas Y: -3229.3883540208517
From Canvas X: -2083.62512379237
From Canvas Y: 1749.9932448612153
Label X: -3.0
Label Y: -6.0
Area: 0.00239
Downstream: J_A5

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OD-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -4969.3722022933725
Canvas Y: 1114.6912851458305
Area: 0.03863
Downstream: Midpoint Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 15.26
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_A3
Last Modified Date: 19 November 2019
Last Modified Time: 16:39:36
Canvas X: -1208.471880248624
Canvas Y: -1592.2778760698557
From Canvas X: 1040.8900916624807
From Canvas Y: -1618.8586574227438
Downstream: Peri A3
End:

Reach: Peri A3
Last Modified Date: 19 November 2019
Last Modified Time: 17:11:22
Canvas X: -2900.809063630636
Canvas Y: -2287.481982732451
From Canvas X: -1208.471880248624
From Canvas Y: -1592.2778760698557
Downstream: J_A4

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 907.45
Energy Slope: 0.078
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Junction: J_A2
Last Modified Date: 19 November 2019
Last Modified Time: 16:38:49
Canvas X: 1228.268204870441
Canvas Y: -1194.1384419832398
Downstream: Peri A2
End:

Junction: J_A1
Last Modified Date: 19 November 2019
Last Modified Time: 16:43:24
Canvas X: 2620.5934752466883
Canvas Y: -899.4126548233039
From Canvas X: 2620.5934752466883
From Canvas Y: -899.4126548233039
Downstream: Peri A1
End:

Reach: Peri A1
Last Modified Date: 19 November 2019
Last Modified Time: 17:10:46
Canvas X: 1228.268204870441
Canvas Y: -1194.1384419832398
From Canvas X: 2620.5934752466883
From Canvas Y: -899.4126548233039
Downstream: J_A2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 1238.52
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: B-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: 294.61279461279446

Canvas Y: 286.1952861952859
Area: 0.00386
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 5.07
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: 1473.0639730639732
Canvas Y: -168.35016835016813
Area: 0.00345
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri A2
Last Modified Date: 19 November 2019
Last Modified Time: 17:11:00
Canvas X: -1208.471880248624
Canvas Y: -1592.2778760698557
From Canvas X: 1228.268204870441
From Canvas Y: -1194.1384419832398
Downstream: J_A3

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 379.41
Energy Slope: 0.005
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: B-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: -455.7170339722252
Canvas Y: -70.82049518426084
Label X: -2.0
Label Y: -1.0
Area: 0.00475
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: B-4
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 1962.7636351605634
Canvas Y: -621.3689401900992
Area: 0.00616
Downstream: Downchute B

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-2
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 1150.8225006942284
Canvas Y: -2112.7270628718834
Label X: 2.0
Label Y: -4.0
Area: 0.00119
Downstream: J_A2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2539.289809823257
Canvas Y: -482.73136952822324
Area: 0.00323
Downstream: J_A1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: J_A4
Last Modified Date: 19 November 2019
Last Modified Time: 16:44:15
Canvas X: -2900.809063630636
Canvas Y: -2287.481982732451
From Canvas X: -3050.8519929059894
From Canvas Y: -2407.391501669781
Downstream: Peri A4
End:

Subbasin: F-4
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -1298.5631198702758
Canvas Y: -2698.5940825632706
From Canvas X: -5282.682440930265
From Canvas Y: -2776.9845831650136
Area: 0.00269
Downstream: J_A3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: F-3
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 114.49385549810722
Canvas Y: -2587.6133866395203
Area: 0.00156
Downstream: J_A3

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Downchute B
Last Modified Date: 19 November 2019
Last Modified Time: 16:37:58
Canvas X: 1228.268204870441
Canvas Y: -1194.1384419832398
From Canvas X: 834.0466727105622
From Canvas Y: -408.14049818109606
Downstream: J_A2

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 380
Energy Slope: 0.333
Mannings n: 0.036
Shape: Triangular
Number of Subreaches: 2
Side Slope: 6.5
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: OA-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2866.3747602812073
Canvas Y: -1450.2860913481982
Label X: -13.0
Label Y: -15.0
Area: 0.00350
Downstream: J_A1

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: OA-2
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: 2441.733111868589
Canvas Y: -2061.77006506237
Label X: -3.0
Label Y: -6.0
Area: 0.00416
Downstream: J_A2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.81
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: AO-13
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: 2000.1057975194653
Canvas Y: -2571.340043157512
Area: 0.01064
Downstream: J_A2

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 5.42
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri A4
Last Modified Date: 19 November 2019
Last Modified Time: 17:10:37
Canvas X: -4520.20202020202
Canvas Y: -2895.622895622895
From Canvas X: -2900.809063630636
From Canvas Y: -2287.481982732451
Downstream: J_A5

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 344.3
Energy Slope: 0.009
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: A-1
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -2382.154882154882

Canvas Y: -134.68013468013487
Label X: -1.0
Label Y: 0.0
Area: 0.01378
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 6.47
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-7
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: -3173.4306729211057
Canvas Y: -1526.2753714659148
From Canvas X: -3304.6443553704594
From Canvas Y: -1198.653675516257
Area: 0.00641
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-5
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -2819.86531986532
Canvas Y: -1026.9360269360268
Area: 0.00445
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-6
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -4108.333852092885
Canvas Y: -856.3666906972885
From Canvas X: -3960.5740832244883
From Canvas Y: -798.9464976052077
Area: 0.0038906
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.66
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-4
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -3785.7850767766695
Canvas Y: -340.9506800670415
Area: 0.0026719
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60

Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-3
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:08
Canvas X: -2382.154882154882
Canvas Y: -572.3905723905718
Area: 0.00191
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: A-2
Last Modified Date: 6 January 2020
Last Modified Time: 15:07:18
Canvas X: -3181.120147163824
Canvas Y: 25.030724698628546
Area: .00039063
Downstream: Downchute A

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Reach: Peri A5
Last Modified Date: 19 November 2019
Last Modified Time: 17:13:19
Canvas X: -6004.385020291189
Canvas Y: 382.58755484831636
From Canvas X: -4520.20202020202
From Canvas Y: -2895.622895622895
Downstream: J_Mid

Route: Kinematic Wave
Channel: Kinematic Wave
Length: 626.81
Energy Slope: 0.009
Mannings n: 0.015
Shape: Trapezoid
Number of Subreaches: 2
Width: 8
Side Slope: 3
Initial Variable: Combined Inflow
Index Parameter Type: Index Flow
Index Flow: 100
Channel Loss: None
End:

Subbasin: F-6
Last Modified Date: 13 December 2019
Last Modified Time: 14:42:32
Canvas X: -6816.037184104709
Canvas Y: 319.4910817090595
From Canvas X: -7137.733702517441
From Canvas Y: 728.1399000549532
Area: 0.00836
Downstream: J_Mid

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: Midpoint Site Outfall
Last Modified Date: 4 November 2019
Last Modified Time: 21:44:15
Canvas X: -6121.783716957593
Canvas Y: 1463.9154354050097
Downstream: Overall Site Outfall
End:

Subbasin: OD-2
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -5688.768051608007
Canvas Y: 4190.02150773637
Area: 0.04775
Downstream: Overall Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 9.67
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: G-7
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -6518.1942682149465
Canvas Y: 3869.5297384327723
From Canvas X: -4814.418668820334
From Canvas Y: 5021.606572309131
Area: 0.00348
Downstream: Overall Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 85

Transform: SCS
Lag: 3.60
Unitgraph Type: STANDARD

Baseflow: None
End:

Subbasin: DO-1
Last Modified Date: 2 January 2020
Last Modified Time: 22:02:09
Canvas X: -4833.71764781123
Canvas Y: 3917.4727632773665
From Canvas X: -841.654778887304
From Canvas Y: -142.65335235378052
Area: 0.00272
Downstream: Overall Site Outfall

Canopy: None
Allow Simultaneous Precip Et: No
Plant Uptake Method: None

Surface: None

LossRate: SCS
Percent Impervious Area: 0.0
Curve Number: 71

Transform: SCS
Lag: 6.06
Unitgraph Type: STANDARD

Baseflow: None
End:

Junction: Overall Site Outfall
Last Modified Date: 4 December 2019
Last Modified Time: 14:23:56
Canvas X: -8322.890474947622
Canvas Y: 4620.729306795858
End:

Basin Layer Properties:
Element Layer:
Name: Icons
Layer shown: Yes
End Layer:
End:

Basin Spatial Properties:
End:

Basin Schematic Properties:
Last View N: 6371.9254009410415
Last View S: -4117.212754667324
Last View W: -8195.442757096444
Last View E: 6581.0295032464455
Maximum View N: 5124.918857076491
Maximum View S: -3594.1660778856867
Maximum View W: -6816.037184104709
Maximum View E: 5590.535772203601
Extent Method: Elements
Buffer: 0
Draw Icons: Yes
Draw Icon Labels: Name
Draw Map Objects: No
Draw Gridlines: No
Draw Flow Direction: No
Draw HillShade Layer: Yes
Draw Elevation Layer: Yes
Elevation Layer Color Palette: Default
Ignore Elevation Color Ramp Scale: No
Use Interpolated Color Ramp for Elevation Layer: Yes
Color Ramp Opacity Level for Elevation Layer: 33.0
Fix Element Locations: No
Fix Hydrologic Order: No
End:

ATTACHMENT 2C

ON-SITE DESIGN –
SURFACE WATER POND APPURTENANCES
DESIGN CALCULATIONS

ON-SITE DESIGN – SURFACE WATER POND APPURTENANCES DESIGN CALCULATIONS
FORT WORTH C&D LANDFILL EXPANSION

5/7/2020

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 24

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the methodology, parameters, and calculations for the design of the North Surface Water Pond, pond outlet pipe structures, and pond appurtenances of the Fort Worth C&D Landfill (site) facility surface water management system. "Appurtenances" refers to: (i) the anti-seep collars of pond outlet pipes associated with the surface water pond; and (ii) riprap apron for pond outlet pipes. Note that hydraulic sizing/design information for each pond is described within Attachment 2B, since the outlet pipe performance (discharge flows, pond elevations, etc.) is based on the hydrology analyses routed through the pond and associated pond outlet pipes. Also note that the hydraulic design of the other culvert at the site and the inlet of the perimeter channel into the North Surface Water Pond, which is not associated with the sizing/hydraulic performance of the surface water pond, is presented in Attachment 2E.

Surface water diversion structures on the final cover system convey runoff through a system of drainage terraces, downchute channels, and perimeter channels to the south towards the midpoint site outfall location to Village Creek or to the north towards the North Surface Water Pond. The North Surface Water Pond consists of four sub-ponds in series (referred to as Series 1, Series 2, Series 3, and Series 4), each with outlet pipes that connect to a downstream sub-pond in the series. The North Surface Water Pond Series 1 is the most downstream pond, and has an existing outlet pipe that discharges into a drainage channel and ultimately to Village Creek at the overall site outfall location. The post-development site outfalls are in the same locations as the current (existing) site outfalls.

The Drainage Report (Attachment 2) in Section 8 describes the construction schedule for the installation of the North Surface Water Pond and other drainage features at the site. The hydrologic modeling and design supporting the surface water management system is described in Attachment 2B: *On-Site Drainage Analysis – Hydrology*. The following sections describe the methodology, design parameters, and results for the appurtenances (anti-seep collars and riprap aprons) supporting the North Surface Water Pond outlet pipes.

2 METHODOLOGY

2.1 Pond Outlet Pipe Design

The pond outlet pipes are designed by utilizing the Hydrologic Modeling System (HEC-HMS) computer program developed through the Hydraulic Engineering Center (HEC) of the United States Army Corps of Engineers (USACE) and the HY-8 Culvert Analysis Program v.7.5 (HY-8). HY-8 was originally developed by the Federal Highway Administration (FHWA) and has since been updated and revised to its current version (Version 7.5). The pond outlet pipes are modeled and their performance assessed based on inflow and elevation-storage relationships of the sub-ponds in series. HEC-HMS is applied for the surface water drainage system to model the pond outlet pipes conveying the peak discharge from North Surface Water Pond. The HEC-HMS model developed to compute the peak inflows for each design rainfall event is discussed within Attachment 2B of the Drainage Report. The HY-8 model simulates flow through the pond outlet pipe and over the pond spillway separately using the discharge flow rate provided by the HEC-HMS model. This is because the HEC-HMS model does not differentiate the amount of discharge flow through the culvert and the spillway separately. The HY-8 model was used to size the riprap aprons at the pond outlet pipes that had flow both through their outlet pipes and spillways during the simulated rainfall events. The North Surface Water Pond Series 1 and Series 2 were the only sub-ponds that had flow through both the outlet pipe and spillway during the rainfall event associated with the riprap apron design (described in detail below). The portion of the total flow that is being conveyed through the outlet pipe was used to size the riprap aprons.

The HEC-HMS model results are considered to be more precise predictions of water levels within the sub-ponds and are the basis for the headwater predictions. Results from the HEC-HMS and HY-8 models were evaluated in order to demonstrate that the computed headwater elevation will not overtop the surface water pond berms at the culvert inlet during the design rainfall event. The tailwater at the ultimate pond outlet pipe of the North Surface Water Pond Series 1 was calculated using Manning's equation as described in Attachment 2E: *On-Site Design – Culverts and Perimeter Drainage Channels*. The performance of each outlet pipe for the surface water pond series was evaluated for the 24-hour rainfall event with a 4% annual chance of occurrence (referred to herein as the "25-year, 24-hour rainfall event") and the 24-hour rainfall event with a 1% annual chance of occurrence (referred to herein as the "100-year, 24-hour rainfall event").

2.2 Anti-Seep Collar Design

Anti-seep collars are required for penetrations through a basin berm to control seepage. The methodology utilized to design the anti-seep collars follows guidance provided in the *Kentucky Division of Water Engineering Memorandum No.* 5, (KDNREP, 1999) and the Tennessee Department of Transportation Drainage Manual (TDOT, 2007). Although these guidance documents are from different states, the methods provided are an industry-standard practice and have a sound technical basis for design at this site. KDNREP (1999) recommends placing anti-seep collars along the length of the outlet structure culvert within the saturated zone such that the anti-seep collars: (i) provide an increase in flow length along the pipe of 15%, and (ii) are spaced at distance of no more than 25 ft apart. This relationship may be described as (KDNREP, 1999):

$$\frac{L_s+2nV}{L_s} \geq 1.15 \qquad (1)$$

where:

L_s = length of pipe within the saturated zone (ft),

V = vertical and horizontal projection of the collar (ft), and

n = number of anti-seep collars.

The length of pipe in the saturated zone, L_s, is computed based on the following assumptions: (i) the groundwater table is located below the elevation of the outlet pipe; (ii) the phreatic surface slopes at a 4 horizontal :1 vertical (4H:1V) slope from the elevation of ponded surface water runoff due to the 25-year, 24-hour rainfall event; and (iii) the interior sideslopes of the North Surface Water Pond Series 1, Series 2, Series 3, and Series 4 are all 3H:1V.

Based on these assumptions, L_s can be computed as follows (TDOT, 2007):

$$L_s = y \times (z+4) \times \left(1 + \frac{S}{0.25 - S}\right) \tag{2}$$

where:

	L_s	=	length of pipe within saturated zone (ft);
	y	=	depth of surface water in the pond after a 25-year, 24-hour rainfall event;
	z	=	slope of the interior embankment sideslope; and
	S	=	slope of the outlet pipe (ft/ft).

Figure 2C-1 further depicts the geometry behind the calculation of L_s.

2.3 Riprap Outlet Apron Design

The riprap apron at the pond series outlet pipes were designed to protect against erosion and scour from the surface water pond outflows. The riprap aprons were sized from the outflow based on the 25-year, 24-hour rainfall event using HEC-HMS and HY-8 model results. The North Surface Water Pond Series 1 and Series 2 outlet pipe riprap aprons were designed using results from the HY-8 model because a portion of the total flow in these pond series discharges from the spillway during the simulated rainfall event. The HY-8 model has the capability of differentiating the amount of flow through both the outlet pipe and spillway separately. The calculated flow through the outlet pipe from HY-8 was used to size the riprap apron for the North Surface Water Pond Series 1 and Series 2. The North Surface Water Pond Series 3 and Series 4 outlet pipe riprap aprons were designed using outflow results from the HEC-HMS model because the water surface elevation during the 25-year, 24-hour rainfall event does not reach the spillway elevation and all outflow is conveyed through the outlet pipe.

The design guidance from the FHWA provides a methodology for calculating the required length of apron (L_a) and d_{50} of the riprap based on the culvert diameter and flow rate. The d_{50} is the stone size of the riprap for which to 50% of the riprap stones are smaller than d_{50} by mass. The riprap size is calculated using the following equation (FHWA, 2006):

$$d_{50} = 0.2D\left(\frac{Q}{D^{2.5}\sqrt{g}}\right)^{4/3} \frac{D}{TW} \tag{3}$$

where: d_{50} = riprap size (ft);

Q = design discharge (cfs);

D = pipe diameter (ft);

TW = tailwater depth (ft); and

g = gravitational constant.

The tailwater depth should be limited to between 0.4D and D. FHWA (2006) recommends the use of a tailwater depth equal to 0.4D if the tailwater is unknown.

The required length and depth of the riprap apron can be estimated based on the pond outlet pipe rise and riprap size as provided in Table 2C-1. The width of the riprap apron at the outlet is recommended as 3D by the FHWA (2006) detail for riprap aprons. The apron width will also widen from the outlet along the required length at a rate of 1 ft width per 3 ft length on each side. Figure 2C-2 provides the standard geometry for the riprap apron.

3 DESIGN PARAMETERS

3.1 Pond Outlet Pipe Parameters

The design parameters for the pond outlet pipes, including geometry and calculated peak discharges as computed by the HEC-HMS, are described in the appendices of Attachment 2B to the Drainage Report for the 25-year, 24-hour and 100-year, 24-hour rainfall events.

The pond outlet pipes were designed to convey both the peak 25-year, 24-hour rainfall discharge and 100-year, 24-hour rainfall discharge while maintaining a water surface elevation in the pond with 0.5 feet of freeboard for the 25-year event and that does not overtop the pond berms for the 100-year event. The proposed pond outlet pipe design parameters are provided in Table 2C-2. It is noted that the peak discharge from the North Surface Water Pond Series 1 and Series 2 outlet pipes were computed in the HY-8 model as some of the outflow from this pond series is also conveyed over the spillway. A Manning's roughness coefficient is selected as 0.012 for concrete pipe culverts, based on guidance in Table 2C-3 (TxDOT, 2019).

The inflow structure into the culverts influences the conveyance of surface water through the culvert. The culvert inflow structures were modeled with a square edge entrance with a headwall. The culvert headwall is to be installed according to the TxDOT standard detail FW-0 for concrete wingwalls with flared wings. TxDOT standard details for wingwalls are available in Figure 2C-3.

3.2 Anti-Seep Collar Design Parameters

Anti-seep collars were designed for each surface water pond outlet pipe, and the design parameters and structure geometry is described herein. Design parameters utilized in Equations (1) and (2) are also provided in Table 2C-2.

3.3 Riprap Outlet Apron Design Parameters

The North Surface Water Pond Series 1 has a computed peak outflow of 360.30 cfs during a 25-year, 24-hour rainfall event, where 149.96 cfs and 210.27 cfs flow through the pipes and the spillway, respectively. The North Surface Water Pond Series 2 has a computed peak outflow into Series 1 of 467.40 cfs during a 25-year, 24-hour rainfall event, where 433.91 cfs and 33.29 cfs flow through the pipes and the spillway, respectively. The HY-8 model divides these peak flow rates obtained from the HEC-HMS model between the pond outlet pipe and overflow spillway. The North Surface Water Pond Series 3 and Series 4 outlet pipe riprap aprons were designed using computed outflows from the HEC-HMS model, as all the pond discharge was routed through the outlet pipe during the 25-year, 24-hour rainfall event. The computed outflows for these pond series and the proposed design parameters used in Equation (3) are listed in Table 2C-4. The riprap aprons were designed for the 25-year, 24-hour peak flow rates through the pond outlet pipes only, as each of the spillways are lined with riprap. For the purposes of riprap apron design, the North Surface Water Pond discharge from outlets were evenly divided between the number of proposed culvert barrels. Also for the purposes of riprap apron design, the tailwater depth of the pipe is considered to be 0.4*D* (FHWA, 2006). The computed tailwater depths for each North Surface Water Pond series are 1.0 foot for Series 1 and 1.8 feet for the three remaining sub-ponds.

4 RESULTS

4.1 Pond Outlet Pipe

The results of the computations of the performance of the North Surface Water Pond Series 1 and Series 2 outlet pipes from the HY-8 model is presented in Table 2C-5 for both the 25-year, 24-hour and 100-year, 24-hour rainfall events. The output graphs for the 25-year and 100-year events for North Surface Water Pond Series 1 are shown on Figure 2C-4 and Figure 2C-5, respectively. The output graphs for the 25-year and 100-year, 24-hour rainfall events for North Surface Water Pond Series 2 are shown on Figure 2C-6 and Figure 2C-7, respectively. The pond outlet pipes provide the capacity to convey the peak flows from the surface water pond without overtopping the perimeter berms. It is important to note that the headwater elevations reported in Table 2C-5 are from the HY-8 output and do not account for storage restrictions within the ponds. The headwater elevations from the HY-8 output are used solely for calculating the flow through the pond outlet pipes for sizing of the riprap aprons as described in Section 4.3. The HEC-HMS headwater values reported previously and in Attachment 2B are considered to be more precise predictions of water levels within the ponds.

The North Surface Water Pond Series 3 and Series 4 water surface elevation does not reach the spillway during the 25-year, 24-hour rainfall events; therefore, all discharge is conveyed through the outlet pipes for this event. The peak water surface elevations do not overtop the perimeter berm for the 100-year, 24-hour rainfall event, as shown in Table 2C-2.

4.2 Anti-Seep Collars

Based on the design parameters described above, the length of the North Surface Water Pond outlet pipes within the saturated zone, L_s, are calculated using Equation (2) and are provided in Table 2C-6.

Anti-seep collars should be spaced no more than 25 ft apart (KDNREP, 1999). The minimum number of seep collars necessary for each of the North Surface Water Pond outlet pipes are provided in Table 2C-6. The minimum vertical and horizontal projection (V) of each seep collar was back calculated by Equation (1). Based on recommendations by Tennessee Department of Transportation (TDOT), the anti-seep collar should extend at least two feet in all directions around the outlet pipe (TDOT, 2007).

To describe the spacing of the anti-seep collars, the first anti-seep collar should be constructed approximately 12.5 feet from the up gradient inlet of the pond outlet pipe. The second anti-seep collar should be spaced 25 feet from the first collar or 37.5 feet from the up gradient end of the pond outlet pipe. The third anti-seep collar, if necessary, should be spaced 25 feet from the second collar or 62.5 feet from the up gradient end of the pond outlet pipe. The anti-seep collars should extend two feet in every direction from the pipe.

4.3 Riprap Outlet Apron

Equation (3) was applied to size the riprap aprons for the surface water pond outlet pipes using the design discharges through the pond outlet pipes based on the HEC-HMS and HY-8 model outputs. The HY-8 model was used to calculate the outflow through the North Surface Water Pond Series 1 and Series 2, while the HEC-HMS model results were used for the North Surface Water Pond Series 3 and Series 4, as previously described.

The flow was assumed to be evenly split between each barrel pipe and the tailwater depth was computed as described in Section 3.3. Based on Equation (3) a minimum d_{50} size for the riprap of was selected. The minimum apron lengths and widths were selected based on Table 2C-1. FHWA (2006) recommends a 3:1 rate of expansion. Results for the riprap outlet aprons dimensions for each pond series are provided in Table 2C-7.

It is noted that since the outlet pipe of the North Surface Water Pond Series 1 is discharging into a stabilized trapezoidal channel lined with geomembrane, the dimensions of the riprap apron are restricted by the downstream channel dimensions. Therefore, the entire width of the channel (8 feet) should be lined with riprap, and the necessary length of the riprap apron is less than the length of the stabilized channel.

5 REFERENCES

FHWA (2006). *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Federal Highway Administration, US Department of Transportation, Hydraulic Engineering Circular No. 14, Third Edition.

KDNREP (1999). *Engineering Memorandum No. 5*, Kentucky Department of Natural Resources and Environmental Protection, Division of Water, reprinted June 1999.

TDOT (2007). *TDOT Design Division Drainage Manual: Chapter VII Stormwater Storage Facilities,* Tennessee Department of Transportation, March 2007.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.

TABLES

Table 2C-1. Riprap Classes and Apron Dimensions (from FHWA, 2006)

Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1]D is the culvert rise.

Table 2C-2. North Surface Water Pond Design Parameters

North Pond Series	Number of Barrels	Manning's Roughness Coefficient	Diameter (ft)	Length of Pipe (ft)	Inlet Elevation (ft)	Outlet Elevation (ft)	Slope of Pipe (ft/ft)	Slope of Interior Embankment Sideslope (H: 1V)	Berm Elevation (ft)	Spillway Elevation (ft)
Series 1	2	0.012	2.5	64.5	588.0	587.4	0.009	3	598.5	597.0
Series 2	3	0.012	4.5	40	597.0	596.5	0.013	3	604.0	603.0
Series 3	2	0.012	4.5	60	603.0	602.5	0.008	3	614.0	613.0
Series 4	2	0.012	4.5	70	613.0	612.5	0.007	3	625.0	624.0

**Table 2C-3. Manning's n Values
(from TxDOT, 2019)**

Material		Manning's n
Asbestos-cement pipe		0.011-0.015
Brick		0.013-0.017
Cast iron pipe		
	Cement-lined & seal coated	0.011-0.015
Concrete (monolithic)		
	Smooth forms	0.012-0.014
	Rough forms	0.015-0.017
	Concrete pipe	0.011-0.015
	Box (smooth)	0.012-0.015
Corrugated-metal pipe -- (2-1/2 in. x 1/2 in. corrugations)		
	Plain	0.022-0.026
	Paved invert	0.018-0.022
	Spun asphalt lined	0.011-0.015
	Plastic pipe (smooth)	0.011-0.015
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. annular)		0.022-0.027
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. helical)		0.011-0.023
Corrugated-metal pipe -- (6 in. by 1 in. helical)		0.022-0.025
Corrugated-metal pipe -- (5 in. by 1 in. helical)		0.025–0.026
Corrugated-metal pipe -- (3 in. by 1 in. helical)		0.027–0.028
Corrugated-metal pipe -- (6 in. by 2 in. structural plate)		0.033–0.035
Corrugated-metal pipe -- (9 in. by 2-1/2 in. structural plate)		0.033–0.037
Corrugated polyethylene		0.010–0.013
	Smooth	0.009-0.015
	Corrugated	0.018–0.025
Spiral rib metal pipe (smooth)		0.012-0.013
Vitrified clay		
	Pipes	0.011-0.015

Table 2C-4. Summary of Calculated Results for North Surface Water Pond

	25-year, 24-hour Rainfall Event			100-year, 24-hour Rainfall Event		
North Surface Water Pond Series	**Total Flow Rate (cfs)**	**Peak Water Surface Elevation (ft)**	**Pond Water Depth (ft)**	**Total Flow Rate (cfs)**	**Peak Water Surface Elevation (ft)**	**Pond Water Depth (ft)**
Series 1	360.30	597.9	9.9	578.00	598.4	10.4
Series 2	467.40	603.3	6.3	639.20	603.9	6.9
Series 3	369.40	611.3	8.3	522.40	613.5	10.5
Series 4	412.80	622.6	9.6	619.80	624.8	11.8

Table 2C-5. North Surface Water Pond Series 1 and Series 2 Outlet Pipe HY-8 Results

	25-Year, 24-Hour Rainfall Event						100-Year, 24-Hour Rainfall Event					
	Total Flow Rate Q_{25}[b] (cfs)	Pipe Flow (cfs)	Pipe Velocity (fps)	Spillway Flow (cfs)	Tailwater Elev (ft)	Headwater Elev[a] (ft)	Total Flow Rate Q_{100}[b] (cfs)	Pipe Flow (cfs)	Pipe Velocity (fps)	Spillway Flow (cfs)	Tailwater Elev (ft)	Headwater Elev[a] (ft)
North Pond Series 1 Outlet	360.30	149.96	15.27	210.27	589.85	597.92	578.00	154.59	15.75	423.23	590.48	598.46
North Pond Series 2 Outlet	467.40	433.91	12.54	33.29	597.90	603.27	639.20	468.39	12.89	170.55	598.40	603.80

[a] Headwater elevations predicted from HY-8 modeling are generally smaller than those predicted from the HEC-HMS model. The HEC-HMS model results (Attachment 2B) are considered to be more precise predictions of water levels within the ponds. The HY-8 model was used to size the riprap aprons at the pond outlet pipe using the portion of the total flow that is being conveyed through the pond outlet pipe. The smaller headwater predicted by the HY-8 model predicts more of the total outflow being conveyed through the pond outlet pipes because less water is allowed to discharge from the pond over the emergency spillway due to the smaller headwater predictions (i.e., conservative for the purposes of riprap sizing).

[b] These values are the total outflow rate from the pond predicted from HEC-HMS model results. These values are used as input to the HY-8 model.

Table 2C-6. North Surface Water Pond Anti-Seep Collar Results

North Pond Series	Length of Pipe Within Saturated Zone, L_s (ft)	Number of Collars Required	Vertical and Horizontal Projection of Each Seep Collar (ft)
Series 1	72.0	3	2.00
Series 2	46.4	2	2.00
Series 3	60.1	2	2.25
Series 4	69.2	3	2.00

Table 2C-7. North Surface Water Pond Outlet Pipe Riprap Apron Results

North Pond Series	d_{50} (in)	Riprap Class	Apron Length (ft)	Downstream Apron Width (ft)	Apron Depth (ft)
Series 1	23	6	20	21	3.7
Series 2	14	4	32	35	2.2
Series 3	19	5	32	35	3.1
Series 4	22	6	36	38	3.4

FIGURES

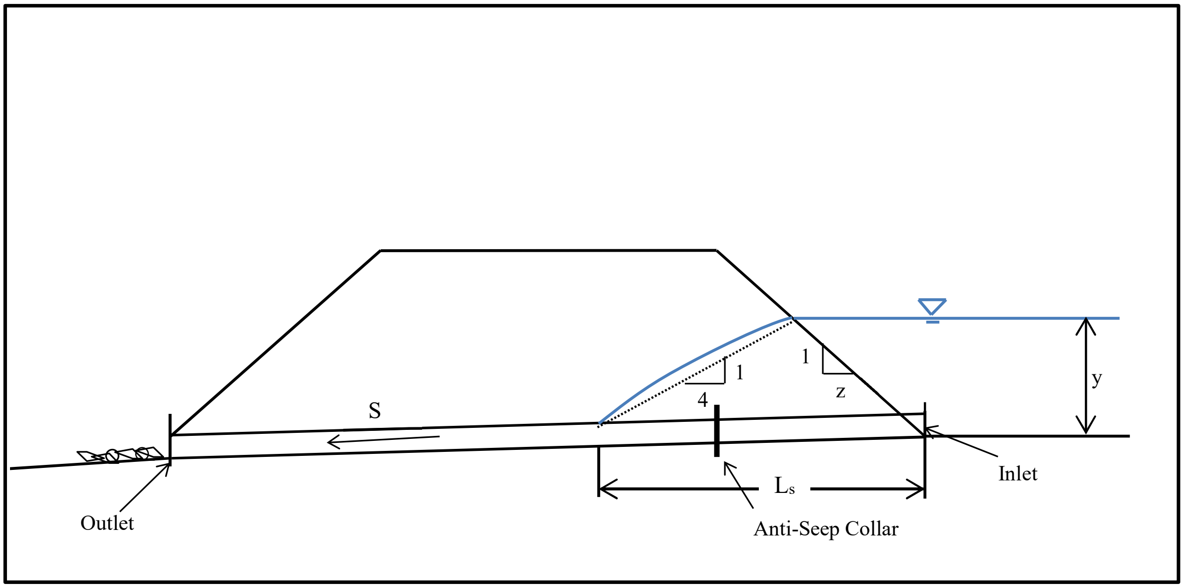

Figure 2C-1. Anti-Seep Collar Design Schematic (not to scale)

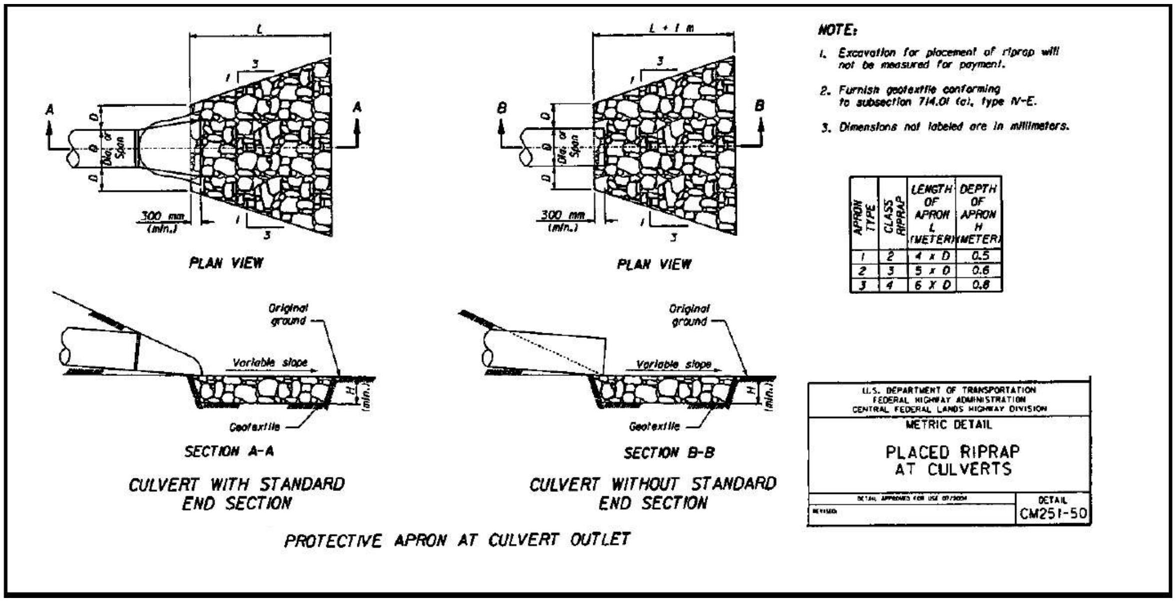

Figure 2C-2. Placed Riprap Apron Standard Detail (from FHWA, 2006)

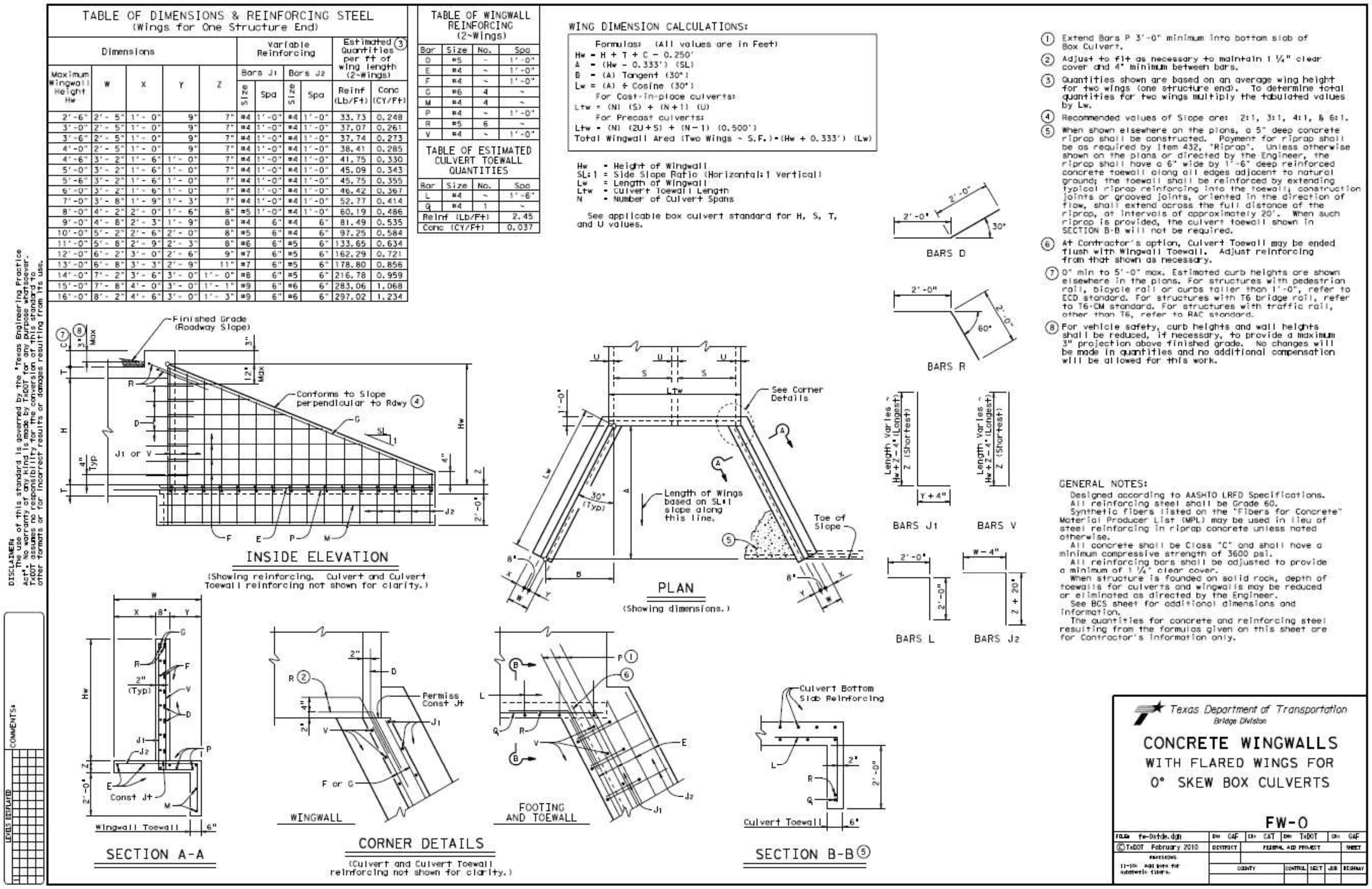

Figure 2C-3. TxDOT Standard Detail FW-0 for Concrete Wingwalls

Source: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/bridge/fw-0stde.pdf (Date Accessed: 12/4/2019)

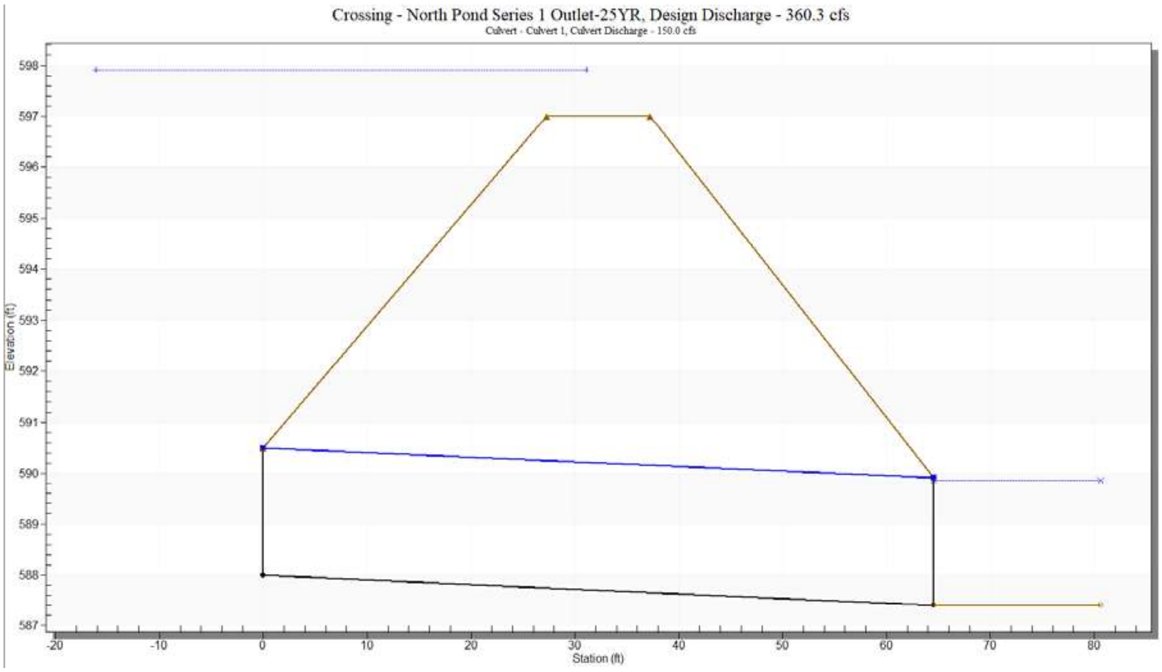

Figure 2C-4. HY-8 Modeling Output for 25-Year Event North Surface Water Pond Series 1 Outlet Pipe

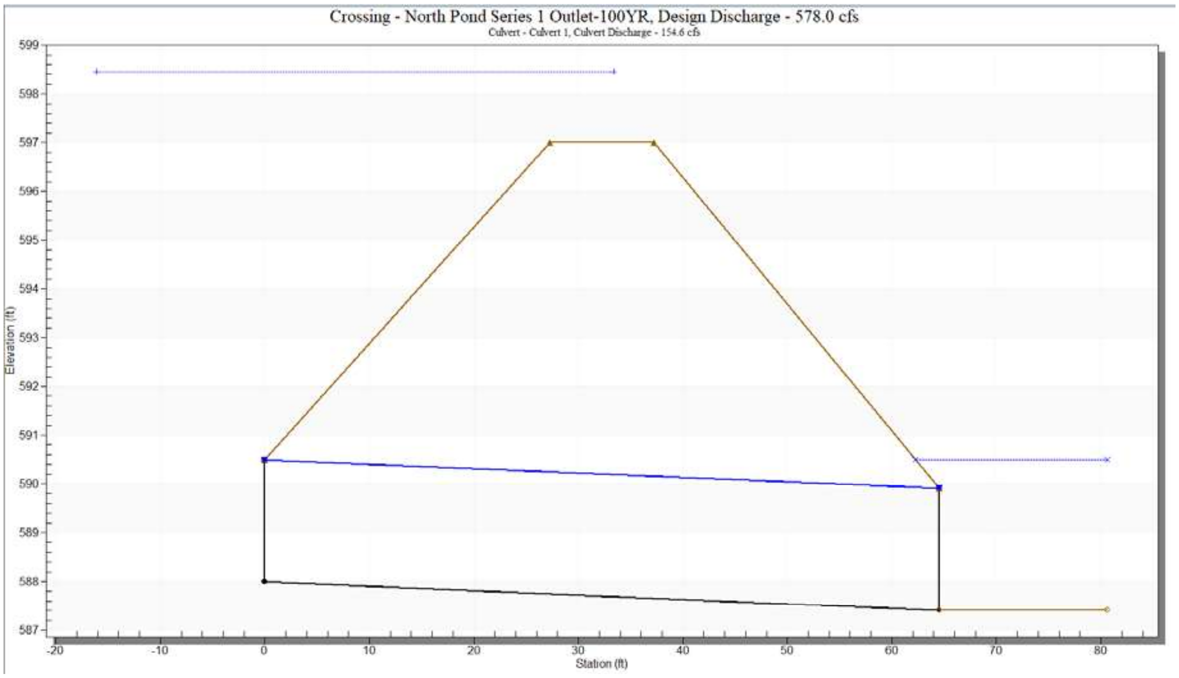

Figure 2C-5. HY-8 Modeling Output for 100-Year Event North Surface Water Pond Series 1 Outlet Pipe

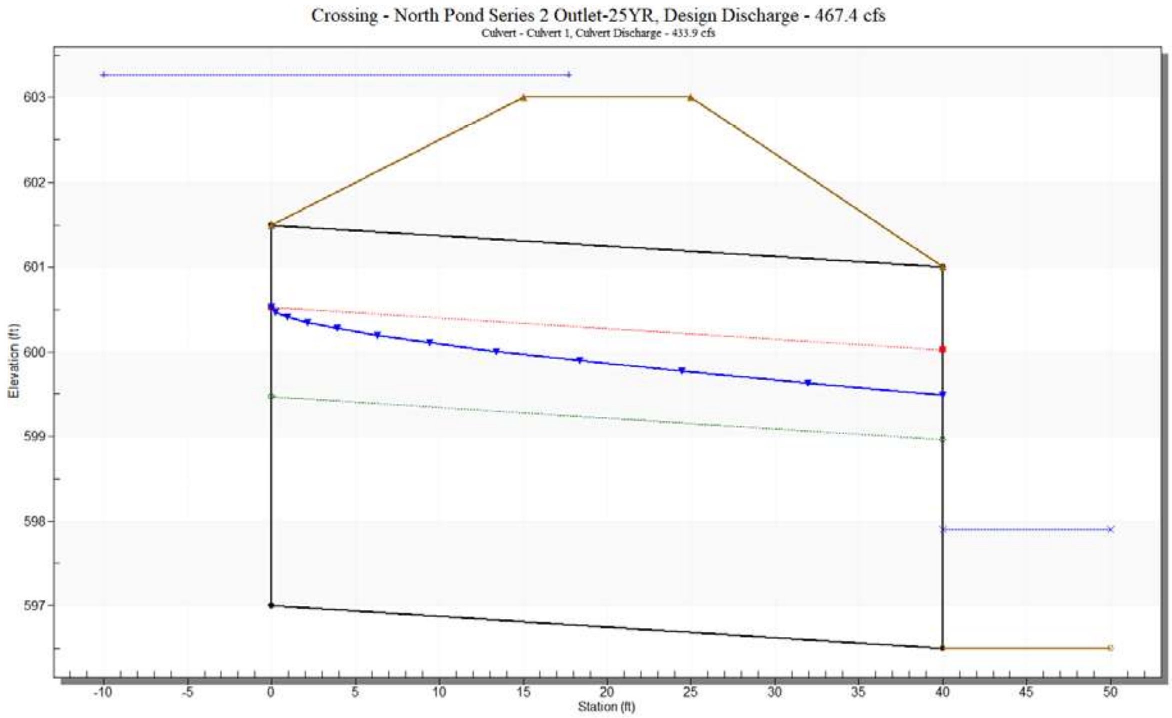

Figure 2C-6. HY-8 Modeling Output for 25-Year Event North Surface Water Pond Series 2 Outlet Pipe

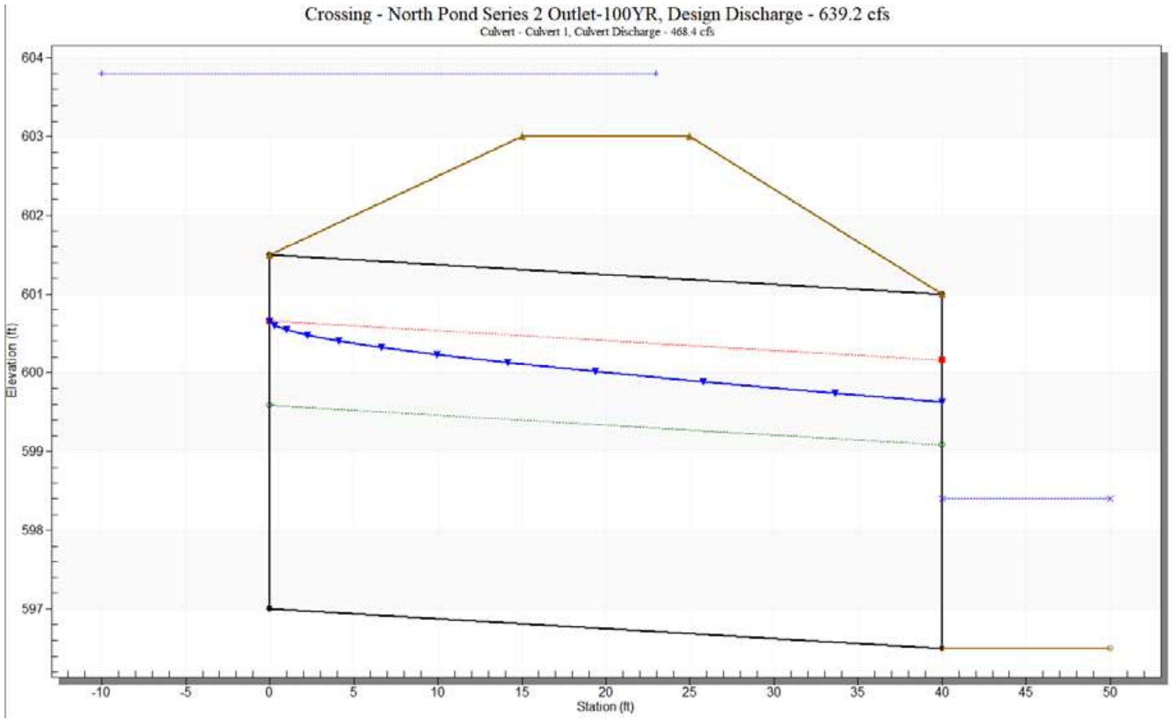

Figure 2C-5. HY-8 Modeling Output for 100-Year Event North Surface Water Pond Series 2 Outlet Pipe

ATTACHMENT 2D

ON-SITE DESIGN – DRAINAGE TERRACES AND DOWNCHUTE CHANNELS

Written by:	**O. Bramlet**	Date:	**01/09/2020**	Reviewed and Revised by:	**S. Graves**	Date:	**2/4/2020; 9/15/2020**
Client:	**TRLC**	Project:	**Fort Worth C&D Landfill**	Project No.:	**GW6953**	Phase No.:	**04**

ON-SITE DESIGN – DRAINAGE TERRACES AND DOWNCHUTE CHANNELS FORT WORTH C&D LANDFILL EXPANSION

STATE OF TEXAS
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LICENSED PROFESSIONAL ENGINEER

9/15/2020

SEALED FOR PERMITTING PURPOSES, CALCULATION PAGES 1 TO 22

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the design of the top deck drainage terraces, sideslope drainage terraces, and downchute channels for the facility surface water management system for the Fort Worth C&D Landfill. As part of the facility surface water management system design, sheet flow runoff from the final cover system is intercepted by drainage terraces located at the base of the top deck surface and on the 3 horizontal: 1 vertical (3H:1V) final cover sideslopes. Top deck and sideslope drainage terraces convey runoff to downchute channels. These downchute channels subsequently convey the runoff to perimeter drainage channels. The perimeter drainage channels convey surface water runoff to either the midpoint site outfall or the North Surface Water Pond. Design of the surface water pond is presented in Attachment 2C. Design of the perimeter channels is presented in Attachment 2E. The Facility Surface Water Management Plan shows the layout of each of these features and can be found in Drawing 2-1 of the Drainage Report (the drawings are in Attachment 2A of the Drainage Report).

2 METHODOLOGY

The top deck drainage terraces and sideslope drainage terraces are designed as grass-lined v-shaped channels (i.e., trapezoidal channels with bottom width equal to zero) and are sized to convey runoff from the 25-year, 24-hour rainfall event with 0.5 feet of freeboard and to convey the 100-year, 24-hour rainfall event without overtopping. Additionally, the average velocity and the average tractive stress are calculated based on the predicted peak flow for each rainfall event. The top deck drainage terraces are located at the base of the top deck surfaces, while the sideslope drainage terraces are spaced a maximum of 200-feet apart horizontally on the 3H:1V final cover sideslopes (see Drawing 2-1 in Attachment 2A). Typical drainage terrace and downchute cross-sections for the final cover system are shown on the drawings presented in Attachment 2 (the Facility Surface Water Drainage Report) of the Site Development Plan (SDP). The hydraulic design of the terrace and downchute drainage features meets or exceeds the design criteria described herein.

Downchute channels are evaluated as articulated concrete block (ACB) lined trapezoidal channels in this calculation package. Other equivalent downchute channel lining materials meeting the design performance criteria addressed in this calculation package may be used. The downchute channels are designed to convey the 25-year, 24-hour rainfall event with 0.5 feet of freeboard (and to convey the 100-year, 24-hour rainfall event without overtopping) down the 3H:1V final cover sideslopes and into the perimeter drainage channels. The peak 25-year, 24-hour rainfall event discharge and resulting calculated average tractive stresses are used to design the lining system of the downchute channels.

The capacity of each downchute channel and drainage terrace is calculated by solving Manning's equation for the depth of flow within each channel or terrace. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad (1)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The average tractive stresses in the downchute or drainage terrace for various flows are estimated by Equation (2) (Chow, 1959).

$$\tau_o = \gamma_w RS \tag{2}$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Each top deck drainage area and sideslope drainage area was modeled as a separate sub-basin in the HEC-HMS model as discussed in Attachment 2B. However, the hydraulic performance of the top deck drainage terraces and sideslope drainage terraces were not directly modeled in the HEC-HMS model. The travel time through these drainage features is minimal and would not significantly impact the results; therefore, the hydraulic performance was modeled using Manning's equation as described above. Furthermore, it is conservative to not explicitly model the drainage terraces because this removes the lag effect in the peak flow rates. The peak flow rate for each top deck and sideslope drainage terrace was assumed to be equal to that of the corresponding drainage area. The drainage downchutes were modeled explicitly in the HEC-HMS model. Each sub-basin was routed to a downchute within the HEC-HMS model to compute the peak discharges within each downchute channel. The locations and contributing areas of the top deck drainage terraces and downchute channels are shown on Drawing 2-3 of Attachment 2A. The resulting peak flow rates from the HEC-HMS model output were used in the Manning's equation to calculate the resulting flow depths and tractive stresses in the drainage features to demonstrate that the design parameters of the drainage features are adequate.

The downchute channel design evaluation is for an articulated concrete block (ACB) channel lining to resist erosive forces. As noted, other equivalent downchute channel lining materials meeting the design performance criteria addressed in this calculation package may be used. For this ACB design, the method relates the tested critical shear stress of an ACB system on a horizontal plane to the design conditions and then accounts for slope by checking that the resistance is adequate to prevent failure. The maximum allowable tractive stress is calculated using the following equation:

$$\tau_0 = \frac{\tau_\theta \chi_2}{\chi_2 \cos\theta - \chi_1 \sin\theta} \quad (3)$$

where: τ_0 = maximum allowable tractive stress at 0° (psf);
τ_θ = maximum allowable tractive stress at θ° (psf); and
χ_2 and χ_1 = extrapolation variables (inches).

ACB-type channel lining is suitable for use on 3H:1V slopes. In fact, the methodology presented in Equation (3) was developed using laboratory flume testing data the ACB Channel Lock 450 system that was conducted on a 3H:1V sideslope bedded on a compacted soil embankment with conditions representative of those expected for this site, for a range of flow rates until failure of the ACB occurred (Ayers, 2001a). This value was used to extend the tested results to a horizontal bed (0° slope) using the moment-balance Equation (3) above to allow the results to be applied to different slope angles. Test data was also extrapolated to ACB systems of different sizes using an overturning moment-balance approach accounting for stabilizing and destabilizing forces. As further described in the subsequent paragraph, there is minimal chance of failure due to sliding of the lining along the plane of the subgrade. The loss of contact is primarily due to the overturning of a block in which failure occurs. The best method for determining failure is in terms of tractive stress, derived in Equation (3) to extrapolate from laboratory settings to hypothetical situations.

According to the ACB design manual (Ayers, 2001b), typical applications of ACBs are on slopes of 2H:1V or flatter. This shows that the design conditions for this site (on 3H:1V slopes) are a typical ACB application condition. The design manual notes that "*the probability of failure due to slipping or sliding of the system matrix along the plane of the subgrade is remote. The loss of intimate contact is most often the result of overturning of a block or group of blocks, in which incipient failure occurs when the overturning moments equal the retaining moments about the downstream contact point of an individual block.*" From the design manual and the flume tests conducted on ACB inclined on a 3H:1V with similar subgrade conditions to that expected for this site, it is apparent that the critical mode of failure for ACB systems on slopes at 2H:1V or flatter is overturning. By using this methodology and confirming that the design conditions can adequately resist an overturning-mode of failure, the design would be expected to adequately resist the less-critical sliding mode of failure.

3 DESIGN PARAMETERS

The design parameters, including channel geometry, Manning's roughness coefficient, and calculated peak discharges for the 25-year and 100-year rainfall events (Attachment 2B), are summarized for each downchute channel and top deck drainage terrace in Table 2D-1 and Table 2D-2, respectively.

The sideslope drainage terraces are designed as a v-shaped tack-on berms constructed on the 3H:1V sideslopes of the final cover system with design parameters summarized in Table 2D-3. Thus, the sideslopes of the terrace are 3H:1V on the final cover side and 2.5H:1V on the berm side and each terrace has a depth of 2.50 ft. The nominal longitudinal slope of each sideslope drainage terrace is approximately 2% and most terraces are laid out to this longitudinal slope. Each of these site-specific conditions was analyzed to confirm that the sideslope drainage terrace design is adequate for the contributing drainage area and terrace slope. Drawing 2-3 shows the location of each sideslope drainage terrace, top deck drainage terrace, and drainage downchute structures on the final cover system.

Each drainage structure is designed to maintain a minimum of 0.5 feet of freeboard during the 25-year, 24-hour rainfall event. Additionally, each terrace and downchute channel is designed to convey the peak flow during the 100-year, 24-hour rainfall event without overtopping. The calculated 25-year average tractive stress is used to design the lining system of each drainage feature.

The downchute channel design evaluation is for an ACB-lined channel to resist erosive forces. As mentioned, other equivalent downchute channel lining materials meeting the design performance criteria addressed in this calculation package may be used. The maximum allowable tractive stress is calculating using Equation (3) above. The critical shear stress for a horizontal bottom width surface for various ACB types is shown in Table 2D-4 (Ayres, 2001a). ACB Channel Lock 800 is proposed for the downchutes. The maximum allowable tractive stress, or shear stress, for the ACB 800 is 12.8 psf as shown in Table 2D-4 (Ayres, 2001a).

As mentioned, the extrapolation variables were developed based on testing of the ACB Channel Lock 450 system on a 3H:1V sideslope. The Ayres (2001a) report indicates that the "performance extrapolation method… is overly conservative when used to estimate the performance of thicker blocks based on tests of thinner blocks." This suggests that the maximum allowable tractive stress for the ACB 800 system is potentially greater than the calculated value of 12.8 psf. The basis for this claim was additional testing conducted on the ACB Channel Lock 800 system on a 2H:1V sideslope until failure. The proposed ACB system is expected to be overly conservative in terms of maximum allowable tractive stress based on testing data conducted on steep slopes. Furthermore, the proposed ACB system will be anchored into the final cover system along the edges of the downchute drainage channel, thus providing additional strength of the system and resistance to erosive forces.

The peak flows applied to the design of each downchute channel are based on the flows from the entire contributing top deck and sideslope areas for the 25-year, 24-hour rainfall event as provided in Attachment 2B. This is considered conservative as the sum of these flows will only influence the performance of the lining materials at the down gradient end of each downchute channel as opposed to the entire length of the downchute channel.

The allowable tractive stress for the ACB-lined downchutes is documented in published research data (e.g., Ayres, 2001a) and selected for design. The ACB-lined downchute is designed to accommodate the design storm event without shifting of the blocks or any loss of embankment soil beneath the ACB system.

Permissible tractive stresses for grass-lined channels range from 0.35 psf to 3.70 psf depending on the retardation class of vegetation. Retardation Class C (which includes Bermuda and Crab grasses among others) is selected for the design of grass lined channels (as shown in Table 2D-5) and has a maximum permissible tractive stress of 1.0 psf (as shown in Table 2D-6 from TxDOT, 2019).

A range of Manning's roughness coefficients for a variety of channel linings are selected from TxDOT (2019) provided in Table 2D-7. For the grass lined channels a roughness value of n = 0.027 was selected. As previously mentioned, the roughness for ACB lined channels was selected as n = 0.036 (Ayers, 2001a).

4 RESULTS

The depth of flow, velocity, and average tractive stress for the peak discharges into each downchute channel, top deck drainage terrace, and each sideslope drainage terrace were calculated using Equations (1) and (2). These calculations for the downchute channels, top deck drainage terraces, and sideslope drainage terraces are summarized in Table 2D-8, Table 2D-9, and Table 2D-10, respectively. Appendix 2D-1 provides spreadsheets used for calculating the results tables for the downchute channel, top deck drainage terrace, and sideslope drainage terrace with the greatest flow rates (i.e., the critical design cases). Drawing 2-3 provides location and layout of each drainage structure discussed within this calculation package.

- Each downchute channel and drainage terrace was calculated to contain the capacity to convey the flows from the 25-year, 24-hour and the 100-year, 24-hour rainfall events.
- Each downchute channel and drainage terrace was designed to maintain at least 0.5 feet of freeboard for the 25-year, 24-hour rainfall event.
- For each downchute channel, the average tractive stresses were calculated to remain below 12.8 psf during the 25-year, 24-hour rainfall event. The average tractive stress for each drainage terrace was calculated to remain below 1.0 psf during the 25-year, 24-hour rainfall event. The selected channel lining materials can adequately resist these tractive stresses.

5 REFERENCES

Ayres Associates (2001a). "*Hydraulic Stability of the Channel-Lock 450 Concrete Block Revetment System*", Ayres Associates, August, 2001.

Ayres Associates (2001b). "*Design Manual for Articulating Concrete Block Systems*", Ayres Associates, September, 2001.

Chow, V.T. (1959). *Open Channel-Hydraulics,* McGraw-Hill.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.

TABLES

Table 2D-1. Design Parameter Summary for Downchute Channels

Downchute Channel Segment	Channel Shape	Longitudinal Channel Slope (%)	Manning's n	Bottom Width (ft)	Depth (ft)	Side Slopes (H:V)	25-year Flow Rate[1] Q_{25} (cfs)	100-year Flow Rate[1] Q_{100} (cfs)
Downchute A	Trapezoidal	33.3	0.036	12.0	2.0	3:1	167.70	226.20
Downchute B	Trapezoidal	33.3	0.036	4.0	2.0	3:1	96.00	129.50
Downchute C	Trapezoidal	33.3	0.036	10.0	2.0	3:1	156.20	210.70
Downchute D	Trapezoidal	33.3	0.036	2.0	2.0	3:1	76.60	103.20
Downchute E	Trapezoidal	33.3	0.036	8.0	2.0	3:1	133.40	179.90

Notes:

1. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-2. Design Parameter Summary for Top Deck Drainage Terraces

Top Deck Channel Segment	Channel Shape	Longitudinal Channel Slope (ft/ft)	Manning's n	Bottom Width (ft)	Depth (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	25-year Flow Rate[1] Q_{25} (cfs)	100-year Flow Rate[1] Q_{100} (cfs)
A-1	V-shaped	0.0322	0.027	0.0	2.0	20:1	3:1	66.20	89.30
C-1	V-shaped	0.0100	0.027	0.0	2.0	20:1	3:1	61.90	83.60

Notes:

1. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-3. Design Parameter Summary for Sideslope Drainage Terraces

Sideslope Channel Segment	Channel Shape	Longitudinal Channel Slope (%)	Manning's n	Bottom Width (ft)	Depth (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	25-year Flow Rate[1] Q_{25} (cfs)	100-year Flow Rate[1] Q_{100} (cfs)
A-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	44.0	62.3
A-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	10.2	13.8
A-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	14.3	19.3
A-5	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	23.8	32.2
A-6	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	20.8	28.0
A-7	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	34.3	46.3
B-1	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	19.6	26.5
B-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	18.5	24.9
B-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	25.4	34.3
B-4	V-shaped	2.50%	0.027	0.0	2.5	2.5:1	3:1	33.0	44.5
C-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	36.1	48.7
C-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	14.3	19.3
C-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	26.4	35.7
D-1	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	3.2	4.3
D-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	6.4	8.7
D-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	5.9	8.0
D-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	43.7	58.9
D-5	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	7.3	9.8
D-6	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	10.1	13.7
E-1	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	15.6	21.1
E-2	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	47.8	64.5
E-3	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	17.7	23.8
E-4	V-shaped	2.00%	0.027	0.0	2.5	2.5:1	3:1	52.4	70.7

Notes:

1. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-4. Channel Lock ACB Performance Variables

(from Ayres, 2001a)

Block Type	Weight in Air (typ.)[2] (lbs.)	Buoyant Weight W_s (lbs.)	χ^1 (in)	χ^2 (in)	χ^3 (in)	χ^4 (in)	b (in)	τ_c at 0° (lb/ft^2)
450[1]	52	27.0	2.25	7.25	3.60	7.25	14.5	11.6
550	64	33.3	2.75	7.25	4.40	7.25	14.5	13.3
800	93	48.4	4.00	7.25	6.40	7.25	14.5	16.5

Notes: 1. Tested block
2. Based on block volume and assuming concrete density of 130 lb/ft^3

3. Maximum allowable tractive stress for Block Types 550 and 800 was calculated using Equation 3 (from Ayres, 2001a) based on conversion for different slope angles.

Table 2D-5. Retardation Class for Lining Materials

(from TxDOT, 2019)

Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30 in. or 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in. or 915 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12 in. or 305 mm)
	Native grass mixture little bluestem, bluestem, blue gamma, other short and long stem midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good Stand, tall (average 24 in. or 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in. or 480 mm)
	Alfalfa	Good stand, uncut (average 11 in or 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 13 in. or 330 mm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13 in. or 330 mm)
C	Crabgrass	Fair stand, uncut (10-to-48 in. or 55-to-1220 mm)
	Bermuda grass	Good stand, mowed (average 6 in. or 150 mm)
	Common lespedeza	Good stand, uncut (average 11 in. or 280 mm)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6-8 in. or 150-200 mm)
	Centipedegrass	Very dense cover (average 6 in. or 150 mm)
	Kentucky bluegrass	Good stand, headed (6-12 in. or 150-305 mm)
D	Bermuda grass	Good stand, cut to 2.5 in. or 65 mm
	Common lespedeza	Excellent stand, uncut (average 4.5 in. or 115 mm)
	Buffalo grass	Good stand, uncut (3-6 in. or 75-150 mm)
	Grass-legume mixture: fall, spring (orchard grass Italian ryegrass, and common lespedeza)	Good Stand, uncut (4-5 in. or 100-125 mm)
	Lespedeza sericea	After cutting to 2 in. or 50 mm (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5 in. or 40 mm
	Bermuda grass	Burned stubble

Table 2D-6. Permissible Shear Stresses for Various Linings

(from TxDOT, 2019)

Protective Cover	(lb./sq.ft.)	t_p (N/m^2)
Retardance Class A Vegetation (See the "Retardation Class for Lining Materials" table above)	3.70	177
Retardance Class B Vegetation (See the "Retardation Class for Lining Materials" table above)	2.10	101
Retardance Class C Vegetation (See the "Retardation Class for Lining Materials" table above)	1.00	48
Retardance Class D Vegetation (See the "Retardation Class for Lining Materials" table above)	0.60	29
Retardance Class E Vegetation (See the "Retardation Class for Lining Materials" table above)	0.35	17
Woven Paper	0.15	7
Jute Net	0.45	22
Single Fiberglass	0.60	29
Double Fiberglass	0.85	41
Straw W/Net	1.45	69
Curled Wood Mat	1.55	74
Synthetic Mat	2.00	96

Table 2D-7. Manning's Roughness Coefficients
(from TxDOT, 2019)

B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2D-8. Summary of Calculated Results for Downchute Channels

Downchute Channel Segment	25-Year Design Rainfall Event					100-Year Design Rainfall Event			
	Peak Flow Rate Q_{25} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)	Minimum Permissible ACB Type[1]	Peak Flow Rate Q_{100} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)
Downchute A	167.70	0.70	17.0	12.5	ACB 800	226.20	0.83	18.8	14.5
Downchute B	96.00	0.86	17.0	12.4	ACB 800	129.50	1.00	18.5	14.1
Downchute C	156.20	0.74	17.3	12.8	ACB 800	210.70	0.87	19.0	14.8
Downchute D	76.60	0.95	16.5	12.0	ACB 800	103.20	1.09	17.9	13.5
Downchute E	133.40	0.76	17.1	12.6	ACB 800	179.90	0.89	18.8	14.5

Notes:

1. ACB 800 indicates ACB Channel Lock 800.

Table 2D-9. Summary of Calculated Results for Top Deck Drainage Terraces

Top Deck Channel Segment	25-Year Design Rainfall Event				100-Year Design Rainfall Event			
	Peak Flow Rate Q_{25} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)	Peak Flow Rate Q_{100} (cfs)	Peak Depth of Flow (ft)	Peak Average Velocity (ft/s)	Peak Average Tractive Stress (psf)
A-1	66.20	0.97	6.07	0.96	89.30	1.09	6.54	1.08
C-1	61.90	1.18	3.86	0.36	83.60	1.32	4.16	0.41

Table 2D-10. Summary of Calculated Results for Sideslope Drainage Terraces

	25-Year, 24-Hour Rainfall Event				100-Year, 24-Hour Rainfall Event			
Sideslope Channel Segment	**Peak Flow Rate Q_{25} (cfs)**	**Peak Depth of Flow (ft)**	**Peak Average Velocity (ft/s)**	**Peak Average Tractive Stress (psf)**	**Peak Flow Rate Q_{100} (cfs)**	**Peak Depth of Flow (ft)**	**Peak Average Velocity (ft/s)**	**Peak Average Tractive Stress (psf)**
A-2	44.00	1.58	6.39	0.93	62.30	1.80	6.98	1.05
A-3	10.20	0.91	4.43	0.53	13.80	1.02	4.78	0.60
A-4	14.30	1.04	4.82	0.61	19.30	1.16	5.20	0.68
A-5	23.80	1.26	5.49	0.74	32.20	1.40	5.91	0.82
B-1	19.60	1.17	5.22	0.68	26.50	1.31	5.63	0.76
B-2	18.50	1.14	5.15	0.67	24.90	1.28	5.55	0.75
B-3	25.40	1.28	5.57	0.75	34.30	1.44	6.01	0.84
B-4	33.00	1.42	5.95	0.83	44.50	1.59	6.41	0.93
C-2	36.10	1.47	6.09	0.86	48.70	1.64	6.56	0.96
C-3	14.30	1.04	4.82	0.61	19.30	1.16	5.20	0.68
C-4	26.40	1.30	5.63	0.76	35.70	1.46	6.07	0.86
C-5	19.00	1.15	5.18	0.68	25.60	1.29	5.58	0.76
D-1	3.20	0.59	3.30	0.34	4.30	0.66	3.57	0.39
D-2	6.40	0.77	3.95	0.45	8.70	0.86	4.26	0.50
D-3	5.90	0.74	3.87	0.44	8.00	0.83	4.17	0.49
D-4	43.70	1.58	6.38	0.92	58.90	1.76	6.88	1.03
D-5	7.30	0.80	4.07	0.47	9.80	0.90	4.39	0.53
D-6	10.10	0.91	4.42	0.53	13.70	1.02	4.78	0.60
E-1	15.60	1.07	4.93	0.63	21.10	1.20	5.32	0.70
E-2	47.80	1.63	6.53	0.96	64.50	1.82	7.04	1.07
E-3	17.70	1.12	5.09	0.66	23.80	1.26	5.49	0.74
E-4	52.40	1.69	6.62	0.97	70.70	1.90	7.14	1.08

Appendix 2D-1

Drainage Feature Calculations

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

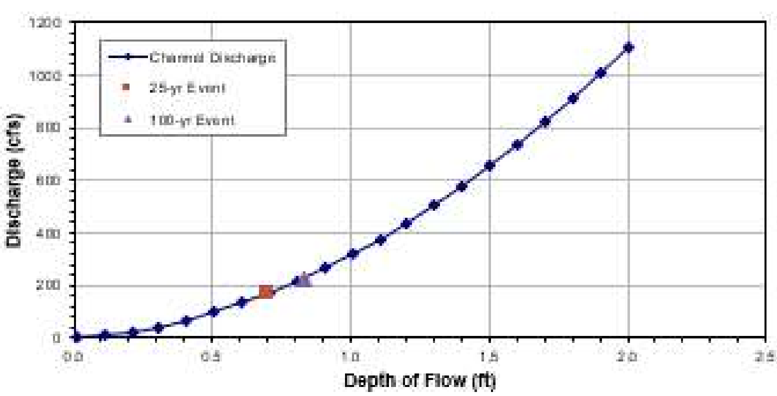
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Downchute A Design**

Peak Discharge, Q_{25} =	167.70	cfs (25-yr Event)
Peak Discharge, Q_{100} =	226.20	cfs (100-yr Event)
Bottom Width, B =	12.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	2.00	ft
Top Width, T =	24.0	ft
Manning's Roughness Coeff., n =	0.04	
Longitudinal Channel Slope, S_o =	0.33	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.12	12.06	0.01	1.11	0.1	0.21	
0.11	1.35	12.69	0.11	5.36	7.2	2.21	
0.21	2.64	13.32	0.20	8.12	21.4	4.12	
0.31	3.99	13.95	0.29	10.36	41.3	5.95	
0.41	5.40	14.58	0.37	12.31	66.4	7.70	
0.51	6.86	15.21	0.45	14.05	96.4	9.39	
0.61	8.39	15.84	0.53	15.64	131.2	11.02	
0.71	9.98	16.47	0.61	17.10	170.6	12.60	
0.81	11.62	17.10	0.68	18.47	214.6	14.14	
0.91	13.33	17.73	0.75	19.75	263.2	15.64	
1.01	15.09	18.36	0.82	20.97	316.4	17.10	
1.10	16.91	18.99	0.89	22.12	374.2	18.53	
1.20	18.80	19.61	0.96	23.23	436.6	19.93	
1.30	20.74	20.24	1.02	24.28	503.6	21.31	
1.40	22.74	20.87	1.09	25.30	575.4	22.66	
1.50	24.80	21.50	1.15	26.28	651.9	23.99	
1.60	26.92	22.13	1.22	27.23	733.2	25.30	
1.70	29.10	22.76	1.28	28.15	819.3	26.60	
1.80	31.34	23.39	1.34	29.05	910.4	27.87	
1.90	33.64	24.02	1.40	29.92	1006.4	29.13	
2.00	36.00	24.65	1.46	30.76	1107.5	30.38	
0.70	9.86	16.42	0.60	17.00	167.54	12.48	Q (25-yr Event)
0.83	12.02	17.25	0.70	18.78	225.79	14.50	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

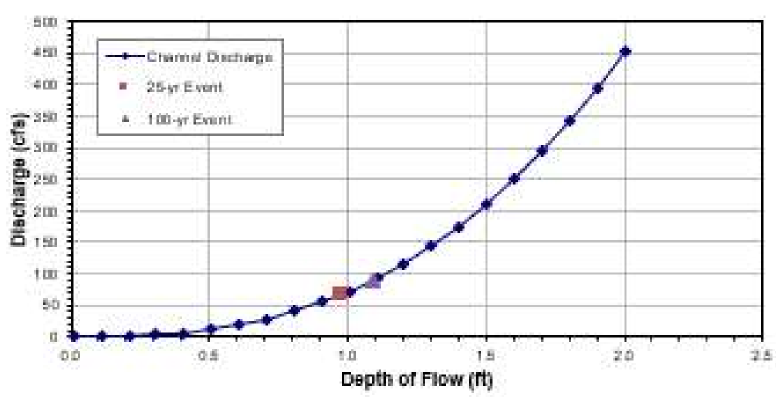
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **A-1 Top Deck Drainage Terrace Design**

Peak Discharge, Q_{25} =	66.20	cfs (25-yr Event)
Peak Discharge, Q_{100} =	89.30	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	20.0	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.00	ft
Top Width, T =	46.0	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0320	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.23	0.00	0.29	0.0	0.01	
0.11	0.14	2.54	0.05	1.41	0.2	0.11	
0.21	0.50	4.85	0.10	2.18	1.1	0.21	
0.31	1.09	7.15	0.15	2.82	3.1	0.31	
0.41	1.91	9.46	0.20	3.40	6.5	0.40	
0.51	2.96	11.77	0.25	3.93	11.7	0.50	
0.61	4.24	14.07	0.30	4.43	18.8	0.60	
0.71	5.74	16.38	0.35	4.90	28.2	0.70	
0.81	7.47	18.69	0.40	5.36	40.0	0.80	
0.91	9.43	21.00	0.45	5.79	54.6	0.90	
1.01	11.62	23.30	0.50	6.20	72.1	1.00	
1.10	14.03	25.61	0.55	6.61	92.7	1.09	
1.20	16.67	27.92	0.60	7.00	116.7	1.19	
1.30	19.54	30.22	0.65	7.38	144.2	1.29	
1.40	22.64	32.53	0.70	7.75	175.5	1.39	
1.50	25.96	34.84	0.75	8.11	210.6	1.49	
1.60	29.51	37.15	0.79	8.47	249.9	1.59	
1.70	33.29	39.45	0.84	8.82	293.5	1.69	
1.80	37.30	41.76	0.89	9.16	341.5	1.78	
1.90	41.54	44.07	0.94	9.49	394.2	1.88	
2.00	46.00	46.37	0.99	9.82	451.7	1.98	
0.97	10.86	22.53	0.48	6.07	65.86	0.96	Q (25-yr Event)
1.09	13.62	25.23	0.54	6.54	89.08	1.08	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

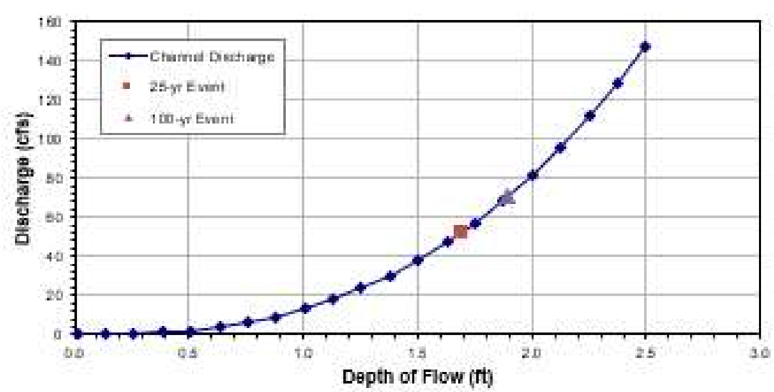
Project: Fort Worth C&D Landfill Expansion

Ditch ID: E-4 Mid-Slope Drainage Berm Design

Peak Discharge, Q_{25} =	52.40	cfs (25-yr Event)
Peak Discharge, Q_{100} =	70.70	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.50	ft
Top Width, T =	13.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.020	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.13	0.05	0.79	0.06	1.22	0.1	0.08	
0.26	0.18	1.52	0.12	1.89	0.3	0.15	
0.38	0.40	2.25	0.18	2.46	1.0	0.22	
0.51	0.71	2.97	0.24	2.96	2.1	0.29	
0.63	1.10	3.70	0.30	3.43	3.8	0.36	
0.76	1.58	4.43	0.36	3.87	6.1	0.43	
0.88	2.14	5.16	0.41	4.28	9.1	0.50	
1.01	2.78	5.89	0.47	4.67	13.0	0.57	
1.13	3.51	6.62	0.53	5.05	17.8	0.65	
1.26	4.33	7.35	0.59	5.42	23.5	0.72	
1.38	5.23	8.08	0.65	5.77	30.2	0.79	
1.50	6.22	8.81	0.71	6.11	38.0	0.86	
1.63	7.29	9.53	0.76	6.44	47.0	0.93	
1.75	8.45	10.26	0.82	6.77	57.2	1.00	
1.88	9.69	10.99	0.88	7.09	68.7	1.07	
2.00	11.02	11.72	0.94	7.40	81.5	1.14	
2.13	12.44	12.45	1.00	7.70	95.8	1.22	
2.25	13.93	13.18	1.06	8.00	111.4	1.29	
2.38	15.52	13.91	1.12	8.29	128.7	1.36	
2.50	17.19	14.64	1.17	8.58	147.4	1.43	
1.69	7.89	9.92	0.80	6.62	52.24	0.97	Q (25-yr Event)
1.90	9.90	11.11	0.89	7.14	70.61	1.08	Q (100-yr Event)

Discharge versus Depth Relationship



ATTACHMENT 2E

ON-SITE DESIGN – CULVERTS AND PERIMETER DRAINAGE CHANNELS

ON-SITE DESIGN – CULVERTS AND PERIMETER DRAINAGE CHANNELS FORT WORTH C&D LANDFILL EXPANSION

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

5/7/2020

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 28

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the design of the perimeter drainage channels and roadway culverts for the proposed facility surface water management system for the Fort Worth C&D Landfill (site). Riprap aprons located at the outlet of culverts and the outlet of perimeter drainage channels into surface water ponds are also designed within this calculation package. However, surface water pond outlet pipe design analyses including the design of appurtenances (which refers to anti-seep collars and riprap aprons) are evaluated separately within Attachment 2C of the Facility Surface Water Drainage Report (Drainage Report).

Top deck and sideslope drainage terraces convey runoff from the final cover to downchute channels. Perimeter drainage channels will be located at the base of the downchute channels around the north, east, and south sides of the landfill.

The south perimeter drainage channel, designated as Storm Water Channel A, conveys surface water from the southern areas of the final cover system and off-site southern drainage areas through a series of reaches (designated as A1, A2, A3, A4, and A5) to the midpoint site outfall. A reach is defined as a segment of a drainage channel with a specific slope, width, depth, and flow rate. The north perimeter drainage channel, designated as Storm Water Channel C, conveys surface water from the northern areas of the final cover and off-site eastern and northern drainage areas to the North Surface Water Pond through a series of reaches (designated as C1, C2, C3, and C4) and a proposed culvert (designated as

Culvert 1). It is noted that Reach C4 conveys surface water off-site from the North Surface Water Pond to the overall site outfall. Storm Water Channel B is an existing roadside ditch located along the eastern site perimeter adjacent to Dick Price Road. Storm Water Channel B conveys surface water to Storm Water Channel C and only has one reach (designated as B1).

Storm Water Channel A and Storm Water Channel B are separated by a local high point near the southeastern corner of the final cover system. Surface water from the eastern areas of the final cover is conveyed directly into Storm Water Channel C through downchute channels, which are discussed in Attachment 2D of the Drainage Report. Also, Drawing 2-1 in Attachment 2A of the Drainage Report shows a plan view of the facility surface water management system.

2 METHODOLOGY

<u>Perimeter Channels</u>

Storm Water Channel A will be a geomembrane-lined trapezoidal channel conveying flows to the midpoint site outfall. Storm Water Channel B is an existing grass-lined v-ditch (i.e., trapezoidal channel with zero bottom width) which conveys flows to the Storm Water Channel C. Storm Water Channel C is an existing geomembrane-lined trapezoidal channel which conveys flows to the North Surface Water Pond. Final cover areas contributing to each perimeter channel reach are modeled in the computer program HEC-HMS for the post-development site conditions, and peak discharges are subsequently computed for each reach. The details including the methodology and design parameters of this analysis are provided in the *On-Site Drainage Analysis – Hydrology* calculations located in Attachment 2B of the Drainage Report. Each reach is designed to convey the peak surface water runoff corresponding the 24-hour rainfall event with a 4% annual chance of occurrence (referred to herein as the "25-year, 24-hour rainfall event") flowing to the channel segment, while maintaining a minimum of 0.5 feet of freeboard in the channel during this rainfall event. In addition, each reach was designed with the sufficient capacity to convey the peak discharge from the 24 hour rainfall event with a 1% annual chance of occurrence (refer to herein as the "100-year, 24-hour rainfall event") without overtopping. Calculations supporting the peak volumes of surface water runoff during these rainfall events are provided in Attachment 2B of the Drainage Report.

Drawing 2-4 in Attachment 2A of the Drainage Report shows the perimeter drainage channel plan and includes reach designations for each perimeter channel segment. Drawings 2-5 and 2-6 provide perimeter drainage profiles for the Storm Water Channels A, B, and C. The typical cross-section and a channel schedule for the perimeter drainage channels are provided in Drawing 2-10. The channel geometry and peak discharge during the design rainfall events are used to calculate the peak velocity and the peak tractive stress during the design rainfall event on the lining of the channel.

It should be noted that channel reaches located along the eastern and northern portions of the currently permitted landfill have already been constructed. The design associated with this lateral expansion for the facility considers the existing channel profile (i.e., design slopes and elevations) from the currently permitted surface water plan for the site.

The capacity of each reach (i.e., drainage channel segment) is calculated and assessed by solving Manning's equation. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad (1)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The peak average tractive stresses on the channel lining for various depths of flow are estimated using the following equation (Chow, 1959):

$$\tau_o = \gamma_w R S \quad (2)$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_W = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Culvert 1

Culvert 1 is designed by utilizing the HY-8 Culvert Analysis Program v.7.5 (HY-8). HY-8 was originally developed by the Federal Highway Administration (FHWA) and has since been updated and revised to its current version (version 7.5). The performance of a culvert is modeled and evaluated based on boundary conditions, culvert configuration, and peak flow criteria. HY-8 is applied for the surface water drainage system to model the box culvert (Culvert 1) conveying the peak discharge from Reach C2 (Storm Water Channel C) beneath a roadway into Reach C3. The performance of Culvert 1 is assessed under two tailwater conditions for the computed water surface elevation within Reach C3 which coincide with the peak discharge during 25-year, 24-hour rainfall event and the 100-year, 24-hour rainfall event. The HEC-HMS model developed in Attachment 2 of this Drainage Report was utilized to compute the peak inflows and tailwater conditions in order to model Culvert 1. Results from the HY-8 model are reviewed to demonstrate that the computed headwater elevation does not overtop the entry driveway at the culvert inlet during the peak discharge.

Riprap Apron Design

The riprap aprons at the outlet of Culvert 1 and at the outlet of Reach C3 into the North Surface Water Pond are designed to protect against erosion and scour from the peak surface water runoff. Each riprap apron is sized from the outflow based on the 25-year, 24-hour rainfall event. The selected design guidance from the Federal Highway Administration (FHWA) provides a methodology for calculating the required length of apron (L_a) and d_{50} of the riprap based on the culvert diameter and flow rate. The d_{50} is the stone size of the riprap for which to 50% of the riprap stones are smaller than d_{50} by mass. The riprap size is calculated using the following equation (FHWA, 2006):

$$d_{50} = 0.2D\left(\frac{Q}{D^{2.5}\sqrt{g}}\right)^{4/3}\frac{D}{TW} \quad (4)$$

where: d_{50} = riprap size (ft),

Q = design discharge (cfs),

D = culvert diameter (ft),

TW = tailwater depth (ft), and

g = gravitational constant.

The tailwater depth should be limited to between 0.4D and D. FHWA (2006) recommends the use of a tailwater depth equal to 0.4D if the tailwater conditions are unknown.

The required length and depth of the riprap apron can be estimated based on the culvert rise and riprap size as provided in Table 2E-1. The width of the riprap apron at the outlet was selected as 3D as recommended by the FHWA (2006) detail for riprap aprons. The apron width will also widen from the outlet along the required length at a rate of 1 ft width per 3 ft length at each edge. Figure 2E-1 provides the typical geometry for the riprap apron.

3 DESIGN PARAMETERS

The design parameters for each channel reach and culvert, including channel geometry and calculated peak discharges as computed by the HEC-HMS model described in Attachment 2B to the Drainage Report for the 25-year and 100-year rainfall events, are summarized in Table 2E-2.

Perimeter Channels

The majority of the perimeter channel reaches are lined with a geomembrane. Manning's roughness values are not specifically available from literature or manufacturers for textured High Density Polyethylene (HDPE) geomembrane. Smooth HDPE Manning's roughness values are approximately 0.01, so it was considered reasonable that a textured geomembrane would be slightly greater. Therefore, a Manning's roughness value of 0.015 for float finish concrete lining was assumed to be representative of the textured HDPE geomembrane channel lining (Table 2E-3 from TxDOT, 2019). This was used for channel sizing design, since a larger roughness value would produce a greater flow depth.

Permissible peak tractive stresses for grass-lined channels range from 0.35 psf to 3.70 psf depending on the retardation class of vegetation. Retardation Class C (which includes Bermuda and Crab grasses among others) was selected for the design of grass lined channels (as shown in Table 2E-4). Grass channels under Retardation Class C have a maximum permissible tractive stress of 1.0 psf (as shown in Table 2E-5 from TxDOT, 2019).

Permissible peak tractive stresses for geomembrane-lined channels are not available from literature or manufacturers for textured or smooth HDPE geomembrane. Therefore, a conservative approach was considered. Table 2E-6 (from Fischenich, 2001) presents the permissible tractive (shear) stress and permissible velocity for a variety of lining materials. Geomembranes are expected to have a large permissible tractive stress (comparable to concrete) due to its smooth and relatively frictionless surface (with minimal roughness for the force of flowing water to act upon), continuous coverage of the channel bed, anchoring at the top of the channel cross-section, and welds between geomembrane panels. Furthermore, geomembranes are less susceptible to erosion or displacement (unlike with many erosion control products). A conservative permissible tractive stress corresponding to unvegetated non-degradable rolled erosion control products (RECPs) of 3.0 psf was selected for geomembrane-lined channels. This permissible tractive stress is expected to significantly underestimate the actual permissible tractive stress of geomembrane-lined channels. The selection of this value is applicable to this design package only to demonstrate adequacy of the design, since, as previously discussed, this approach is likely quite conservative.

Culvert 1

The concrete box Culvert 1 is designed using the following parameters to convey both the peak 25-year, 24-hour rainfall event discharge and the peak 100-year, 24-hour rainfall event discharge. The inlet invert and outlet invert elevations are 639.46 ft MSL and 638.81 ft MSL, respectively, with a culvert slope of 0.51%. A Manning's roughness coefficient is selected as 0.012 for concrete box culverts, based on guidance in Table 2E-8 from TxDOT (2019). The peak inflow into the culvert is computed by HEC-HMS for both rainfall events, as discussed in Attachment 2B. The peak inflow from Reach C2 into Culvert 1 is calculated as 275.20 cfs and 375.40 cfs for the 25-year, 24-hour and 100-year, 24-hour rainfall events, respectively.

The inflow structure into the culvert influences the conveyance of surface water through the culvert. The box culvert inflow structure was modeled with a beveled 45 degree wingwall. The culvert headwall is to be installed according to the TxDOT standard detail

FW-0 for concrete wingwalls with flared wings. A TxDOT standard detail for wingwalls is available in Figure 2E-2.

For the purposes of the outlet riprap apron design, Culvert 1 was considered as three 4.5-ft diameter culverts, with the peak inflow from Reach C2 evenly divided between each culvert barrel. Also for the purposes of riprap apron design, the tailwater depth was considered to be the depth in the downstream channel reach (Reach C3). The peak tailwater depth during the 25-year, 24-hour rainfall event is 2.77 ft.

Riprap Apron Design

Riprap aprons are sized for: (i) the outflow of Culvert 1 and (ii) the outflow of Reach C3 into the North Surface Water Pond. The design parameters describing the conditions for riprap apron design for Culvert 1 are described above. Meanwhile, the peak discharge of Reach C3 into the North Surface Water Pond Series 4 during the 25-year, 24-hour rainfall event is 465.10 cfs. The 8 ft (base width) by 3.5 ft (channel depth) trapezoidal channel was considered as two representative 3.79 ft circular culverts (corresponding to the area of the peak depth of flow within the channel). Each representative culvert is assumed to convey half the peak 25-year, 24-hour rainfall event discharge, solely for the purposes of riprap apron design. Since the invert elevation of Reach C3 is above the peak pond elevation for the 25-year, 24-hour rainfall event, the tailwater depth was taken as the peak depth within Reach C3.

4 RESULTS

The depth of flow, velocity, and average tractive stress for the calculated discharge for each perimeter drainage channel reach during the design rainfall event were calculated using Equations (1) and (2). Calculations for each perimeter channel reach were performed using spreadsheets with results that are summarized in Table 2E-9. Spreadsheet results for the channel reach with the largest peak flow rate for each perimeter channel are presented in Appendix 2E-1. For both rainfall events, the performance of Culvert 1 from HY-8 modeling is presented in Table 2E-9 and shown on Figures 2E-3 and 2E-4.

- The available freeboard in all perimeter channel reaches is calculated to be greater than 0.5 feet during the 25-year, 24-hour rainfall event.
- Each perimeter channel reach was designed to be able to convey the 100-year, 24-hour rainfall event without overtopping as presented in Table 2E-9.

- The average tractive stress during the 25-year, 24-hour rainfall event within each of the perimeter channel reaches is calculated to remain below the maximum one (1) psf (acceptable for grass-lined channels) or below 3.0 psf (acceptable as conservatively applied for geomembrane-lined channels).
- Culvert 1 contains the capacity to convey the flow from Reach C2 to C3 without overtopping the roadway at the culvert inlet wingwall.
- The minimum d_{50} size of the riprap apron was computed by Equation (3) for the outflow of each necessary discharge structure as summarized in Table 2E-10. In addition, the selected riprap class, apron depths and lengths are provided within the table for each riprap apron.

FHWA (2006) recommends an apron width of 3 times the outlet diameter at the up gradient end of the apron near the culvert outlet and a 3:1 rate of expansion at each edge along the length of the apron. However, since each structure is discharging into a stabilized geomembrane-lined trapezoidal channel or surface water pond, the dimensions of the riprap aprons are restricted by the channel dimensions. Therefore, the entire width of the channel (8 feet) should be lined with riprap for Culvert 1. The full apron width will be provided at the outlet of each perimeter channel into the North Surface Water Pond.

5 REFERENCES

Chow, V.T (1959). *Open Channel-Hydraulics,* McGraw-Hill.

FHWA (2006). *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Federal Highway Administration, US Department of Transportation, Hydraulic Engineering Circular No. 14, Third Edition.

Fischenich, C. (2001). *Stability Thresholds for Stream Restoration Materials*.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.

TABLES

Table 2E-1. Riprap Classes and Apron Dimensions

(from FHWA, 2006)

Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1]D is the culvert rise.

Table 2E-2. Design Parameter Summary for Perimeter Drainage Channels and Culverts

Perimeter Channel/ Culvert	Channel Shape	Longitudinal Channel Slope (ft/ft)	Manning's n	Bottom Width (ft)	Depth (ft)	Side Slopes (H:V)	Channel Lining	25-year, 24-hour Flow Rate Q_{25} (cfs)	100-year, 24-hour Flow Rate Q_{100} (cfs)
Perimeter Reach A1	Trapezoid	0.005	0.015	3.0	3.0	3:1	Geomembrane	36.00	48.60
Perimeter Reach A2	Trapezoid	0.005	0.015	8.0	3.0	3:1	Geomembrane	196.10	270.00
Perimeter Reach A3	Trapezoid	0.076	0.015	13.0	1.5	3:1	Geomembrane	217.70	298.40
Perimeter Reach A4	Trapezoid	0.022	0.015	8.0	3.5	3:2	Geomembrane	216.90	298.20
Perimeter Reach A5	Trapezoid	0.008	0.015	8.0	3.5	3:3	Geomembrane	405.90	553.90
Perimeter Reach B1	Triangular	0.025	0.027	0.0	1.8	3:1	Native Vegetation	30.80	41.50
Perimeter Reach C1	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	275.60	376.60
Perimeter Reach C2	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	275.20	375.40
Perimeter Reach C3	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	465.10	639.10
Perimeter Reach C4	Trapezoid	0.005	0.015	8.0	3.5	3:1	Geomembrane	358.60	577.40
Culvert 1	Box	0.005	0.012	4.0	4.5	-	Concrete	275.20	375.40

Table 2E-3. Manning's n Values for Open Channels (from TxDOT, 2019)

Type of channel	Manning's n
B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
3. Dragline-excavated or dredged	
a. No vegetation	0.025-0.033
b. Light brush on banks	0.035-0.060
4. Rock cuts	
a. Smooth and uniform	0.025-0.040
b. Jagged and irregular	0.035-0.050
5. Unmaintained channels	
a. Dense weeds, high as flow depth	0.050-0.120
b. Clean bottom, brush on sides	0.040-0.080
c. Clean bottom, brush on sides, highest stage	0.045-0.110
d. Dense brush, high stage	0.080-0.140
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2E-4. Retardation Class for Lining Materials

(from TxDOT, 2019)

Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30 in. or 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in. or 915 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12 in. or 305 mm)
	Native grass mixture little bluestem, bluestem, blue gamma, other short and long stem midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good Stand, tall (average 24 in. or 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in. or 480 mm)
	Alfalfa	Good stand, uncut (average 11 in or 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 13 in. or 330 mm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13 in. or 330 mm)
C	Crabgrass	Fair stand, uncut (10-to-48 in. or 55-to-1220 mm)
	Bermuda grass	Good stand, mowed (average 6 in. or 150 mm)
	Common lespedeza	Good stand, uncut (average 11 in. or 280 mm)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6-8 in. or 150-200 mm)
	Centipedegrass	Very dense cover (average 6 in. or 150 mm)
	Kentucky bluegrass	Good stand, headed (6-12 in. or 150-305 mm)
D	Bermuda grass	Good stand, cut to 2.5 in. or 65 mm
	Common lespedeza	Excellent stand, uncut (average 4.5 in. or 115 mm)
	Buffalo grass	Good stand, uncut (3-6 in. or 75-150 mm)
	Grass-legume mixture: fall, spring (orchard grass Italian ryegrass, and common lespedeza)	Good Stand, uncut (4-5 in. or 100-125 mm)
	Lespedeza sericea	After cutting to 2 in. or 50 mm (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5 in. or 40 mm
	Bermuda grass	Burned stubble

Table 2E-5. Permissible Shear Stress for Various Linings
(from TxDOT, 2019)

Protective Cover	(lb./sq.ft.)	t_p (N/m^2)
Retardance Class A Vegetation (See the "Retardation Class for Lining Materials" table above)	3.70	177
Retardance Class B Vegetation (See the "Retardation Class for Lining Materials" table above)	2.10	101
Retardance Class C Vegetation (See the "Retardation Class for Lining Materials" table above)	1.00	48
Retardance Class D Vegetation (See the "Retardation Class for Lining Materials" table above)	0.60	29
Retardance Class E Vegetation (See the "Retardation Class for Lining Materials" table above)	0.35	17
Woven Paper	0.15	7
Jute Net	0.45	22
Single Fiberglass	0.60	29
Double Fiberglass	0.85	41
Straw W/Net	1.45	69
Curled Wood Mat	1.55	74
Synthetic Mat	2.00	96

Table 2E-6. Permissible Shear Stresses for Various Linings (from Fischenich, 2001)

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
D. Goff, K. (1999).
E. Gray, D.H., and Sotir, R.B. (1996).
F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
H. Norman, J. N. (1975).
I. Schiechtl, H. M. and R. Stern. (1996).
J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

Table 2E-7. Manning's n Values for Closed Conduits

(from TxDOT, 2019)

Material		Manning's n
Asbestos-cement pipe		0.011-0.015
Brick		0.013-0.017
Cast iron pipe		
	Cement-lined & seal coated	0.011-0.015
Concrete (monolithic)		
	Smooth forms	0.012-0.014
	Rough forms	0.015-0.017
	Concrete pipe	0.011-0.015
	Box (smooth)	0.012-0.015
Corrugated-metal pipe -- (2-1/2 in. x 1/2 in. corrugations)		
	Plain	0.022-0.026
	Paved invert	0.018-0.022
	Spun asphalt lined	0.011-0.015
	Plastic pipe (smooth)	0.011-0.015
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. annular)		0.022-0.027
Corrugated-metal pipe -- (2-2/3 in. by 1/2 in. helical)		0.011-0.023
Corrugated-metal pipe -- (6 in. by 1 in. helical)		0.022-0.025
Corrugated-metal pipe -- (5 in. by 1 in. helical)		0.025–0.026
Corrugated-metal pipe -- (3 in. by 1 in. helical)		0.027–0.028
Corrugated-metal pipe -- (6 in. by 2 in. structural plate)		0.033–0.035
Corrugated-metal pipe -- (9 in. by 2-1/2 in. structural plate)		0.033–0.037
Corrugated polyethylene		0.010–0.013
	Smooth	0.009-0.015
	Corrugated	0.018–0.025
Spiral rib metal pipe (smooth)		0.012-0.013
Vitrified clay		
	Pipes	0.011-0.015

Table 2E-8. Channel Capacity Calculation Results

Perimeter Channel Segment	25-year Flow Rate Q_{25} (cfs)	Depth of Flow (ft)	Average Velocity (ft/s)	Average Tractive Stress (psf)	25-year Freeboard (ft)	100-year Flow Rate Q_{100} (cfs)	Depth of Flow (ft)	Average Velocity (ft/s)	Average Tractive Stress (psf)
Perimeter Reach A1	36.00	1.07	5.43	0.21	1.93	48.60	1.23	5.87	0.24
Perimeter Reach A2	196.10	1.80	8.13	0.39	1.20	270.00	2.12	8.88	0.44
Perimeter Reach A3	217.70	0.72	19.90	2.93	0.78	298.40	0.86	22.13	3.44
Perimeter Reach A4	216.90	1.28	14.28	1.32	2.22	298.20	1.51	15.65	1.51
Perimeter Reach A5	405.90	2.34	11.55	0.73	1.16	553.90	2.72	12.56	0.83
Perimeter Reach B1	30.80	1.28	6.24	0.94	0.52	41.50	1.43	6.73	1.05
Perimeter Reach C1	275.60	2.14	8.93	0.45	1.36	376.60	2.50	9.72	0.51
Perimeter Reach C2	275.20	2.14	8.92	0.45	1.36	375.40	2.49	9.71	0.51
Perimeter Reach C3	465.10	2.77	10.28	0.55	0.73	639.10	3.23	11.19	0.63
Perimeter Reach C4	358.60	2.42	9.73	0.51	1.08	577.40	3.05	11.05	0.62

Table 2E-9. Culvert 1 Capacity Analysis Results

Design Case	Total Flow Rate Q (cfs)	Pipe Flow (cfs)	Pipe Velocity (fps)	Roadway Flow (cfs)	Tailwater Elev (ft)	Headwater Elev (ft)
25-year, 24-hour	275.20	275.20	9.42	0.0	640.95	643.42
100-year, 24-hour	375.40	375.40	10.10	0.0	641.31	644.46

Table 2E-10. Riprap Apron Design Summary

Riprap Apron Structure	Riprap Size d_{50} (ft)	Riprap Class	Apron Depth (ft)	Apron Length (ft)
Culvert 1	0.40	1	1.0	18.0
Perimeter Reach C3	1.72	6	3.4	30.4

FIGURES

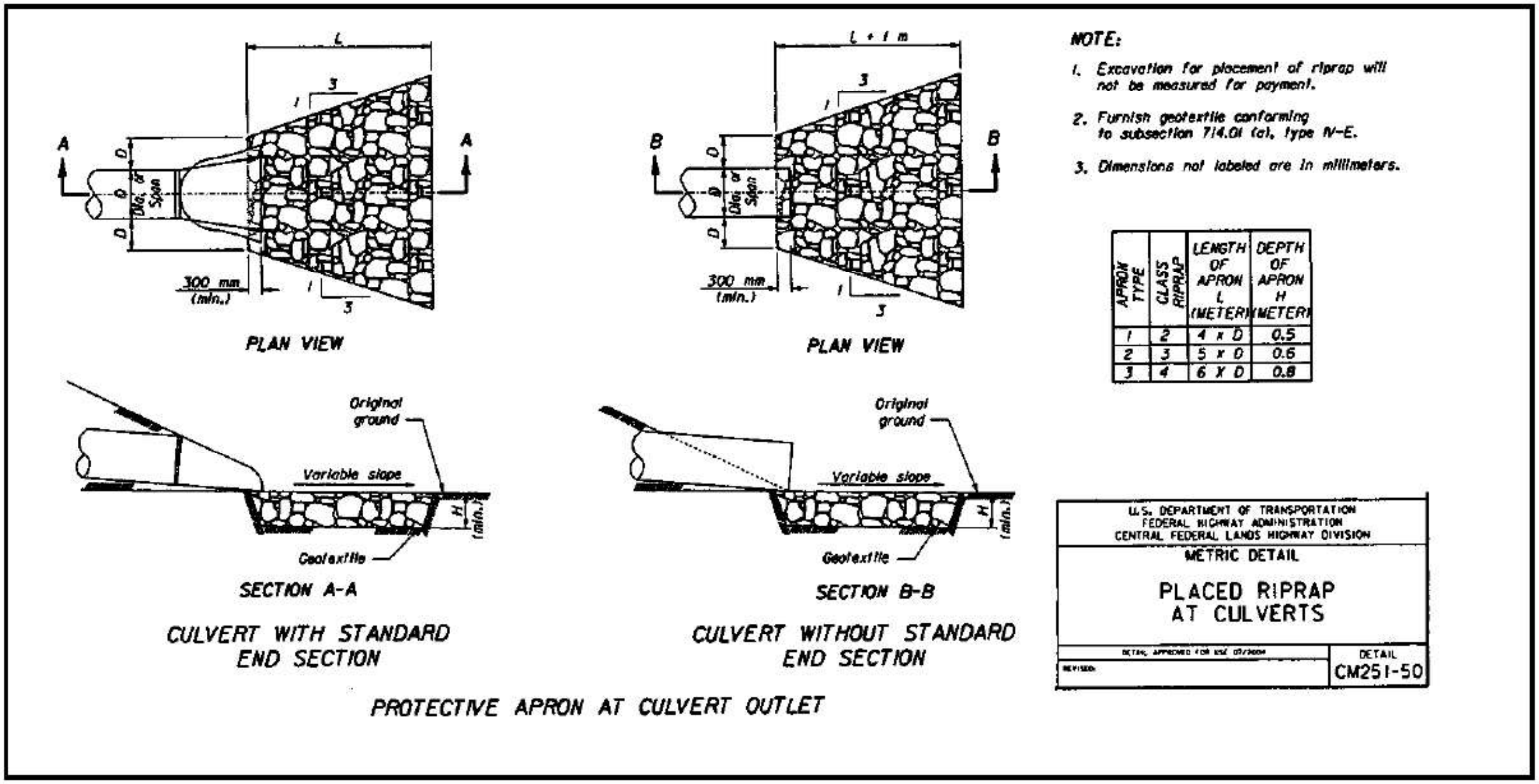


Figure 2E-1. Typical Geometry of Riprap Aprons at Culverts

(from FHWA, 2006)

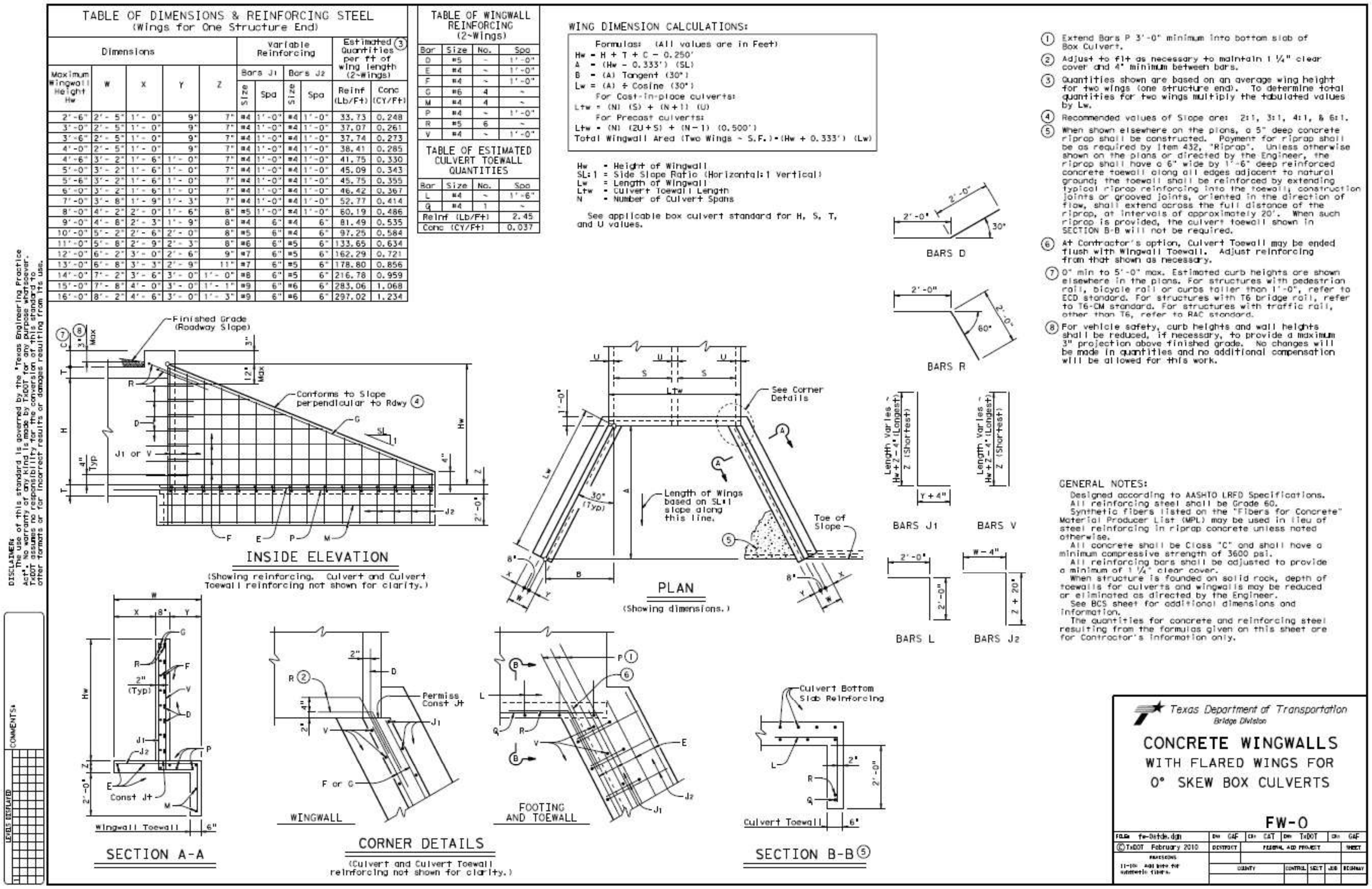


Figure 2E-2. TxDOT Standard Detail FW-0 for Concrete Wingwalls

Source: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/bridge/fw-0stde.pdf (Date Accessed: 12/4/2019)

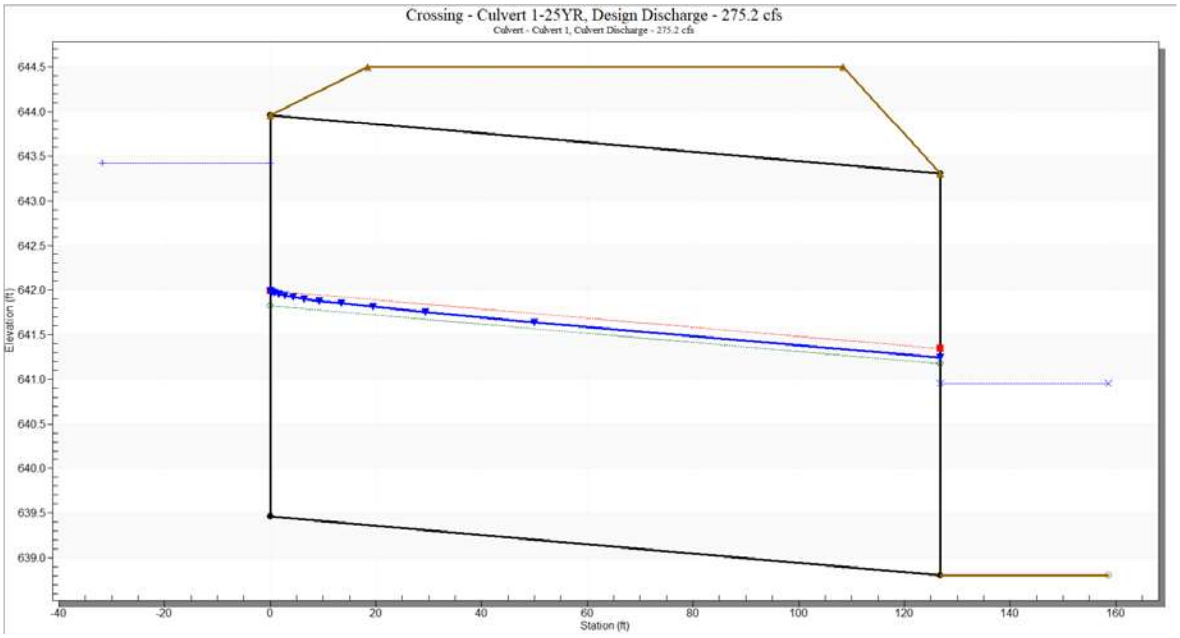


Figure 2E-3. HY-8 Modeling Output for 100-Year Event Culvert 1

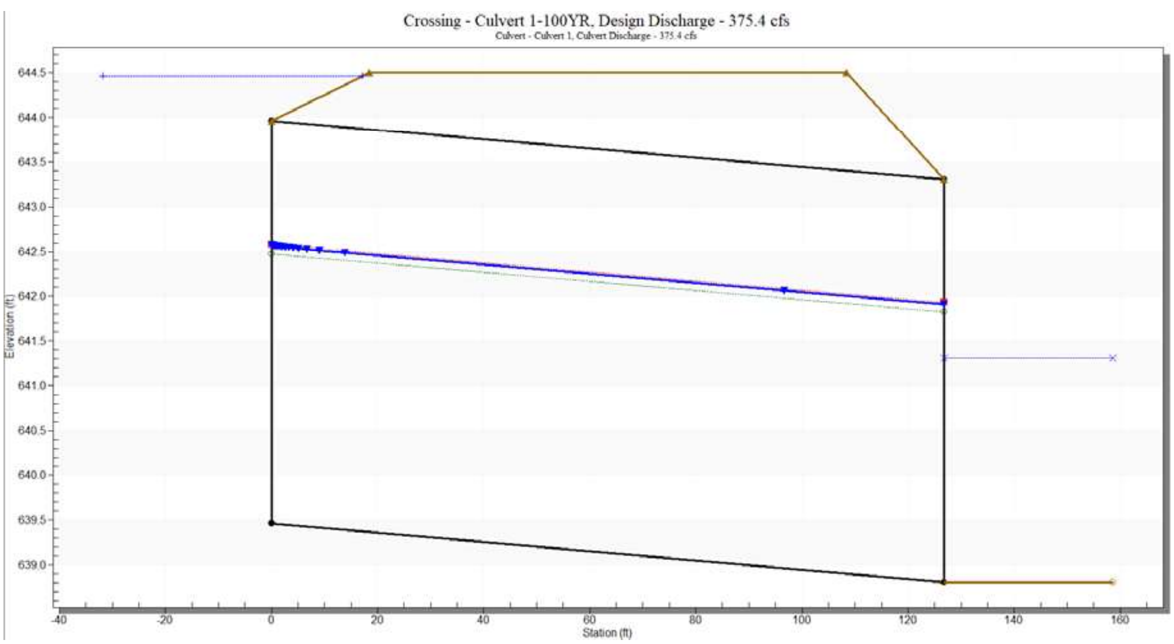


Figure 2E-4. HY-8 Modeling Output for 25-Year Event Culvert 1

Appendix 2E-1
Perimeter Channel Calculations

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

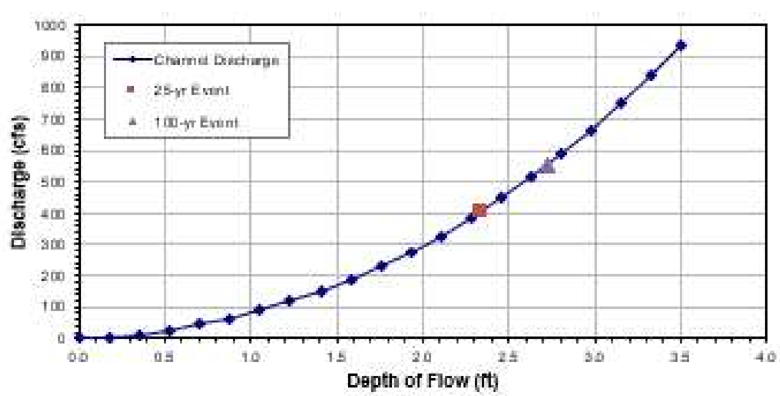
Project: Fort Worth C&D Landfill Expansion

Ditch ID: Perimeter Reach A5 Design

Peak Discharge, Q_{25} =	405.90	cfs (25-yr Event)
Peak Discharge, Q_{100} =	553.90	cfs (100-yr Event)
Bottom Width, B =	8.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	3.50	ft
Top Width, T =	29.0	ft
Manning's Roughness Coeff., n =	0.015	
Longitudinal Channel Slope, S_o =	0.008	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.08	8.06	0.01	0.40	0.0	0.00	
0.18	1.58	9.17	0.17	2.68	4.2	0.08	
0.36	3.26	10.27	0.32	4.03	13.1	0.15	
0.53	5.12	11.37	0.45	5.09	26.1	0.21	
0.71	7.17	12.48	0.57	5.98	42.9	0.27	
0.88	9.40	13.58	0.69	6.77	63.6	0.33	
1.06	11.81	14.69	0.80	7.49	88.4	0.38	
1.23	14.40	15.79	0.91	8.14	117.3	0.43	
1.41	17.18	16.89	1.02	8.76	150.4	0.48	
1.58	20.14	18.00	1.12	9.33	188.0	0.53	
1.76	23.28	19.10	1.22	9.88	230.0	0.58	
1.93	26.60	20.20	1.32	10.40	276.8	0.62	
2.10	30.11	21.31	1.41	10.91	328.4	0.67	
2.28	33.80	22.41	1.51	11.39	385.0	0.72	
2.45	37.68	23.51	1.60	11.86	446.8	0.76	
2.63	41.73	24.62	1.70	12.31	513.9	0.80	
2.80	45.97	25.72	1.79	12.76	586.4	0.85	
2.98	50.39	26.83	1.88	13.19	664.5	0.89	
3.15	54.99	27.93	1.97	13.61	748.3	0.93	
3.33	59.78	29.03	2.06	14.02	838.1	0.98	
3.50	64.75	30.14	2.15	14.42	933.9	1.02	
2.34	35.09	22.78	1.54	11.55	405.32	0.73	Q (25-yr Event)
2.72	44.05	25.23	1.75	12.56	553.22	0.83	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

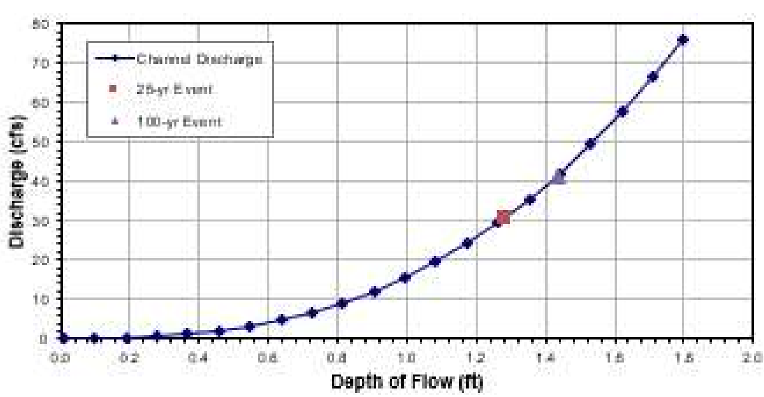
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Perimeter Reach B1** **Design**

Peak Discharge, Q_{25} =	30.80	cfs (25-yr Event)
Peak Discharge, Q_{100} =	41.50	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	1.80	ft
Top Width, T =	10.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.025	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.25	0.0	0.01	
0.10	0.03	0.63	0.05	1.13	0.0	0.07	
0.19	0.11	1.20	0.09	1.74	0.2	0.14	
0.28	0.23	1.76	0.13	2.25	0.5	0.20	
0.37	0.41	2.33	0.17	2.72	1.1	0.27	
0.46	0.63	2.89	0.22	3.14	2.0	0.34	
0.55	0.90	3.46	0.26	3.54	3.2	0.40	
0.64	1.22	4.03	0.30	3.91	4.8	0.47	
0.73	1.58	4.59	0.34	4.27	6.8	0.53	
0.82	2.00	5.16	0.39	4.62	9.2	0.60	
0.91	2.46	5.72	0.43	4.95	12.2	0.67	
0.99	2.97	6.29	0.47	5.27	15.6	0.73	
1.08	3.53	6.86	0.51	5.58	19.7	0.80	
1.17	4.13	7.42	0.56	5.88	24.3	0.86	
1.26	4.79	7.99	0.60	6.18	29.6	0.93	
1.35	5.49	8.55	0.64	6.47	35.5	0.99	
1.44	6.24	9.12	0.68	6.75	42.1	1.06	
1.53	7.04	9.69	0.73	7.03	49.5	1.13	
1.62	7.88	10.25	0.77	7.30	57.5	1.19	
1.71	8.78	10.82	0.81	7.57	66.4	1.26	
1.80	9.72	11.38	0.85	7.83	76.1	1.32	
1.28	4.93	8.10	0.61	6.24	30.74	0.94	Q (25-yr Event)
1.43	6.17	9.07	0.68	6.73	41.47	1.05	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

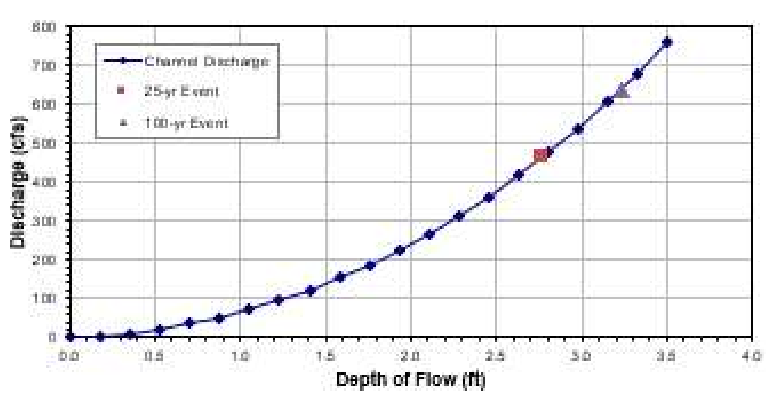
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Perimeter Reach C3** **Design**

Parameter	Value	Units
Peak Discharge, Q_{25} =	465.10	cfs (25-yr Event)
Peak Discharge, Q_{100} =	639.10	cfs (100-yr Event)
Bottom Width, B =	8.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Channel Depth, Y =	3.50	ft
Top Width, T =	29.0	ft
Manning's Roughness Coeff., n =	0.015	
Longitudinal Channel Slope, S_o =	0.005	ft/ft

Depth of Flow Y ft	Area of Flow A ft²	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft³/s	Avg. Tractive Stress τ_0 lb/ft²	Comments
0.01	0.08	8.06	0.01	0.32	0.0	0.00	
0.18	1.58	9.17	0.17	2.17	3.4	0.05	
0.36	3.26	10.27	0.32	3.27	10.6	0.10	
0.53	5.12	11.37	0.45	4.13	21.1	0.14	
0.71	7.17	12.48	0.57	4.85	34.8	0.18	
0.88	9.40	13.58	0.69	5.49	51.6	0.22	
1.06	11.81	14.69	0.80	6.07	71.7	0.25	
1.23	14.40	15.79	0.91	6.61	95.1	0.28	
1.41	17.18	16.89	1.02	7.10	122.0	0.32	
1.58	20.14	18.00	1.12	7.57	152.5	0.35	
1.76	23.28	19.10	1.22	8.02	186.6	0.38	
1.93	26.60	20.20	1.32	8.44	224.5	0.41	
2.10	30.11	21.31	1.41	8.85	266.4	0.44	
2.28	33.80	22.41	1.51	9.24	312.3	0.47	
2.45	37.68	23.51	1.60	9.62	362.4	0.50	
2.63	41.73	24.62	1.70	9.99	416.8	0.53	
2.80	45.97	25.72	1.79	10.35	475.6	0.56	
2.98	50.39	26.83	1.88	10.70	539.0	0.59	
3.15	54.99	27.93	1.97	11.04	607.0	0.61	
3.33	59.78	29.03	2.06	11.37	679.8	0.64	
3.50	64.75	30.14	2.15	11.70	757.5	0.67	
2.77	45.20	25.52	1.77	10.28	464.77	0.55	Q (25-yr Event)
3.23	57.08	28.42	2.01	11.19	638.50	0.63	Q (100-yr Event)

Discharge versus Depth Relationship



ATTACHMENT 2F

ON-SITE DESIGN – ACTIVE FACE SURFACE WATER CONTROLS

Written by:	O. Bramlet	Date:	01/03/2020	Reviewed and Revised by:	S. Graves	Date:	2/4/2020; 09/15/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

ON-SITE DESIGN – ACTIVE FACE SURFACE WATER CONTROLS
FORT WORTH C&D LANDFILL EXPANSION

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER
9/15/2020

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 17

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the analysis for the sizing of the diversion, containment, and run-on berms to be utilized at the active face (i.e., areas of exposed waste) during development of the Fort Worth C&D Landfill (Figure 2F-1). The diversion containment and run-on berms will be utilized to keep clean surface water separate from potentially contaminated water, to minimize the generation of contaminated water, prevent runoff/discharge of contaminated water, and prevent migration of contaminated water to the surface run-on water. Contaminated water will be managed in a timely manner and in accordance with the Contaminated Water Management Plan presented in Appendix IVA of the Site Operating Plan (SOP).

Diversion berms are temporary soil berms constructed up-gradient from the active working face to intercept flow before it comes in contact with waste. These temporary diversion berms will be used to route the clean runoff around active areas into the surface water management system and away from the active face. Meanwhile, temporary containment and run-on berms (down-gradient from, and generally at the base of the active working face), constructed with soil, will be used to contain contaminated water and prevent the migration of contaminated water from the active face, as well as to prevent the run-on of clean surface water draining from adjacent areas onto the active face. The specific objectives of the analysis include (i) calculating the maximum up-gradient drainage area which can be managed by each diversion berm for the 25-year rainfall event; and (ii) calculating the required height of each temporary containment and run-on berm to contain the contaminated runoff and prevent surface run-on resulting from the 25-year rainfall event.

2 ASSUMPTIONS AND PROCEDURES

The following sections discuss the assumptions and procedures for the design of the temporary diversion berms and temporary containment and run-on berms.

2.1 Diversion Berm

It is assumed that temporary diversion berms will be installed with flow line (longitudinal) slopes ranging from 0.5% to 2%. Temporary diversion berms will be placed up-gradient from the active working face. The temporary diversion berms are assumed to be "tack-on" berms with a 2.5:1 side slope (see Figure 2F-1 of this calculation package) to form a v-shaped channel. A channel depth of 2.5 feet was assumed (i.e., this is a fixed parameter of these calculations). The Rational Method described in the Texas Department of Transportation *Hydraulic Design Manual* (TxDOT, 2019) is used to calculate the peak surface water discharge (since the drainage area will be less than 200 acres). A given diversion berm is anticipated to temporarily manage drainage areas on the order of 30 acres or more and is designed accordingly as presented herein. The channels were sized assuming they are flowing full, considered adequate since they are interior and temporary site features, and given other conservative selections of parameters as documented herein. The following steps were utilized to calculate the drainage areas that each diversion berm can accommodate.

1. Compute the discharge capacity of diversion berms with 0.5%, 1%, 1.5%, and 2% slopes using Manning's Equation for open channel flow.

2. Apply the Rational Method to compute the up-gradient drainage area that would produce the discharge capacity calculated in Step 1.

Manning's equation was used to estimate the peak discharge capacity of the v-shaped channel created by a temporary diversion berm. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad (1)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The peak discharge from the contributing drainage area by the Rational Method can be computed by:

$$Q = C \times I \times A \qquad (2)$$

where:

Q = peak design discharge (cfs),

C = runoff coefficient (dimensionless),

I = design rainfall intensity (in/hr), and

A = drainage area (acres).

The design rainfall intensity in Equation (2) is calculated using guidance in the TxDOT *Hydraulic Design Manual* (TxDOT, 2019). In September 2018, the National Oceanic and Atmospheric Administration (NOAA) released updated "Atlas 14" precipitation frequency estimates for Texas. This new rainfall data is currently considered by TxDOT (2019) to be the best available data for calculating design rainfall intensity. TxDOT (2019) also recommends 10 minutes as the minimum time of concentration for the Rational Method because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high. The rainfall intensity for the 25-year, 10-minute duration rainfall event is 7.92 inches per hour (in/hr) for the site, as shown in Table 2F-1 (NOAA, 2018).

Equation (2) is rearranged, and the watershed drainage area was back-calculated for each potential flow line slope of a temporary diversion berm.

2.2 Containment and Run-On Berms

It is assumed that temporary containment and run-on berms (which may be a shared berm, provided that the berm height is the larger of the two required heights) will be constructed with 3H:1V side slopes and will be constructed to varying heights, depending on the geometry of the working face, storage area, and resulting calculated volume of contaminated water and surface run-on water to be stored on each respective side of the berm(s). These containment and run-on berms are designed to have one foot (1-ft) of freeboard. The required height of the containment berms is calculated for drainage areas ranging from 0.5 to 4.0 acres (to encompass a range of potential active area sizes in and around the working face itself) and contaminated water storage areas ranging from 0.1 to 1.0 acres. The required height of the run-on berms is calculated for drainage areas ranging from 2.0 to 30.0 acres (to account for a range of potential up-gradient excavation area sizes adjacent to an active Sector/working face) and surface run-on water storage areas ranging from 0.25 to 5.0 acres. The following steps were utilized to calculate the height required for each of the containment and run-on berm scenarios.

1. Calculate the 25-year, 24-hour rainfall volume to be captured behind the containment and run-on berm.

2. Calculate the height of the containment and run-on berm required to hold the volume of water calculated in Step 1, and then add 1-ft of freeboard to calculate the resulting total berm height (i.e., the required minimum berm height).

The total required storage volume of surface water is calculated by:

$$V = A_D \times R \qquad (3)$$

where:

V = total storage volume (ft^3),

A_D = drainage area (ft^2), and

R = 25-year, 24-hour rainfall depth (ft).

For these calculations, 100% of the precipitation over the drainage area is considered surface water runoff that requires containment (i.e., no infiltration). This is a conservative assumption for sizing of these berms because it is likely that some infiltration will occur. The 25-year, 24-hour rainfall depth is provided in Table 2F-2.

The required height for each of the containment and run-on berm scenarios is computed by Equation (4):

$$H = V/A_S + 1.0 \text{ ft freeboard} \tag{4}$$

where:

V = total storage volume (ft^3),

H = total height of containment or run-on berm (ft), and

A_S = storage area (ft^2).

3 DESIGN PARAMETERS

The following sections discuss the justification behind the selected design parameters for the temporary diversion berms and temporary containment and run-on berms.

3.1 Diversion Berm

The Manning's Roughness Coefficient (*n*) for the diversion berm was selected as 0.02 for clean, recently completed earth channels that are straight and uniform, as shown in Table 2F-3 (TxDOT, 2019). The peak discharge flowing to the channel is calculated using the Rational Method.

A runoff coefficient (C) was selected based on information provided by TxDOT (2019) for rural watersheds, as shown in Table 2F-4. The runoff coefficients provided apply to storms of up to a 10-year frequency. The total runoff coefficient is based on the sum of the four runoff components in Table 2F-4. The 25-year runoff coefficient is calculated using the following equation:

$$C = C_r + C_i + C_v + C_s \tag{5}$$

The following runoff coefficient is estimated for the steep 3H:1V side slope drainage areas:

$$C = 0.35 + 0.16 + 0.08 + 0.12 = 0.71$$

For a conservative design approach, a minimum time of concentration of 10 minutes was used to calculate the rainfall intensity from Table 2F-1. TxDOT (2019) recommends 10 minutes for the minimum time of concentration because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high, as discussed above.

3.2 Containment and Run-On Berm

The temporary containment and run-on berms were sized by determining the rainfall depth from NOAA Atlas 14 precipitation frequency estimates for Texas (TxDOT, 2019). The rainfall depth for the 25-year, 24-hour rainfall event is listed as 7.17 inches (0.60 feet).

4 RESULTS

The results of the temporary diversion berms calculation are summarized in Table 2F-5 for each assumed flow line slope. The drainage areas calculated represent the maximum drainage area that each temporary diversion berm configuration can accommodate for the 25-year, 24-hour design rainfall event. It should be noted that multiple diversion berms may be constructed if, during operations, a larger area than those calculated in Table 2F-5 will be draining towards the active face, in order to comply with the drainage area requirements presented herein for the given berm height and the selected flow line slope.

The results of the temporary containment and run-on berms calculations are summarized in Table 2F-6 and Table 2F-7, respectively. It is noted that the results presented in Table 2F-6 and Table 2F-7 cover various combinations of drainage areas and water storage areas, to allow for flexibility of site operations. The facility will use this information to select the required berm height based on the corresponding dimensions of the drainage area and storage area. It is noted that a licensed professional engineer is required to size the containment and run-on berms if conditions are not consistent or otherwise addressed by the current design presented in the tables. As mentioned, for most cases, it is expected that a temporary berm will act as both containment and run-on berm, provided that it must have the larger of the two required heights in order to serve the dual-purpose of acting as a containment berm and a run-on berm. However, it should be noted that separate containment and run-on berms meeting the requirements presented herein for a given drainage situation may be constructed at the facility's discretion.

Additionally, if the working face is built directly on top of the protective cover of the liner system (i.e., for the first lift of waste placed in a newly lined sector), the containment and run-on berm shall be installed within the lined area of the cell or phase.

5 REFERENCES

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TABLES

Written by:	O. Bramlet	Date:	01/03/2020	Reviewed by:	S. Graves	Date:	2/4/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

Table 2F-1. NOAA Atlas 14 Point Precipitation Frequency Estimates for Rainfall Intensity (from NOAA, 2018)

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**4.90** (3.71-6.47)	**5.75** (4.39-7.51)	**7.13** (5.42-9.36)	**8.28** (6.22-11.0)	**9.86** (7.18-13.5)	**11.1** (7.85-15.6)	**12.3** (8.52-17.8)	**13.7** (9.19-20.2)	**15.5** (10.1-23.6)	**16.9** (10.7-26.4)
10-min	**3.92** (2.97-5.18)	**4.61** (3.52-6.02)	**5.71** (4.35-7.51)	**6.64** (4.98-8.84)	**7.92** (5.76-10.9)	**8.92** (6.31-12.5)	**9.92** (6.84-14.3)	**10.9** (7.36-16.2)	**12.3** (8.00-18.8)	**13.4** (8.46-20.9)
15-min	**3.26** (2.47-4.30)	**3.82** (2.92-4.99)	**4.72** (3.60-6.21)	**5.48** (4.12-7.30)	**6.53** (4.74-8.94)	**7.34** (5.19-10.3)	**8.16** (5.63-11.8)	**9.03** (6.07-13.3)	**10.2** (6.64-15.6)	**11.1** (7.05-17.4)
30-min	**2.27** (1.72-2.99)	**2.65** (2.02-3.47)	**3.27** (2.49-4.30)	**3.79** (2.85-5.05)	**4.51** (3.28-6.17)	**5.06** (3.58-7.10)	**5.62** (3.88-8.10)	**6.23** (4.19-9.20)	**7.06** (4.59-10.8)	**7.72** (4.89-12.1)
60-min	**1.47** (1.11-1.94)	**1.73** (1.32-2.26)	**2.14** (1.63-2.81)	**2.48** (1.87-3.31)	**2.96** (2.15-4.05)	**3.33** (2.35-4.67)	**3.71** (2.56-5.34)	**4.12** (2.77-6.08)	**4.69** (3.05-7.16)	**5.15** (3.26-8.05)
2-hr	**0.900** (0.686-1.18)	**1.07** (0.818-1.38)	**1.34** (1.02-1.74)	**1.56** (1.18-2.06)	**1.88** (1.38-2.55)	**2.13** (1.52-2.97)	**2.40** (1.66-3.42)	**2.68** (1.81-3.92)	**3.09** (2.02-4.65)	**3.41** (2.17-5.26)
3-hr	**0.664** (0.508-0.866)	**0.794** (0.609-1.02)	**0.998** (0.767-1.29)	**1.17** (0.890-1.54)	**1.43** (1.05-1.92)	**1.62** (1.16-2.25)	**1.83** (1.27-2.60)	**2.06** (1.40-2.99)	**2.39** (1.56-3.57)	**2.65** (1.69-4.05)
6-hr	**0.393** (0.303-0.509)	**0.474** (0.366-0.602)	**0.600** (0.464-0.771)	**0.710** (0.542-0.926)	**0.867** (0.641-1.16)	**0.993** (0.714-1.36)	**1.13** (0.789-1.58)	**1.27** (0.867-1.83)	**1.48** (0.973-2.19)	**1.65** (1.06-2.49)
12-hr	**0.230** (0.178-0.295)	**0.278** (0.216-0.350)	**0.353** (0.275-0.450)	**0.418** (0.321-0.540)	**0.510** (0.379-0.677)	**0.584** (0.422-0.792)	**0.663** (0.466-0.918)	**0.748** (0.512-1.06)	**0.869** (0.574-1.27)	**0.966** (0.621-1.44)
24-hr	**0.135** (0.105-0.172)	**0.163** (0.127-0.204)	**0.207** (0.162-0.262)	**0.245** (0.189-0.314)	**0.299** (0.223-0.392)	**0.342** (0.248-0.458)	**0.387** (0.273-0.530)	**0.436** (0.300-0.610)	**0.506** (0.336-0.727)	**0.562** (0.363-0.824)
2-day	**0.078** (0.061-0.099)	**0.094** (0.074-0.117)	**0.119** (0.094-0.150)	**0.141** (0.110-0.179)	**0.172** (0.129-0.223)	**0.196** (0.143-0.260)	**0.222** (0.158-0.301)	**0.250** (0.173-0.346)	**0.290** (0.194-0.412)	**0.323** (0.209-0.466)
3-day	**0.057** (0.045-0.072)	**0.068** (0.054-0.085)	**0.087** (0.069-0.108)	**0.102** (0.080-0.129)	**0.124** (0.094-0.161)	**0.142** (0.104-0.187)	**0.160** (0.114-0.216)	**0.181** (0.125-0.248)	**0.210** (0.140-0.295)	**0.233** (0.152-0.334)
4-day	**0.045** (0.036-0.057)	**0.054** (0.043-0.067)	**0.069** (0.055-0.086)	**0.081** (0.064-0.102)	**0.099** (0.075-0.127)	**0.113** (0.083-0.148)	**0.128** (0.091-0.171)	**0.144** (0.100-0.196)	**0.167** (0.112-0.233)	**0.185** (0.121-0.264)
7-day	**0.029** (0.023-0.036)	**0.035** (0.028-0.043)	**0.044** (0.035-0.054)	**0.052** (0.041-0.065)	**0.063** (0.048-0.081)	**0.072** (0.053-0.094)	**0.082** (0.059-0.109)	**0.092** (0.064-0.125)	**0.107** (0.072-0.148)	**0.119** (0.078-0.167)
10-day	**0.022** (0.018-0.028)	**0.027** (0.021-0.033)	**0.034** (0.027-0.041)	**0.040** (0.031-0.049)	**0.048** (0.037-0.061)	**0.055** (0.041-0.071)	**0.062** (0.045-0.082)	**0.070** (0.049-0.094)	**0.081** (0.054-0.111)	**0.089** (0.059-0.125)
20-day	**0.014** (0.012-0.018)	**0.017** (0.014-0.021)	**0.021** (0.017-0.026)	**0.024** (0.019-0.030)	**0.029** (0.022-0.037)	**0.033** (0.024-0.042)	**0.037** (0.026-0.048)	**0.041** (0.029-0.054)	**0.047** (0.032-0.063)	**0.052** (0.034-0.071)
30-day	**0.011** (0.009-0.014)	**0.013** (0.011-0.016)	**0.016** (0.013-0.020)	**0.019** (0.015-0.023)	**0.022** (0.017-0.028)	**0.025** (0.019-0.032)	**0.028** (0.020-0.036)	**0.031** (0.022-0.040)	**0.035** (0.024-0.047)	**0.038** (0.025-0.052)
45-day	**0.009** (0.007-0.011)	**0.011** (0.009-0.013)	**0.013** (0.011-0.016)	**0.015** (0.012-0.019)	**0.018** (0.014-0.022)	**0.020** (0.015-0.025)	**0.022** (0.016-0.029)	**0.025** (0.017-0.032)	**0.028** (0.019-0.037)	**0.030** (0.020-0.041)
60-day	**0.008** (0.007-0.010)	**0.009** (0.008-0.011)	**0.011** (0.009-0.014)	**0.013** (0.011-0.016)	**0.016** (0.012-0.019)	**0.018** (0.013-0.022)	**0.019** (0.014-0.025)	**0.021** (0.015-0.028)	**0.024** (0.017-0.032)	**0.026** (0.018-0.035)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Table 2F-2. NOAA Atlas 14 Point Precipitation Frequency Estimates for Rainfall Depth (from NOAA, 2018)

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.408** (0.309-0.539)	**0.479** (0.366-0.626)	**0.594** (0.452-0.780)	**0.690** (0.518-0.919)	**0.822** (0.598-1.13)	**0.925** (0.654-1.30)	**1.03** (0.710-1.48)	**1.14** (0.766-1.68)	**1.29** (0.838-1.97)	**1.41** (0.891-2.20)
10-min	**0.654** (0.495-0.864)	**0.768** (0.586-1.00)	**0.952** (0.725-1.25)	**1.11** (0.830-1.47)	**1.32** (0.960-1.81)	**1.49** (1.05-2.09)	**1.65** (1.14-2.38)	**1.82** (1.23-2.69)	**2.05** (1.33-3.13)	**2.23** (1.41-3.48)
15-min	**0.815** (0.617-1.08)	**0.955** (0.729-1.25)	**1.18** (0.900-1.55)	**1.37** (1.03-1.83)	**1.63** (1.19-2.23)	**1.83** (1.30-2.58)	**2.04** (1.41-2.94)	**2.26** (1.52-3.33)	**2.55** (1.66-3.90)	**2.78** (1.76-4.35)
30-min	**1.13** (0.858-1.50)	**1.32** (1.01-1.73)	**1.64** (1.25-2.15)	**1.90** (1.42-2.53)	**2.26** (1.64-3.09)	**2.53** (1.79-3.55)	**2.81** (1.94-4.05)	**3.11** (2.09-4.60)	**3.53** (2.29-5.39)	**3.86** (2.44-6.03)
60-min	**1.47** (1.11-1.94)	**1.73** (1.32-2.26)	**2.14** (1.63-2.81)	**2.48** (1.87-3.31)	**2.96** (2.15-4.05)	**3.33** (2.35-4.67)	**3.71** (2.56-5.34)	**4.12** (2.77-6.08)	**4.69** (3.05-7.16)	**5.15** (3.26-8.05)
2-hr	**1.80** (1.37-2.36)	**2.13** (1.64-2.76)	**2.67** (2.05-3.48)	**3.13** (2.36-4.13)	**3.77** (2.75-5.11)	**4.27** (3.04-5.93)	**4.79** (3.32-6.83)	**5.37** (3.63-7.84)	**6.17** (4.03-9.31)	**6.82** (4.34-10.5)
3-hr	**1.99** (1.53-2.60)	**2.38** (1.83-3.06)	**3.00** (2.30-3.88)	**3.53** (2.67-4.64)	**4.28** (3.14-5.78)	**4.88** (3.48-6.75)	**5.51** (3.83-7.80)	**6.20** (4.20-8.98)	**7.17** (4.69-10.7)	**7.95** (5.07-12.2)
6-hr	**2.35** (1.81-3.05)	**2.84** (2.19-3.61)	**3.60** (2.78-4.62)	**4.25** (3.25-5.55)	**5.19** (3.84-6.95)	**5.95** (4.28-8.15)	**6.75** (4.72-9.46)	**7.63** (5.19-10.9)	**8.87** (5.83-13.1)	**9.86** (6.32-14.9)
12-hr	**2.77** (2.15-3.56)	**3.35** (2.60-4.22)	**4.25** (3.31-5.42)	**5.03** (3.87-6.51)	**6.15** (4.57-8.15)	**7.04** (5.09-9.55)	**7.99** (5.62-11.1)	**9.02** (6.17-12.8)	**10.5** (6.91-15.3)	**11.6** (7.49-17.3)
24-hr	**3.24** (2.52-4.12)	**3.91** (3.06-4.90)	**4.97** (3.90-6.29)	**5.88** (4.55-7.54)	**7.17** (5.36-9.41)	**8.20** (5.96-11.0)	**9.28** (6.56-12.7)	**10.5** (7.20-14.6)	**12.1** (8.05-17.5)	**13.5** (8.71-19.8)
2-day	**3.76** (2.95-4.75)	**4.52** (3.56-5.62)	**5.72** (4.52-7.19)	**6.76** (5.26-8.60)	**8.24** (6.20-10.7)	**9.41** (6.88-12.5)	**10.7** (7.58-14.4)	**12.0** (8.31-16.6)	**13.9** (9.29-19.8)	**15.5** (10.0-22.4)
3-day	**4.10** (3.23-5.15)	**4.92** (3.90-6.10)	**6.23** (4.94-7.79)	**7.35** (5.75-9.30)	**8.95** (6.75-11.6)	**10.2** (7.49-13.5)	**11.6** (8.24-15.5)	**13.0** (9.03-17.9)	**15.1** (10.1-21.3)	**16.8** (10.9-24.1)
4-day	**4.34** (3.44-5.45)	**5.22** (4.14-6.44)	**6.60** (5.25-8.22)	**7.79** (6.10-9.82)	**9.48** (7.18-12.2)	**10.8** (7.96-14.2)	**12.2** (8.76-16.4)	**13.8** (9.60-18.8)	**16.0** (10.7-22.4)	**17.8** (11.6-25.3)
7-day	**4.88** (3.88-6.07)	**5.86** (4.67-7.18)	**7.40** (5.91-9.15)	**8.73** (6.88-10.9)	**10.6** (8.09-13.6)	**12.1** (8.97-15.8)	**13.7** (9.87-18.2)	**15.5** (10.8-20.9)	**17.9** (12.1-24.8)	**19.9** (13.0-28.1)
10-day	**5.34** (4.26-6.62)	**6.39** (5.12-7.81)	**8.06** (6.46-9.93)	**9.49** (7.51-11.8)	**11.5** (8.81-14.7)	**13.2** (9.76-17.1)	**14.9** (10.7-19.6)	**16.7** (11.7-22.5)	**19.4** (13.1-26.6)	**21.5** (14.1-30.0)
20-day	**6.91** (5.55-8.49)	**8.11** (6.57-9.89)	**10.0** (8.13-12.3)	**11.7** (9.30-14.4)	**14.0** (10.7-17.5)	**15.7** (11.7-20.1)	**17.5** (12.7-22.9)	**19.6** (13.8-25.9)	**22.4** (15.2-30.4)	**24.8** (16.3-34.1)
30-day	**8.21** (6.63-10.1)	**9.55** (7.79-11.6)	**11.7** (9.53-14.3)	**13.5** (10.8-16.6)	**16.0** (12.3-20.0)	**17.9** (13.3-22.7)	**19.8** (14.4-25.7)	**22.0** (15.5-28.9)	**25.1** (17.1-33.7)	**27.6** (18.2-37.6)
45-day	**9.98** (8.09-12.2)	**11.6** (9.50-14.0)	**14.2** (11.6-17.3)	**16.4** (13.2-20.1)	**19.4** (15.0-24.1)	**21.7** (16.2-27.4)	**24.0** (17.5-30.8)	**26.5** (18.8-34.6)	**30.0** (20.5-40.0)	**32.9** (21.8-44.4)
60-day	**11.5** (9.38-14.0)	**13.4** (11.0-16.2)	**16.5** (13.5-20.0)	**19.1** (15.4-23.3)	**22.6** (17.5-28.0)	**25.3** (19.0-31.8)	**28.0** (20.5-35.8)	**30.9** (22.0-40.2)	**34.9** (23.9-46.2)	**38.0** (25.2-51.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Table 2F-3. Manning's Roughness Coefficients for Open Channels (from TxDOT, 2019)

Type of channel	Manning's n
c. Cultivated areas, no crop	0.020-0.040
d. Cultivated areas, mature row crops	0.025-0.045
e. Cultivated areas, mature field crops	0.030-0.050
f. Scattered brush, heavy weeds	0.035-0.070
g. Light brush and trees in winter	0.035-0.060
h. Light brush and trees in summer	0.040-0.080
i. Medium to dense brush in winter	0.045-0.110
j. Medium to dense brush in summer	0.070-0.160
k. Trees, dense willows summer, straight	0.110-0.200
l. Trees, cleared land with tree stumps, no sprouts	0.030-0.050
m. Trees, cleared land with tree stumps, with sprouts	0.050-0.080
n. Trees, heavy stand of timber, few down trees, flood stage below branches	0.080-0.120
o. Trees, heavy stand of timber, few down trees, flood stage reaching branches	0.100-0.160
3. Major streams (top width at flood stage > 100 ft)	
a. Regular section with no boulders or brush	0.025-0.060
b. Irregular rough section	0.035-0.100
B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050

Written by:	O. Bramlet	Date:	01/03/2020	Reviewed by:	S. Graves	Date:	2/4/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

Table 2F-4. Runoff Coefficients for Rural Watersheds (from TxDOT, 2019)

Watershed characteristic	Extreme	High	Normal	Low
Relief - C_r	0.28-0.35 Steep, rugged terrain with average slopes above 30%	0.20-0.28 Hilly, with average slopes of 10-30%	0.14-0.20 Rolling, with average slopes of 5-10%	0.08-0.14 Relatively flat land, with average slopes of 0-5%
Soil infiltration - C_i	0.12-0.16 No effective soil cover; either rock or thin soil mantle of negligible infiltration capacity	0.08-0.12 Slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 Normal; well drained light or medium textured soils, sandy loams	0.04-0.06 Deep sand or other soil that takes up water readily; very light, well-drained soils
Vegetal cover - C_v	0.12-0.16 No effective plant cover, bare or very sparse cover	0.08-0.12 Poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area has good cover	0.06-0.08 Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in cultivated crops	0.04-0.06 Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface Storage - C_s	0.10-0.12 Negligible; surface depressions few and shallow, drainageways steep and small, no marshes	0.08-0.10 Well-defined system of small drainageways, no ponds or marshes	0.06-0.08 Normal; considerable surface depression, e.g., storage lakes and ponds and marshes	0.04-0.06 Much surface storage, drainage system not sharply defined; large floodplain storage, large number of ponds or marshes
Table 4-11 note: The total runoff coefficient based on the 4 runoff components is $C = C_r + C_i + C_v + C_s$				

Written by: O. Bramlet Date: 01/03/2020 Reviewed by: S. Graves Date: 2/4/2020

Client: TRLC Project: Fort Worth C&D Landfill Project No.: GW6953 Phase No.: 04

Table 2F-5. Diversion Berm Drainage Area Sizing

Depth of Channel (ft)	Diversion Berm Flow Line Slope (%)	Maximum Predicted Flow Velocity (ft/s)	Maximum Predicted Flow Rate (cfs)	Maximum Drainage Area (ac)
2.5	0.5%	5.9	100.8	17.9
	1.0%	8.3	142.5	25.3
	1.5%	10.2	174.6	31.0
	2.0%	11.7	201.6	35.8

Note:

1. The back-calculated maximum allowable drainage area for the channel dimensions (geometry and slope) given above, as calculated by the Rational Method, assumes that the channel created by the diversion berm is flowing full when conveying the peak discharge during the 25-year rainfall event and to the maximum contributing drainage area.

Written by:	O. Bramlet	Date:	01/03/2020	Reviewed and Revised by:	S. Graves	Date:	2/4/2020; 09/15/2020
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Table 2F-6. Containment Berm Heights for Various Drainage and Storage Areas

Containment Berm Drainage Area (ac)	Containment Berm Storage Volume (ac-ft)	Contaminated Water Storage Area (ac)	Minimum Required Berm Height (ft)
0.5	0.30	0.10	4.0
		0.25	2.2
		0.50	1.6
1.0	0.60	0.10	7.0
		0.25	3.4
		0.50	2.2
1.5	0.90	0.25	4.6
		0.50	2.8
		0.75	2.2
2.0	1.20	0.25	5.8
		0.50	3.4
		0.75	2.6
3.0	1.79	0.40	5.5
		0.75	3.4
		1.00	2.8
4.0	2.39	0.50	5.8
		0.75	4.2
		1.00	3.4

Notes:

1. The calculated required berm height includes 1-ft of freeboard for the containment berm.
2. Table is intended as a guide for the landfill operator, as during operation, the active working face location will change as filling progresses, and new containment berms will be constructed accordingly. The containment storage areas and corresponding berm heights are based on flat (horizontal) storage areas. Containment berm storage volumes are provided as a guide for design of areas that are not horizontal and flat (see Note 3).
3. A licensed professional engineer is required to size the containment berms if conditions are not consistent or otherwise covered by the current design presented.

Table 2F-7. Run-On Berm Heights for Various Drainage and Storage Areas

Run-On Berm Drainage Area (ac)	Run-On Berm Storage Volume (ac-ft)	Run-On Water Storage Area (ac)	Minimum Required Berm Height (ft)
2.0	1.20	0.25	5.8
		0.50	3.4
		0.75	2.6
4.0	2.39	0.50	5.8
		0.75	4.2
		1.00	3.4
10.0	5.98	1.00	7.0
		2.00	4.0
		3.00	3.0
15.0	8.96	2.00	5.5
		3.00	4.0
		4.00	3.2
20.0	11.95	2.00	7.0
		3.00	5.0
		4.00	4.0
25.0	14.94	3.00	6.0
		4.00	4.7
		5.00	4.0
30.0	17.93	3.00	7.0
		4.00	5.5
		5.00	4.6

Notes:

1. The calculated required berm height includes 1-ft of freeboard for the containment berm.
2. Table is intended as a guide for the landfill operator, as during operation, the excavation areas contributing run-on towards the berm next to the active area will change as filling progresses, and new run-on berms will be constructed accordingly. The run-on storage areas and corresponding berm heights are based on flat (horizontal) storage areas. The Run-on berm storage volumes are provided as a guide for design of areas that are not horizontal and flat (see Note 3).
3. A licensed professional engineer is required to size the run-on berms if conditions are not consistent or otherwise covered by the current design presented.

FIGURES

- Figure 2F-1. Typical/Schematic of Active Fill Area Section (Not to Scale (NTS))

Written by: **O. Bramlet** Date: **01/03/2020** Reviewed & Revised by: **S. Graves** Date: **2/4/2020**

Client: **TRLC** Project: **Fort Worth C&D Landfill** Project No.: **GW6953** Phase No.: **04**

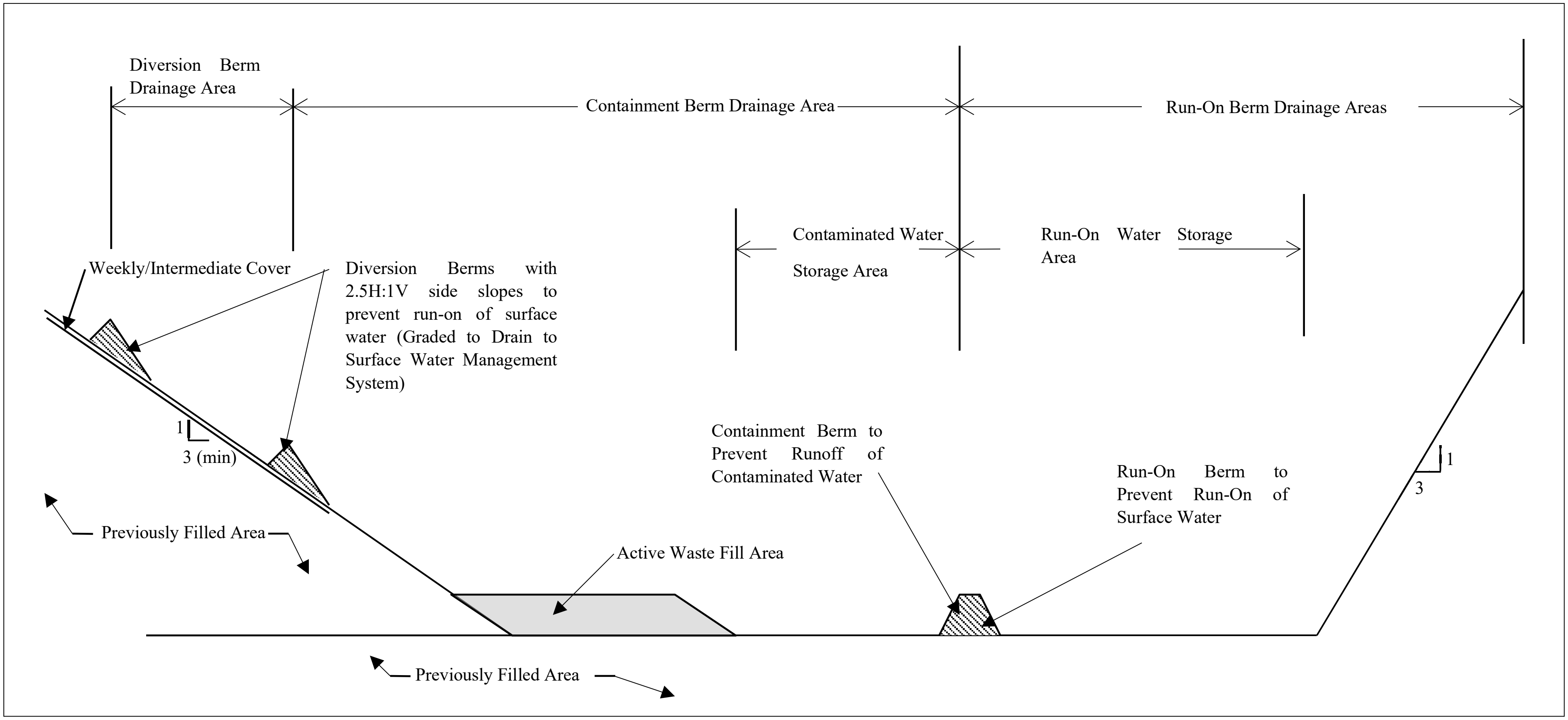

Figure 2F-1. Typical/Schematic of Active Fill Area Section (Not to Scale (NTS))

Note: If the working face is built directly on top of the protective cover of the liner system (i.e., during the first waste lift in a new lined sector), the containment and run-on berm shall be constructed within the lined area.

ATTACHMENT 2G

INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

Prepared for:
Texas Regional Landfill Company, LP

PERMIT AMENDMENT APPLICATION
PART III – SITE DEVELOPMENT PLAN
ATTACHMENT 2G

INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

FORT WORTH C&D LANDFILL
MSW PERMIT NO. 1983D
FORT WORTH, TARRANT COUNTY, TEXAS

Prepared by:

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FOR PERMIT PURPOSES ONLY

May 2020

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86557
LICENSED
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5/7/2020
FOR PERMIT PURPOSES ONLY
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM
REGISTRATION NO. F-1182

DRAWINGS

APPENDICES

1. INTRODUCTION

The purpose of this document is to provide a plan for controlling erosion and sediment on intermediate cover for the Fort Worth C&D Landfill (the landfill). Erosion control is necessary to maintain the integrity of the intermediate cover and to prevent off-site discharge of sediments. This Intermediate Cover Erosion and Sediment Control Plan (ICESCP) has been developed to address the requirements identified in Title 30 Texas Administrative Code (30 TAC) §330.305.

As required by 30 TAC §330.305(d), the landfill has been designed to provide effective erosional stability to top deck surfaces and external side slopes during all phases of landfill operation, closure, and post-closure care. Top deck surfaces and external side slopes are:

- those above grade slopes that directly drain to the facility surface water management system (i.e., areas where the surface water directly flows to a perimeter channel or surface water pond);
- those slopes that have received intermediate or final cover; and
- those surfaces that have either reached their permitted elevation, or will subsequently remain inactive for longer than 180 days.

Slopes that drain to areas of ongoing waste placement, pre-excavated areas, areas that have received only weekly cover, or areas under construction which have not received waste are not considered external side slopes.

The top deck surfaces and external side slopes will be covered with weekly cover, intermediate cover, or final cover. The definitions of each of these cover systems and their respective erosion and sediment control practices are provided below.

1.1 Weekly Cover

Weekly cover is defined in 30 TAC §330.165(b) for Type IV landfills. Weekly cover consists of six inches of well-compacted earthen material (or approved alternative) not previously mixed with garbage, rubbish, or other solid waste. The rate of cover must be no less than weekly, unless the Texas Commission on Environmental Quality (TCEQ) Executive Director approves another schedule. The placement and erosion control practices for weekly cover areas are addressed in the Site Operating Plan (SOP).

1.2 Intermediate Cover

Intermediate cover is defined in 30 TAC §330.165(c). Intermediate cover consists of at least 12 inches of suitable earthen material and is graded and maintained to prevent erosion and ponding of water. All areas that have received waste but will be inactive for longer than 180 days will be provided with intermediate cover. Information regarding the erosion and sediment control practices for intermediate cover is provided in Section 3 of this ICESCP. Additional information regarding placement, maintenance, and repair of intermediate cover is located in Section 5 of this ICESCP and Section 24 of the SOP.

1.3 Final Cover

1.3.1 Reference to Closure Plan

Final cover is defined in 30 TAC §330, Subchapter K. The final cover system for the landfill is described in the Closure Plan located in Attachment 7 of the Site Development Plan (SDP). As areas of the landfill reach final grade, the final cover system and the permanent surface water management system will be installed, which includes vegetated top deck and side slopes, drainage terraces, and downchute channels.

1.3.2 Erosional Stability of the Final Cover

The long-term erosional stability of the final cover slopes is demonstrated using the Revised Universal Soil Loss Equation (RUSLE) and is presented in Attachment 3E of the SDP. As shown in Attachment 3E and further described in the Closure Plan (Attachment 7), the calculated long-term annual soil loss is less than the long-term permissible value, indicating that the final cover system is designed with adequate resistance to erosion. Refer to these aforementioned attachments for additional discussion to clarify the ground coverage percentage and other assumptions that factor in to the calculated long-term annual soil loss. In particular, the "Conclusions and Recommendations" section of Attachment 3E discusses usage of soil loss results including how they relate to ground coverage. Additionally, the erosional stability of the side slope drainage terraces, top deck drainage terraces, and downchutes is demonstrated based on calculated flow velocity and is presented in Attachment 2D.

1.3.3 Final Cover Maintenance

Maintenance requirements for areas with final cover during operations and after closure are addressed, respectively, in Section 24 of the SOP and Section 3 of the Post-Closure Plan Attachment 8 of the SDP).

1.4 Landfill Perimeter Areas

The permanent surface water management system design includes features in the landfill perimeter areas outside the footprint of the disposal area. Runoff will be conveyed from the landfill to perimeter drainage channels and culverts and ultimately routed to the on-site surface water pond or midpoint site outfall. These features provide for non-erosive drainage of runoff from the landfill and surrounding site areas. Perimeter drainage channels will be utilized during development and operation of the landfill and will ultimately convey surface water runoff from the final cover or intermediate cover slopes. The erosional stability of the permanent drainage channels is demonstrated based on calculated flow velocity and is presented in Attachment 2E. Maintenance requirements for perimeter drainage features are addressed in Section 3 in the Post-Closure Plan located in Attachment 8 of the SDP.

2. INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DESIGN

As required by 30 TAC §330.305(d), the landfill design must provide effective erosional stability to top deck surfaces and external side slopes. An Intermediate Cover Erosion Analysis was performed and is included in Appendix 2G-1 of this ICESCP.

2.1 Permissible Soil Loss and Non-Erodible Velocity

A permissible soil loss of 50 tons/acre/year is used as the design criteria to which the calculated soil loss for intermediate cover is compared (TCEQ, 2018). For the purposes of the site-specific erosion and sediment control design, the permissible soil loss is the "permissible soil loss for comparable soil-slope lengths and soil-cover conditions" referred to by 30 TAC §330.305(d)(2). For comparison purposes, 50 tons/acre is equivalent to a soil thickness of 0.25 in. (six mm) for a soil with a typical bulk density of 110 pcf.

The permissible non-erodible velocity of five (5) ft/sec is used as the design criteria to which the estimated flow velocities are compared. *Storm Water Management Guidelines for Construction Activities* (TxDOT, 2002) indicates that flow velocities should not exceed four (4) ft/sec in sandy soils or five (5) ft/sec in more cohesive soils. Five (5) ft/sec is appropriate for this facility because it is anticipated that intermediate cover will be constructed of cohesive soils that are readily available at the site.

2.2 Intermediate Cover Erosion Analysis Results

The Intermediate Cover Erosion Analysis is presented in Appendix 2G-1 of this ICESCP. The Revised Universal Soil Loss Equation (RUSLE) is used in the Intermediate Cover Erosion Analysis to calculate the annual soil loss. Results from the Intermediate Cover Erosion Analysis indicate that adequate erosional stability of the intermediate cover on the top deck and side slopes can be achieved with stabilized soil surfaces and surface water diversions. To achieve effective erosional stability, the maximum parallel offset (horizontal) of the temporary diversion structures is 550-ft on the top deck. The maximum parallel offset for the external 3H:1V side slopes is dependent on the ground cover attained on the interim cover. For 60%, 70%, and 80% ground cover on the interim cover system, the maximum parallel offset of terraces on the external 3H:1V side slopes is 300-ft, 500-ft, and 680-ft, respectively. These distances are based on a soil stabilization practice method that provides a cropping management factor (C) corresponding to the above options for percentage of ground cover. on the top deck and external side slopes. The C values correspond to ground cover consisting of grass, grass-like plants, mulch, or organic matter at least two inches deep covering the specified percentage of the surface of the intermediate cover.

3. EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES (BMPS)

Based on the Intermediate Cover Erosion Analysis presented in Appendix 2G-1 of this ICESCP, soil stabilization and surface water diversion BMPs are required for erosional stability of the intermediate cover on the top deck surface and external side slopes during landfill operations. Drawing 2G-1 depicts a plan view of the site to show an example configuration of a landfill development phase, showing the areas requiring erosion and sediment controls addressed in this plan. Descriptions of the required soil stabilization and drainage controls are provided below. Optional BMPs that may be used in addition to the required BMPs at the landfill operator's discretion are also described.

3.1 Soil Stabilization

The purpose of soil stabilization is to provide a ground cover that limits the rainfall impact energy, provides a limited amount of water storage through rainfall interception, and limits sheet flow runoff velocity by increasing surface roughness. In the natural condition, soil is stabilized by native vegetation. As previously described, the temporary soil stabilization practice must provide a maximum C value of 0.042 for intermediate cover. These C values correspond to ground cover consisting of grass, grass-like plants, mulch, or organic matter at least two inches deep covering at least 60% of the surface of the intermediate cover. Intermediate cover will be installed in accordance with the requirements of the SOP, will be stabilized with at least 60% ground cover within 180 days following installation, and will be maintained until final cover is installed or waste filling operations resume. Placement of intermediate cover and stabilization activities will be documented in the Site Operating Record. Details of the soil stabilization BMPs that will be implemented are listed below.

- Vegetation – Vegetation, as a BMP, is the sowing or sodding of fast-germinating annual or perennial grasses, grains, or legumes to provide a vegetative stabilization for disturbed areas. With leaves and stems above ground and fibrous roots below ground, vegetation can provide an effective and long-lasting ground cover. Lack of water and lack of or improper use of soil amendments will usually result in poor vegetation establishment. Seed may be applied to the landfill surface by broadcasting, drilling, hydraulic methods such as hydroseeding or hydromulching, or other methods. Vegetation types, rates of application, and other specifications for establishing vegetation are left to the discretion of the landfill operator, but should be in accordance with temporary vegetation BMP standards or guidelines published by relevant State or local agencies, appropriate for the area. An example of a standard vegetation specification is published in TxDOT (2014), the *Texas Department of Transportation (TxDOT) Standard Specification for Construction and Maintenance of Highways, Streets, and Bridges*, Item 162 (sodding) and Item 164 (seeding). Use of this particular standard specification is not required but is provided as an example of a common and widely-used specification that provides vegetation-related BMPs. Intermediate cover must achieve a relatively uniform ground cover of at least 60% within 180 days following placement. If vegetation establishment at the minimum density specified above cannot be achieved (due to drought, temperatures, or other unforeseen conditions), then additional soil stabilization BMPs (e.g., mulch) will be implemented until the required vegetation density is achieved.

- Mulch – Mulching is the application of a layer of organic, biodegradable material which is spread over areas where vegetation is not yet established. Types of mulch include compost, shredded wood, straw, or manufactured products. Mulch may be distributed over the ground surface dry or hydraulically applied as slurry. If applied dry, the mulch must be tracked into the surface to prevent the mulch from being washed away. If mulch is to be used as the only soil stabilization feature (i.e., without vegetation), a two-inch (minimum) thick layer of "primary grind" mulch is required. Note that "primary grind" mulch is mulch obtained from the primary run from an industrial tub grinder. Primary grind mulch is very coarse mulch that mats together and resists washing away. It is noted that this technique has been used successfully in stabilizing intermediate cover side slopes at similar landfill projects within Texas. Types of mulch slurries include hydromulch, bonded fiber matrix (BFM), flexible growth medium (FGM), as well as other commercially available products. Slurry mixtures typically include a tackifier or binder which increases the strength and durability of the mulch. Seed can also be added to the slurry, in which case the ground surface would be stabilized with a mulch/vegetation composite. If mulch is used in lieu of vegetation for intermediate cover, then the mulch will be applied to cover all of the area requiring stabilization within 180 days of intermediate cover installation. If mulch is used in conjunction with vegetation, then the mulch will be applied to areas where the vegetation fails to establish, or the mulch will be used as a supplemental layer to encourage vegetative growth while providing some degree of soil stabilization until vegetation becomes established.

3.2 Surface Water Diversions

The purpose of a surface water diversion structure is to limit the length of slope over which surface water runoff can travel as sheet flow or shallow concentrated flow. The diversion concentrates and laterally conveys surface water in a non-erosive manner to the perimeter ditch or downchute. Surface water diversion BMPs that will be implemented are listed below.

- Side Slope Drainage Terraces – The proposed final grading plan includes tack-on terraces on the external 3H:1V side slopes of the landfill. These terraces will be constructed of intermediate cover overlying waste and will have a flow line (or longitudinal) slope of approximately 2%. The surface of the intermediate cover within the terrace will be stabilized with vegetation or mulch. Rolled erosion control products may also be used for stabilization of the drainage terraces. Details showing the required dimensions and spacing of the built-in terraces are provided on Drawing 2G-2. Design calculations for these side slope drainage terraces on the intermediate cover surface are provided in Appendix 2G-2.

- Top Deck Drainage Terraces – Top deck drainage terraces are open channels used to collect flow from top deck surfaces and convey it to the temporary downchute channels along the side slopes in a non-erosive manner. Top deck drainage terraces are designed as v-shaped channels with 3H:1V and 5% side slopes and a flow line slope of approximately 0.15%. Details showing the required dimensions and layout of the drainage features are provided on Drawing 2G-2. Design calculations for the top deck drainage terraces on the intermediate cover surface are provided in Appendix 2G-2.

- Temporary Downchutes – Temporary downchutes (also known as downdrains or let-downs) are open channels used to collect flow from surface water diversion structures and convey it down the side slope in a non-erosive manner. Downchutes will be constructed using soil berms to create an above-grade channel, or will be excavated to create a depressed channel (in which case a minimum of one foot of intermediate cover will be maintained beneath the downchute). The bottom and side slopes of the temporary downchute channel will be lined with turf reinforcement mat, geomembrane, reno mattress/articulated block, or other alternative lining material to prevent erosion. If an alternative lining material is used, the lining material must have a Manning's n equal to or less than 0.015. The lining material must be able to tolerate the anticipated velocity and tractive stress at the design flow rate and corresponding calculated depth of flow. All equivalency evaluations performed pursuant to these criteria will be placed in the Site Operating Record. A rip rap apron will be installed at the downstream end of the downchutes to provide erosion protection. Details showing the required dimensions and information on these structures are provided on Drawing 2G-2. Design calculations for these temporary structures are provided in Appendix 2G-2.

3.3 Optional Erosion and Sediment Control BMPs

As demonstrated in the Intermediate Cover Erosion Analysis included in Appendix 2G-1, the soil stabilization and surface water diversion BMPs specified above in Sections 3.1 and 3.2 are the only BMPs required to limit soil loss in accordance with 30 TAC §330.305(d). No other BMPs are required. However, other erosion and sediment control BMPs may be implemented during landfill operations at the operator's discretion in order to reduce soil losses even further than required or to provide temporary erosion and sediment controls during the period between installation of intermediate cover and establishment of vegetation or mulch on the top deck and external side slopes. Examples of optional BMPs that may be implemented are listed below.

- Silt Fence – Silt fence consists of filter fabric supported by wire mesh netting or other backing stretched between either wooden or metal posts with the lower edge of the fabric securely embedded in the soil. Silt fence may be located as needed to intercept and filter sheet flow. Typical locations of silt fence include along the toe or crest of external side slopes and should be installed at a fairly level grade. Silt fence may not be used in areas of concentrated flow (e.g., channels and diversions). The maximum drainage area to the silt fence should not exceed the manufacturer's specification, but in no case shall the drainage area be greater than 0.5 acre per 100 ft of fence. A typical silt fence detail is provided on Drawing 2G-3.

- Biodegradable Logs – Biodegradable logs (or filter socks) consist of a biodegradable core material contained in a synthetic mesh sock or tube and are installed above, across, or below slopes to intercept and filter sheet flow. The logs are anchored to the surface using stakes or other methods and should be installed at a fairly level grade. Biodegradable logs may not be used in areas of concentrated flow (e.g., channels and diversions). The maximum drainage area to the biodegradable logs should not exceed 0.5 acre per 100 ft of log. A typical biodegradable log detail is provided on Drawing 2G-3.

- Organic Berms – Organic berms (or organic filter berms) are linear berms constructed of mulch or a mix of mulch and compost. Organic berms may be located as needed to intercept and filter sheet flow. Typical locations of organic berms include along the toe or crest of external side slopes. Organic berms may not be used in areas of concentrated flow (e.g., channels, terraces, and diversions). The maximum drainage area to the organic berms should not exceed 0.5 acre per 100 ft of berm. A typical organic berm detail is provided on Drawing 2G-3.

4. INTERMEDIATE COVER INSTALLATION AND STABILIZATION SCHEDULE

The schedule for installation of intermediate cover and associated erosion and sediment control BMPs is as follows:

- Areas with weekly cover that remain inactive for periods greater than 180 days will receive intermediate cover.

- Intermediate cover diversion structures and downchutes will be installed as soon as practical following placement of intermediate cover, but in no case more than 180 days from when intermediate cover is installed.

- Intermediate cover will be stabilized with vegetation or mulch as soon as practical following placement of intermediate cover. A minimum of 60% land cover (corresponding to a maximum cropping management factor of 0.042) will be established over the intermediate cover areas within 180 days from intermediate cover construction.

- The intermediate cover and temporary erosion control structures will be maintained as detailed in Section 5 below (the Intermediate Cover Erosion and Sediment Control Maintenance Plan).

- Final cover will be constructed incrementally as the site develops. Temporary erosion control features will be removed as permanent erosion control structures are constructed.

5. INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL MAINTENANCE PLAN

The landfill operator will restore and repair the intermediate cover areas and their erosion and sediment control features in the event of washout or failure. Excess silt buildup, weeds and other debris that are adversely affecting flow in diversion structures will be removed to restore their design configuration, followed by re-stabilizing the disturbed areas as appropriate. Site inspections by landfill personnel will be performed weekly in accordance with the facility's Texas Pollutant Discharge Elimination System (TPDES) Multi-Sector General Permit. Written records of these inspections and maintenance activities will be maintained in the Site Operating Record, as further discussed in the Site Operating Plan (SOP).

The following items will be evaluated during the inspections:

- presence of adequate vegetation coverage (grass and/or mulch) to meet the applicable minimum ground cover percentages specified herein;
- adequacy of the spacing between interim diversion structures on side slopes in accordance with the table on Drawing 2G-2;
- erosion of intermediate cover areas, perimeter ditches, diversion channels, downchutes, and other drainage features;
- settlement of intermediate cover areas, diversion channels, downchutes, and other drainage features;
- silt and sediment build-up in diversion channels, perimeter ditches, downchutes, and surface water ponds;
- presence of ponded water on intermediate cover or behind diversion structures;
- obstructions in drainage features;
- presence of erosion or sediment discharge at off-site surface water discharge locations; and
- functionality of temporary erosion and sediment control features.

Maintenance activities will be performed to correct damaged or deficient items noted during the site inspections. These activities will be performed as soon as possible after the inspection. Damaged or deficient items will be corrected within seven days of detection unless access is restricted due to weather, ground conditions, and other site-specific conditions.

Maintenance activities will consist of the following, as needed:

- placement of additional vegetation or mulch on areas with deficient coverage;
- adjustments to, or installation of, interim diversion structures that are found to be spaced inadequately;
- placement, grading, and stabilization of additional soils in eroded areas or in areas which have settled;
- replacement of riprap or other structural armoring;
- removal of obstructions from drainage features;
- removal of silt and sediment build-up from the erosion and sediment controls;
- removal of ponded water on the intermediate cover or behind diversion structures;
- repairs to erosion and sedimentation controls; and
- installation of additional erosion and sedimentation controls, as needed.

Inspection, maintenance, and recordkeeping frequencies and techniques are discussed below.

- Site inspections by landfill personnel will be performed weekly.
- Documentation of the inspection will be included in the Site Operating Record.
- Documentation of maintenance activities that were performed to correct damaged or deficient items noted during the site inspections will be included in the Site Operating Record.
- Landfill personnel will be trained to perform inspections, install, and maintain erosion and sediment control features.

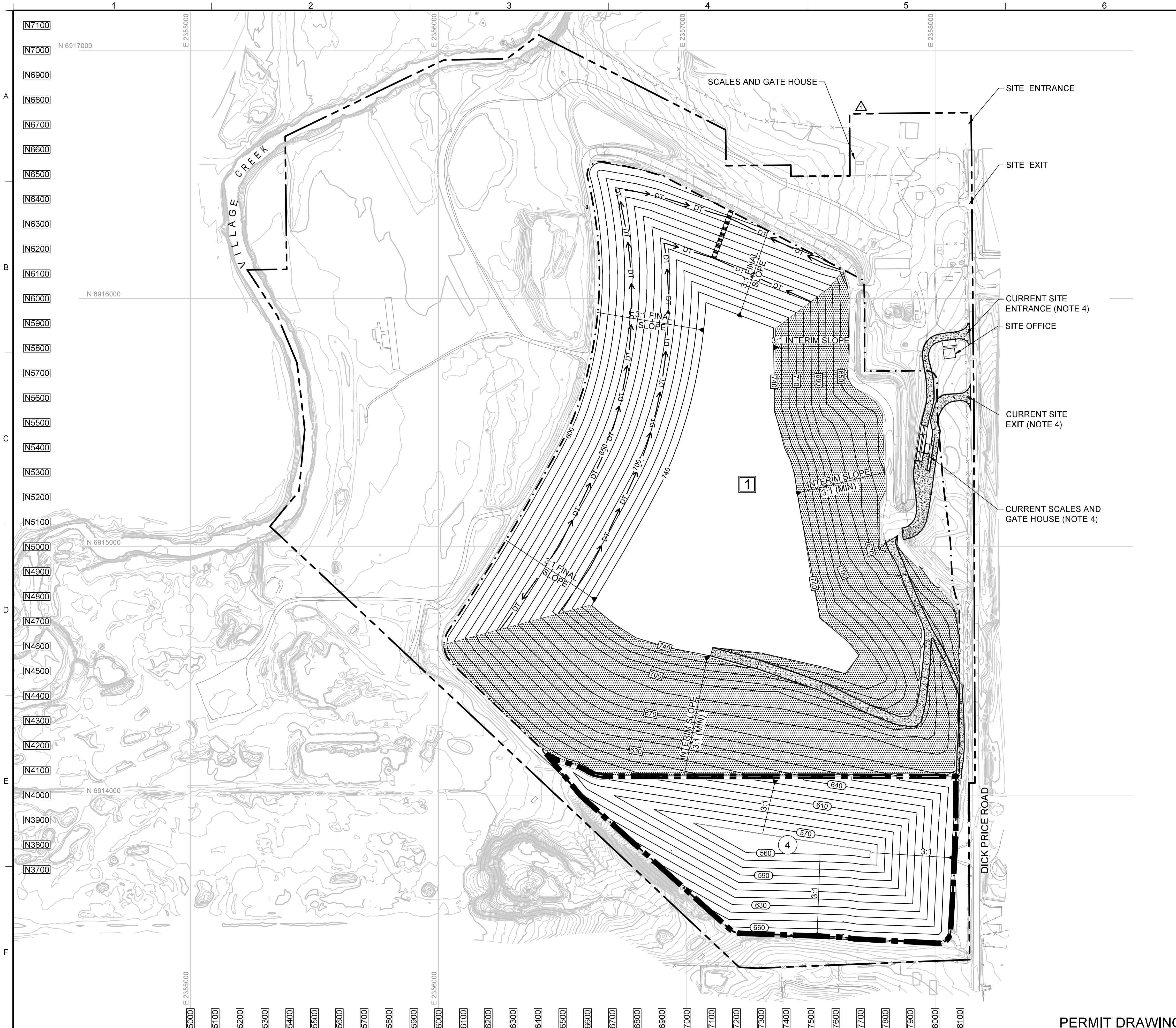
6. REFERENCES

TCEQ (2018). Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill, Regulatory Guidance 417 (RG-417), Texas Commission on Environmental Quality, Waste Permits Division, Revised May 2018.

TxDOT (2002). *Storm Water Management Guidelines for Construction*, Texas Department of Transportation.

TxDOT (2014). Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Texas Department of Transportation, 1 November 2014.

TxDOT (2019). *Hydraulic Design Manual*, Texas Department of Transportation, revised September 2019.



LEGEND

- EXISTING GROUND ELEVATION CONTOUR (FT, MSL) (NOTES 1, 2)
- EXISTING ROAD
- EXISTING FENCE
- EXISTING BUILDING
- EXISTING WATER LINE
- LANDFILL ACCESS / HAUL ROAD (NOTE 4)
- COORDINATE GRID (NOTE 2)
- PERMIT BOUNDARY
- LIMIT OF WASTE
- SITE GRID
- SECTOR DESIGNATION
- PROPOSED FINAL GROUND ELEVATION (FT, MSL)
- INTERIM WASTE SLOPE
- PROPOSED TOP OF LINER BASE GRADES (FT, MSL)
- FILLING PHASE DESIGNATION
- CELL EXCAVATION AREA
- FINAL COVER DRAINAGE TERRACE AND FLOW DIRECTION
- FINAL COVER DOWNCHUTE DRAINAGE CHANNEL
- STABILIZATION (NOTE 4)

0 200' 400'
SCALE IN FEET

NOTES:

1. EXISTING TOPOGRAPHIC BASE MAP COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 06 MARCH 2019 BY DALLAS AERIAL SURVEYS, INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED BY THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988. COORDINATE GRID BASED ON TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS NORTH CENTRAL ZONE (4202), NORTH AMERICAN DATUM OF 1983 (NAD-83).
3. THIS PLAN REPRESENTS A "SNAPSHOT" OF GENERAL CONDITIONS FOR INTERMEDIATE COVER EROSION AND SEDIMENT CONTROLS DURING DEVELOPMENT OF PHASE 1 AND MAY NOT REFLECT THE EXACT CONFIGURATION OF THE LANDFILL OR LOCATION OF CONTROLS. ACTUAL EROSION AND SEDIMENT CONTROL FEATURES WILL VARY BASED ON LANDFILL DEVELOPMENT.
4. DETAILS AND INFORMATION ON THE REQUIRED SPACING OF INTERIM DRAINAGE TERRACES IS PROVIDED ON DRAWING 2G-2. THE DESIGN CALCULATIONS ARE PRESENTED IN APPENDIX 2G-2.
5. DIVERSION STRUCTURES MUST BE INSTALLED AND STABILIZED WITHIN 180 DAYS FOLLOWING PLACEMENT INTERMEDIATE COVER.
6. STABILIZATION MAY CONSIST OF VEGETATION, MULCH, OR COMBINATION OF BOTH. THE STABILIZATION MUST OBTAIN AT LEAST 60% COVERAGE WITHIN 180 DAYS FOLLOWING PLACEMENT OF INTERMEDIATE COVER. IF MULCH IS USED AS THE ONLY STABILIZATION FEATURE, A MINIMUM LAYER THICKNESS OF 2 INCHES IS REQUIRED AND AT LEAST 50% (BY BULK VOLUME) MUST CONSIST OF PARTICLES WITH DIMENSIONS EQUIVALENT TO THAT OBTAINED FROM THE PRIMARY RUN FROM AN INDUSTRIAL TUB GRINDER.

STATE OF TEXAS
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12/14/2020

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1	DEC 2020	RESPONSE TO NOD 2	JJV	SMG
-	MAY 2020	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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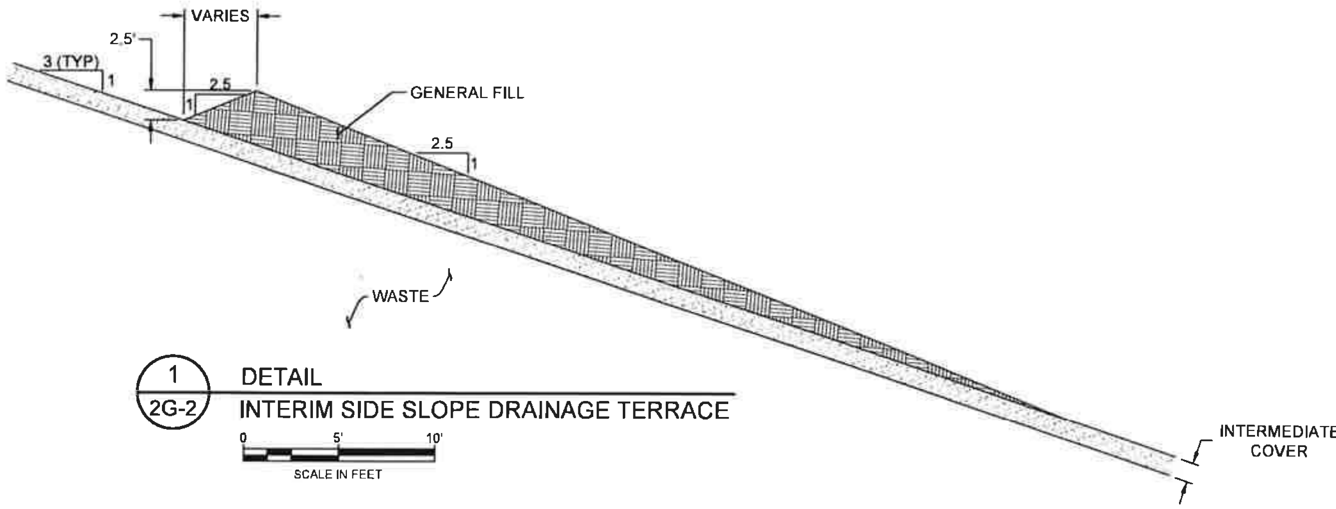
TITLE: EXAMPLE INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

PROJECT: FORT WORTH C&D LANDFILL EXPANSION
PERMIT AMENDMENT APPLICATION - PERMIT NO. MSW-1983D

PERMIT DRAWING

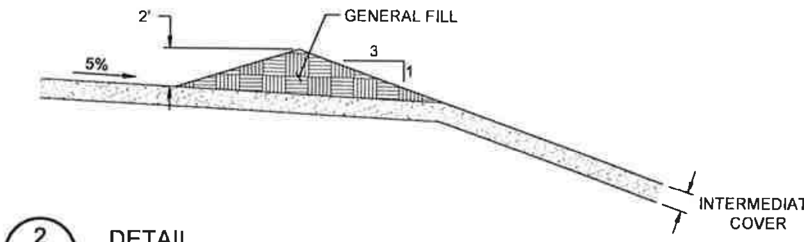
PROJECT NO.:	GW6953	DESIGN BY:	SMG	REVIEWED BY:	BG	PART NO.: III	DRAWING: 2G-1
FILE:	GW6953P2G1	DRAWN BY:	JJV / KH	APPROVED BY:	SMG		

DRAWING: Austin P:\CADD\Projects\Ft worth c&d landfill\PERMIT\landfill expansion (gw6953)\DRAWINGS\GW6953P2G1.dwg PLOTTED: Dec 07, 2020 - 2:38pm



1 / 2G-2 DETAIL
INTERIM SIDE SLOPE DRAINAGE TERRACE

0 5' 10' SCALE IN FEET

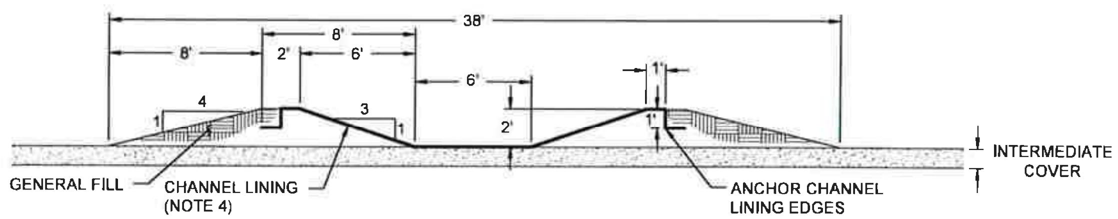


2 / 2G-2 DETAIL
INTERIM TOP DECK DRAINAGE TERRACE (NOTE 2)

0 5' 10' SCALE IN FEET

NOTES:

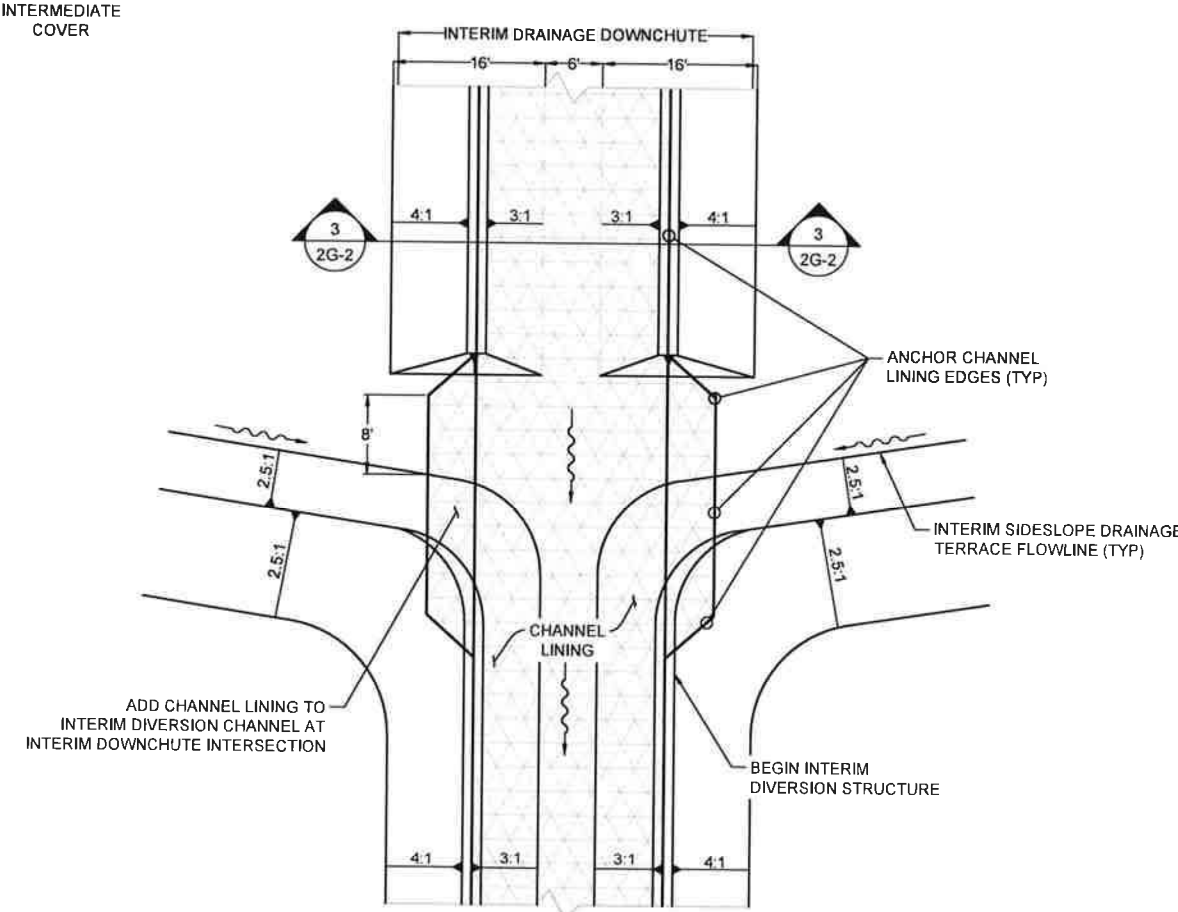
1. THE INTERIM DIVERSION STRUCTURES CONSTRUCTED ON SIDE SLOPES SHALL BE SPACED ACCORDING TO THE MAXIMUM ALLOWABLE DRAINAGE TERRACE SPACING TABLE (SEE BELOW) AND INTERIM COVER STABILIZATION METHOD. THE FLOWLINE SLOPE OF THE CHANNEL SHALL BE APPROXIMATELY 2%.
2. THE DIVERSION STRUCTURES CONSTRUCTED ON 5% TOP DECK SURFACES SHALL BE SPACED A MAXIMUM OF 675 FT HORIZONTALLY. THE FLOWLINE SLOPE OF THE CHANNEL SHALL BE APPROXIMATELY 0.15%.
3. ROLLED EROSION CONTROL PRODUCTS IF USED WITHIN THE DIVERSION CHANNELS MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
4. THE BOTTOM AND SIDESLOPES OF THE DOWNCHUTE CHANNEL WILL BE LINED WITH TURF REINFORCEMENT MAT, GEOMEMBRANE, RENO MATTRESS, OR OTHER ALTERNATIVE LINING MATERIAL TO PREVENT EROSION. IF AN ALTERNATIVE LINING MATERIAL IS USED, THE LINING MATERIAL MUST HAVE A MANNING'S N LESS THAN 0.015. THE LINING MATERIAL MUST BE ABLE TO TOLERATE THE ANTICIPATED VELOCITY AND TRACTIVE STRESS AT THE DESIGN FLOW RATE AND CORRESPONDING CALCULATED DEPTH OF FLOW. ALL EQUIVALENCY EVALUATIONS PERFORMED PURSUANT TO THESE CRITERIA WILL BE PLACED IN THE FACILITY OPERATING RECORD.
5. RIPRAP APRON SHALL BE A MINIMUM OF 2' THICK AND SHALL HAVE D_{50} = 12" AND D_{MAX} = 24"; APRON WIDTH = 24' MIN.



3 / 2G-2 DETAIL
TYPICAL INTERIM DRAINAGE DOWNCHUTE CROSS SECTION

0 5' 10' SCALE IN FEET

MAXIMUM ALLOWABLE DRAINAGE TERRACE SPACING				
		MAXIMUM ALLOWABLE TERRACE SPACING		
INTERIM COVER STABILIZATION METHOD	REQUIRED MINIMUM GROUND COVER	5% TOP DECK	33% SIDE SLOPES	CHANNEL DEPTH (FT)
GRASS	60%	675-FT	250-FT	2.5
GRASS & MULCH	70%	675-FT	450-FT	2.5
MULCH	80%	675-FT	600-FT	2.5



5/7/2020

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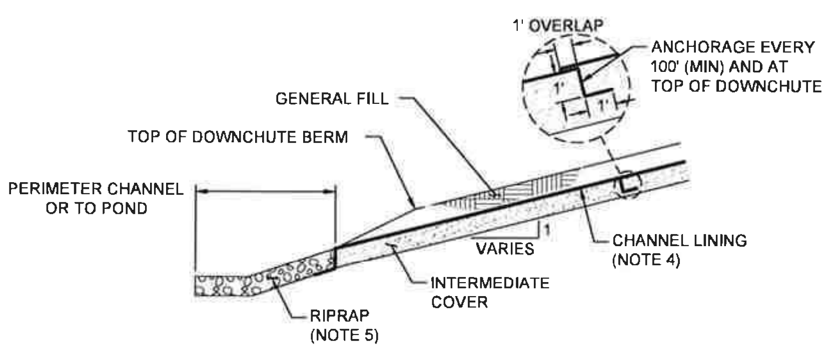

4 / 2G-2 DETAIL
TYPICAL INTERIM DRAINAGE DOWNCHUTE

0 5' 10' SCALE IN FEET

5 / 2G-2 DETAIL
TYPICAL INTERIM DRAINAGE DIVERSION STRUCTURE AND DOWNCHUTE INTERSECTION

0 10' 20' SCALE IN FEET

IIIF-E-305

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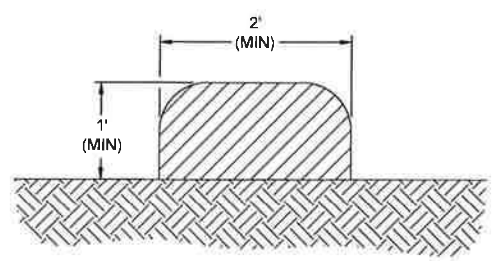
TITLE: INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DETAILS I

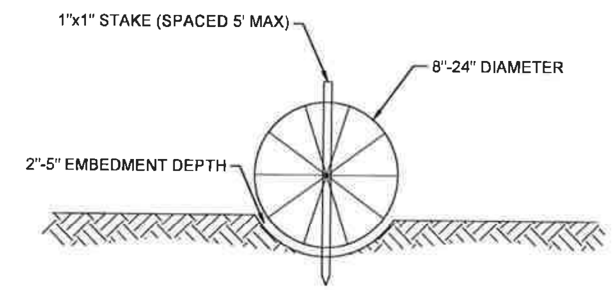
PROJECT: FORT WORTH C&D LANDFILL EXPANSION
PERMIT AMENDMENT APPLICATION - PERMIT NO. MSW-1983D

PROJECT NO.: GW6953	DESIGN BY: SMG	REVIEWED BY: BG	PART NO.: III	DRAWING: 2G-2
FILE: GW6953P2G2	DRAWN BY: JJV / KH	APPROVED BY: SMG		

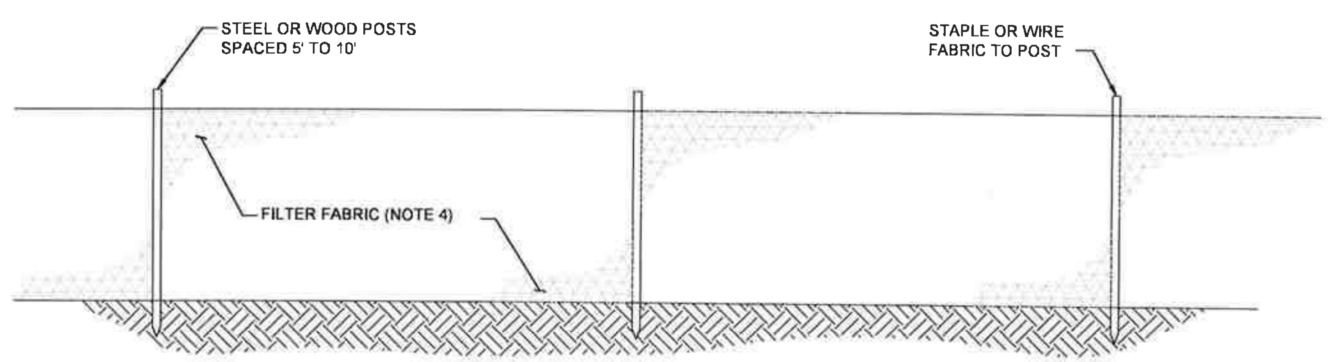
DRAWING: Austin P:\CAD\Projects\Ft worth c&d landfill expansion (gw6953)\DRAWINGS\GW6953P2G2.dwg PLOTTED: May 05, 2020 - 2:32pm



6 / 2G-3 DETAIL
ORGANIC BERM
SCALE: NTS



7 / 2G-3 DETAIL
BIODEGRADABLE LOG
SCALE: NTS



8 / 2H-3 DETAIL
SILT FENCE
SCALE: NTS

NOTES:

1. THE EROSION AND SEDIMENT CONTROL FEATURES SHOWN ON THIS FIGURE ARE OPTIONAL AND MAY BE IMPLEMENTED DURING LANDFILL OPERATIONS AT THE OPERATOR'S DISCRETION IN ORDER TO REDUCE SOIL LOSSES EVEN FURTHER THAN REQUIRED OR TO PROVIDE TEMPORARY EROSION AND SEDIMENT CONTROLS DURING THE PERIOD BETWEEN INSTALLATION OF THE INTERMEDIATE COVER AND ESTABLISHMENT OF VEGETATION OR MULCH ON THE EXTERNAL SLOPES.
2. IF USED, THE OPTIONAL EROSION AND SEDIMENT CONTROL FEATURES MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS, THE DETAILS SHOWN ON THIS FIGURE, OR OTHER PUBLISHED SOURCE (E.G., TXDOT OR MUNICIPAL OR COUNTY GOVERNMENT AGENCY).
3. THE MAXIMUM DRAINAGE AREA TO THE SILT FENCE, ORGANIC BERM, AND BIODEGRADABLE LOG SHALL NOT EXCEED THE MANUFACTURER'S RECOMMENDATION, BUT IN NO CASE SHALL THE DRAINAGE AREA BE GREATER THAN 0.5 ACRE PER 100 FT. THESE OPTIONAL FEATURES MAY NOT BE USED IN AREAS OF CONCENTRATED FLOW (FOR EXAMPLE, DITCHES, CHANNELS, AND TERRACES).
4. THE LOWER EDGE OF THE SILT FENCE FILTER FABRIC SHALL BE SECURELY EMBEDDED IN THE SOIL.
5. ORGANIC BERMS MAY BE CONSTRUCTED OF MULCH, WOODCHIPS, BRUSH, COMPOST, OR SHREDDED WOODWASTE.
6. BIODEGRADABLE LOGS MAY CONSIST OF MUSH SOCKS FILLED WITH MULCH, WOODCHIPS, BRUSH, COMPOST, OR SHREDDED WOODWASTE.

STATE OF TEXAS
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5/7/2020

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TITLE: INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DETAILS II

PROJECT: FORT WORTH C&D LANDFILL EXPANSION
PERMIT AMENDMENT APPLICATION - PERMIT NO. MSW-1983D

PROJECT NO.:	GW6953	DESIGN BY:	SMG	REVIEWED BY:	BG	PART NO.: III	DRAWING: 2G-3
FILE:	GW6953P2G3	DRAWN BY:	JJV / KH	APPROVED BY:	SMG		

PERMIT DRAWING

APPENDIX 2G-1

INTERMEDIATE COVER EROSION ANALYSIS

Written by:	O. Bramlet	Date:	01/09/2019	Reviewed by:	S. Graves	Date:	2/4/2020
Client:	TRLC	Project:	Fort Worth C&D Landfill	Project No.:	GW6953	Phase No.:	04

INTERMEDIATE COVER EROSION ANALYSIS

5/7/2020

STATE OF TEXAS
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SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 21

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the intermediate cover erosion analysis for the Fort Worth C&D Landfill. This package provides calculations for the annual soil loss from the external-facing intermediate cover top deck and side slope surfaces under potential interim conditions during operations. In addition, estimates of flow velocities on the previously mentioned slopes are provided for the purpose of assessing whether the surface water velocities will remain below permissible non-erodible velocities.

2 PROJECT BACKGROUND

The landfill intermediate cover system includes a surface water management system. Intermediate cover placement of the landfill is expected to be completed as areas reach final elevations and await the construction of the final cover system. The intermediate cover system is comprised of a top deck surface and side slopes designed with temporary drainage features until the final cover system is constructed. The top deck of the landfill will have a surface slope of approximately 5% and flow into top deck drainage terraces. The side slopes of the intermediate cover on external-facing slopes will be constructed with a grade of 3 horizontal to 1 vertical (3H:1V) (i.e., 33.3%). The landfill's surface water management system includes the following permanent and temporary drainage features: top deck drainage terraces, downchute channels, side slope drainage terraces, perimeter drainage channels, and a surface water pond. The proposed top deck drainage terraces will convey flow from the top deck to the downchute channels and into the perimeter drainage channels. The proposed side slope drainage terraces will collect and convey surface water runoff from the side slopes to the downchute channels. The perimeter drainage channels will also convey flow from these diversion structures to the surface water pond located to the north of the landfill and those to the south of the landfill will convey flow to the midpoint site outfall.

A permissible soil loss of 50 tons/acre/year is adopted for the purposes of these calculations (TCEQ, 2018). Also, sheet flow and shallow concentrated flow velocities are evaluated to verify that the predicted velocity of runoff is maintained below the permissible erodible velocity of the intermediate cover soil, which is established as five (5) ft/sec for cohesive soil as recommended by TxDOT (2002).

3 CALCULATION METHODOLOGY

The method to calculate the soil erosion loss over the project area was obtained from the guidance document *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)* (USDA, 1997) as well as previously published information provided by USDA. This document presents the Revised Universal Soil Loss Equation (RUSLE) and guidance for each of the equation's parameters. The RUSLE is described as follows:

$$A = R \times K \times LS \times C \times P$$

where:

A	=	the computed spatial average annual soil loss (tons/acre/year),
R	=	the average annual rainfall runoff erosivity factor,
K	=	the soil erodibility factor,
LS	=	the topographic factor,
C	=	the cover management factor, and
P	=	the erosion control practice factor.

The sheet flow and shallow concentrated flow velocities are estimated using guidance provided in TxDOT (2019) and USDA (2010). TxDOT (2019) indicates that sheet flow velocities (for distances up to 100 ft) may be estimated based on slope and surface conditions using Manning's kinematic solution to estimate sheet flow travel time:

$$T_t = \frac{0.007(nL)^{0.8}}{P_{2-24}{}^{0.5} S^{0.4}}$$

where: T_t = travel time for sheet flow (hr);

n = roughness coefficient;

L = flow length (ft);

$P_{2\text{-}24}$ = 2-year, 24-hour rainfall (in.); and

S = slope of hydraulic grade line (land slope, ft/ft).

The sheet flow velocity is $V = L / T_t$. The 2-year, 24-hour rainfall depth is provided by the National Oceanic Atmospheric Association's (NOAA) Precipitation Frequency Data Server for Atlas 14. The 2-year, 24-hour rainfall depth is 3.91 inches (NOAA, 2018). Roughness coefficient values for sheet flow are provided in Table 2G-1-1.

For shallow concentrated flow, the velocity can be estimated using the equation provided by USDA (2010), as follows:

$$V = K_v \times S^{1/2}$$

where:

V = shallow concentrated flow velocity (ft/s),

K_v = velocity factor (ft/s), and

S = slope (ft/ft).

The velocity factor (K_v) is selected from the description of the surface cover as provided in Table 2G-1-2. The estimates of sheet flow and shallow concentrated flow velocities are compared to the permissible non-erodible velocity of five (5) ft/sec for cohesive soil as recommended by TxDOT (2002).

4 RUSLE PARAMETERS

4.1 Rainfall Runoff Erosivity Factor (R)

The rainfall runoff erosivity factor is defined as the average annual rainfall erosion index specific for the project area. Based on USDA (1997), the value of R was determined to be approximately 275 for Fort Worth, Texas, as shown in Figure 2G-1-1.

4.2 Soil Erodibility Factor (K)

The soil erodibility factor is a function of the physical and chemical properties of the soil and is specific to the source of the cover material. The soil erodibility factor can be thought of as the ease with which soil is detached by splash during rainfall or by surface flow. The soils to be used for the intermediate cover system of the landfill are expected to be based on the native soils available at the project site or from local off-site sources. For soil loss calculation purposes, assessments were made of on-site soils and those nearby, using the Tarrant County soil survey (USDA, 1981). This information shows that the site and nearby area has soils that are a combination of a number of soil classifications, including the following: Frio, Gasil, Birome-Aubrey-Rayex, Arents, and Crosstell. The Frio silty clay, Gasil fine sandy loam, and Gasil sandy clay loam formations constitute the majority of the site and will be used for intermediate cover materials. A soil survey map of the site vicinity was previously provided on Figure 2B-2 that is included in Attachment 2B of the Facility Surface Water Drainage Report – "On-Site Drainage Analysis – Hydrology."

The Web Soil Survey tool operated by the USDA Natural Resources Conservation Service (NRCS) (2019) was consulted for Tarrant County for information on the corresponding soil erodibility factors. The value of K for the project location soils near the surface varies from 0.15 to 0.28, where the estimate considers the erodibility of fine-earth fraction for material less than two mm in size (using the Kf erosion factor provided in Table 2G-1-3). Thus, the use of 0.28 in the calculation is a conservative value of the formations that are most predominant at the site and surrounding areas (i.e., the most likely source of future intermediate cover).

4.3 Topographic Factor (LS)

The slope length factor and slope steepness factor are typically combined into one topographic factor, LS, to facilitate field application of these equation components. USDA (1997) presents values of the LS factor for slope lengths in feet up to 1,000 feet and percent slopes up to 60%, as shown in Table 2G-1-4. To manage surface water runoff from the intermediate surface slopes and terraces, temporary surface water diversion structures will be installed on the intermediate cover system. The surface water diversion features will be placed to limit soil erosion.

The average slope length on the intermediate cover system was used to determine the LS factor. This length provides an estimate of soil loss over the entire intermediate cover system. The top deck surface slope will consist of a 5% grade along a length of approximately 550 ft. The intermediate cover system consists of a 3H:1V (i.e., 33.3%) side slope with periodic "tack-on" side slope drainage terraces. Three options are evaluated for ground coverage scenarios: 60%, 70%, and 80% ground coverage. The reason for evaluating different ground coverage percentages is to provide flexibility to the operator on the resulting required terrace spacing, based on the ground coverage that the facility is able to achieve. The maximum side slope length is approximately 680 ft which is used as a limiting factor on the erosion analysis. The following LS factors are selected from Table 2G-1-4 and apply to the average length along the top deck and side slopes of the intermediate cover system of the landfill:

- Top Deck – 5% slope over a length of 550 ft, LS = 1.81
- Side Slopes (60% Cover) – 33% slope over a length of 300 ft, LS = 14.96
- Side Slopes (70% Cover) – 33% slope over a length of 500 ft, LS = 22.44
- Side Slopes (80% Cover) – 33% slope over a length of 680 ft, LS = 28.76

4.4 Cover Management Factor (C)

The cover management factor is a function of the type of land cover, based on three factors: (i) the vegetative cover in direct contact with the soil surface, (ii) the canopy cover, and (iii) the effects at and beneath the surface. The intermediate cover is categorized as Pasture, Range, and Idle Land, with C values provided in Table 2G-1-5 (USDA, 1977). The land cover is assumed to have no appreciable canopy and a ground cover surface that is grass, mulch, grass-like plants, decaying compacted duff, or litter at least two inches deep. It is noted that the terms "duff" and "litter" are terms used by USDA and refer to types of organic ground cover material, not waste. For these conditions, the "C" values in Table 2G-1-5 vary depending on the percent ground cover.

For 60% ground cover of grass the C value is 0.042. For 70% ground cover of grass/mulch, by interpolating on the table, the C value is 0.0275. For 80% ground cover of mulch, the C value is 0.013. These three ground cover scenarios will be evaluated herein.

4.5 Erosion Control Practice Factor (P)

The erosion control practice factor considers topographical practices that will reduce erosion by altering runoff drainage patterns. This factor generally applies to agricultural cropping practices and is not anticipated for the landfill. Therefore, the P factor is assumed to be equal to one.

5 FLOW VELOCITY PARAMETERS

5.1 Watercourse Slope

The watercourse slopes for estimating the maximum flow velocities are as follows:

- Top Deck – 5% slope;
- Side Slopes – 3H:1V (33.3%) slope

5.2 Surface Condition

For sheet flow velocity calculation purposes, the surface condition of the intermediate cover is assumed to be: (i) minimum percent ground cover 60%; (ii) no appreciable canopy; and (iii) ground cover at surface is grass, grass-like plants, decaying compacted duff, or litter at least two inches deep. Only the 60% ground cover scenario is evaluated, since a 70% (or greater) ground cover will result in lower velocities. For estimating sheet flow velocities for flow distances less than 100 ft using TxDOT (2019), a roughness coefficient of n = 0.05 for fallow surfaces and n = 0.15 for short grass prairies as shown in Table 2G-1-1.

The surface conditions most applicable to the intermediate cover conditions are "nearly bare ground" and "short grass pasture and lawns." To estimate the shallow concentrated flow velocity for 60% ground coverage, a weighted average flow velocity is calculated from the "nearly bare ground" and "short grass pasture and lawns" flow velocities based on the ground coverage of each cover condition. Note that this surface condition is applicable for grass and grass-like plants. For ground cover consisting of decaying compacted duff or litter (e.g., mulch), the most applicable representative surface condition for velocity calculation purposes is "forest with heavy ground litter and hay meadows." While the mulch-covered slopes of the landfill are not situated in a forest, the mulched surface will have a surface condition (or "roughness") that is best compared to "heavy ground litter" found in a forest (i.e., decaying duff and litter, twigs, etc.). However, the "short grass pasture and lawns" cover will result in larger velocities, and therefore, the mulch cover will not be considered in estimating shallow concentrated flow velocities.

For estimating shallow concentrated flow velocities for flow distances more than 100 ft using USDA (2010), a velocity factor (K_v) of 9.965 is selected from Table 2G-1-2 for a "nearly bare and untilled" surface and K_v = 6.962 for "short-grass pasture." The velocity factor is applied with the slope to estimate the velocity of the interim cover condition for shallow concentrated flow (after 100-ft of sheet flow).

6 RESULTS

6.1 RUSLE

Applying the RUSLE with the parameters defined above, the computed soil loss in tons/acre/year is calculated as follows:

$$A = R \times K \times LS \times C \times P$$

Top Deck Slopes, 60% ground cover:

$$A = 275 \times 0.28 \times 1.81 \times 0.042 \times 1 = 5.85 \text{ tons/acre/year}$$

Side Slopes, 60% ground cover, 300-ft slope length between terraces:

$$A = 275 \times 0.28 \times 14.96 \times 0.042 \times 1 = 48.37 \text{ tons/acre/year}$$

Top Deck Slopes, 70% ground cover:

$$A = 275 \times 0.28 \times 1.81 \times 0.0275 \times 1 = 3.83 \text{ tons/acre/year}$$

Side Slopes, 70% ground cover, 500-ft slope length between terraces:

$$A = 275 \times 0.28 \times 22.44 \times 0.0275 \times 1 = 47.52 \text{ tons/acre/year}$$

Top Deck Slopes, 80% ground cover:

$$A = 275 \times 0.28 \times 1.81 \times 0.013 \times 1 = 1.81 \text{ tons/acre/year}$$

Side Slopes, 80% ground cover, 680-ft slope length between terraces:

$$A = 275 \times 0.28 \times 28.76 \times 0.013 \times 1 = 28.79 \text{ tons/acre/year}$$

As shown above, the calculated annual soil loss from the intermediate cover on the top deck and side slope surfaces are less than the 50 tons/acre/year permissible rate of soil loss for interim conditions. These results show that if 60% ground cover is present, the side slope terraces should be placed no greater than 300-ft apart. If 70% ground cover is present, the side slope terraces may be placed up to 500-ft apart. If 80% ground cover is present during interim conditions, the side slope terraces may be placed up to 680-ft apart. It is expected that 60%, 70%, and 80% ground cover can be achieved with grassing, a combination of grassing and mulching, and mulching, respectively. Table 2G-1-6 summarizes allowable side slope terrace spacing under each ground cover option.

6.2 Erodible Velocity

As mentioned previously, sheet flow velocity estimates are performed only for the more conservative condition of having only 60% ground cover. The estimated velocities are as follows:

Top Deck Slopes (5%): For sheet flow (length up to 100 ft)

- $V = L / T_t = 100 / [0.007\times(0.05\times100)^{0.8}/(3.91^{0.5}\times0.05^{0.4})] = 0.7$ ft/s (for bare ground) and
- $V = L / T_t = 100 / [0.007\times(0.15\times100)^{0.8}/(3.91^{0.5}\times0.05^{0.4})] = 0.3$ ft/s (for grass).

The weighted average value for the sheet flow velocity for 60% ground cover is calculated as:

$$\text{Top Deck Sheet Flow Velocity} = 0.7 \times 0.40 + 0.3 \times 0.60 = 0.4 \text{ ft/s}$$

For distances greater than 100-ft on the top deck, where flow becomes shallow concentrated flow, the velocity estimates using the previously mentioned equation are calculated as:

Top Deck Slopes (5%): For shallow concentrated flow (lengths over 100 ft)

- $V = K_v \times S^{1/2} = 9.965 \times 0.05^{1/2} = 2.2$ ft/s (for bare ground) and
- $V = K_v \times S^{1/2} = 6.962 \times 0.05^{1/2} = 1.6$ ft/s (for grass).

The weighted average value for the shallow concentrated flow velocity for 60% ground cover is calculated as:

Top Deck Shallow Concentrated Flow Velocity = 2.2 × 0.40 + 1.6 × 0.60 = 1.8 ft/s

Side Slopes (33%): For sheet flow (length up to 100 ft)

- $V = L / T_t = 100 / [0.007 \times (0.05 \times 100)^{0.8} / (3.91^{0.5} \times 0.33^{0.4})] = 1.4$ ft/s (for bare ground) and
- $V = L / T_t = 100 / [0.007 \times (0.15 \times 100)^{0.8} / (3.91^{0.5} \times 0.33^{0.4})] = 0.6$ ft/s (for grass).

The weighted average value for the sheet flow velocity for 60% ground cover is calculated as:

Side Slopes Sheet Flow Velocity = 1.4 × 0.40 + 0.6 × 0.60 = 0.9 ft/s

For distances greater than 100-ft on the top deck, where flow becomes shallow concentrated flow, the velocity estimates using the previously mentioned equation are calculated as:

Side Slopes (33%): For shallow concentrated flow (lengths over 100 ft)

- $V = K_v \times S^{1/2} = 9.965 \times 0.33^{1/2} = 5.8$ ft/s (for bare ground) and
- $V = K_v \times S^{1/2} = 6.962 \times 0.05^{1/2} = 4.0$ ft/s (for grass).

The weighted average value for the shallow concentrated flow velocity for 60% ground cover is calculated as:

Side Slopes Shallow Concentrated Flow Velocity = 5.8 × 0.40 + 4.0 × 0.60 = 4.7 ft/s

As shown above, the estimated flow velocities are less than the permissible non-erosive velocity of 5.0 ft/s.

7 CONCLUSIONS

The ground surface cover condition and maximum terrace spacing requirements are computed above and summarized in Table 2G-1-6. Based on the calculations presented herein, the following conclusions are drawn:

- For the conditions analyzed herein, the calculated soil loss from the intermediate cover is less than the permissible soil loss of 50 tons/acre/year, which is acceptable.
- For the conditions analyzed herein, the estimated velocities for the top deck and side slope surfaces were calculated to be less than the permissible non-erosive velocity of five (5) ft/sec, which is acceptable.
- To provide effective erosional stability on the external facing 5% top deck slope surfaces, a horizontal spacing of 550-ft between temporary diversion structures is acceptable for a 60% or greater ground cover of grass/mulch or the like.
- To provide effective erosional stability on the external facing 33% side slopes when there is a 60% ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 300-ft.
- To provide effective erosional stability on the external facing 33% side slopes when there is a 70% or greater ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 500-ft.
- To provide effective erosional stability on the external facing 33% side slopes when there is a 80% or greater ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 680-ft corresponding to the maximum side slope length.

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TABLES

Table 2G-1-1. Sheet Flow Roughness Coefficients for Calculating Sheet Flow Travel Time (from TxDOT, 2019)

Surface description		n_{ol}
Fallow (no residue)		0.05
Cultivated soils:	Residue $cover \leq 20\%$	0.06
	Residue cover > 20%	0.17
Grass:	Short grass prairie	0.15
	Dense grasses	0.24
	Bermuda	0.41
Range (natural):		0.13
Woods:	Light underbrush	0.40
	Dense underbrush	0.80

Table 2G-1-2. Equations and Assumptions Relating Shallow Concentrated Flow Velocity to Surface Slope (from USDA, 2010)

Flow type	Depth (ft)	Manning's *n*	Velocity equation (ft/s)
Pavement and small upland gullies	0.2	0.025	$V = 20.328(s)^{0.5}$
Grassed waterways	0.4	0.050	$V=16.135(s)^{0.5}$
Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions	0.2	0.051	$V=9.965(s)^{0.5}$
Cultivated straight row crops	0.2	0.058	$V=8.762(s)^{0.5}$
Short-grass pasture	0.2	0.073	$V=6.962(s)^{0.5}$
Minimum tillage cultivation, contour or strip-cropped, and woodlands	0.2	0.101	$V=5.032(s)^{0.5}$
Forest with heavy ground litter and hay meadows	0.2	0.202	$V=2.516(s)^{0.5}$

Table 2G-1-3. Soil Erodibility Factor K for Frio and Gasil Soils (from USDA, 2019)

Map Unit Symbol	Map Unit Name	Soil Erodibility Factor, Kf
27	Frio silty clay, frequently flooded	0.24
30	Gasil fine sandy loam, 3 to 8 percent slopes	0.28
31	Gasil sandy clay loam, graded, 1 to 5 percent slopes	0.15

Table 2G-1-4. Values for Topographic Factor, LS, for High Ratio of Rill to Interrill Erosion[1] (from USDA, 1997)

	Horizontal slope length (ft)																
Slope (%)	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

[1]Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil)

Table 2G-1-5. C Factor Cover Values for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland[1]

(from USDA, 1977)

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy[2/]	Canopy Cover[3/] %	Type[4/]	Percent Ground Cover					
			0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

1/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years. Also to be used for burned forest land and forest land that has been harvested less than three years ago.

2/ Average fall height of waterdrops from canopy to soil surface: m = meters.

3/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

4/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface), and/or undecayed residue.

Table 2G-1-6. Summary of Maximum Allowable Drainage Terrace Spacing

Interim Cover Stabilization Method	Required Minimum Ground Cover	Maximum Allowable Terrace Spacing		Calculated Velocity < Permissible Velocity?
		5% Top Deck	33% Side Slopes	
Grass	60%	550-ft	300-ft	Yes
Grass & Mulch	70%	550-ft	500-ft	Yes
Mulch	80%	550-ft	680-ft	Yes

FIGURES

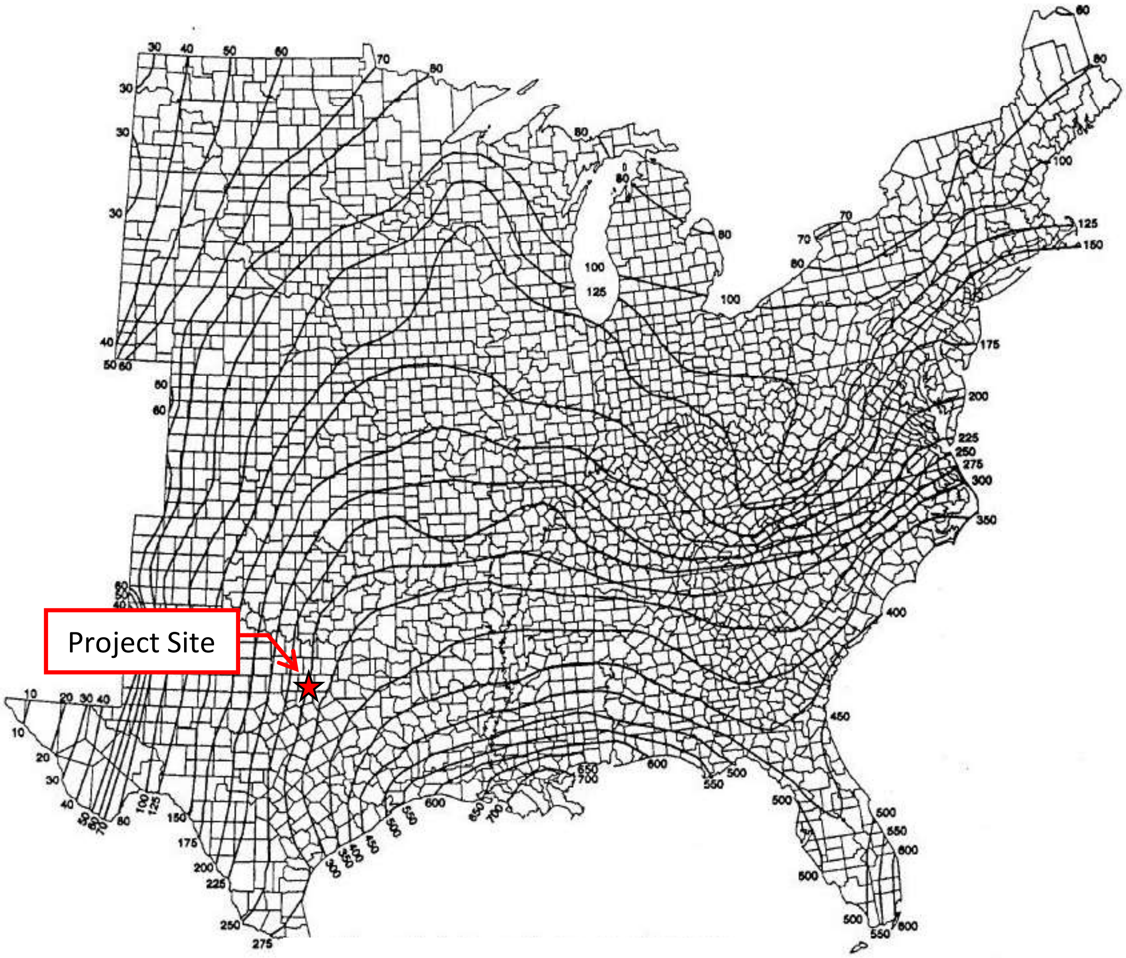

Figure 2G-1-1. Average Annual Rainfall Runoff Erosivity Factor, R, Isoerodent Map (from USDA, 1997)

APPENDIX 2G-2

HYDRAULIC DESIGN OF INTERMEDIATE COVER DIVERSION STRUCTURES

Written by: **O. Bramlet** Date: **01/09/2020** Reviewed by: **S. Graves** Date: **2/4/2020**

Client: **TRLC** Project: **Fort Worth C&D Landfill** Project No.: **GW6953** Phase No.: **04**

HYDRAULIC DESIGN OF INTERMEDIATE COVER DIVERSION STRUCTURES

STATE OF TEXAS
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5/7/2020

SEALED FOR PERMITTING PURPOSES, CALCULATION PAGES 1 TO 17

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the hydraulic design of the intermediate cover diversion structures for the proposed expansion of the Fort Worth C&D Landfill. This package provides calculations for the peak runoff discharges flowing to diversion structures and the sizing design of intermediate cover surface water diversion structures, including side slope drainage terraces, top deck drainage terraces, and downchute channels.

2 CALCULATION METHODOLOGY

The following sections describe the calculation methodology applied to design the temporary diversion structures for the intermediate cover.

2.1 Hydrology

Per 30 TAC §330.305(f)(1), the peak runoff discharge to each temporary diversion structure is calculated by the Rational Method, as outlined in Texas Department of Transportation (TxDOT) *Hydraulic Design Manual* (TxDOT, 2019). The equation for the Rational Method is applied as follows:

$$Q = C \times I \times A \qquad (1)$$

where:

Q = peak runoff discharge (cfs),

C = runoff coefficient,

I = rainfall intensity (in/hr), and

A = drainage area (acres).

In September 2018, the National Oceanic and Atmospheric Administration (NOAA) released updated precipitation frequency estimates for Texas. This rainfall data is currently considered by TxDOT (2019) to be the best available data for calculating design rainfall intensity. TxDOT (2019) also recommends 10 minutes as the minimum time of concentration for the Rational Method because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high. The rainfall intensity for the 25-year, 10-minute duration rainfall event is 7.92 inches per hour (in/hr) for the site (NOAA, 2018).

2.2 Hydraulic Design of Diversion Structures

Manning's equation is applied to the calculate peak discharge rates through each intermediate cover diversion structure. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad (4)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

R = hydraulic radius = A/P (ft),

P = wetted perimeter (ft), and

S = longitudinal slope (ft/ft).

The tractive stresses in the channel for various depths of flow are estimated using the following equation (Chow, 1959):

$$\tau_o = \gamma_w R S \qquad (5)$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Each diversion structure is designed to convey the peak runoff discharge from the 25-year rainfall event as calculated by the Rational Method. The depth of flow, maximum velocity, and tractive stress for the design rainfall event through each channel reach is calculated using Manning's equation and the tractive stress equation.

3 DESIGN PARAMETERS

The following sections describe the selected parameters applied in the calculations of the peak runoff discharge by the Rational Method and the capacity of the drainage structures by Manning's equation.

3.1 Drainage Areas

The diversion structures on the intermediate cover are designed for the runoff from contributing drainage areas during landfill operating conditions. It is envisioned that the temporary side slope drainage terraces, top deck drainage terraces, and temporary downchutes on the intermediate cover system will be installed to approximate the post-development (i.e., final) drainage patterns of the final cover system. Accordingly, the drainage areas contributing to each of these structures during interim conditions are selected based on the largest area that contributes to the type of structure according to the grading plan layout of the final cover grades. The largest top deck area (8.82 acres) that contributes to a single drainage terrace is selected to design the typical top deck drainage terraces on the intermediate cover. The sum of the largest top deck (8.82 acres) and side slope (4.09 acres) areas which combine to a single downchute is selected as the design drainage area (12.91 acres) for the typical downchute channel on the intermediate cover.

Meanwhile, side slope drainage terraces will have a maximum spacing of 300-ft, 500-ft, or 680-ft apart depending on the ground cover applied (and resulting ground cover percentage) to the 3H:1V intermediate cover side slopes. The longest side slope drainage terrace (approximately 1,940-ft in length) is selected for the design of the typical side slope drainage terraces for each spacing. The drainage area selected for the design of side slope drainage terraces is calculated based on the longest length and the maximum spacing for each ground cover scenario for the intermediate cover side slopes.

3.2 Runoff Coefficients

A runoff coefficient (C) was selected based on information provided by TxDOT (2019) for rural watersheds, as shown in Table 2G-2-1. The total runoff coefficient is based on the sum of the four runoff components in Table 2G-2-1. The 25-year runoff coefficient is calculated using the following equation:

$$C = (C_r + C_i + C_v + C_s) \quad (6)$$

The following runoff coefficient is estimated for the steep 3H:1V side slope drainage areas:

$$C = (0.35 + 0.16 + 0.08 + 0.12) = 0.710$$

The following runoff coefficient is estimated for the flatter (5%) top deck drainage areas:

$$C = (0.14 + 0.16 + 0.08 + 0.12) = 0.500$$

The following runoff coefficient is estimated for the drainage areas contributing to the downchute channels using a weighted average of the top deck and side slope runoff coefficients per the drainage areas listed above:

$$C = (8.82\text{ ac} \times 0.500 + 4.09\text{ ac} \times 0.710) / (8.82\text{ ac} + 4.09\text{ ac}) = 0.567$$

3.3 Manning's Roughness Coefficient

Manning's roughness coefficient (n) is a measure of the surface roughness of a pipe, conduit, channel or other hydraulic structure. As the Manning's roughness coefficient increases, the resistance to flow within a channel increases. As shown in Table 2G-2-2 (TxDOT, 2019), Manning's roughness coefficients were selected based on a grass-lined side slope drainage terrace and top deck drainage terrace and geomembrane lined interim downchute channel. A Manning's roughness coefficient of n = 0.027 was selected for grass-lined channels. A Manning's roughness coefficient of n = 0.015 was selected for geomembrane lined downchute channels based on a representative value for lined channels with similar roughness as a float finished concrete lining. Roughness values are not available for textured HDPE geomembrane; smooth HDPE has a roughness of approximately 0.01, so it is reasonable that textured geomembrane would be slightly greater.

3.4 Hydraulic Design

Each intermediate cover diversion structure is designed to convey the 25-year rainfall event. Additionally for structures that have a flow velocity of greater than five ft/s during the 25-year rainfall event, a channel lining (e.g., geomembrane, riprap, articulated concrete blocks) is required until the final cover system is constructed.

4 CALCULATIONS

The peak runoff discharge to each temporary drainage structure was calculated by the Rational Method. The results from these calculations are presented in Table 2G-2-3.

Based on the calculated runoff discharge, each temporary diversion structure was sized by applying Manning's equation. These calculations were performed using the spreadsheets presented at the end of this calculation package. The design parameters and results of the hydraulic design of each component of the intermediate cover surface water management system are summarized in Table 2G-2-4.

5 CONCLUSIONS

Results from calculations presented in this calculation package indicate that the proposed surface water diversion structures for Fort Worth C&D Landfill intermediate cover will collect and control the runoff resulting from a 25-year rainfall event. These calculations indicate that the temporary downchute channels and drainage terraces should be lined with an erosion resistant channel lining material until the final cover system is constructed.

6 REFERENCES

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TABLES

Table 2G-2-1. Runoff Coefficients for Rural Watersheds

(from TxDOT, 2019)

	Extreme	**High**	**Normal**	**Low**
Relief - C_f	*0.28-0.35* steep, rugged terrain with average slopes above 30%	0.20-0.28 hilly, with average slopes of 10-30%	0.14-0.20 rolling, with average slopes of 5-10%	0.08-0.14 relatively flat land, with average slopes of 0-5%
Soil Infiltration - C_i	0.12-0.16 no effective soil cover either rock or thin soil mantle of negligble infiltration capacity	0.08-0.12 slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 normal; well drained light or medium textured soils, sandy loams	0.04-0.06 deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover - C_v	0.12-0.16 no effective plan cover, bare or very sparse cover	0.08-0.12 poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area over good cover	0.06-0.08 fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in culitvated crops	0.04-0.06 good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface - C_s	0.10-0.12 negligible; surface depression few and shallow, drainageways steep and small, no marshes	0.08-0.10 well defined system of small drainageways, no ponds or marshes	0.06-0.08 normal; considerable surface depression storage lakes and ponds and marshes	0.04-0.06 much surface storage, drainage system not sharply defined; large floodplain storage of large number of ponds or marshes
NOTE: The total runoff coefficient based on the four runoff components is $C = C_r + C_i + C_v + C_s$				

Table 2G-2-2. Manning's Roughness Coefficients (from TxDOT, 2019)

B. Excavated or dredged channels	
1. Earth, straight and uniform	
a. Clean, recently completed	0.016-0.020
b. Clean, after weathering	0.018-0.025
c. Gravel, uniform section, clean	0.022-0.030
d. With short grass, few weeds	0.022-0.033
2. Earth, winding and sluggish	
a. No vegetation	0.023-0.030
b. Grass, some weeds	0.025-0.033
c. Deep weeds or aquatic plants in deep channels	0.030-0.040
d. Earth bottom and rubble sides	0.028-0.035
e. Stony bottom and weedy banks	0.025-0.040
f. Cobble bottom and clean sides	0.030-0.050
g. Winding, sluggish, stony bottom, weedy banks	0.025-0.040
h. Dense weeds as high as flow depth	0.050-0.120
C. Lined channels	
1. Asphalt	0.013-0.016
2. Brick (in cement mortar)	0.012-0.018
3. Concrete	
a. Trowel finish	0.011-0.015
b. Float finish	0.013-0.016
c. Unfinished	0.014-0.020
d. Gunite, regular	0.016-0.023
e. Gunite, wavy	0.018-0.025
4. Riprap (n-value depends on rock size)	0.020-0.035
5. Vegetal lining	0.030-0.500

Table 2G-2-3. Intermediate Cover Peak Discharge Calculations for the 25-year Rainfall Event

Diversion Structure	Spacing (ft) [2]	A (acres)	C	I (in/hr)	Q (cfs)
Side Slope Drainage Terraces [1]	300	13.36	0.710	7.92	75.13
Side Slope Drainage Terraces [1]	500	22.27	0.710	7.92	125.22
Side Slope Drainage Terraces [1]	680	30.28	0.710	7.92	170.30
Top Deck Drainage Terraces	-	8.82	0.500	7.92	34.93
Downchutes	-	12.91	0.567	7.92	57.97

Notes:

1. The maximum side slope drainage area is estimated based on the terrace spacing shown above, and a maximum terrace length of 1,940 ft.
2. Spacing of terraces on the side slopes is varied based on the assumed ground cover scenarios, as described in Appendix 2G-1.

Table 2G-2-4. Summary of Intermediate Cover Hydraulic Design Results

Diversion Structure	Spacing (ft)	Bottom Width (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	Channel Depth (ft)	Manning's n	Flowline Slope (ft/ft)	Design Depth of Flow (ft)	Design Velocity (ft/s)	Tractive Stress (psf)	Channel Lining Required?
Side Slope Drainage Terrace	300	0.00	2.5:1	3:1	2.50	0.027	0.020	1.93	7.31	1.13	Yes
Side Slope Drainage Terrace	500	0.00	2.5:1	3:1	2.50	0.027	0.020	2.34	8.31	1.37	Yes
Side Slope Drainage Terrace	680	0.00	2.5:1	3:1	3.00	0.027	0.020	2.61	9.04	1.56	Yes
Top Deck Drainage Terrace	-	0.00	3:1	20:1	2.00	0.027	0.0015	1.36	1.64	0.06	No
Downchute Channel	-	5.00	3:1	3:1	1.00	0.015	0.333	0.33	24.91	5.96	Yes

MANNING'S EQUATION CALCULATIONS

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

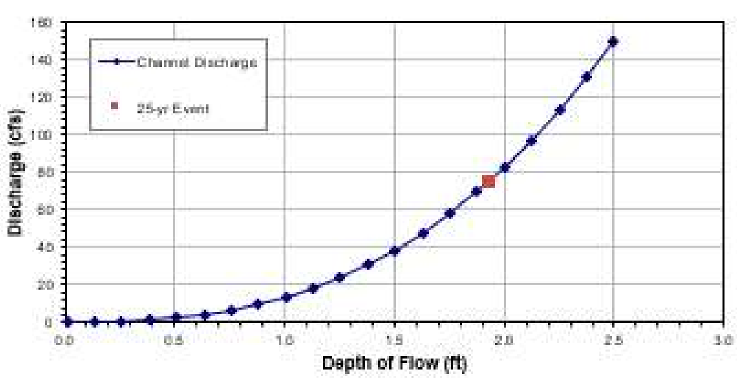
Project: Fort Worth C&D Landfill Expansion

Ditch ID: Interim Side Slope Drainage Terrace, 300-ft Spacing

Runoff Coefficient, C =	0.71	
25-year Rainfall Intensity, I =	7.92	in/hr
Longest Drainage Terrace Length =	1940	ft
Terrace Spacing =	300	ft
Contributing Drainage Area, A =	13.36	acres
Peak Discharge, Q_{25} =	75.13	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.50	ft
Top Width, T =	13.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0200	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.13	0.05	0.79	0.06	1.24	0.1	0.08	
0.26	0.18	1.52	0.12	1.92	0.4	0.15	
0.38	0.40	2.25	0.18	2.49	1.0	0.22	
0.51	0.71	2.97	0.24	3.00	2.1	0.30	
0.63	1.10	3.70	0.30	3.47	3.8	0.37	
0.76	1.58	4.43	0.36	3.92	6.2	0.44	
0.88	2.14	5.16	0.41	4.34	9.3	0.52	
1.01	2.78	5.89	0.47	4.73	13.2	0.59	
1.13	3.51	6.62	0.53	5.12	18.0	0.66	
1.26	4.33	7.35	0.59	5.49	23.8	0.74	
1.38	5.23	8.08	0.65	5.84	30.6	0.81	
1.50	6.22	8.81	0.71	6.19	38.5	0.88	
1.63	7.29	9.53	0.76	6.53	47.6	0.95	
1.75	8.45	10.26	0.82	6.86	57.9	1.03	
1.88	9.69	10.99	0.88	7.18	69.6	1.10	
2.00	11.02	11.72	0.94	7.49	82.6	1.17	
2.13	12.44	12.45	1.00	7.80	97.0	1.25	
2.25	13.93	13.18	1.06	8.10	112.9	1.32	
2.38	15.52	13.91	1.12	8.40	130.3	1.39	
2.50	17.19	14.64	1.17	8.69	149.3	1.47	
1.93	10.25	11.30	0.91	7.31	74.96	1.13	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

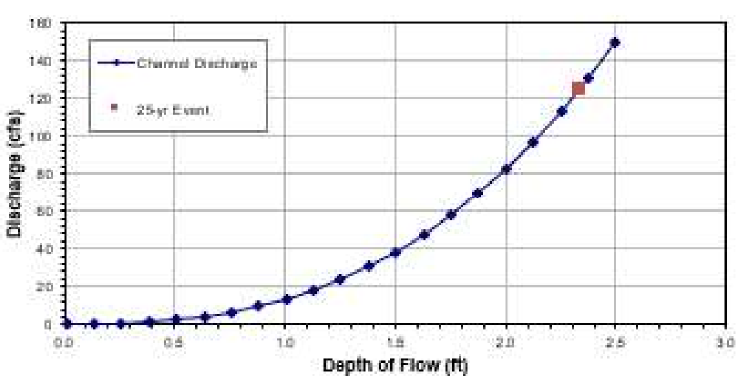
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Interim Side Slope Drainage Terrace, 500-ft Spacing**

Runoff Coefficient, C =	0.71	
25-year Rainfall Intensity, I =	7.92	in/hr
Longest Drainage Terrace Length =	1940	ft
Terrace Spacing =	500	ft
Contributing Drainage Area, A =	22.27	acres
Peak Discharge, Q_{25} =	125.22	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	2.50	ft
Top Width, T =	13.8	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0200	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.13	0.05	0.79	0.06	1.24	0.1	0.08	
0.26	0.18	1.52	0.12	1.92	0.4	0.15	
0.38	0.40	2.25	0.18	2.49	1.0	0.22	
0.51	0.71	2.97	0.24	3.00	2.1	0.30	
0.63	1.10	3.70	0.30	3.47	3.8	0.37	
0.76	1.58	4.43	0.36	3.92	6.2	0.44	
0.88	2.14	5.16	0.41	4.34	9.3	0.52	
1.01	2.78	5.89	0.47	4.73	13.2	0.59	
1.13	3.51	6.62	0.53	5.12	18.0	0.66	
1.26	4.33	7.35	0.59	5.49	23.8	0.74	
1.38	5.23	8.08	0.65	5.84	30.6	0.81	
1.50	6.22	8.81	0.71	6.19	38.5	0.88	
1.63	7.29	9.53	0.76	6.53	47.6	0.95	
1.75	8.45	10.26	0.82	6.86	57.9	1.03	
1.88	9.69	10.99	0.88	7.18	69.6	1.10	
2.00	11.02	11.72	0.94	7.49	82.6	1.17	
2.13	12.44	12.45	1.00	7.80	97.0	1.25	
2.25	13.93	13.18	1.06	8.10	112.9	1.32	
2.38	15.52	13.91	1.12	8.40	130.3	1.39	
2.50	17.19	14.64	1.17	8.69	149.3	1.47	
2.34	15.05	13.70	1.10	8.31	125.06	1.37	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

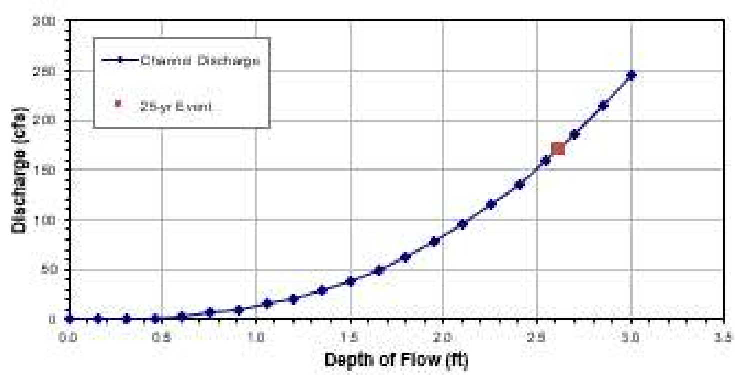
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Interim Side Slope Drainage Terrace, 680-ft Spacing**

Runoff Coefficient, C =	0.71	
25-year Rainfall Intensity, I =	7.92	in/hr
Longest Drainage Terrace Length =	1940	ft
Terrace Spacing =	680	ft
Contributing Drainage Area, A =	30.28	acres
Peak Discharge, Q_{25} =	170.30	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	2.5	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	3.00	ft
Top Width, T =	16.5	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0204	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.06	0.00	0.22	0.0	0.01	
0.16	0.07	0.93	0.07	1.40	0.1	0.10	
0.31	0.26	1.81	0.15	2.18	0.6	0.18	
0.46	0.58	2.68	0.22	2.83	1.6	0.27	
0.61	1.02	3.56	0.29	3.42	3.5	0.36	
0.76	1.58	4.44	0.36	3.96	6.2	0.45	
0.91	2.26	5.31	0.43	4.46	10.1	0.54	
1.06	3.07	6.19	0.50	4.94	15.2	0.63	
1.21	4.00	7.06	0.57	5.40	21.6	0.72	
1.36	5.05	7.94	0.64	5.83	29.5	0.81	
1.51	6.23	8.81	0.71	6.25	39.0	0.90	
1.65	7.53	9.69	0.78	6.66	50.2	0.99	
1.80	8.95	10.56	0.85	7.06	63.2	1.08	
1.95	10.49	11.44	0.92	7.44	78.1	1.17	
2.10	12.16	12.31	0.99	7.82	95.1	1.26	
2.25	13.95	13.19	1.06	8.18	114.2	1.35	
2.40	15.87	14.06	1.13	8.54	135.5	1.44	
2.55	17.90	14.94	1.20	8.89	159.2	1.53	
2.70	20.06	15.81	1.27	9.24	185.3	1.61	
2.85	22.34	16.69	1.34	9.57	213.9	1.70	
3.00	24.75	17.56	1.41	9.91	245.2	1.79	
2.61	18.80	15.31	1.23	9.04	169.99	1.56	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

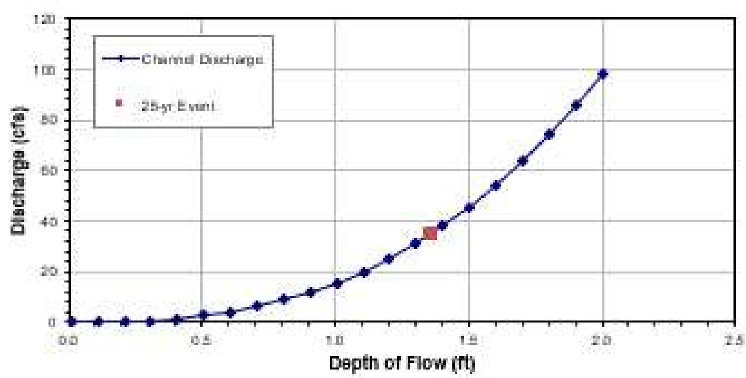
Project: Fort Worth C&D Landfill Expansion

Ditch ID: **Interim Top Deck Drainage Terrace**

Runoff Coefficient, C =	0.500	
25-year Rainfall Intensity, I =	7.92	in/hr
Contributing Drainage Area, A =	8.82	acres
Peak Discharge, Q_{25} =	34.93	cfs (25-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.0	horizontal :1 vertical
Right Side Slope, Z_2 =	20.0	horizontal :1 vertical
Channel Depth, Y =	2.00	ft
Top Width, T =	46.0	ft
Manning's Roughness Coeff., n =	0.027	
Longitudinal Channel Slope, S_o =	0.0015	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.00	0.23	0.00	0.06	0.0	0.00	
0.11	0.14	2.54	0.05	0.31	0.0	0.01	
0.21	0.50	4.85	0.10	0.47	0.2	0.01	
0.31	1.09	7.15	0.15	0.61	0.7	0.01	
0.41	1.91	9.46	0.20	0.74	1.4	0.02	
0.51	2.96	11.77	0.25	0.85	2.5	0.02	
0.61	4.24	14.07	0.30	0.96	4.1	0.03	
0.71	5.74	16.38	0.35	1.06	6.1	0.03	
0.81	7.47	18.69	0.40	1.16	8.7	0.04	
0.91	9.43	21.00	0.45	1.25	11.8	0.04	
1.01	11.62	23.30	0.50	1.34	15.6	0.05	
1.10	14.03	25.61	0.55	1.43	20.1	0.05	
1.20	16.67	27.92	0.60	1.52	25.3	0.06	
1.30	19.54	30.22	0.65	1.60	31.2	0.06	
1.40	22.64	32.53	0.70	1.68	38.0	0.07	
1.50	25.96	34.84	0.75	1.76	45.6	0.07	
1.60	29.51	37.15	0.79	1.83	54.1	0.07	
1.70	33.29	39.45	0.84	1.91	63.5	0.08	
1.80	37.30	41.76	0.89	1.98	73.9	0.08	
1.90	41.54	44.07	0.94	2.05	85.3	0.09	
2.00	46.00	46.37	0.99	2.13	97.8	0.09	
1.36	21.21	31.49	0.67	1.64	34.82	0.06	Q (25-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

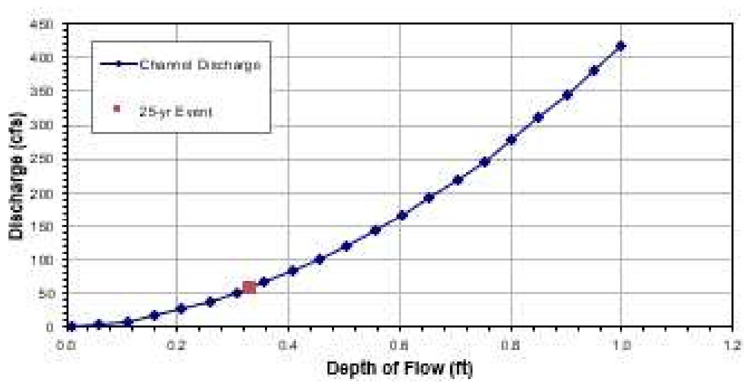
Project: Fort Worth C&D Landfill Expansion

Ditch ID: Interim Downchute Channel, 3:1 Slope

Runoff Coefficient, C =	0.567	
25-year Rainfall Intensity, I =	7.92	in/hr
Contributing Drainage Area, A =	12.91	acres
Peak Discharge, Q_{25} =	57.97	cfs (25-yr Event)
Bottom Width, B =	6.00	ft
Left Side Slope, Z_1 =	3.0	horizontal :1 vertical
Right Side Slope, Z_2 =	3.0	horizontal :1 vertical
Channel Depth, Y =	1.00	ft
Top Width, T =	12.0	ft
Manning's Roughness Coeff., n =	0.015	
Longitudinal Channel Slope, S_o =	0.3333	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_0 lb/ft^2	Comments
0.01	0.06	6.06	0.01	2.65	0.2	0.21	
0.06	0.37	6.38	0.06	8.56	3.1	1.20	
0.11	0.69	6.69	0.10	12.61	8.7	2.14	
0.16	1.03	7.00	0.15	15.94	16.4	3.05	
0.21	1.38	7.32	0.19	18.84	26.0	3.92	
0.26	1.74	7.63	0.23	21.44	37.4	4.75	
0.31	2.12	7.94	0.27	23.81	50.6	5.56	
0.36	2.52	8.25	0.31	26.00	65.5	6.35	
0.41	2.93	8.57	0.34	28.05	82.2	7.11	
0.46	3.36	8.88	0.38	29.97	100.6	7.86	
0.51	3.80	9.19	0.41	31.79	120.7	8.59	
0.55	4.25	9.51	0.45	33.53	142.5	9.30	
0.60	4.72	9.82	0.48	35.18	166.0	9.99	
0.65	5.20	10.13	0.51	36.77	191.3	10.68	
0.70	5.70	10.45	0.55	38.30	218.3	11.35	
0.75	6.21	10.76	0.58	39.77	247.1	12.01	
0.80	6.74	11.07	0.61	41.20	277.7	12.66	
0.85	7.28	11.39	0.64	42.58	310.2	13.31	
0.90	7.84	11.70	0.67	43.93	344.4	13.94	
0.95	8.41	12.01	0.70	45.23	380.6	14.57	
1.00	9.00	12.32	0.73	46.51	418.6	15.19	
0.33	2.32	8.10	0.29	24.91	57.76	5.96	Q (25-yr Event)

Discharge versus Depth Relationship



APPENDIX IIIF-G-A

EXCERPTS FROM THE APPROVED CLOMR APPLICATION

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

08/10/2023

APPENDIX B

FEMA CERTIFICATION FORMS

U.S. DEPARTMENT OF HOMELAND SECURITY
FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 1660-0016
Expires February 28, 2014

PAPERWORK BURDEN DISCLOSURE NOTICE

Public reporting burden for this form is estimated to average 1 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless it displays a valid OMB control number. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Department of Homeland Security, Federal Emergency Management Agency, 1800 South Bell Street, Arlington, VA 20958-3005, Paperwork Reduction Project (1660-0016). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

PRIVACY ACT STATEMENT

AUTHORITY: The National Flood Insurance Act of 1968, Public Law 90-448, as amended by the Flood Disaster Protection Act of 1973, Public Law 93-234.

PRINCIPAL PURPOSE(S): This information is being collected for the purpose of determining an applicant's eligibility to request changes to National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRM).

ROUTINE USE(S): The information on this form may be disclosed as generally permitted under 5 U.S.C § 552a(b) of the Privacy Act of 1974, as amended. This includes using this information as necessary and authorized by the routine uses published in DHS/FEMA/NFIP/LOMA-1 National Flood Insurance Program (NFIP); Letter of Map Amendment (LOMA) February 15, 2006, 71 FR 7990.

DISCLOSURE: The disclosure of information on this form is voluntary; however, failure to provide the information requested may delay or prevent FEMA from processing a determination regarding a requested change to a (NFIP) Flood Insurance Rate Maps (FIRM).

A. REQUESTED RESPONSE FROM DHS-FEMA

This request is for a (check one):

☒ CLOMR: A letter from DHS-FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

☐ LOMR: A letter from DHS-FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See 44 CFR Ch. 1, Parts 60, 65 & 72)

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Example: 480301 480287	City of Katy Harris County	TX TX	48473C 48201C	0005D 0220G	02/08/83 09/28/90
480582	Tarrant County	TX	48439C	0340K	09/25/09

2. a. Flooding Source: Village Creek

   b. Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH) ☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

3. Project Name/Identifier: Fort Worth C&D Landfill

4. FEMA zone designations affected: AE and X (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

5. Basis for Request and Type of Revision:

   a. The basis for this revision request is (check all that apply)

   ☒ Physical Change ☒ Improved Methodology/Data ☒ Regulatory Floodway Revision ☐ Base Map Changes
   ☐ Coastal Analysis ☒ Hydraulic Analysis ☐ Hydrologic Analysis ☐ Corrections
   ☐ Weir-Dam Changes ☐ Levee Certification ☐ Alluvial Fan Analysis ☐ Natural Changes
   ☒ New Topographic Data ☐ Other (Attach Description)

   Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

b. The area of revision encompasses the following structures (check all that apply)

Structures: ☐ Channelization ☐ Levee/Floodwall ☐ Bridge/Culvert

☐ Dam ☒ Fill ☐ Other (Attach Description)

6. ☒ Documentation of ESA compliance is submitted (required to initiate CLOMR review). Please refer to the instructions for more information.

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☒ Yes Fee amount: $6,500

☐ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm for Fee Amounts and Exemptions.

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Gary Bartels	Company: Texas Regional Landfill, LP	
Mailing Address: 9100 South I-35W Alvarado, Tx 75009	Daytime Telephone No.: 817-705-6072	Fax No.:
	E-Mail Address: gary.bartels@wasteconnections.com	
Signature of Requester (required): Gary J Bartels	Date: 5-25-2022	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirements for when fill is placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. For Conditional LOMR requests, the applicant has documented Endangered Species Act (ESA) compliance to FEMA prior to FEMA's review of the Conditional LOMR application. For LOMR requests, I acknowledge that compliance with Sections 9 and 10 of the ESA has been achieved independently of FEMA's process. For actions authorized, funded, or being carried out by Federal or State agencies, documentation from the agency showing its compliance with Section 7(a)(2) of the ESA will be submitted. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Clair Davis, P.E., C.F.M., Floodplain Administrator	Community Name: City of Fort Worth	
Mailing Address: 200 Texas Street Fort Worth, TX 76102	Daytime Telephone No.: 817-392-5981	Fax No.:
	E-Mail Address: clair.davis@fortworthtexas.gov	
Community Official's Signature (required): [signature]	Date: 5/31/2022	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Charles R. Marsh	License No.: 105073	Expiration Date: 09/30/2022
Company Name: Weaver Consultants Group, LLC	Telephone No.: 817-735-9770	Fax No.: 817-735-9775
Signature: [signature]	Date: 5.25.22	E-Mail Address: cmarsh@wcgrp.com

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☒ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER
Seal (Optional)

IIIF-G-A-43

U.S. DEPARTMENT OF HOMELAND SECURITY
FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 1660-0016
Expires February 28, 2014

PAPERWORK BURDEN DISCLOSURE NOTICE

Public reporting burden for this form is estimated to average 1 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless it displays a valid OMB control number. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Department of Homeland Security, Federal Emergency Management Agency, 1800 South Bell Street, Arlington, VA 20958-3005, Paperwork Reduction Project (1660-0016). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

PRIVACY ACT STATEMENT

AUTHORITY: The National Flood Insurance Act of 1968, Public Law 90-448, as amended by the Flood Disaster Protection Act of 1973, Public Law 93-234.

PRINCIPAL PURPOSE(S): This information is being collected for the purpose of determining an applicant's eligibility to request changes to National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRM).

ROUTINE USE(S): The information on this form may be disclosed as generally permitted under 5 U.S.C § 552a(b) of the Privacy Act of 1974, as amended. This includes using this information as necessary and authorized by the routine uses published in DHS/FEMA/NFIP/LOMA-1 National Flood Insurance Program (NFIP); Letter of Map Amendment (LOMA) February 15, 2006, 71 FR 7990.

DISCLOSURE: The disclosure of information on this form is voluntary; however, failure to provide the information requested may delay or prevent FEMA from processing a determination regarding a requested change to a (NFIP) Flood Insurance Rate Maps (FIRM).

A. REQUESTED RESPONSE FROM DHS-FEMA

This request is for a (check one):

☒ CLOMR: A letter from DHS-FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

☐ LOMR: A letter from DHS-FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See 44 CFR Ch. 1, Parts 60, 65 & 72)

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Example: 480301 480287	City of Katy Harris County	TX TX	48473C 48201C	0005D 0220G	02/08/83 09/28/90
480582	Tarrant County	TX	48439C	0340K	09/25/09

2. a. Flooding Source: Village Creek

   b. Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH)
   ☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

3. Project Name/Identifier: Fort Worth C&D Landfill

4. FEMA zone designations affected: AE and X (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

5. Basis for Request and Type of Revision:

   a. The basis for this revision request is (check all that apply)

   ☒ Physical Change ☒ Improved Methodology/Data ☒ Regulatory Floodway Revision ☐ Base Map Changes
   ☐ Coastal Analysis ☒ Hydraulic Analysis ☐ Hydrologic Analysis ☐ Corrections
   ☐ Weir-Dam Changes ☐ Levee Certification ☐ Alluvial Fan Analysis ☐ Natural Changes
   ☒ New Topographic Data ☐ Other (Attach Description)

   Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

IIIF-G-A-44

b. The area of revision encompasses the following structures (check all that apply)			
Structures:	☐ Channelization	☐ Levee/Floodwall	☐ Bridge/Culvert
	☐ Dam	☒ Fill	☐ Other (Attach Description)

6. ☒ Documentation of ESA compliance is submitted (required to initiate CLOMR review). Please refer to the instructions for more information.

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☒ Yes Fee amount: $6,500

☐ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm for Fee Amounts and Exemptions.

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Gary Bartels	Company: Texas Regional Landfill, LP	
Mailing Address: 9100 South I-35W Alvarado, Tx 75009	Daytime Telephone No.: 817-705-6072	Fax No.:
	E-Mail Address: gary.bartels@wasteconnections.com	
Signature of Requester (required): Gary J Bartels	Date: 5-25-2022	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirements for when fill is placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. For Conditional LOMR requests, the applicant has documented Endangered Species Act (ESA) compliance to FEMA prior to FEMA's review of the Conditional LOMR application. For LOMR requests, I acknowledge that compliance with Sections 9 and 10 of the ESA has been achieved independently of FEMA's process. For actions authorized, funded, or being carried out by Federal or State agencies, documentation from the agency showing its compliance with Section 7(a)(2) of the ESA will be submitted. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Clair Davis, P.E., C.F.M., Floodplain Administrator	Community Name: City of Fort Worth	
Mailing Address: 200 Texas Street Fort Worth, TX 76102	Daytime Telephone No.: 817-392-5981	Fax No.:
	E-Mail Address: clair.davis@fortworthtexas.gov	
Community Official's Signature (required): [signature]	Date: 5/31/2022	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Charles R. Marsh	License No.: 105073	Expiration Date: 09/30/2022
Company Name: Weaver Consultants Group, LLC	Telephone No.: 817-735-9770	Fax No.: 817-735-9775
Signature: [signature]	Date: 5-25-22	E-Mail Address: cmarsh@wcgrp.com

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☒ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

Seal (Optional)

IIIF-G-A-46

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

MAJOR PERMIT AMENDMENT APPLICATION

VOLUME 3 OF 4

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/10/2023

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

This document is intended for permitting purposes only.

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIG
GEOLOGY REPORT

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

08/10/2023

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11

CONTENTS

GEOLOGY REPORT CERTIFICATION

Site Information

Site: Fort Worth C&D Landfill

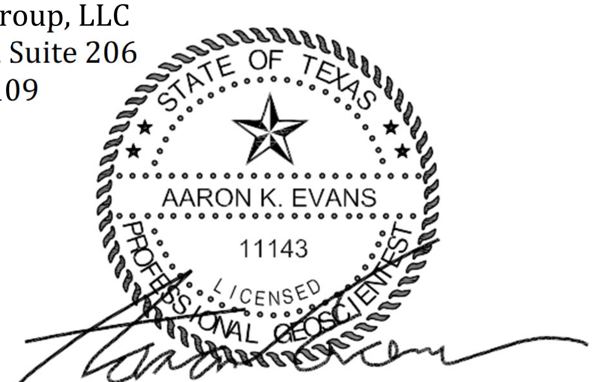
Site Location: Tarrant County

MSW Permit No.: 1983E

Qualified Groundwater Scientist Statement

I, Aaron K. Evans, am a Texas-licensed professional geoscientist and a qualified groundwater scientist as defined in Title 30 TAC §330.3(120). I have prepared the Geology Report which constitutes Appendix IIIG of this permit application. In my professional opinion, the Geology Report is in compliance with the requirements specified in Title 30 TAC §330.63(e). This report has been completed specifically for the Fort Worth C&D Landfill. The only warranty made by me in connection with this report is that I have used that degree of care and skill ordinarily exercised under similar conditions by reputable members of my profession, practicing in the same or similar locality. No other warranty, expressed or implied, is intended.

Firm/Address: Weaver Consultants Group, LLC
6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109



08/10/2023

Signature: ______________________________
Aaron K. Evans, P.G., Texas License No. 11143

Date: 08/10/2023

3.1.5 Main Street Limestone

Underlying the Grayson Shale, the Main Street Limestone consists of hard, dry limestone interbedded with dry, calcareous, clayey shale that ranges in thickness from about 28 to 31 feet across the site. It is noted that the BEG (1987) regional geologic formation taxonomy categorized the Grayson Shale and Main Street Limestone as a single undivided formation. Laboratory permeability testing indicates a vertical hydraulic conductivity ranging from 2.06×10^{-8} to 9.83×10^{-8} cm/sec.

3.1.6 Pawpaw Formation

The Pawpaw Formation underlies the Main Street Limestone and consists predominately of hard, dry, calcareous shale. None of the existing boreholes have penetrated the vertical extent of the Pawpaw beneath the site. The uppermost contact of Pawpaw to overlying Main Street Limestone sediments is below elevation 525 ft-msl as observed in onsite borings. No site-specific hydrogeological data exists for this deep-bedded dry shale formation.

3.1.7 Stratigraphic Interpretation

The existing subsurface characterization delineates Alluvium and Woodbine outcrop based on general sedimentary composition and taking into consideration regional geology as depicted by the Bureau of Economic Geology in the Geologic Atlas of Texas, Dallas Sheet (BEG, 1987).

Figures IIIG-A-1 (Regional Geologic Map) and IIIG-C-33 (Surface Geology Map) show the site location and regional formational outcrop areas. As indicated, Quaternary Alluvium (Qal) is isolated to the westernmost facility permit boundary proximal to Village Creek, the Woodbine Formation (Kwb) is isolated in the eastern permit boundary, and the Grayson Formation (Kgm) is interpreted to outcrop in a limited area within the central portion of the permit boundary. These outcrop areas appear to be generally consistent with site-specific subsurface investigation findings.

Alluvium sediments are typically observed to include a basal layer of coarse-grained sands and/or gravel as described in lithologic logs for monitor wells MW-2, MW-5, MW-6, MW-7, and MW-8. Alternatively, Woodbine sediments are generally comprised of sand and clay without the presence of basal gravels or with lithologic descriptions for gravelly soils that suggest a makeup of ironstone or calcareous nodules. The lithologic logs for the borings advanced in 1989 by Freeze and Nichols and 1991 by Baker-Shifflet include formational associations with some logged site-specific strata. These include notable Woodbine Formation sediment designations logged in borings B-16/16A and B-22/22A. In the central portion of the site, the residual weathering of Grayson Formation shale sediments is indicated by the more prevalent occurrence of clay and shaly clay above indurated unweathered

Grayson shale sediments. Figure IIIG-C-34 in Appendix IIG-C (Woodbine Formation Thickness Isopach Map) illustrates the general estimated thickness of Woodbine sediments as interpreted from previously advanced borings and based on pre-development surface grades. As indicated, Woodbine sediment thickness increases toward the east commensurate with the regional dip of the formation.

Delineating precise surficial formational contacts among the Alluvium, Woodbine, and Grayson sediments can be difficult given some of the similarities in sedimentary composition. For this reason, the hydrogeologic characterization is conservatively interpreted to include both an Alluvium and Woodbine groundwater monitoring system network. The facility's groundwater monitoring systems are further discussed in Attachment IIIH.

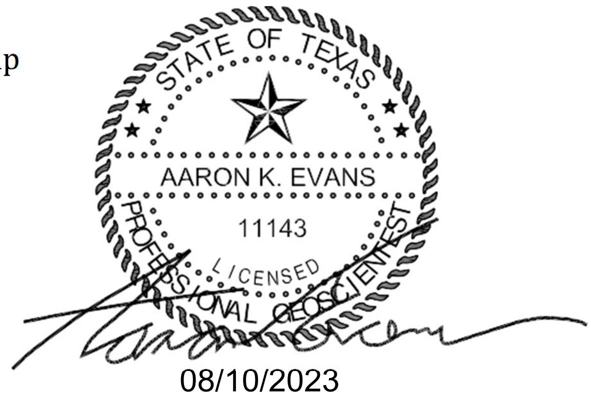
APPENDIX IIIG-C

SITE GEOLOGIC DATA

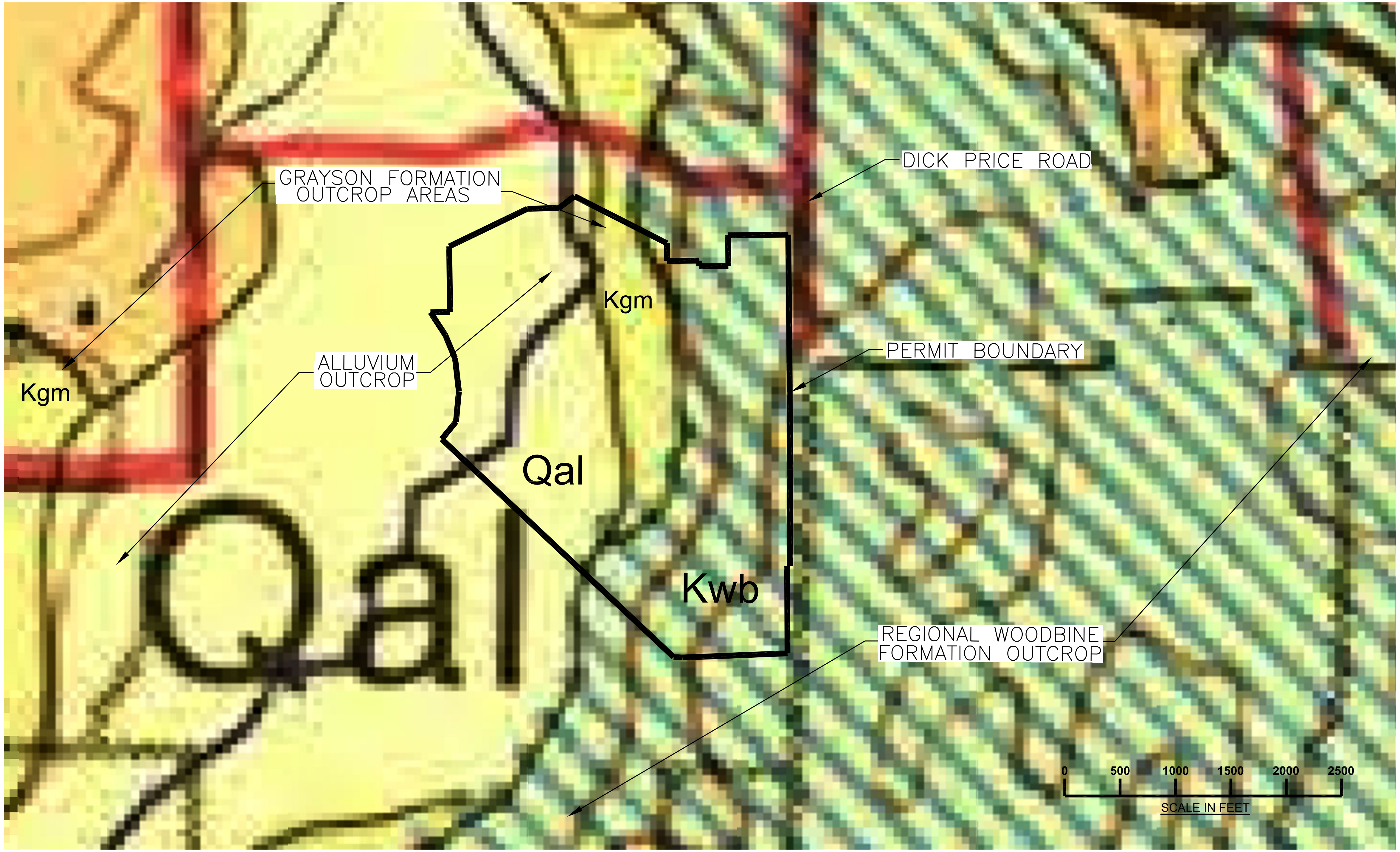
STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

08/10/2023

CONTENTS


STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST
08/10/2023

ADDITIONAL GEOLOGY FIGURES



N

LEGEND

(line)	PERMIT BOUNDARY (APPROXIMATE)
Qal	QUATERNARY ALLUVIUM OUTCROP
Kwb	WOODBINE FORMATION OUTCROP
Kgm	GRAYSON FORMATION OUTCROP

GEOLOGIC ATLAS OF TEXAS, DALLAS SHEET

GAYLE SCOTT MEMORIAL EDITION

REVISED 1987

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST

08/10/2023

NOTES:

1. SURFACE GEOLOGY MODIFIED FROM BUREAU OF ECONOMIC GEOLOGY REGIONAL GEOLOGIC MAP OF TEXAS, DALLAS SHEET, 1987.
2. LOCALIZED FORMATIONAL OUTCROP AREAS MAY VARY FROM THOSE DEPICTED BY THE REGIONAL GEOLOGIC MAP.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2023
FILE: 0771-356-11
CAD: IIIG-C-33_SURFACE GEO. MAP.DWG

DRAWN BY: JDW
DESIGN BY: AKE
REVIEWED BY: NT

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
TEXAS REGIONAL LANDFILL COMPANY, LP

REVISIONS

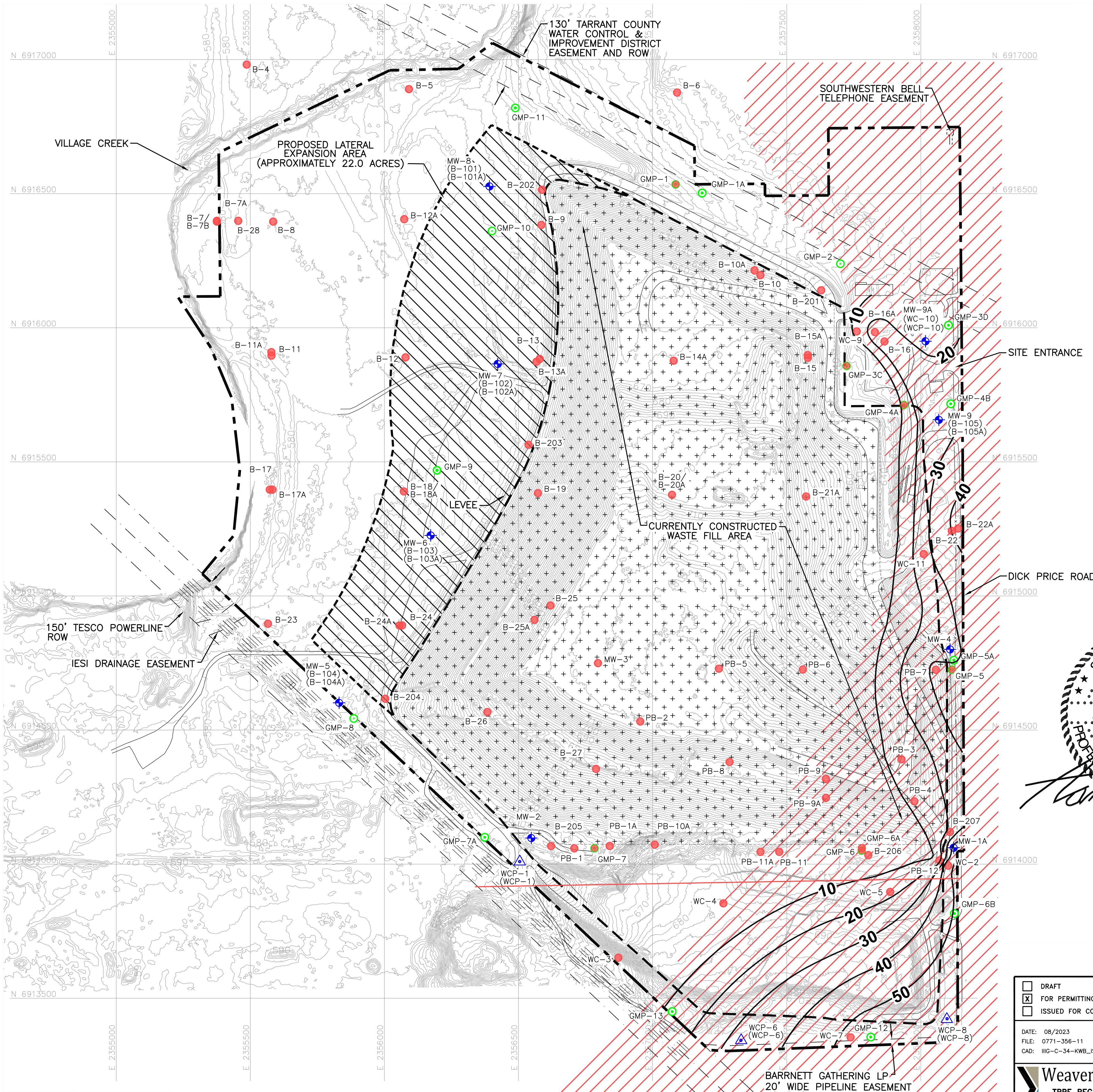
NO.	DATE	DESCRIPTION
1	08/2023	2ND TCEQ COMMENT RESPONSE

MAJOR PERMIT AMENDMENT
SURFACE GEOLOGY MAP

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS

WWW.WCGRP.COM

FIGURE IIIG-C-33



LEGEND

— · — · —	PERMIT BOUNDARY
— — — —	PERMITTED LIMITS OF WASTE
- - - - -	PROPOSED LIMITS OF WASTE
630	EXISTING CONTOUR
N 6915000	STATE PLANE COORDINATE
— · — ·	EASEMENT
+ + +	CURRENTLY CONSTRUCTED WASTE FILL AREA
\\\\\\	PROPOSED LATERAL EXPANSION AREA
MW-7	EXISTING GROUNDWATER MONITORING WELL
GMP-1	EXISTING LANDFILL GAS MONITORING PROBE
B-16	PREVIOUSLY DRILLED BOREHOLE LOCATION
WCP-1 (WP-1)	EXISTING GROUNDWATER PIEZOMETER LOCATION
40	WOODBINE THICKNESS CONTOUR IN FEET (SEE NOTE 5)
//////	APPROXIMATE WOODBINE FORMATION OUTCROP (SEE NOTE 6)

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY FIRMATEK, FROM AERIAL PHOTOGRAPHY FLOWN 02-17-2022. GRID COORDINATES BASED ON TEXAS STATE PLANE COORDINATE SYSTEM NAD 83.
2. THE EXISTING PERMIT BOUNDARY REPRODUCED FROM THE CURRENTLY APPROVED SITE DEVELOPMENT PLAN BY GEOSYNTEC CONSULTANTS, INC., DATED DECEMBER 2020.
3. BOREHOLE AND FORMER GROUNDWATER MONITOR WELL COORDINATES OBTAINED FROM APPENDIX 4 (GEOLOGY REPORT) OF THE CURRENTLY APPROVED SITE DEVELOPMENT PLAN PREPARED BY GEOSYNTEC CONSULTANTS, INC., DATED DECEMBER 2020. EXISTING GROUNDWATER MONITOR WELL COORDINATES FROM MAY 2023 ASBUILT SURVEY BY WCG.
4. GAS MONITORING PROBE LOCATION COORDINATES OBTAINED FROM ATTACHMENT 6 (LANDFILL GAS MANAGEMENT PLAN) OF THE CURRENTLY APPROVED SITE DEVELOPMENT PLAN PREPARED BY GEOSYNTEC CONSULTANTS, INC., DATED DECEMBER 2020, AND THE GAS PROBE INSTALLATION REPORT BY SCS ENGINEERS DATED JANUARY 2022.
5. WOODBINE FORMATION THICKNESS ESTIMATED FROM SITE-SPECIFIC BORING SEDIMENTARY COMPOSITION AND PREDEVELOPMENT SURFACE TOPOGRAPHY.
6. WOODBINE FORMATION OUTCROP ESTIMATED FROM REGIONAL GEOLOGIC MAP (BEG, 1987) AND SEDIMENTARY COMPOSITION OF SITE-SPECIFIC BORINGS.

STATE OF TEXAS
AARON K. EVANS
11143
PROFESSIONAL GEOSCIENTIST
LICENSED

08/10/2023

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2023
FILE: 0771-356-11
CAD: IIIG-C-34-KWB_ISOPACH.DWG

DRAWN BY: JDW
DESIGN BY: AKE
REVIEWED BY: NT

PREPARED FOR
TEXAS REGIONAL LANDFILL COMPANY, LP

REVISIONS

NO.	DATE	DESCRIPTION
1	08/2023	2ND TCEQ COMMENT RESPONSE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT
WOODBINE FORMATION THICKNESS ISOPACH MAP
FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS

WWW.WCGRP.COM

FIGURE IIIG-C-34

O:\0771\356\EXPANSION 2022\PART III\IIIG\CLEAN\IIIG-C-34-WOODBINE ISOPACH MAP.dwg, sford, 1:2

FORT WORTH C&D LANDFILL
TARRANT COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1983E

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIH
GROUNDWATER SAMPLING AND ANALYSIS PLAN

Prepared for

Texas Regional Landfill Company, LP

February 2023
Revised June 2023

Revised August 2023

STATE OF TEXAS
AARON K. EVANS
11143
LICENSED
PROFESSIONAL GEOSCIENTIST
08/10/2023

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0771-356-11-35

data. These data are summarized in Figure IIIH-A-2 (Groundwater Monitoring Well Details) in Appendix IIH-A. Typical groundwater monitoring well specifications are depicted in Figure IIIH-A-3 in Appendix IIIH-A. Review of monitoring well installation records indicate that the facility's existing monitoring wells were constructed in accordance with the requirements of Title 30 TAC §330.421.

All parts of the groundwater monitoring system will be operated and maintained so that they perform to design specifications throughout the life of the monitoring program. Any monitoring well that is damaged to the extent that it is no longer suitable for sampling will be reported to the TCEQ who may make a determination about whether to repair or replace the well. Well plugging and abandonment will be performed by a Texas-licensed monitoring well driller in accordance with TCEQ and any other applicable regulatory requirements. One monitoring well was plugged and abandoned prior to 2023 (MW-3) and the State of Texas Plugging Report is provided in Appendix IIIH-A. No monitoring well will be plugged and abandoned without prior written authorization from TCEQ. Any replacement monitoring well installation will be performed in accordance with Title 30 TAC §330.421 by a Texas-licensed monitoring well driller. Monitoring well construction will provide for the maintenance of the integrity of the borehole, collection of representative groundwater samples from the uppermost aquifer, and prevention of migration of groundwater and surface water within the borehole in accordance with Title 30 TAC §330.421(a).

New or replacement monitoring well installations will be surveyed for horizontal and vertical control by a Texas-licensed Registered Professional Land Surveyor prior to initiation of groundwater sampling in accordance with Title 30 TAC §330.421(d).

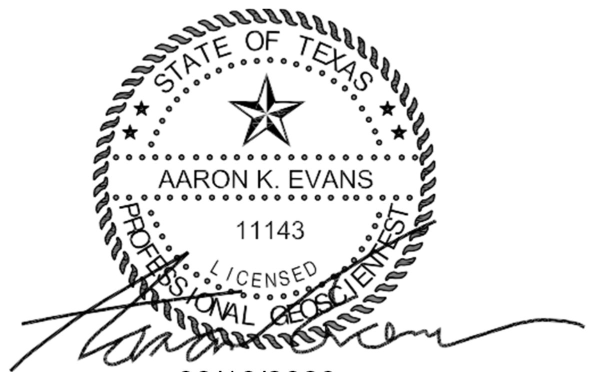
2.3 Groundwater Monitoring Program

Facility detection monitoring wells will be sampled annually for the detection monitoring parameters listed in 40 Code of Federal Regulations (CFR), Part 258, Appendix I, which are also listed in Table 5-1 in Section 5.1. Details regarding groundwater sampling, analyses, and statistical comparison procedures are discussed in the following sections of Appendix IIIH.

In accordance with Title 30 TAC §403(e)(3), the facility will promptly notify the executive director, and any local pollution agency with jurisdiction that has requested to be notified, in writing of changes in facility construction or operation or changes in adjacent property that affect or are likely to affect the direction and rate of groundwater flow and the potential for detecting groundwater contamination and that may require the installation of additional monitoring wells or sampling points. Such additional wells or sampling points require a modification of the site development plan which will be requested in accordance with Title 30 TAC §305.70(j).

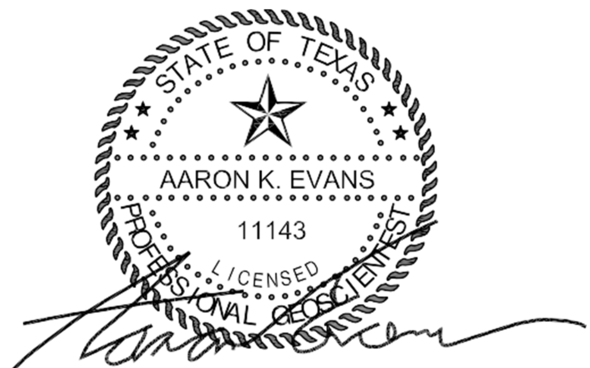
APPENDIX IIIH-A

GROUNDWATER MONITORING SYSTEM



08/10/2023

CONTENTS



08/10/2023

STATE OF TEXAS PLUGGING REPORT for Tracking #11086

Owner:	**Ft. Worth C & D Landfill**	Owner Well #:	**MW3**
Address:	**4144 Dick Price Rd. Ft. Worth, TX 76060**	Grid #:	**32-23-7**
Well Location:	**4144 Dick Price Rd. Ft. Worth, TX 76060**	Latitude:	**32° 37' 51" N**
		Longitude:	**097° 14' 19" W**
Well County:	**Tarrant**	Elevation:	**No Data**

Well Type: **Monitor**

Drilling Information

Company: **No Data**

Date Drilled: **No Data**

Driller: **No Data**

License Number: **No Data**

Borehole:

Diameter (in.)	*Top Depth (ft.)*	*Bottom Depth (ft.)*
4		**23**

Plugging Information

Date Plugged: **3/11/2003**

Plugger: **Brian Kern**

Plug Method: **Pour in 3/8 bentonite chips when standing water in well is less than 100 feet depth, cement top 2 feet**

Casing Left in Well:

No Data

Plug(s) Placed in Well:

No Data

Certification Data: The driller certified that the driller plugged this well (or the well was plugged under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the reports(s) being returned for completion and resubmittal.

Company Information: **Total Support Services**

**P.O. Box 81621
Austin, TX 78708**

Driller Name: **Brian Kern**

License Number: **54611**

Comments: **No Data**