SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
TCEQ REGISTRATION NO. -----
McLENNAN COUNTY, TEXAS

RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

Prepared for:

SANDY CREEK SERVICES, LLC
2161 Rattlesnake Road
Riesel, Texas 76682

Prepared by:

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Revision 0 – October 2021
SCS Project No. 16221059.00

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STATE OF TEXAS
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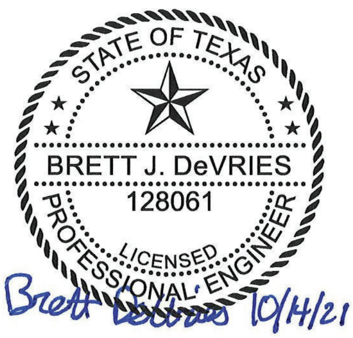
PROFESSIONAL ENGINEER
Brett DeVries 10/14/21

SCS Engineers
TBPE Reg. # F-3407

1 PE CERTIFICATION (40 CFR §257.81(a))



I, Brett DeVries, Ph.D., P.E., hereby certify that this enclosed Run-on and Run-off Control System Plan for the Sandy Creek Energy Station Solid Waste Disposal Facility meets the requirements in 30 TAC §352.811 and 40 CFR §257.81(a) and (b). This plan was prepared by or under my supervision. I am a duly licensed Professional Engineer under the laws of the State of Texas.

Brett DeVries, Ph.D., P.E.
(printed or typed name)

License number __128061____________________

My license renewal date is __9/30/2022______

2 INTRODUCTION

This Run-on and Run-off Control Plan has been prepared for the Sandy Creek Services, LLC (Owner) and NAES Sandy Creek Energy Station (Operator) of the Sandy Creek Energy Station (Plant) Solid Waste Disposal Facility (Landfill), located in Riesel, McLennan County, Texas. The plan has been prepared consistent with Title 30 of the Texas Administrative Code (30 TAC), Chapter 352.811 and Title 40 of the Code of Federal Regulations (40 CFR), Part 257.81.

Specifically, consistent with 30 TAC §352.811 and 40 CFR §257.81(a), the run-on and run-off control systems have been designed to prevent stormwater flow onto the working face of the Landfill, and collect and control flow from the active portion (i.e., contact water) of the Landfill during peak discharge from a 25-year, 24-hour storm event. Run-on and run-off from the working face of the Landfill will be handled in a manner that complies with the Texas Pollutant Discharge Elimination System (TPDES) consistent with 40 CFR §257.81(b) and Section 3 of this plan. Additionally, run-on and run-off control systems are designed to convey post-closure (following final cover installation) run-on and runoff from a 25-year, 24-hour storm event. This includes the design of downchutes, drainage swales, and perimeter drainage channels conveying the discharge from the Landfill area to the existing stormwater pond.

This plan is applicable for Landfill, which is comprised of Cells 1, 2, and 3. At the time of preparing this plan, Cells 1 and 2 are existing active cells. A portion of Cell 3 (inclusive of Subcells 3A through 3D) will be operational after construction is completed in 2021. Future Subcells within Cell 3 will be operated consistent with this plan.

Consistent with 40 CFR §257.81(c)(4), this plan will be revised every five (5) years from the completion date of the last plan. Additionally, the plan will be amended whenever there is a change in conditions that would substantially affect the existing plan, in accordance with 30 TAC §352.131. The Owner/Operator will comply with recordkeeping, notification, and internet requirements outlined in the Site Operating Plan (SOP, see Part V).

3 STORMWATER, LEACHATE, AND CONTACT WATER MANAGEMENT

Surface water (i.e., stormwater and contact water) will be managed in accordance with this plan throughout the active life of the Landfill to minimize the amount of stormwater that comes into contact with waste, contact water, or leachate. Water that does not come in contact with waste or leachate will be managed as stormwater (i.e. non-contact water). This stormwater runoff from the Landfill will be conveyed to the perimeter stormwater management system, comprised of perimeter channels and existing stormwater pond, by drainage swales/downchutes and overland flow before being discharged from the Landfill registration boundary.

Surface water run-on onto the working face or areas of exposed waste will be controlled using temporary diversion berms. Diversion berms will be constructed on the up-hill side of the working face to divert stormwater away from the working face and into the stormwater management system (evaporative leachate pond), thus reducing the volume of contact water and leachate generated. Cells 2 and 3 utilize interim cell berms to minimize the amount of leachate generated during Landfill operation. Stormwater collected in subcells that have not been in contact with waste will be discharged as uncontaminated water into the stormwater pond.

Contact water will be contained within the exposed waste areas, including working face, by using temporary containment berms and directed to the leachate collection and removal system, which discharges into the leachate evaporation pond. Site grading of the exposed waste areas will be regularly conducted to provide drainage, promote run-off, and minimize ponding of water over areas containing waste in accordance with the Site Operating Plan (Attachment 7). Additionally, at no time will contact water be allowed to discharge into the stormwater management system, offsite into waters of the United States, or onto adjacent properties. Surface water that infiltrates into the underlying waste will be managed as leachate in accordance with Part IV, Appendix IV.B, related to the Leachate Collection and Removal System Plan and Part V, SOP.

Methodologies described in the Texas Department of Transportation's Hydraulic Design Manual (revised September 2019) were used to estimate the volume of water that will be diverted around the working face or contained at the working face. These methodologies were also used to develop an approach for estimating the height of temporary diversion and containment berms required to contain and divert stormwater from coming into contact with waste. The design calculations and sizing of the diversion and containment berms for a 25 year, 24-hour storm event are provided in Appendix IV.D3 of this plan.

4 POST-CLOSURE STORMWATER MANAGEMENT

4.1 ANALYSIS METHODOLOGY

4.1.1 HYDROLOGIC ANALYSIS METHODS

Surface water discharges were estimated for a 25-year, 24-hour storm event using AutoCAD Civil 3D Hydraflow Hydrographs Extension. Hydraflow Hydrographs was also used to develop hydrographs for the post-closure conditions for computation of the peak flow rates from individual drainage areas of the Landfill into the perimeter stormwater management system. These peak flows were used in the design of the major surface water drainage features proposed for the Landfill (i.e. perimeter drainage channels, downchutes, and drainage swales).

Hydraflow Hydrographs for Autodesk Civil 3D (2020) is an application for urban hydrologic and hydraulic systems engineering, which can be used for analyzing the hydrologic properties of watersheds, determining runoff from synthetic storms, and planning or modeling stormwater control measures, such as detention ponds. The Hydraflow Hydrographs model represents a watershed as a network of hydrologic and hydraulic components. The modeling process results in the computation of hydrographs for surface water runoff, channel-flow, and detention basin storage within the watershed. The program then combines and routes the hydrographs through user-defined up- and down-gradient drainage features to defined watershed outlets.

4.1.1.1 Major Calculation Parameters

Input parameters for the Hydraflow Hydrographs model are described below and presented in Appendix IV.D1 of this plan. Appendix IV.D1 includes precipitation data, SCS Curve Numbers, Manning's coefficients, and drainage channel information used in the model.

Watershed Drainage Areas

Drainage areas are generally assumed to be areas that share similar run-on and run-off characteristics, surface features, and typically discharge to a single reach (i.e., channel), detention basin, or off-site discharge location. The on-site watershed drainage areas and surrounding drainage features modeled using Hydraflow Hydrographs are presented on Drawing IV.D2. Due to the existing topography and existing outer drainage channels located to the east of the Landfill, no watershed drainage areas have stormwater run-on onto the Landfill registration boundary. As such, generally all drainage areas outside the perimeter stormwater management system either generates stormwater run-off away from the Landfill (i.e., west side of the Landfill) or is intercepted by the existing outer drainage channels and is directed around the Landfill.

Hypothetical Precipitation Distribution

The hypothetical precipitation distribution was derived from the NOAA Atlas 14, Precipitation Frequency Data Server (consistent with the September 2019 memo developed by the Texas Commission on Environmental Quality [TCEQ]). A Type III storm event with a return period of 25-years and duration of 24-hours was used for the hydrologic modeling. This storm event is associated with approximately 7.42 inches of precipitation, which was assumed to be evenly distributed across the entire Landfill watershed for the return period. Input parameters discussed above are provided in Appendix IV.D1.

Curve Numbers (CN)

Curve number (CN) values for the final cover and surrounding areas were selected based on the cover type. A CN value of 80 was used for post-closure conditions for final cover. Reference tables for these CN values are provided in Appendix IV.D1. Based on the soil survey map of the Landfill area (as shown in Appendix IV-D3), on-site soils are predominantly clay, silty clay, and sandy loam. Therefore, Hydrologic Soil Group (HSG) C and D are appropriate for the final cover and surrounding drainage area. CN of 80 is a representative assumption for HSG C/D (i.e., open space, fair to good drainage conditions).

Routing and Hydrograph Methods

The routing and hydrograph method represents the methodology used by the model to develop hydrographs for each drainage area, channel, and detention basin; which are then combined by the program to represent the watershed being analyzed. Hydraflow Hydrographs uses the SCS hydrograph method for calculating runoff hydrographs. Time of concentrations for SCS hydrographs were estimated using the Technical Release 55 (TR-55) method. The TR-55 method was developed by the Natural Resources Conservation Service (formerly the Soil Conservation Service), method as shown in the Hydraflow Hydrographs Model Input Parameters, which are related to Post-Closure Drainage Area Conditions provided in Appendix IV.D1.

Perimeter channel routing from the Landfill drainage areas to an existing stormwater pond was completed as shown in Appendix IV.D2. Hydraflow Hydrographs uses the Modified Att-Kin routing method for calculating channel hydrographs. The input parameters for the model are based on the length, channel geometry, slope, and surface roughness of the channel. Input parameters for post-closure drainage channels are summarized in Appendix IV.D1. Channel capacity, velocity, and peak flow depths were estimated using Manning's equation, as described in 4.1.2.2 of this plan.

As part of this Plan, the existing stormwater pond will be used at the detention basin for the Landfill. This detention basin (stormwater pond) was constructed to reduce the combined peak flow rates from the post-closure subbasins to a level that will not adversely impact down-gradient properties. Input parameters for the stormwater pond are included in the Hydraflow Hydrographs Model output file (i.e., Pond Report) provided in Appendix IV.D2.

4.1.2 HYDRAULIC ANALYSIS METHOD

This section describes the methodology used for evaluating hydraulic parameters, including geometry and peak flow velocities, for the stormwater conveyance structures, such as drainage swales (topslope and sideslope), downchutes, drainage channels, and detention basin outlet structure that are or will be constructed at the Landfill. This section also describes the methodology for evaluating the overland flow velocity on the final cover slopes.

4.1.2.1 Permissible Non-Erosive Flow Velocities

The peak flow velocities were calculated using the methodologies described herein, and were compared to the permissible non-erosive flow velocity for vegetated Landfill slopes or drainage features. Landfill cover or drainage features experiencing erosive velocities (i.e., in excess of the defined non-erosive velocity) will be armored or protected using structural controls.

In accordance with published literature, as provided with calculations in Appendix IV.D3 of this plan, permissible non-erosive flow velocities are defined as velocities less than or equal to 5 to 7 feet per second (fps) depending on the slope for vegetated perimeter channels, drainage swales, and final cover slopes.

4.1.2.2 Analysis of Drainage Swales and Downchutes

Drainage swales (i.e., final cover topslope and sideslope swales) and downchutes are structural controls used to convey runoff from the Landfill cover to the perimeter drainage system and to reduce cover erosion by limiting uninterrupted flow lengths. These structures will be installed on final cover as depicted on Drawings IV.D1 and IV.D2, and as needed on immediate cover to control erosion of the intermediate as the Landfill is developed, as described in the SOP (see Part V).

Drainage swales will be installed following construction and placement of final cover and as needed on intermediate cover to the representative grades coinciding with the elevations and/or maximum spacing between swales. The maximum horizontal spacing between drainage swales will be 175 horizontal feet on a 3.5:1 slope, as discussed in Section 4.2. Drainage swales and downchutes on final cover will be installed at the general locations depicted on Drawings IV.D1 and IV.D2.

The methodology for sizing drainage swales and downchutes is described below and Section 4.2. Drainage swale and downchute details are depicted on Drawing IV.D3.

Rational Method

The Rational Method was used to estimate peak runoff from typical contributing areas for design of the drainage swales and downchutes installed on final cover. Contributing areas at this Landfill are less than 200 acres, therefore the Rational Method is applicable. The Rational Method estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time-of-concentration (the time required for water to flow from the most remote point of the drainage area to the location being analyzed).

The Rational Method is expressed as the following:

$$Q = CIA$$

Where, Q = maximum rate of runoff, cfs
C = runoff coefficient representing a ratio of runoff to rainfall

I = average rainfall intensity for a duration equal to the time-of-concentration, inches per hour
A = drainage area contributing to the discharge location, acres

The runoff coefficient (C) used for the drainage swale and downchute analysis is described in the calculations provided in Appendix IV.D3. The 25-year, 24-hour rainfall intensity (I) was determined for McLennan County using Atlas of Depth-Duration Frequency (DDF) of Precipitation of Annual Maxima for Texas spreadsheet by Texas Department of Transportation (TXDOT), assuming a minimum time-of-concentration (tc) of 10 minutes for sizing Landfill drainage swales and downchutes. A depiction of the contributing areas (A) used for the analysis of swales and downchutes is provided on Drawing IV.D2-B.

Manning's Equation for Uniform Flow

Hydraulic analysis of the drainage swale and downchute geometry was performed using Manning's uniform flow equation. The uniform flow assumption used by Manning's equation is applicable to long prismatic channels of uniform slope, such as those proposed for the drainage swales or downchutes.

The general form of Manning's equation is:

$$V = \frac{1.49R^{0.667}S^{0.5}}{n}$$

Where, V = Velocity of flow, fps
n = Manning's "n"
R = Hydraulic Radius, ft, or

$$R = \frac{A}{P}$$

S = Friction slope for non-uniform flow or channel slope for uniform flow, ft/ft
A = Area of water perpendicular to direction of flow, sf
P = Wetted perimeter, ft

Using the relationship Q = VA, Manning's equation can be written as:

$$Q = \frac{1.49AR^{0.667}S^{0.5}}{n}$$

The uniform flow assumption equates the slope of the structure to the friction slope. Therefore, the slope of the channel can be used for "S" in Manning's equation for computation of uniform flow. Using the peak flow rate for a 25-year, 24-hour storm event calculated using the Rational Method (described above), the velocity and peak flow depth within drainage swales and downchutes was calculated using Manning's equation.

The following assumptions were used when evaluating the peak velocity with drainage swales and downchutes:

- Drainage swales will be grass-lined for velocities less than or equal to 5 fps. These structures were designed assuming a Manning's "n" of 0.027.
- When velocities exceed 5 fps, typically downchutes, the structure will be lined with armoring materials, as described below.
- Armoring materials will include: rip rap or turf reinforcement mats (TRM) for intermediate cover drainage swales; gabions, rip rap, TRM, or flexible membrane liner for intermediate cover downchutes; and gabions for final cover downchutes. In any case, these structures were designed assuming a Manning's "n" of 0.033, as this surface roughness provides the greatest flow depth within the respective structure for the referenced armoring materials.
- Energy dissipation in the form of gabions, rip rap, or dissipation blocks will be installed at the confluence of downchutes and the Landfill toe of slope and/or perimeter drainage channels.

Both the drainage swale and downchute cross-sections will be capable of retaining the peak flow rate, as calculated using the Rational Method described above. A peak flow analysis was performed for drainage swales and downchutes installed on final cover. Calculations using Manning's equation for the hydraulic properties of the drainage swales and downchutes were performed using the AutoCAD Civil 3D Hydraflow Express Extension (2020). This flow analysis and the Hydraflow Express output summary sheets for these calculations are presented in Appendix IV.D3.

4.1.2.3 Flow Capacity of Drainage Channels

The existing east perimeter channel and proposed west perimeter channel are designed to convey run-off from the developed Landfill to the existing stormwater pond. The peak flow rates obtained from Hydraflow Hydrographs for contributing subbasins were used to evaluate the flow capacity of the perimeter drainage channels. Hydraflow Express was used to confirm that the designed channel geometry, depth, and invert slope will provide sufficient capacity to discharge the 25-year, 24-hour storm event. The following assumptions were incorporated into the channel modeling:

- Manning's coefficient values of 0.027 for grass-lined channels or 0.033 for rip rap/TRM-lined channels was used for the analysis.
- Channels were designed with trapezoidal cross-sections with 3H:1V sideslopes (see Drawing IV.D5).
- Each channel was analyzed for peak flow for the 25-year, 24-hour storm event with freeboard above the flow depth associated with the peak flow rate was added to the channel design.

Information derived from the Hydraflow Express output files includes channel flow depth and peak velocity at the peak flow conditions. The respective Hydraflow Express output files for each of the perimeter channels are included in Appendix IV.D3.

4.1.2.4 Stormwater Pond Outlet Structure

The stormwater pond, which will be used as a detention basin for the Landfill, has two existing outlet structures, including a 10-inch diameter bleed pipe at an invert elevation of 439 ft. and a set of three, 36-inch diameter pipes at an invert elevation of 450 ft[1]. Each of these outlet structures are located on the south end of the pond.

An elevation-area-discharge relationship was developed for the pond based on the constructed pond elevations, and utilized in the Hydraflow Hydrographs for routing run-off through the detention basin. The discharge relationships for the stormwater pond are provided in Appendix IV.D2 of this report as part of the Hydraflow Hydrographs output file (i.e., Pond Report).

4.1.2.5 Overland Flow Velocity

An analysis was performed to evaluate overland flow velocities on final cover slopes. Overland flow is defined as the combination of sheet flow and shallow concentrated flow conditions. Sheet flow velocity is defined as the ratio of the sheet flow length to the sheet flow time of concentration. Calculated overland flow velocities were compared to the permissible non-erosive flow velocities, as defined in Section 4.1.2.1 of this plan.

In accordance with TR-55, sheet flow occurs on slopes at lengths less than 100 feet, whereas shallow concentrated flow begins at lengths greater than 100 feet. The time-of-concentration (tc) for sheet flow on the Landfill slopes was analyzed using Kinematic Wave procedures, which are referenced in TR-55.

The shallow concentrated flow velocity was analyzed by calculating the shallow concentrated flow depth, which was derived using Manning's Equation. Based on the shallow concentrated flow depth, the peak flow rate and velocity were calculated using the Rational Method and the Continuity Equation (Q=VA) assuming a unit width of flow (w = 1-foot).

These methods were performed to demonstrate that the overland flow velocity on final cover slopes will be below 5 fps at the designed swale spacing of 175 feet. The greatest potential slopes and flow lengths for final cover slopes, as described in Appendix IV.D3, Hydraulic Analysis – Overland Flow Velocity Analysis, were evaluated. The flow lengths provided were selected to maintain velocities less than permissible non-erosive flow velocities (see Section 4.1.2.1 of this plan) and maintain soil loss less than the permissible soil loss limits (see Section 4.2 of this plan).

Sample calculations for overland flow velocity on typical final cover areas are presented in Appendix IV.D3, Hydraulic Analysis – Overland Flow Velocity Analysis. As presented in the calculations, flow velocities will be maintained at less than the maximum permissible non-erosive velocities for the respective vegetated cover.

4.2 SOIL LOSS ANALYSIS METHOD

The Universal Soil Loss Equation (USLE)/Revised Universal Soil Loss Equation (RUSLE) was used to calculate the soil loss resulting from precipitation contacting the final cover. The estimated

[1] Based on the Run-on and Run-off Control System Plan prepared by Geosyntec Consultants in 2016.

soil loss was compared to the permissible soil loss for intermediate and final cover, as defined by the TCEQ. Consistent with TCEQ guidelines ("Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill", TCEQ, Revised May 2018), the soil loss demonstration should pertain to the top dome surfaces and external embankment sideslopes for final cover phases of Landfill operation.

The USLE/RUSLE is an empirical equation which estimates soil losses from rainfall and runoff. The USLE was developed by statistical analysis of many plot-years of rainfall, runoff, and sediment loss data from many small plots located around the country. The USLE is supported by the National Resource Conservation Service (NRCS).

The Universal Soil Loss Equation is:

$$A=RKLSCP$$

Where
A = average annual soil loss (tons/acre/ year)
R = rainfall and runoff erosivity index for a given location
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cover and management factor
P = erosion control practice factor

The input parameters into the USLE/RUSLE and soil loss calculations for final cover are presented in Appendix IV.D4 of this attachment.

4.2.1 Final Cover Soil Loss

The purpose of calculating the soil loss from final cover is to evaluate the frequency (i.e., spacing between drainage swales) at which the drainage swales must be installed to maintain soil loss at less than or equal to 3 tons/acre/year (maximum permissible soil loss recommended by the TCEQ for final cover slopes). Soil loss on final cover was calculated for the sideslopes and topslopes. The analysis for the topslope is based on the greatest flow length of 125 ft on the 3 percent topslope. Drainage swales on final cover sideslopes will be installed at a maximum spacing of 175 horizontal feet or 50 vertical feet, assuming a 3.5H:1V sideslope. Soil loss calculations for final cover were based on the assumption that vegetation would be established following application of final cover, and that the vegetation would provide approximately 90 percent ground coverage.

Based on the results, the maximum erosion potential of the final cover was estimated to be 0.30 tons/acre/year and 2.6 tons/acre/year on the topslope and sideslope, respectively, as shown in Appendix IV.D4.

5 POST-CLOSURE CONDITIONS

Post-closure conditions with delineated drainage areas and direction of surface water flow to the existing stormwater pond are depicted on Drawings IV.D1 and IV.D2-A. Additionally, a general layout of the post-closure drainage system, including perimeter drainage channels, is also presented on Drawings IV.D1 and IV.D2-A. As shown on the drawings, rainfall coming into contact with the Landfill final cover slopes will be collected as run-off in drainage swales located at set intervals on the final cover slopes, as described in Section 4.1.2.2 of this plan. Run-off will flow within the drainage swales, roughly parallel to the slope, into gabion-lined downchutes, from which it will be conveyed to the toe of the Landfill and into the drainage channels or discharge directly into the existing stormwater pond. The stormwater discharged into the pond will evaporate or discharge through the previously discussed set of outlet structures.

5.1 DRAINAGE FEATURE MODELING

5.1.1 DRAINAGE SWALES AND DOWNCHUTES

The drainage swales were designed to have peak flow velocities of less than 7 feet per second with only vegetation proposed for the channel lining. Downchutes were designed with gabion lining. As described in this section, the peak flow rates in the drainage swales and downchutes were determined from the Hydraflow Hydrograph output for the respective contributing drainage areas. The peak velocity and flow depth within each channel were calculated using Hydraflow Express, based on the proposed geometry. The Hydraflow Hydrograph output files for each channel are included in Appendix IV.D3. Cross-sections for a typical drainage swale and downchute are presented on the Drawings IV.D5 and IV.D6, respectively.

5.1.2 DRAINAGE CHANNEL DESIGN

The channels were designed to have peak flow velocities of less than 7 feet per second where only vegetation is proposed for the channel lining. For velocities greater than approximately 7 feet per second, the channels were designed with either rip rap lining, gabions, or TRM. The hydraulic analysis of the perimeter drainage channels is described in Section 4.1.2.3. As described in this section, the peak flow rates in the channels were determined from the Hydraflow Hydrograph output for the respective contributing drainage areas. The peak velocity and flow depth within each channel were calculated using Hydraflow Express, based on the proposed channel geometry. A summary of the channel design parameters, which were incorporated into Hydraflow Hydrograph and Hydraflow Express, are included in Appendix IV.D1. Additionally, the Hydraflow Express output files for each channel are included in Appendix IV.D3. A typical channel cross-section is presented on Drawing IV.D5.

5.1.3 EXISTING STORMWATER POND

The existing stormwater pond was modeled consistent with the constructed elevations and outlet structures, as described in Section 4.1.2.4. The stormwater from the Landfill will be detained in the stormwater pond until the depth of water within the pond reaches an elevation of 439 ft. and will then continuously discharge. Under a 25-year, 24-hour storm event, the 36-inch diameter outlet pipes will not be necessary for discharge. As such, the pond will provide sufficient capacity for the 25-year, 24-hour storm event.

5.2 SUMMARY OF POST-CLOSURE MODELING RESULTS

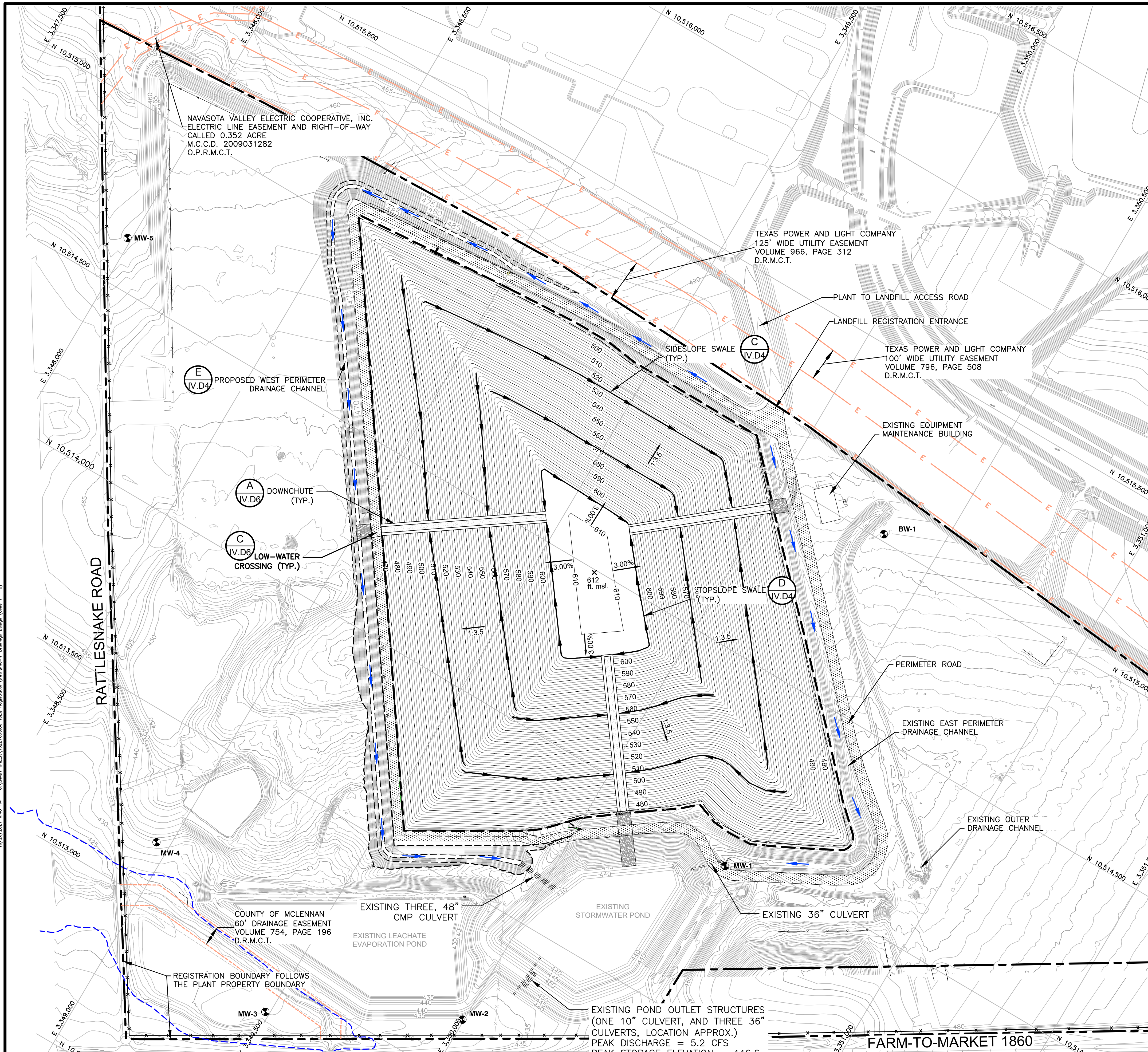
This Run-on and Run-off Control Plan has been prepared consistent with 30 TAC Chapter 352.811 and Title 40 of the Code of Federal Regulations (40 CFR), Part 257.81 for run-on and run-off controls for coal combustion residual (CCR) Landfills. Specifically, consistent with 30 TAC §352.811 and 40 CFR §257.81(a), the run-on and run-off control systems were designed to prevent stormwater flow onto exposed waste areas, including the working face, of the Landfill, and collect and control contact water from the active portion of the Landfill during peak discharge from a 25-year, 24-hour storm event. Run-on and run-off from the working face of the Landfill will be handled in manner that complies with the Texas Pollutant Discharge Elimination System (TPDES) consistent with 40 CFR §257.81(b) and Section 3 of this plan. Additionally, run-on and run-off control systems are designed to convey post-closure (following final cover installation) run-on and runoff from a 25-year, 24-hour storm event. This includes the design of downchutes, drainage swales, and drainage channels conveying the discharge from the Landfill area to the existing stormwater pond.

Post-closure conditions are represented by the fully developed Landfill, with final closure having been completed, and all drainage features in-place and operational, as described in Section 5 and presented on Drawings IV.D1 and IV.D2-A. Input parameters for the Hydraflow Hydrograph modeling performed for post-closure conditions are presented in Appendix IV.D1. The results of Hydraflow Hydrograph modeling of the post-closure conditions are included in Appendix IV.D2.

As shown in the Pond Report, which is included in Appendix IV.D2, there will be minimal discharge from the existing 10-inch outlet pipe for the design event (i.e., 25-year 24-hour event). The peak water elevation in the existing pond for this event is anticipated to be at 446.6 ft. No discharge is anticipated from the three 36-inch outlet pipes that are installed at an invert elevation of 450 ft.; however, these pipes are designed in an effort to prevent overtopping of the pond in an unlikely event that the pond peak water elevation exceeds the invert elevation of the outlet pipes.

Discharge velocities from the drainage features will be below the 7 feet per second threshold, which typically is considered the threshold for erosion damage. This will be accomplished by dissipating discharge velocities where needed.

DRAWINGS



0 150 300
SCALE IN FEET

LEGEND

450	EXISTING CONTOURS (SEE NOTE 1)
	PLANT PROPERTY BOUNDARY
	LANDFILL REGISTRATION BOUNDARY (SEE NOTE 3)
	REGISTERED LIMITS OF WASTE
N 10,516,500 E 3,347,000	STATE PLANE COORDINATES
MW-1	EXISTING GROUNDWATER MONITORING WELL
450	PROPOSED FINAL COVER CONTOUR
	PROPOSED DRAINAGE SWALES
	PROPOSED DOWNCHUTES
	CHANNEL FLOW DIRECTION
	EXISTING FENCE
	EXISTING DRAINAGE EASEMENT
E	EXISTING ELECTRICAL EASEMENT
	100-YEAR FLOOD PLAIN (SEE NOTE 2)
	PERIMETER ROAD

NOTES:

1. THE EXISTING CONTOUR MAP SHOWN ON THIS DRAWING WAS COMPILED FROM AN AERIAL SURVEY CONDUCTED BY DALLAS AERIAL SURVEY, INC. IN NOVEMBER, 2020 AND EXISTING TOPOGRAPHY BY BLACK & VEATCH CORPORATION DATED APRIL 2006. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLAN COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD83) 1983.
2. 100-YEAR FLOOD PLAIN IS DESIGNATED AS ZONE A, BASED ON FIRM PANEL 48309C0600D, DATED 10/20/2019.
3. REGISTRATION BOUNDARY IS FROM AN EXHIBIT AND FIELD NOTES FOR A 148.84 ACRES SOLID WASTE DISPOSAL FACILITY TRACT DEVELOPED BY WALKER PARTNERS IN SEPTEMBER 2021.

STATE OF TEXAS
BRETT J. DeVRIES
128061
LICENSED
PROFESSIONAL ENGINEER
Brett DeVries 10/14/21

FOR REGISTRATION PURPOSES ONLY

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

CLIENT: SANDY CREEK SERVICES, LLC
2161 RATTLESNAKE ROAD
RIESEL, TEXAS 76682

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1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16221059.00 | DSN. BY: BJD | DWN. BY: AGA | CHK. BY: SS | Q/A RVW BY: SS | APP. BY: BJD

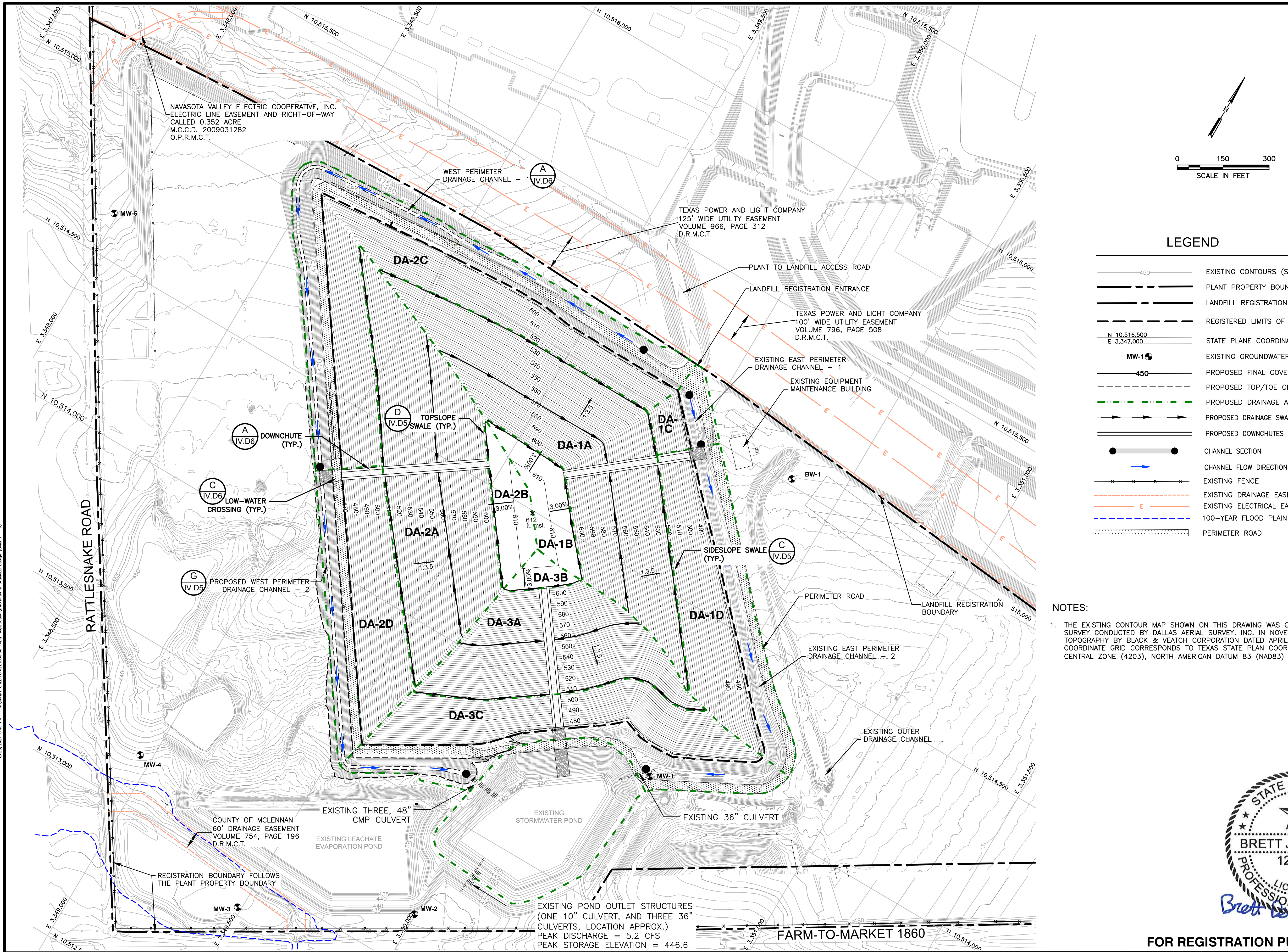
CADD FILE: INTERIM DRAINAGE DESIGN (CELLS 1 - 3)

DATE: 9/2021

SCALE: AS SHOWN

DRAWING NO. **IV.D1**

10/26/2021 6:48 PM G:\SANDY CREEK\16221059.00 TCEQ Registration\DWG\Interim Drainage Design (Cells 1 - 3)



LEGEND

450	EXISTING CONTOURS (SEE NOTE 1)
	PLANT PROPERTY BOUNDARY
	LANDFILL REGISTRATION BOUNDARY
	REGISTERED LIMITS OF WASTE
N 10,516,500 E 3,347,000	STATE PLANE COORDINATES
MW-1	EXISTING GROUNDWATER MONITORING WELL
450	PROPOSED FINAL COVER CONTOUR
	PROPOSED TOP/TOE OF SLOPE
	PROPOSED DRAINAGE AREA
	PROPOSED DRAINAGE SWALES
	PROPOSED DOWNCHUTES
	CHANNEL SECTION
	CHANNEL FLOW DIRECTION
	EXISTING FENCE
	EXISTING DRAINAGE EASEMENT
E	EXISTING ELECTRICAL EASEMENT
	100-YEAR FLOOD PLAIN
	PERIMETER ROAD

NOTES:

1. THE EXISTING CONTOUR MAP SHOWN ON THIS DRAWING WAS COMPILED FROM AN AERIAL SURVEY CONDUCTED BY DALLAS AERIAL SURVEY, INC. IN NOVEMBER, 2020 AND EXISTING TOPOGRAPHY BY BLACK & VEATCH CORPORATION DATED APRIL 2006. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLAN COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD83) 1983.

STATE OF TEXAS
BRETT J. DeVRIES
128061
LICENSED PROFESSIONAL ENGINEER
Brett DeVries 10/14/21

FOR REGISTRATION PURPOSES ONLY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

REV | DATE | DESCRIPTION | BY

DRAWING TITLE: RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN SCHEMATIC

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

CLIENT: SANDY CREEK SERVICES, LLC 2161 RATTLESNAKE ROAD RIESEL, TEXAS 76682

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16221059.00 | DSN. BY: BJD | DWN. BY: AGA | CHK. BY: SS | Q/A RVW BY: SS | APP. BY: BJD

CADD FILE: INTERIM DRAINAGE DESIGN (CELLS 1 – 3)

DATE: 9/2021

SCALE: AS SHOWN

DRAWING NO. **IV.D2-A**

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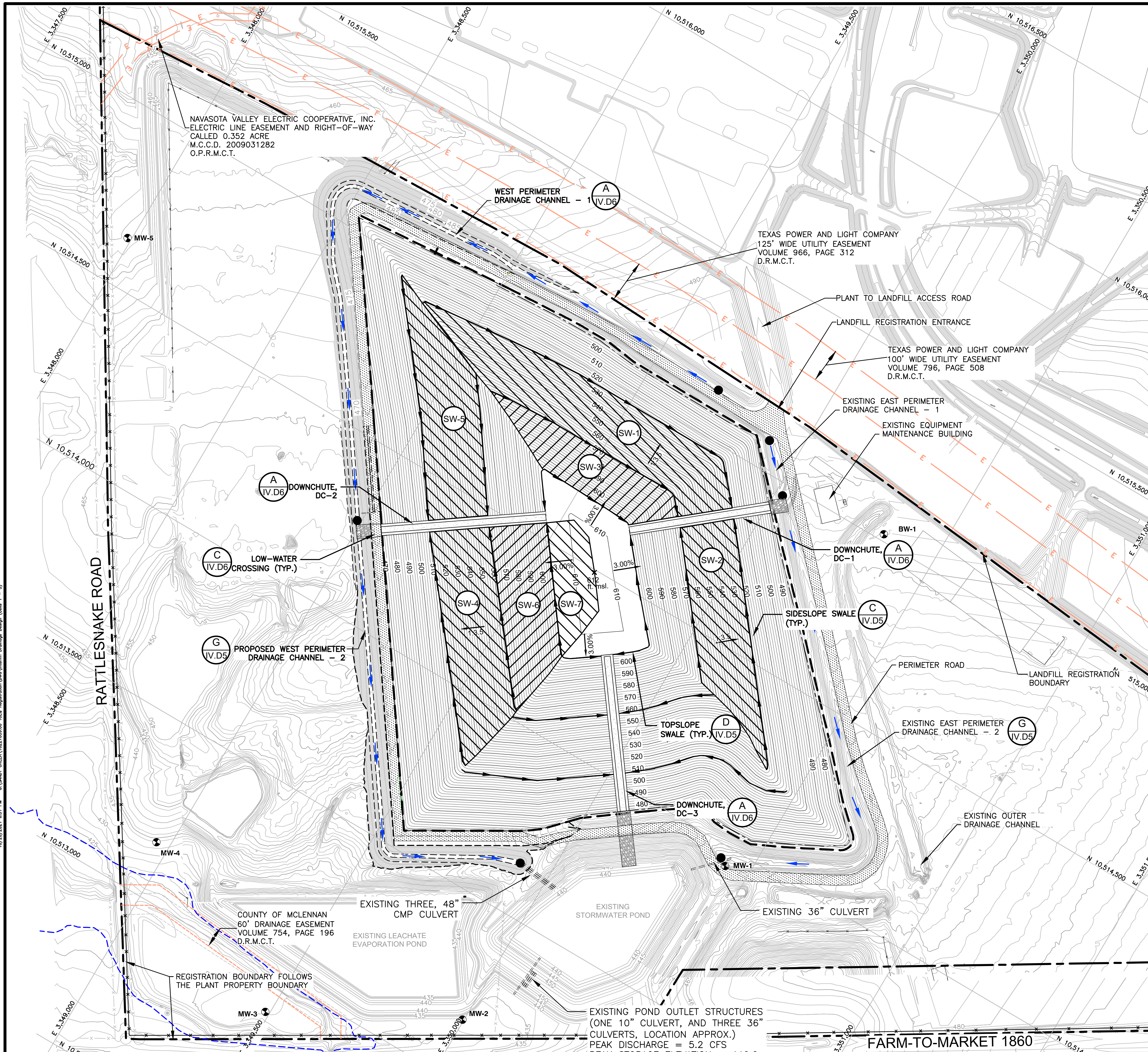

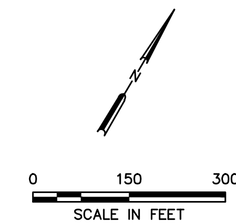

LEGEND

450	EXISTING CONTOURS (SEE NOTE 1)
	PLANT PROPERTY BOUNDARY
	LANDFILL REGISTRATION BOUNDARY
	REGISTERED LIMITS OF WASTE
N 10,516,500 E 3,347,000	STATE PLANE COORDINATES
MW-1	EXISTING GROUNDWATER MONITORING WELL
450	PROPOSED FINAL COVER CONTOUR
	PROPOSED TOP/TOE OF SLOPE
	PROPOSED DRAINAGE AREA
	PROPOSED DRAINAGE SWALES
	PROPOSED DOWNCHUTES
	CHANNEL SECTION
	CHANNEL FLOW DIRECTION
	EXISTING FENCE
	EXISTING DRAINAGE EASEMENT
E	EXISTING ELECTRICAL EASEMENT
	100-YEAR FLOOD PLAIN
	PERIMETER ROAD
	DRAINAGE SWALE AREA

NOTES:

1. THE EXISTING CONTOUR MAP SHOWN ON THIS DRAWING WAS COMPILED FROM AN AERIAL SURVEY CONDUCTED BY DALLAS AERIAL SURVEY, INC. IN NOVEMBER, 2020 AND EXISTING TOPOGRAPHY BY BLACK & VEATCH CORPORATION DATED APRIL 2006. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLAN COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD83) 1983.

STATE OF TEXAS
BRETT J. DeVRIES
128061
LICENSED PROFESSIONAL ENGINEER
Brett DeVries 10/14/21

FOR REGISTRATION PURPOSES ONLY

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: **DRAINAGE SWALE AND DOWNCHUTE AREA SCHEMATIC**

PROJECT TITLE: **SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION**

CLIENT: **SANDY CREEK SERVICES, LLC 2161 RATTLESNAKE ROAD RIESEL, TEXAS 76682**

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16221059.00 | DSN. BY: BJD | DWN. BY: AGA | CHK. BY: SS | Q/A RVW BY: SS | APP. BY: BJD

CADD FILE: INTERIM DRAINAGE DESIGN (CELLS 1 – 3)

DATE: 9/2021

SCALE: AS SHOWN

DRAWING NO. **IV.D2-B**

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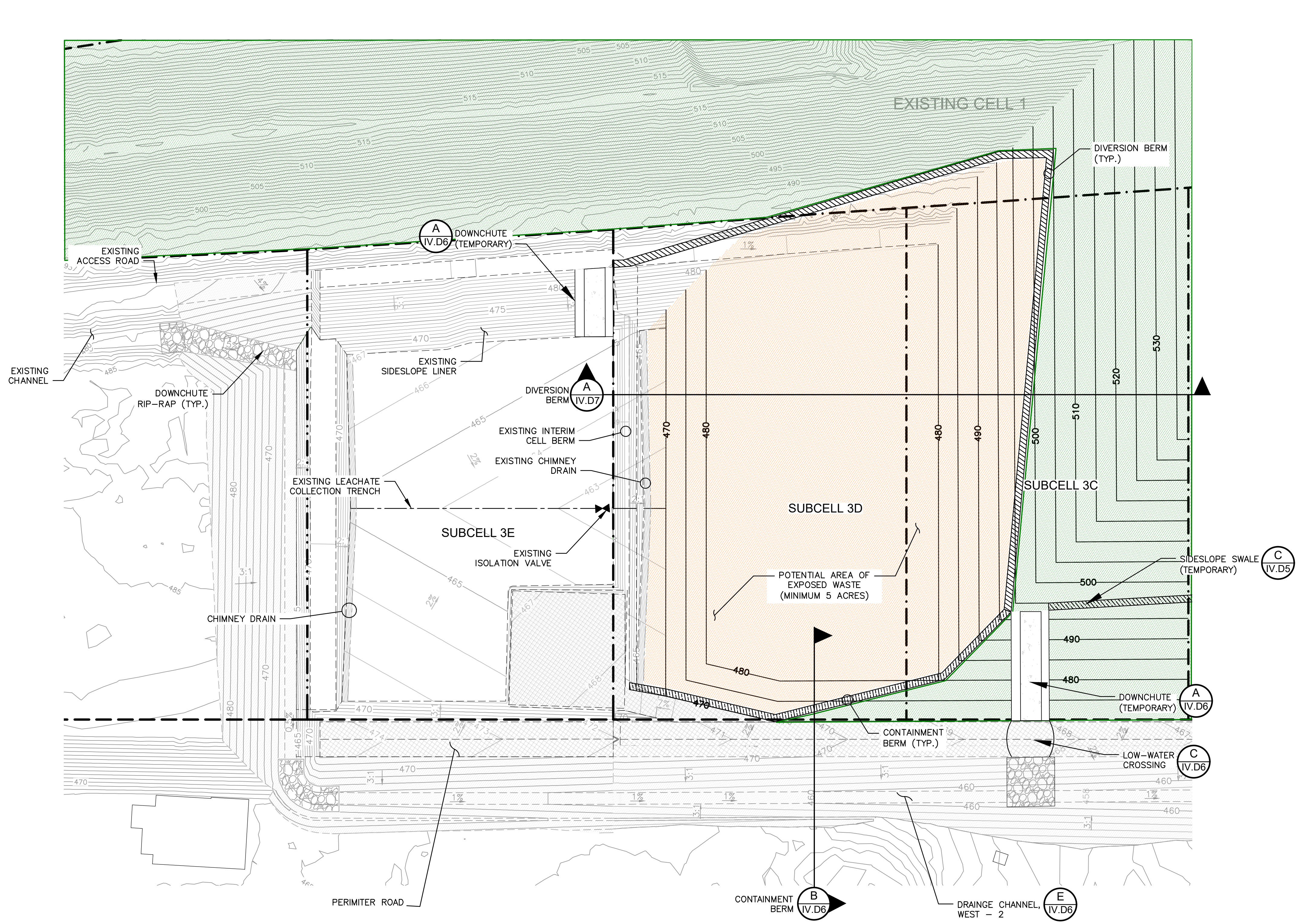

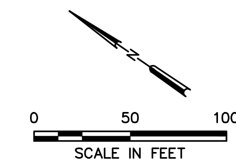

LEGEND

- EXISTING CONTOURS (SEE NOTE 1)
- REGISTERED LIMITS OF WASTE
- EXISTING CELL BOUNDARY
- PROPOSED SUBCELL BOUNDARY
- EXISTING TOE/TOP OF SLOPE
- EXISTING LEACHATE COLLECTION TRENCH
- EXISTING ISOLATION VALVE
- EXISTING CHIMNEY DRAIN
- EXISTING ACCESS ROAD
- AREA OF EXPOSED WASTE
- AREA OF INTERIMEDIATE/FINAL COVER
- PROPOSED DIVERSION BERM
- PROPOSED CONTAINMENT BERM
- PROPOSED TEMPORARY SWALE
- PROPOSED DOWNCHUTES

NOTES:

1. THE EXISTING CONTOUR MAP SHOWN ON THIS DRAWING WAS COMPILED FROM AN AERIAL SURVEY CONDUCTED BY DALLAS AERIAL SURVEY, INC. IN NOVEMBER, 2020 AND EXISTING TOPOGRAPHY BY BLACK & VEATCH CORPORATION DATED APRIL 2006. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLAN COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD83) 1983.
2. THIS DRAWING DEPICTS A HYPOTHETICAL SCNEARIO DURING FILLING FOR MANAGEMENT OF CONTACT WATER AND DIVERSION OF STORMWATER AWAY FROM EXPOSED ASH AREAS. CALCULATIONS FOR DIVERSION BERMS ARE SHOWN IN APPENDIX IV.D3.

STATE OF TEXAS
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Brett DeVries 10/14/21

FOR REGISTRATION PURPOSES ONLY

REV	DATE	DESCRIPTION	BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: EXAMPLE INTERIM STORMWATER/ CONTACT WATER MANAGEMENT PLAN

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

CLIENT: SANDY CREEK SERVICES, LLC
2161 RATTLESNAKE ROAD
RIESEL, TEXAS 76682

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

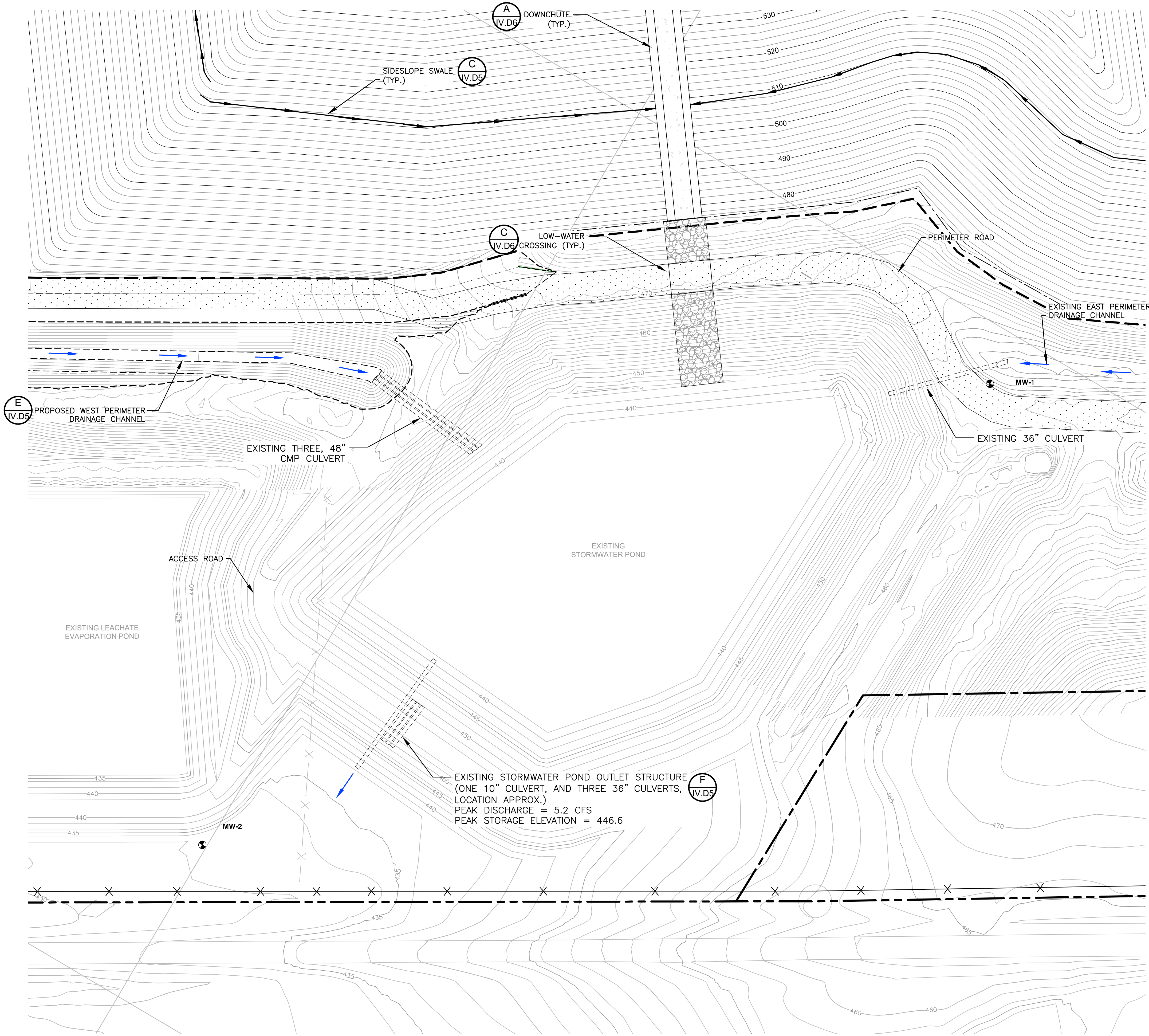
PROJ. NO. 16221059.00 | DWN. BY: AGA | CHK. BY: SS | DSN. BY: BJD | Q/A RVW BY: SS | APP. BY: BJD

CADD FILE: INTERIM CELL 3 - PHASE 2 - CONTACT WATER PLAN

DATE: 9/2021

SCALE: AS SHOWN

DRAWING NO. **IV.D3**



0 50 100
SCALE IN FEET

LEGEND

- EXISTING CONTOURS (SEE NOTE 1)
- PLANT PROPERTY BOUNDARY
- LANDFILL REGISTRATION BOUNDARY
- REGISTERED LIMITS OF WASTE
- MW-1 EXISTING GROUNDWATER MONITORING WELL
- 450 PROPOSED FINAL COVER CONTOUR
- PROPOSED DRAINAGE SWALES
- PROPOSED DOWNCHUTES
- CHANNEL FLOW DIRECTION
- EXISTING FENCE
- PERIMETER ROAD

NOTES:

1. THE EXISTING CONTOUR MAP SHOWN ON THIS DRAWING WAS COMPILED FROM AN AERIAL SURVEY CONDUCTED BY DALLAS AERIAL SURVEY, INC. IN NOVEMBER, 2020 AND EXISTING TOPOGRAPHY BY BLACK & VEATCH CORPORATION DATED APRIL 2006. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLAN COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD83) 1983.

STATE OF TEXAS
BRETT J. DeVRIES
128061
LICENSED
PROFESSIONAL ENGINEER
Brett DeVries 10/4/21

FOR REGISTRATION PURPOSES ONLY

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: EXISTING STORMWATER POND PLAN

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

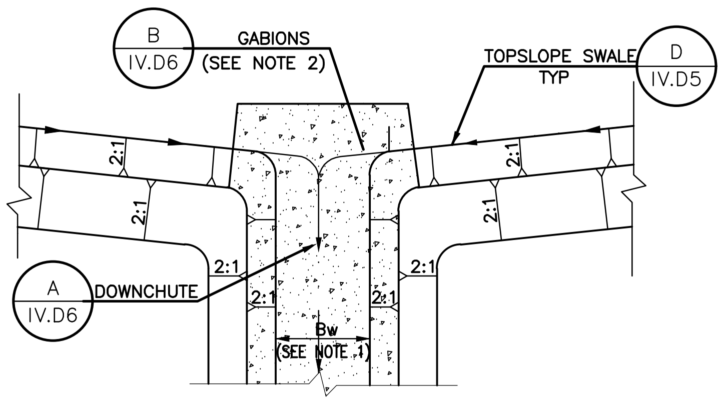
CLIENT: SANDY CREEK SERVICES, LLC
2161 RATTLESNAKE ROAD
RIESEL, TEXAS 76682

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS, INC.
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16221059.00 | DWN. BY: AGA | Q/A RVW BY: SS
DSN. BY: BJD | CHK. BY: SS | APP. BY: BJD

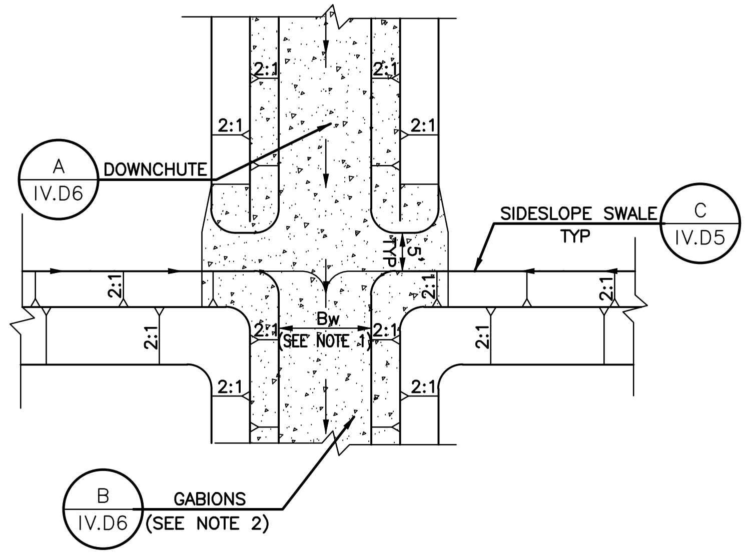
CADD FILE: INTERIM DRAINAGE DESIGN (CELLS 1 – 3)
DATE: 9/2021
SCALE: AS SHOWN
DRAWING NO. IV.D4

10/26/2021 7:06 PM G:\SANDY CREEK\16221059.00 TCEQ Registration\DWG\Interim Drainage Design (Cells 1 – 3)



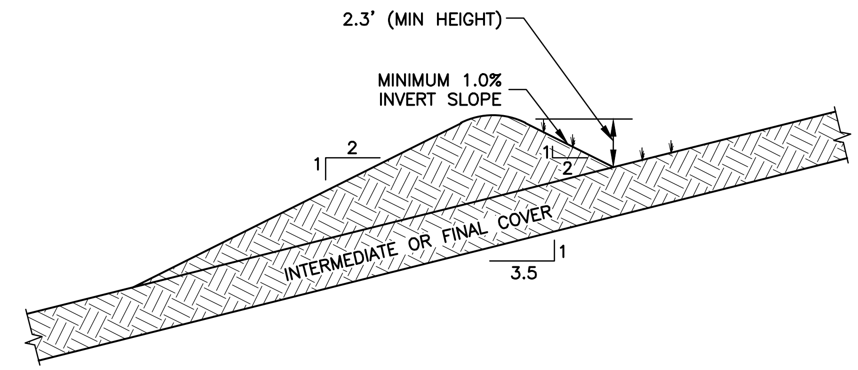
SWALE/DOWNCHUTE CONFLUENCE (A / IV.D5)

NTS



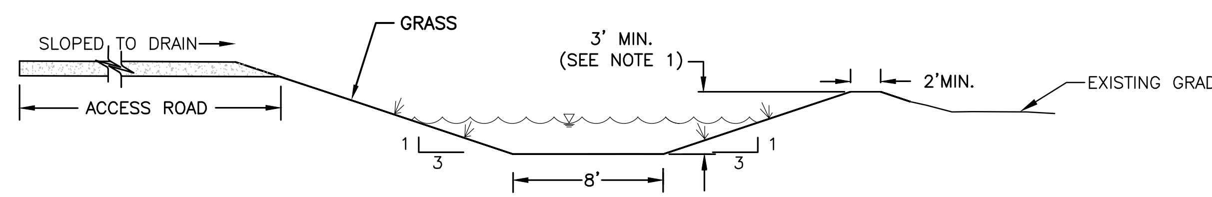
SWALE/DOWNCHUTE CONFLUENCE (B / IV.D5)

NTS



SIDESLOPE SWALE (C / IV.D5)

NTS

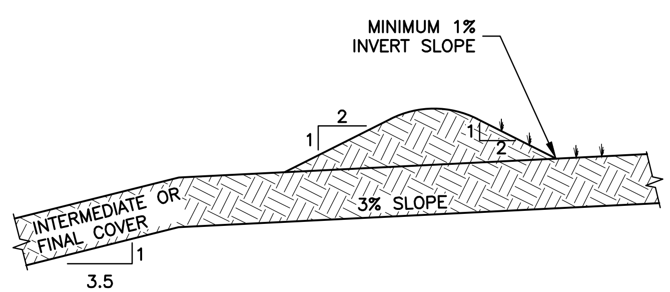


NOTE:

1. DESIGNED DRAINAGE CHANNEL DEPTH WILL INCLUDE MINIMUM 1-FOOT FREEBOARD ABOVE D_{25} (DEPTH AT 25-YEAR, 24 HOUR STORM EVENT), AS PRESENTED IN APPENDIX IV.D1.

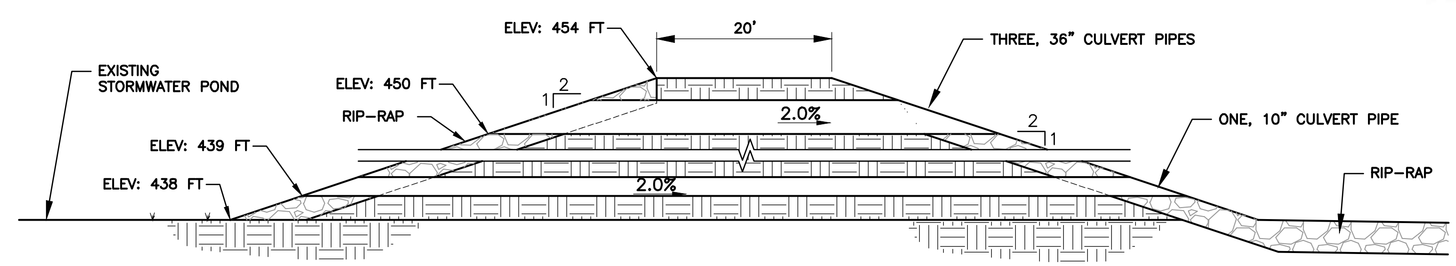
DRAINAGE CHANNEL (E / IV.D5)

NTS



TOPSLOPE SWALE (D / IV.D5)

NTS



EXISTING STORMWATER POND OUTLET STRUCTURE (F / IV.D5)

NTS

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TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: SURFACE WATER DRAINAGE DETAILS - 1

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

CLIENT: SANDY CREEK SERVICES, LLC 2161 RATTLESNAKE ROAD RIESEL, TEXAS 76682

SCS ENGINEERS
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PROJ. NO. 16221059.00 | DSN. BY: BJD | DRN. BY: AGA | CHK. BY: SS | Q/A RVW BY: SS | APP. BY: BJD

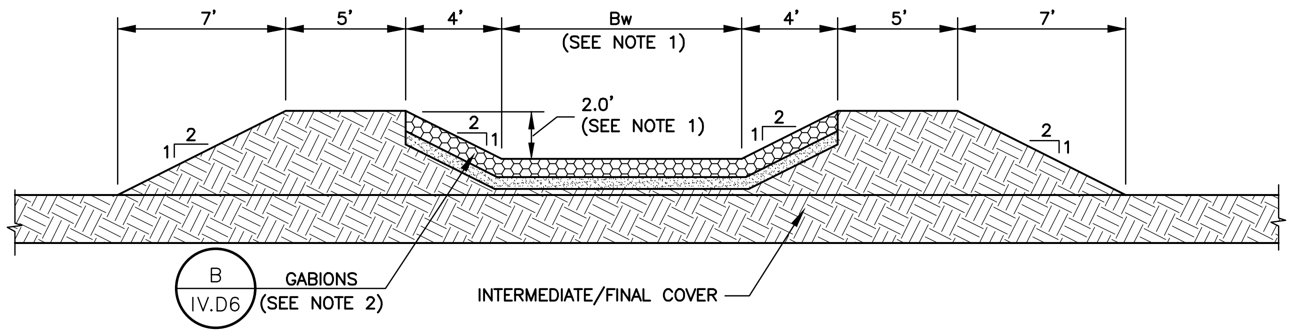
CADD FILE: DRAINAGE - LEACH AND CONT WATER PLAN

DATE: 9/2021

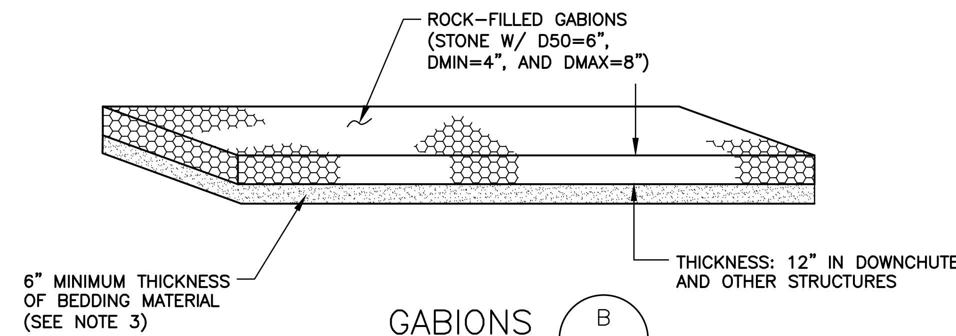
SCALE: AS SHOWN

DRAWING NO. **IV.D5**

10/26/2021 6:55 PM G:\SANDY CREEK\16221059.00 TCEQ Registration\DWG\Drainage - Leach and Cont Water Plan



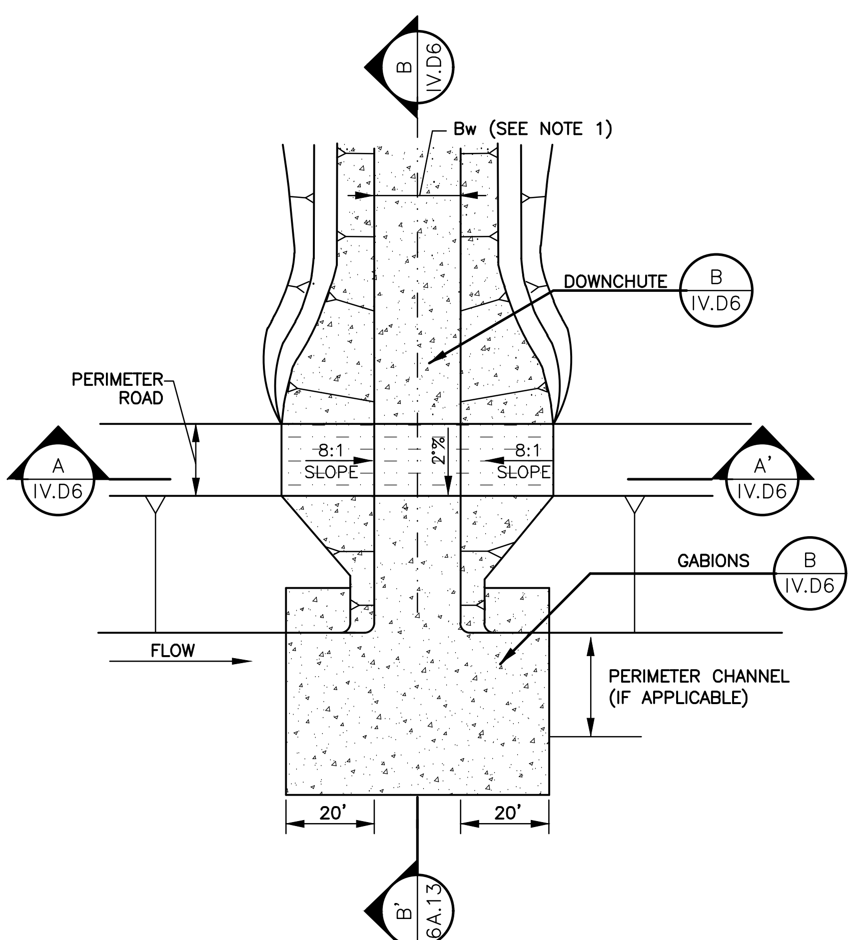
DOWNCHUTE (A / IV.D6)
NTS



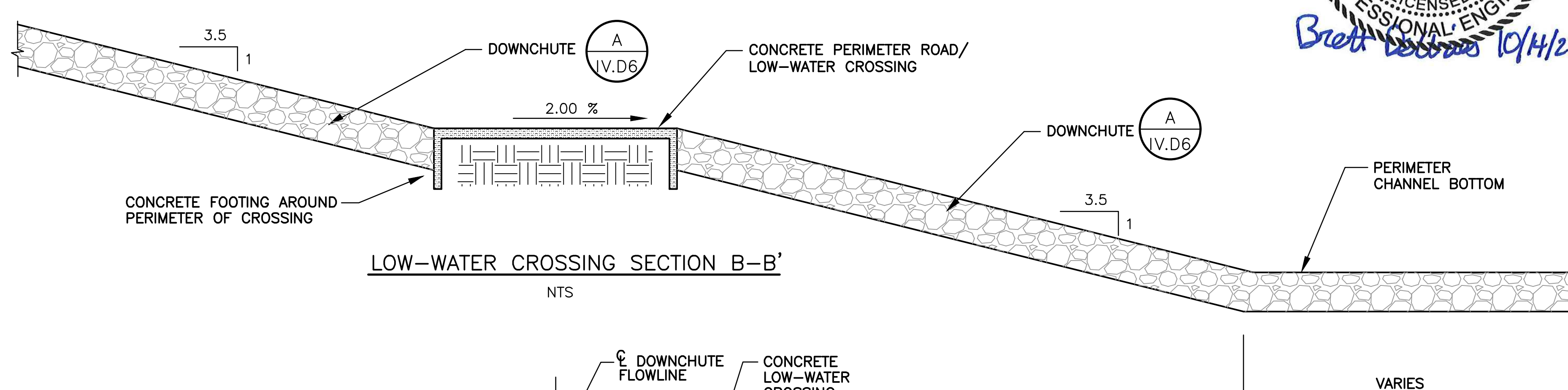
GABIONS (B / IV.D6)
NTS

NOTES, DETAILS A – C:

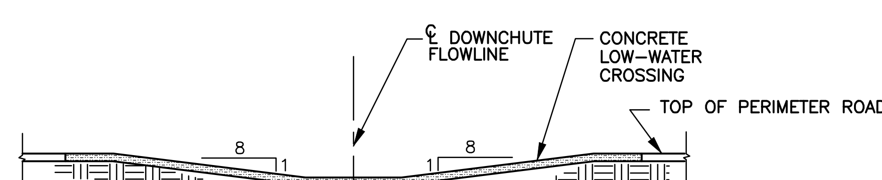
1. DESIGN OF DOWNCHUTES IS PRESENTED IN APPENDIX IV.D3. DOWNCHUTES WILL BE CONSTRUCTED WITH A MINIMUM BOTTOM WIDTH, Bw, OF 15' FOR FINAL COVER. TYPICAL DOWNCHUTE DEPTH IS 2 FEET FOR INDIVIDUAL DOWNCHUTES ON FINAL COVER. FINAL DEPTHS TO BE DETERMINED DURING CLOSURE DESIGN.
2. DOWNCHUTES INSTALLED ON INTERMEDIATE COVER WILL BE LINED WITH GABIONS, RIP RAP, TRM OR FLEXIBLE MEMBRANE LINER; DOWNCHUTES INSTALLED ON FINAL COVER WILL BE LINED WITH GABIONS.
3. BEDDING MATERIAL WILL CONSIST OF A COARSE SAND OR FINE CRUSHED STONE.
4. LOW WATER CROSSINGS ONLY WILL BE INSTALLED AT LOCATIONS WHERE VEHICLE CROSSING OF DOWNCHUTE IS NECESSARY.



LOW-WATER CROSSING (C / IV.D6)
NTS



LOW-WATER CROSSING SECTION B-B'
NTS



LOW-WATER CROSSING SECTION A-A'
NTS

STATE OF TEXAS
BRETT J. DeVRIES
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PROFESSIONAL ENGINEER
Brett DeVries 10/14/21

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10/26/2021 6:55 PM G:\SANDY CREEK\16221059.00 TCEQ Registration\DWG\Drainage - Leach and Cont Water Plan

REV. | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: SURFACE WATER DRAINAGE DETAILS - 2

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

CLIENT: SANDY CREEK SERVICES, LLC 2161 RATTLESNAKE ROAD RIESEL, TEXAS 76682

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
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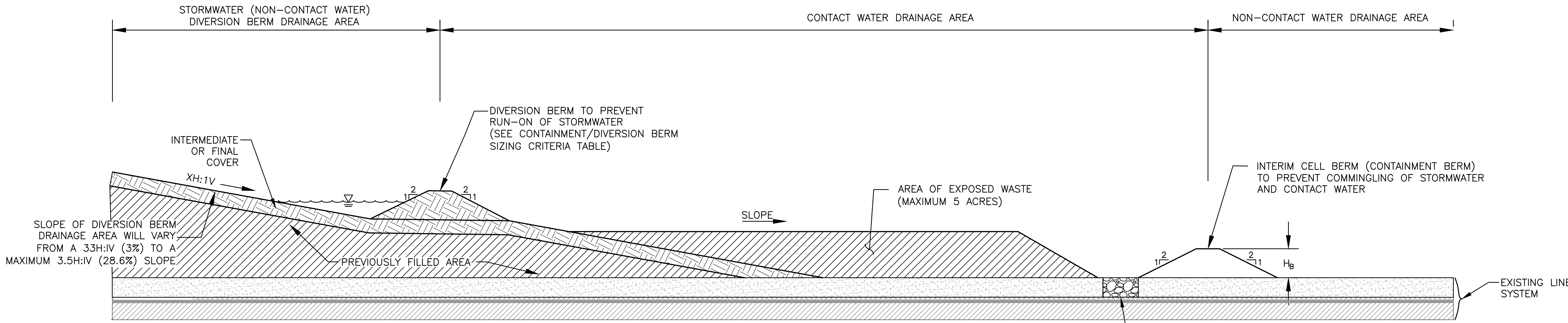
PROJ. NO. 16221059.00 | DSN. BY: BJD | DWN. BY: AGA | CHK. BY: SS | Q/A RVW BY: SS | APP. BY: BJD

CADD FILE: DRAINAGE – LEACH AND CONT WATER PLAN

DATE: 9/2021

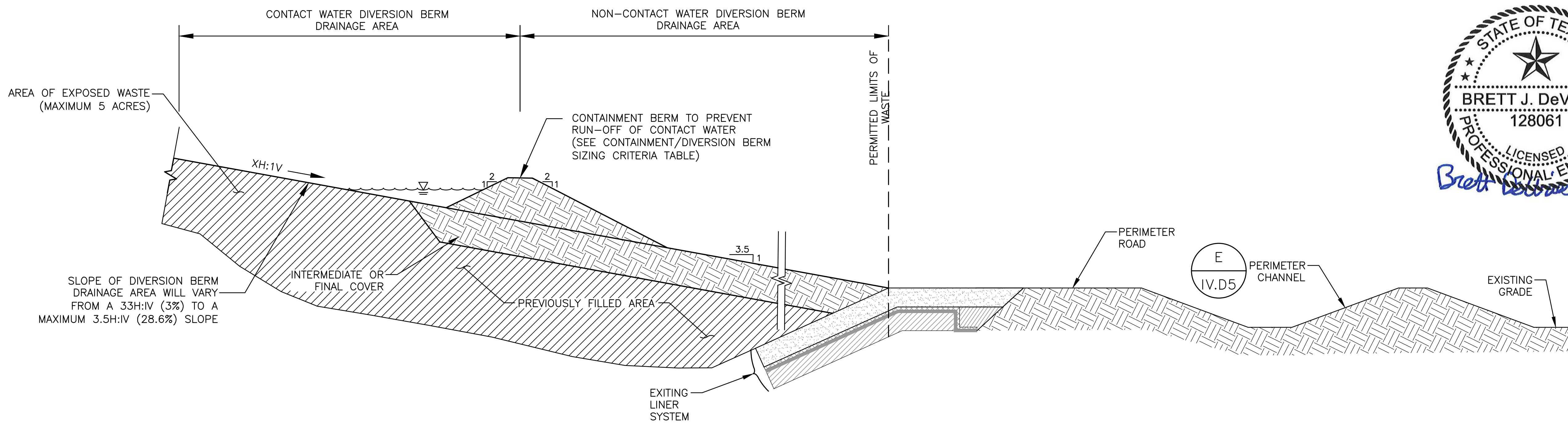
SCALE: AS SHOWN

DRAWING NO. IV.D6



DIVERSION BERM (A / IV.D7)

NTS

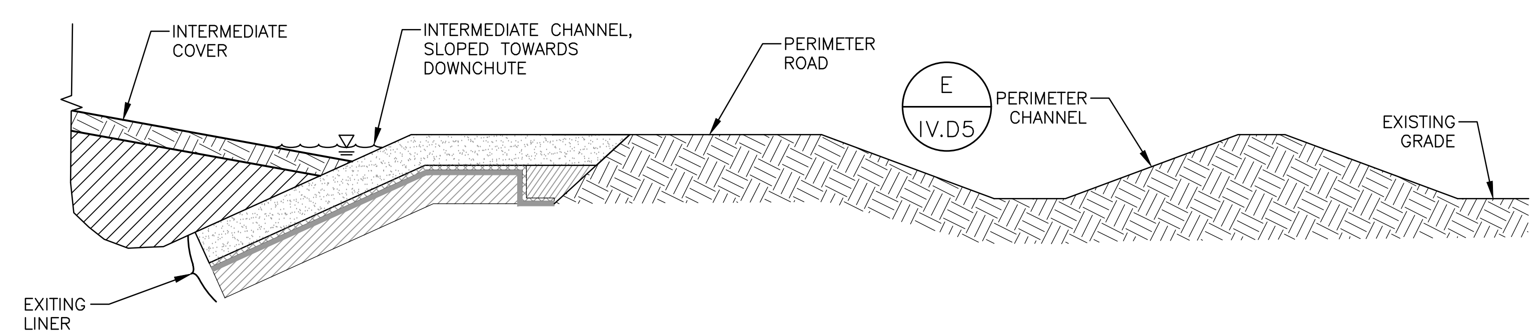


CONTAINMENT BERM (B / IV.D7)

NTS

CONTAINMENT/DIVERSION BERM SIZING CRITERIA *						
DIVERSION BERM DRAINAGE AREA (ACRES)	MINIMUM 3%			MAXIMUM 28.6%		
	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)
0.5	1.9	0.3	1.3	1.9	0.5	1.5
1.0	3.9	0.4	1.4	3.9	0.7	1.7
2.0	7.7	0.5	1.5	7.7	0.9	1.9
5.0	19.4	0.6	1.6	19.4	1.3	2.3
8.0	31.0	0.8	1.8	31.0	1.5	2.5

* CONTAINMENT/DIVERSION BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDELINE TO PREVENT RUN-ON OF STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. SUPPORTING CALCULATIONS ARE INCLUDED ON THE CONTAINMENT AND DIVERSION BERM SUMMARY SHEET IN APPENDIX IV.D3 (TABLE 2).



PERIMETER STORMWATER MANAGEMENT DETAIL (C / IV.D7)

NTS

FOR REGISTRATION PURPOSES ONLY

STATE OF TEXAS — BRETT J. DeVRIES — 128061 — LICENSED PROFESSIONAL ENGINEER

Brett DeVries 10/14/21

REV | DATE | DESCRIPTION | BY

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: CONTACT WATER MANAGEMENT DETAILS

PROJECT TITLE: SANDY CREEK ENERGY STATION SOLID WASTE DISPOSAL FACILITY TCEQ REGISTRATION APPLICATION

CLIENT: SANDY CREEK SERVICES, LLC 2161 RATTLESNAKE ROAD RIESEL, TEXAS 76682

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
1901 CENTRAL DRIVE, SUITE 550, BEDFORD, TX 76021
PH (817) 571-2288 FAX NO. (817) 571-2188

PROJ. NO. 16221059.00 | DSN. BY: BJD | DWN. BY: AGA | CHK. BY: SS | Q/A RVW BY: SS | APP. BY: BJD

CADD FILE: DRAINAGE – LEACH AND CONT WATER PLAN

DATE: 9/2021

SCALE: AS SHOWN

DRAWING NO. **IV.D7**

10/26/2021 6:55 PM G:\SANDY CREEK\16221059.00 TCEQ Registration\DWG\Drainage – Leach and Cont Water Plan

APPENDIX IV.D1

HYDRAFLOW HYDROGRAPH MODEL INPUT PARAMETERS

- Precipitation Data
- SCS Curve Numbers
- Manning's Coefficients
- Post-Closure Drainage Area Conditions
- Post-Closure Drainage Channels

SCS Engineers
TBPE Reg. # F-3407

PRECIPITATION DATA

NOAA Atlas 14, Volume 11, Version 2
Location name: Riesel, Texas, USA*
Latitude: 31.4743°, Longitude: -96.9592°
Elevation: 480.95 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point 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	0.428 (0.324-0.565)	0.501 (0.383-0.655)	0.621 (0.473-0.816)	0.721 (0.541-0.960)	0.859 (0.624-1.18)	0.966 (0.684-1.36)	1.08 (0.742-1.55)	1.19 (0.801-1.76)	1.35 (0.876-2.06)	1.47 (0.932-2.31)
10-min	0.682 (0.516-0.901)	0.800 (0.610-1.05)	0.992 (0.755-1.30)	1.15 (0.865-1.53)	1.38 (1.00-1.89)	1.55 (1.10-2.18)	1.72 (1.19-2.49)	1.90 (1.28-2.82)	2.14 (1.39-3.28)	2.33 (1.47-3.65)
15-min	0.861 (0.652-1.14)	1.01 (0.768-1.32)	1.24 (0.946-1.63)	1.44 (1.08-1.92)	1.71 (1.25-2.35)	1.92 (1.36-2.71)	2.14 (1.48-3.09)	2.37 (1.59-3.50)	2.68 (1.74-4.09)	2.92 (1.85-4.57)
30-min	1.21 (0.915-1.60)	1.41 (1.08-1.85)	1.74 (1.32-2.28)	2.01 (1.51-2.68)	2.39 (1.73-3.27)	2.68 (1.89-3.76)	2.97 (2.05-4.29)	3.29 (2.21-4.87)	3.73 (2.42-5.70)	4.07 (2.58-6.38)
60-min	1.57 (1.19-2.07)	1.84 (1.40-2.40)	2.27 (1.73-2.99)	2.64 (1.98-3.51)	3.15 (2.28-4.30)	3.53 (2.50-4.97)	3.94 (2.72-5.68)	4.38 (2.94-6.48)	4.99 (3.24-7.64)	5.49 (3.47-8.59)
2-hr	1.90 (1.45-2.48)	2.26 (1.73-2.91)	2.83 (2.17-3.67)	3.31 (2.51-4.37)	4.01 (2.93-5.43)	4.55 (3.24-6.33)	5.12 (3.56-7.31)	5.76 (3.89-8.41)	6.65 (4.34-10.0)	7.37 (4.68-11.4)
3-hr	2.08 (1.60-2.71)	2.50 (1.92-3.19)	3.16 (2.43-4.08)	3.73 (2.84-4.89)	4.55 (3.35-6.13)	5.20 (3.72-7.20)	5.90 (4.11-8.36)	6.68 (4.52-9.68)	7.77 (5.08-11.7)	8.66 (5.52-13.3)
6-hr	2.41 (1.86-3.10)	2.94 (2.27-3.69)	3.74 (2.90-4.77)	4.45 (3.41-5.78)	5.49 (4.07-7.33)	6.34 (4.57-8.68)	7.26 (5.08-10.2)	8.28 (5.64-11.9)	9.75 (6.40-14.4)	11.0 (7.00-16.6)
12-hr	2.74 (2.13-3.49)	3.37 (2.61-4.17)	4.32 (3.38-5.45)	5.17 (4.00-6.64)	6.43 (4.81-8.49)	7.47 (5.42-10.1)	8.62 (6.07-11.9)	9.91 (6.78-14.0)	11.8 (7.78-17.2)	13.4 (8.58-20.0)
24-hr	3.09 (2.43-3.90)	3.83 (2.99-4.69)	4.94 (3.90-6.17)	5.94 (4.63-7.55)	7.42 (5.58-9.68)	8.63 (6.30-11.5)	9.99 (7.08-13.6)	11.5 (7.93-16.1)	13.8 (9.16-19.9)	15.8 (10.1-23.2)
2-day	3.47 (2.76-4.34)	4.33 (3.44-5.28)	5.65 (4.51-7.00)	6.81 (5.35-8.57)	8.49 (6.42-10.9)	9.82 (7.20-13.0)	11.3 (8.06-15.3)	13.0 (9.02-18.0)	15.6 (10.4-22.3)	17.9 (11.5-25.9)
3-day	3.77 (3.01-4.68)	4.69 (3.75-5.71)	6.13 (4.92-7.55)	7.38 (5.83-9.23)	9.16 (6.95-11.7)	10.6 (7.77-13.8)	12.1 (8.65-16.2)	13.9 (9.65-19.0)	16.6 (11.1-23.5)	18.9 (12.2-27.2)
4-day	4.03 (3.23-4.99)	4.99 (4.02-6.06)	6.50 (5.24-7.98)	7.80 (6.18-9.71)	9.64 (7.34-12.3)	11.1 (8.18-14.4)	12.7 (9.07-16.9)	14.5 (10.1-19.7)	17.2 (11.5-24.1)	19.5 (12.6-27.9)
7-day	4.71 (3.80-5.77)	5.72 (4.64-6.90)	7.32 (5.94-8.91)	8.68 (6.93-10.7)	10.6 (8.14-13.4)	12.1 (9.01-15.7)	13.8 (9.92-18.2)	15.6 (10.9-21.0)	18.3 (12.3-25.3)	20.5 (13.3-28.9)
10-day	5.26 (4.27-6.42)	6.32 (5.16-7.60)	7.99 (6.52-9.69)	9.42 (7.55-11.6)	11.4 (8.80-14.3)	13.0 (9.69-16.7)	14.7 (10.6-19.2)	16.5 (11.6-22.1)	19.1 (12.9-26.3)	21.3 (13.9-29.8)
20-day	6.86 (5.61-8.28)	8.05 (6.67-9.65)	10.0 (8.25-12.0)	11.6 (9.41-14.1)	13.9 (10.7-17.2)	15.5 (11.7-19.7)	17.3 (12.6-22.3)	19.1 (13.5-25.2)	21.6 (14.6-29.3)	23.6 (15.4-32.6)
30-day	8.18 (6.73-9.81)	9.48 (7.92-11.3)	11.7 (9.69-13.9)	13.4 (10.9-16.2)	15.8 (12.3-19.5)	17.6 (13.2-22.1)	19.3 (14.1-24.8)	21.2 (15.0-27.7)	23.6 (16.0-31.7)	25.4 (16.7-34.8)
45-day	10.1 (8.36-12.0)	11.5 (9.73-13.8)	14.0 (11.7-16.7)	16.0 (13.0-19.1)	18.5 (14.5-22.6)	20.4 (15.4-25.4)	22.1 (16.2-28.2)	23.9 (17.0-31.1)	26.3 (17.9-35.0)	28.0 (18.4-38.1)
60-day	11.8 (9.84-14.1)	13.4 (11.4-16.0)	16.1 (13.5-19.1)	18.2 (14.9-21.7)	20.9 (16.4-25.4)	22.8 (17.3-28.3)	24.6 (18.1-31.2)	26.4 (18.7-34.1)	28.7 (19.5-38.0)	30.3 (20.0-40.9)

[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.

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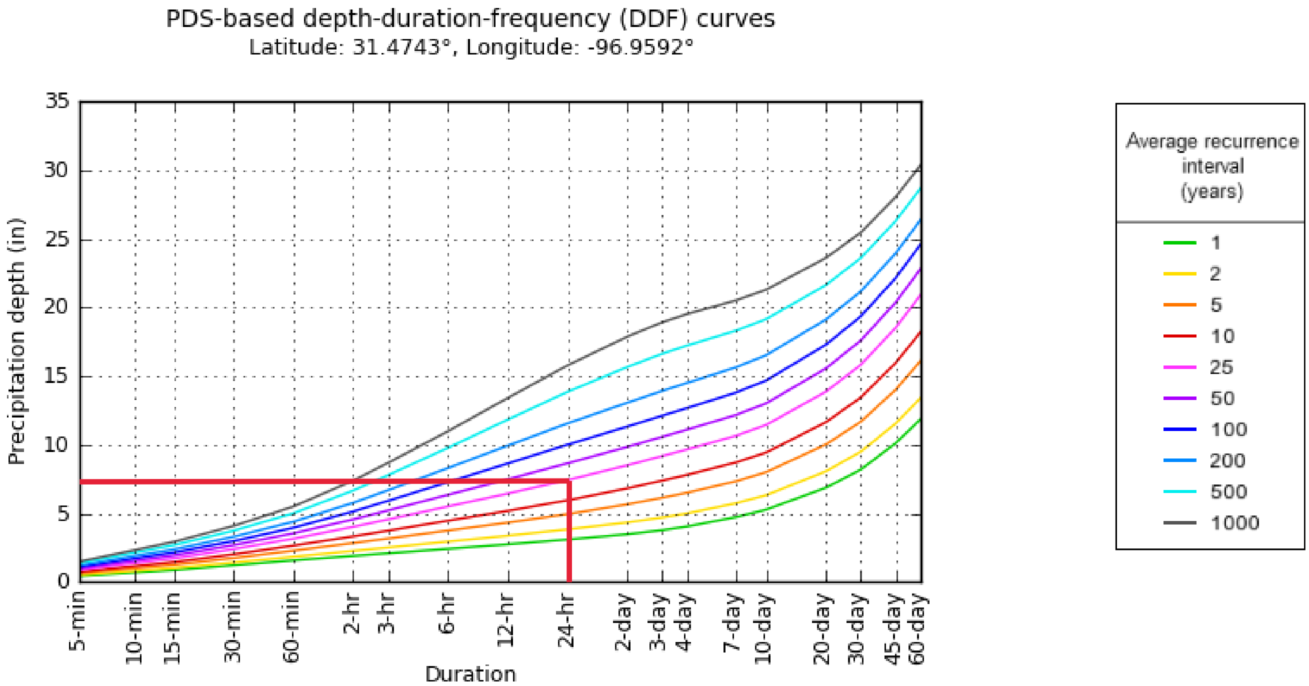
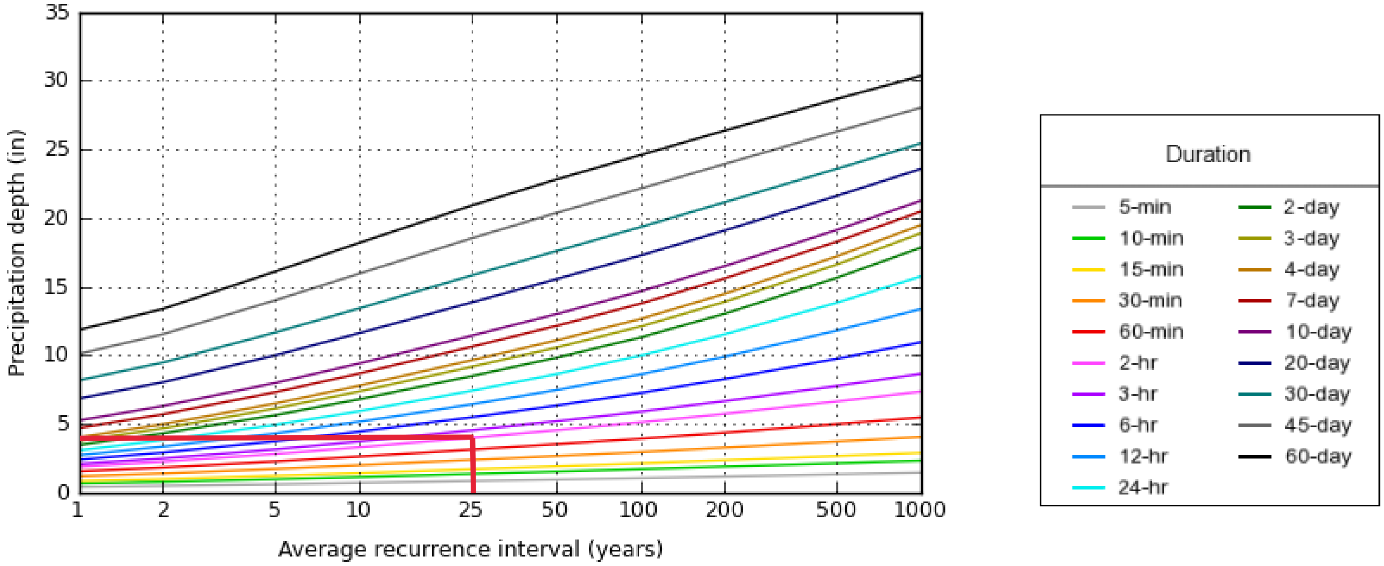
PF graphical





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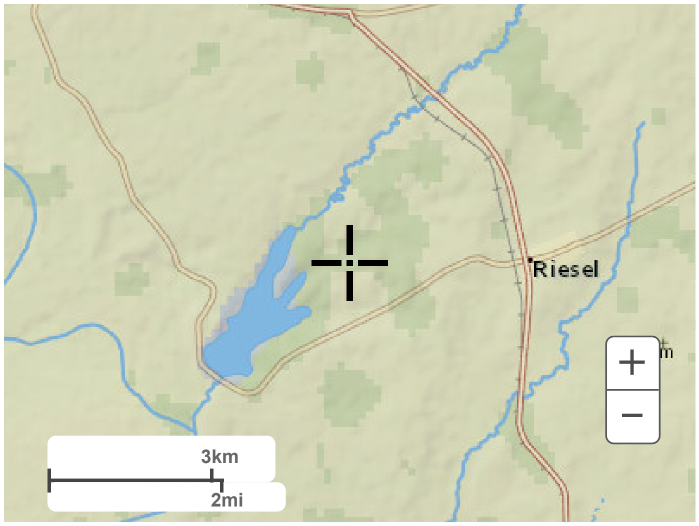
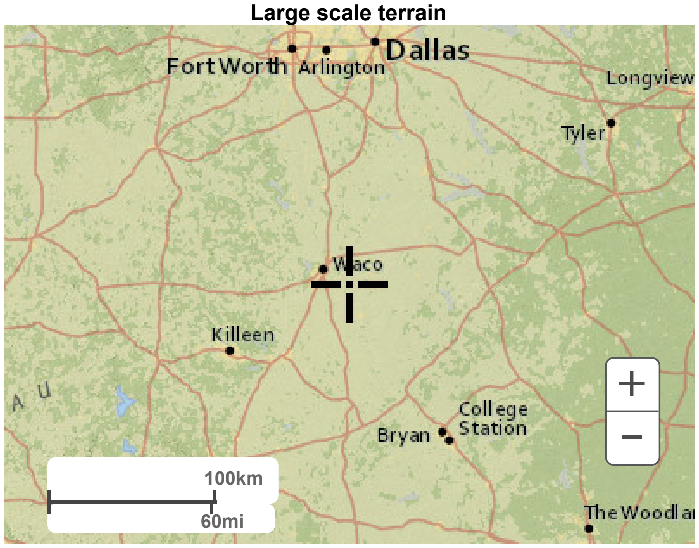
Maps & aerials

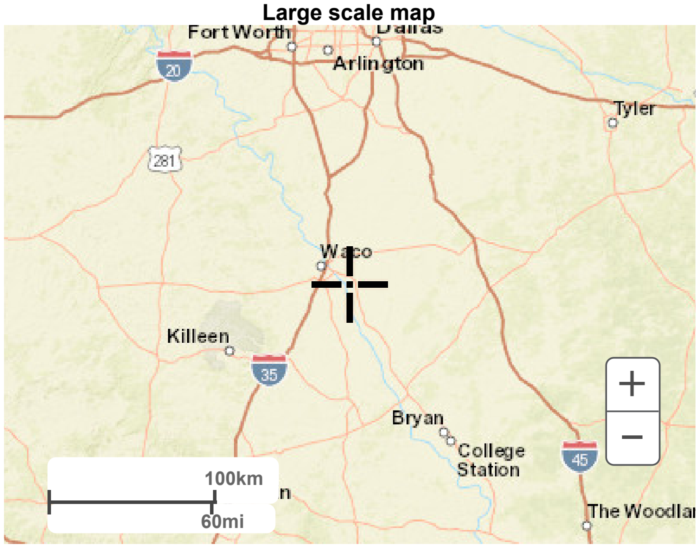
Small scale terrain



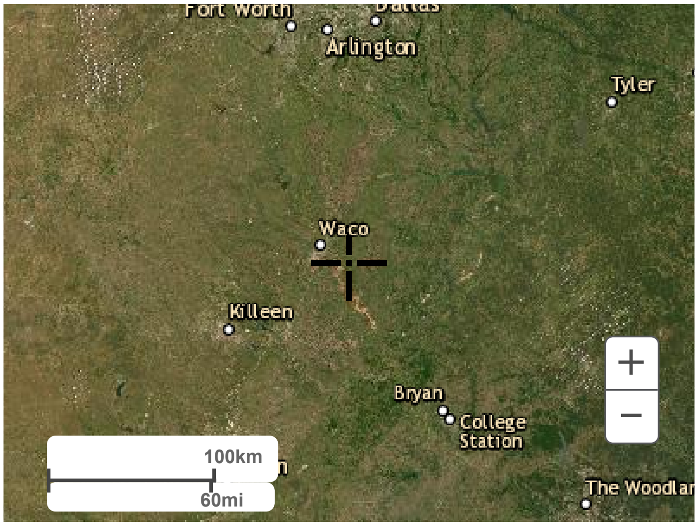
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
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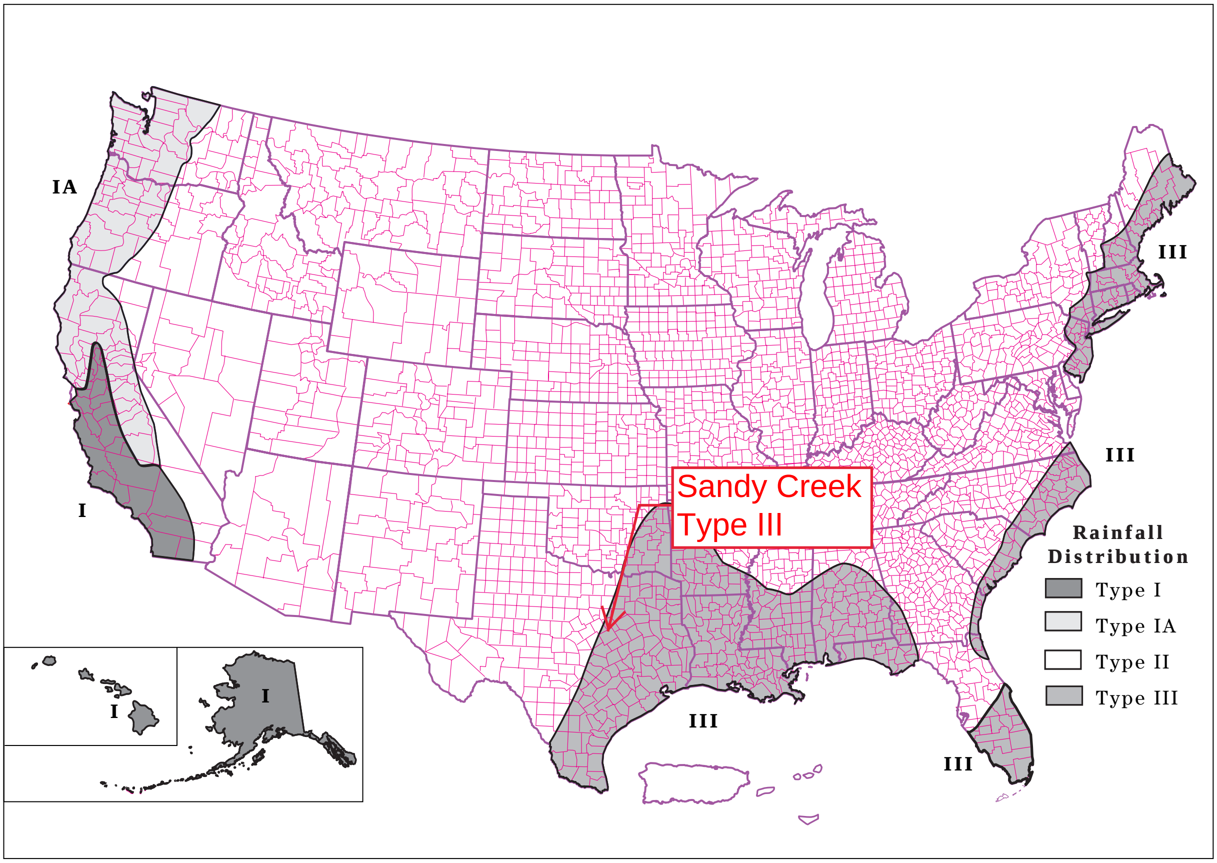
Figure B-2 Approximate geographic boundaries for NRCS (SCS) rainfall distributions



Rainfall data sources

This section lists the most current 24-hour rainfall data published by the National Weather Service (NWS) for various parts of the country. Because NWS Technical Paper 40 (TP-40) is out of print, the 24-hour rainfall maps for areas east of the 105th meridian are included here as figures B-3 through B-8. For the area generally west of the 105th meridian, TP-40 has been superseded by NOAA Atlas 2, the Precipitation-Frequency Atlas of the Western United States, published by the National Ocean and Atmospheric Administration.

East of 105th meridian

Hershfield, D.M. 1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 40. Washington, DC. 155 p.

West of 105th meridian

Miller, J.F., R.H. Frederick, and R.J. Tracey. 1973. Precipitation-frequency atlas of the Western United States. Vol. I Montana; Vol. II, Wyoming; Vol III, Colorado; Vol. IV, New Mexico; Vol V, Idaho; Vol. VI, Utah; Vol. VII, Nevada; Vol. VIII, Arizona; Vol. IX, Washington; Vol. X, Oregon; Vol. XI, California. U.S. Dept. of Commerce, National Weather Service, NOAA Atlas 2. Silver Spring, MD.

Alaska

Miller, John F. 1963. Probable maximum precipitation and rainfall-frequency data for Alaska for areas to 400 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. of Commerce, Weather Bur. Tech. Pap. No. 47. Washington, DC. 69 p.

Hawaii

Weather Bureau. 1962. Rainfall-frequency atlas of the Hawaiian Islands for areas to 200 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 43. Washington, DC. 60 p.

Puerto Rico and Virgin Islands

Weather Bureau. 1961. Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands for areas to 400 square miles, durations to 24 hours, and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 42. Washington, DC. 94 P.

SCS CURVE NUMBERS

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Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

TR-55

Table 2-2a Runoff curve numbers for urban areas [1/]

Cover description: Cover type and hydrologic condition	Average percent impervious area [2/]	Curve numbers for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3/]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		[illegible]	[illegible]	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4/]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5/]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

Final Cover and Surrounding Drainage Areas
CN = 80

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

MANNING'S COEFFICIENTS

Sandy Creek Energy Station
Solid Waste Disposal Facility
Hydraulic Analysis Manning's "n"
References

Post-closure Conditions

Description	Use	Reference	Mannings "n"
Drainage swales, short grass and some weeds, established channels.	Hydraflow Hydrographs Extension model for swales	See Item 3, Table 4.1, "Design Hydrology and Sedimentology for Small Catchments", Haan et al.	0.027
Downchutes, gabion or rip rap lined, established channels.	Hydraflow Hydrographs Extension model for downchutes	See Item 4, Table 4.1, "Design Hydrology and Sedimentology for Small Catchments", Haan et al.	0.033
Drainage Channels, short grass and some weeds, established channels	Hydraflow Hydrographs Extension model for routing reaches.	See Item 3, Table 4.1, "Design Hydrology and Sedimentology for Small Catchments", Haan et al.	0.027
Drainage Channels, rip rap or TRM lined, established channels.	N/A	See Item 4, Table 4.1, "Design Hydrology and Sedimentology for Small Catchments", Haan et al.	0.033

Note: Manning's "n" used for drainage swales, downchutes, and channels were incorporated into Hydraflow Hydrographs Extension for Autodesk Civil 3D, as well as the Hydraulic Analysis using Hydraflow Express Extension for Autodesk Civil 3D.
Reference: C.T. Haan, B.J. Barfield, J.C. Hayes. *Design Hydrology and Sedimentology for Small Catchments*. Academic Press. 1994.

Design Hydrology and Sedimentology for Small Catchments

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An Irish engineer named Manning found that the equation

$$v = KR^{2/3}S^{1/2}$$

fit experimental data quite nicely. This equation is known as Manning's equation and differs from Chezy's equation only in the exponent on R. So that the factor related to the channel roughness would increase as roughness increased, Manning's equation is generally written as

$$v = (1/n)R^{2/3}S^{1/2}$$

in the metric system with v in meters per second and R in meters. The coefficient n is known as Manning's n. In the English system of units, Manning's equation is

$$v = \frac{1.49}{n}R^{2/3}S^{1/2}, \qquad (4.23)$$

where v is in fps, R is in feet, and S is in feet per foot. Tables of Manning's n are widely available. Table 4.1 is such a table taken from several sources, drawing heavily on Schwab *et al.* (1966, 1971). Manning's n is influenced by many factors, including the physical roughness of the channel surface, the irregularity of the channel cross section, channel alignment and bends, vegetation, silting and scouring, and obstruction within the channel. Chow (1959) displays some photographs of typical channels and the associated values for Manning's n.

Figure 4.9 contains some useful relationships for calculating the hydraulic properties of A, P, R, and top width, T, for three common channels. For natural channels, these properties are best determined from measurements based on the actual cross sections of the channel.

Table 4.1 Typical Values for Manning's n

Type and description of conduits	n Values[a] Min.	Design	Max.
Channels, lined			
Asphaltic concrete, machine placed		0.014	
Asphalt, exposed prefabricated		0.015	
Concrete	0.012	0.015	0.018
Concrete, rubble	0.016		0.029
Metal, smooth (flumes)	0.011		0.015
Metal, corrugated	0.021	0.024	0.026
Plastic	0.012		0.014
Shotcrete	0.016		0.017
Wood, planed (flumes)	0.009	0.012	0.016
Wood, unplaned (flumes)	0.011	0.013	0.015
Channels, earth			
Earth bottom, rubble sides	0.028	0.032	0.035
Drainage ditches, large, no vegetation			
(a) < 2.5 hydraulic radius	0.040		0.045
(b) 2.5–4.0 hydraulic radius	0.035		0.040
(c) 4.0–5.0 hydraulic radius	0.030		0.035
(d) > 5.0 hydraulic radius	0.025		0.030
Small drainage ditches	0.035	0.040	0.040
Stony bed, weeds on bank	0.025	0.035	0.040
Straight and uniform	0.017	0.0225	0.025
Winding, sluggish	0.0225	0.025	0.030
Channels, vegetated			
(See subsequent discussion)			

Type and description of conduits	n Values[a] Min.	Design	Max.
Natural Streams			
(3) (a) Clean, straight bank, full stage, no rifts or deep pools	0.025	0.027	0.033
(2) (b) Same as (a) but some weeds and stones	0.030		0.040
(1) (c) Winding, some pools and shoals, clean	0.035	0.040	0.050
(d) Same as (c), lower stages, more ineffective slopes and sections	0.040		0.055
(e) Same as (c), some weeds and stones	0.033		0.045
(f) Same as (d), stony sections	0.045		0.060
(g) Sluggish river reaches, rather weedy or with very deep pools	0.050		0.080
(h) Very weedy reaches	0.075		0.150
Pipe			
Asbestos cement		0.009	
Cast iron, coated	0.011	0.013	0.014
Cast iron, uncoated	0.012		0.015
Clay or concrete drain tile (4–12 in.)	0.010	0.0108	0.020
Concrete	0.010	0.014	0.017
Metal, corrugated	0.021	0.025	0.0255
Steel, riveted and spiral	0.013	0.016	0.017
Vitrified sewer pipe	0.010	0.014	0.017
Wood stave	0.010	0.013	
Wrought iron, black	0.012		0.015
Wrought iron, galvanized	0.013	0.016	0.017

[a] Selected from numerous sources.

Urban Hydrology for Small Watersheds

TR-55

United States Department of Agriculture

Natural Resources Conservation Service

Conservation Engineering Division

Technical Release 55

June 1986

Revision 0

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Post-Closure, landfill final cover
Grass: Short grass prairie n = 0.15 Post-Development, landfill final cover.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}\, s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation.

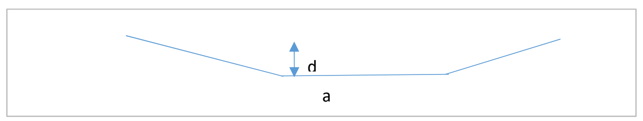
POST-CLOSURE DRAINAGE AREA CONDITIONS

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
POST-CLOSURE DRAINAGE AREA

2-yr, 24-hr Rainfall Depth = 3.83 inches

Hyd. No.	Contributing Drainage Areas	Area (acres)	Curve Number (CN)	Sheet Flow				Shallow Concentrated Flow (Swales)				Open Channel Flow								Time of Concentration (Tc)			
				Surface Description	Length (feet)	Slope (ft/ft)	Manning n	Surface Description	Length (feet)	Slope (ft/ft)	Avg. Velocity (ft/s)	Surface Description	Length (feet)	Slope (ft/ft)	Manning n	Cross-sectional Area (ft2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Avg. Velocity (ft/s)	Sheet Flow T_c (min)	Shallow Concentrated Flow T_c (min)	Channel Flow T_c (min)	Total T_c (min)
1	DA-1A	8.5	80.0	Grass	160	0.286	0.15	Grass	860	0.010	4.0	Grass	430	0.286	0.033	4.8	16.4	0.3	10.7	5	4	1	9
2	DA-1B	1.2	80.0	Grass	125	0.030	0.15	Grass	240	0.010	4.0	-	-	-	-	-	-	-	-	9	1	-	10
3	DA-1C	1.2	80.0	Grass	140	0.286	0.15	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	4
5	DA-1D	5.4	80.0	Grass	175	0.286	0.15	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	5
8	DA-2A	7.9	80.0	Grass	175	0.286	0.15	Grass	570	0.010	4.0	Grass	550	0.286	0.033	4.8	16.4	0.3	10.7	5	2	1	8
9	DA-2B	1.1	80.0	Grass	125	0.030	0.15	Grass	295	0.010	4.0	-	-	-	-	-	-	-	-	9	1	-	10
10	DA-2C	10.3	80.0	Grass	150	0.286	0.15	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	4
12	DA-2D	4.7	80.0	Grass	175	0.286	0.15	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	5
15	DA-3A	4.9	80.0	Grass	175	0.286	0.15	Grass	330	0.010	4.0	Grass	290	0.286	0.033	3.2	15.9	0.2	8.3	5	1	1	7
16	DA-3B	0.4	80.0	Grass	125	0.030	0.15	Grass	150	0.010	4.0	-	-	-	-	-	-	-	-	9	1	-	10
17	DA-3C	6.7	80.0	Grass	175	0.286	0.15	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	5
18	Stormwater Pond	5.5	98.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Channel Section:



Total Area = 58 acres

	a (ft)	d (ft)	water depth (ft)	left slope (%)	right slope (%)	Area (ft2)	Wetted P (ft)
DA-1A Downchute	15	2.0	0.31	50.0	50.0	4.8	16.4
DA-2A Downchute	15	2.0	0.30	50.0	50.0	4.8	16.4
DA-3A Downchute	15	2.0	0.21	50.0	50.0	3.2	15.9

Methodology:

Reference: United States Department of Agriculture. Hydrology National Engineering Handbook, Part 630 (May 2010). Chapter 15, Time of Concentration.

Sheet Flow T_c

$$T_t = \frac{0.007(nl)^{0.8}}{(P_2)^{0.5} S^{0.4}}$$ (eq. 15-8)

where:

T_t = travel time, h
n = Manning's roughness coefficient (0.15, short-grass prairie)
l = sheet flow length, ft
P_2 = 2-year, 24-hour rainfall, in. (3.83 inches)
S = slope of land surface, ft/ft

Shallow Concentrated Flow (Swales) T_c

See Drainage Swale Flow Analysis, Appendix IV.D3, for max velocity of 4 fps.

Channel Flow T_c

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n}$$ (eq. 15-10)

where:

V = Average velocity, ft/s
r = hydraulic radius, ft
$= \frac{a}{P_w}$
a = cross-sectional flow area, ft2
P_w = Wetted perimeter, ft
s = slope of the hydraulic grade line, ft/ft
n = Manning's n value for open channel flow (0.027, grass or 0.033, gabions/TRM)

POST-CLOSURE DRAINAGE CHANNELS

Hyd. No. [1]	Channel Name	Receiving Basin	Channel Length (ft)	Bottom Slope (ft/ft)	Bottom Width (ft)	Sideslope (XH:1V)	Flow (cfs)	Flow velocity (fps)	Normal Depth (ft)	Depth (ft)	Mannings Coefficient	Lining Material
4	East - 1	Stormwater Pond	190	0.0100	8	3	9.86	2.68	0.40	3.00	0.027	Grass
7	East - 2	Stormwater Pond	1,480	0.0100	8	3	76.07	5.18	1.25	3.00	0.027	Grass
11	West - 1	Stormwater Pond	280	0.0100	8	3	43.66	4.35	0.93	3.00	0.027	Grass
14	West - 2	Stormwater Pond	1,335	0.0100	8	3	101.45	5.61	1.46	3.00	0.033	Grass

Notes:
1.) Hyd. No. refers to Hydraflow Hydrograph modeling input. See Appendix IV.D2.

APPENDIX IV.D2

HYDRAFLOW HYDROGRAPH OUTPUT FILE

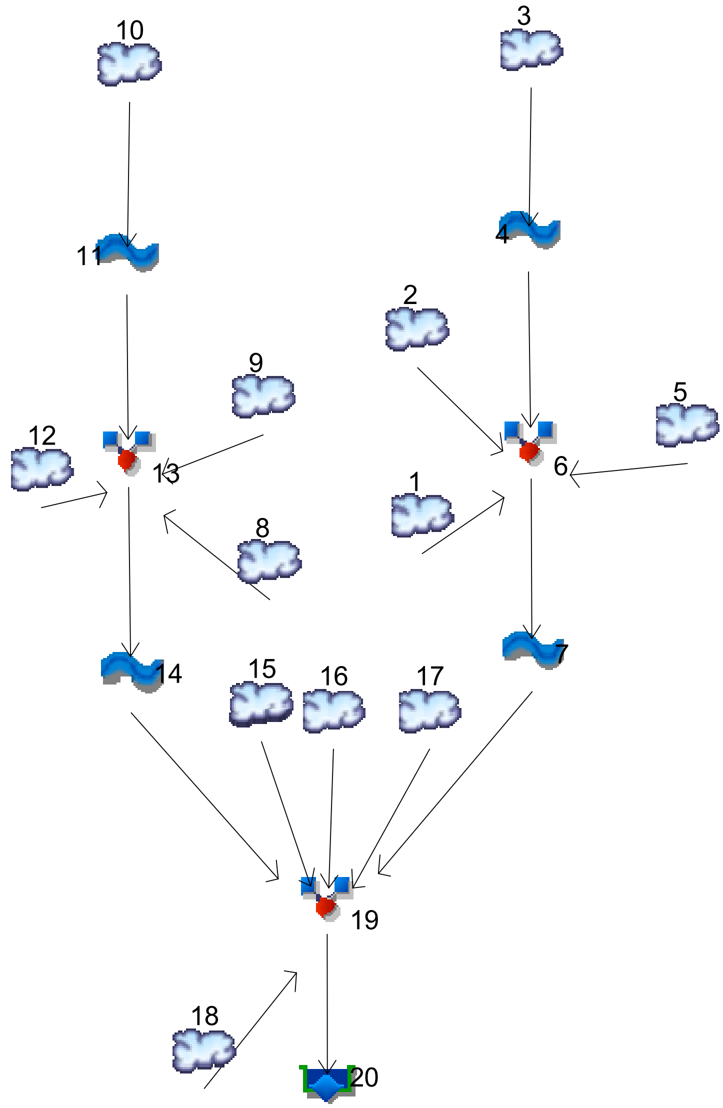
STATE OF TEXAS
BRETT J. DeVRIES
128061
LICENSED
PROFESSIONAL ENGINEER

Brett DeVries 10/14/21

SCS Engineers
TBPE Reg. # F-3407

Watershed Model Schematic

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020



IV.D2-2

Project: Sandy Creek - Post-Development Model (092021).gpw	Monday, 10 / 4 / 2021

Hydrograph Summary Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	45.41	2	726	156,851	------	------	------	DA-1A
2	SCS Runoff	5.905	2	728	22,836	------	------	------	DA-1B
3	SCS Runoff	6.840	2	724	20,760	------	------	------	DA-1C
4	Reach	6.878	2	726	20,759	3	------	------	East Channel - 1
5	SCS Runoff	30.78	2	724	93,418	------	------	------	DA-1D
6	Combine	85.61	2	726	293,864	1, 2, 4, 5	------	------	Inflow to East Channel - 2
7	Reach	76.07	2	730	293,862	6	------	------	East Channel - 2
8	SCS Runoff	42.21	2	726	145,779	------	------	------	DA-2A
9	SCS Runoff	5.413	2	728	20,933	------	------	------	DA-2B
10	SCS Runoff	58.71	2	724	178,187	------	------	------	DA-2C
11	Reach	43.66	2	728	178,183	10	------	------	West Channel - 1
12	SCS Runoff	27.07	2	724	82,156	------	------	------	DA-2D
13	Combine	112.33	2	726	427,051	8, 9, 11, 12	------	------	Inflow to West Channel - 2
14	Reach	101.45	2	730	427,048	13	------	------	West Channel - 2
15	SCS Runoff	62.43	2	726	215,624	------	------	------	DA-3A
16	SCS Runoff	1.840	2	728	7,117	------	------	------	DA-3B
17	SCS Runoff	38.28	2	724	116,185	------	------	------	DA-3C
18	SCS Runoff	38.60	2	724	134,400	------	------	------	Stormwater Pond Area
19	Combine	287.57	2	728	1,194,238	7, 14, 15, 16, 17, 18	------	------	Pond Inflow
20	Reservoir	5.198	2	1252	1,066,999	19	446.59	975,015	Existing Pond

Sandy Creek - Post-Development Model (092021).gpw	Return Period: 25 Year	Monday, 10 / 4 / 2021

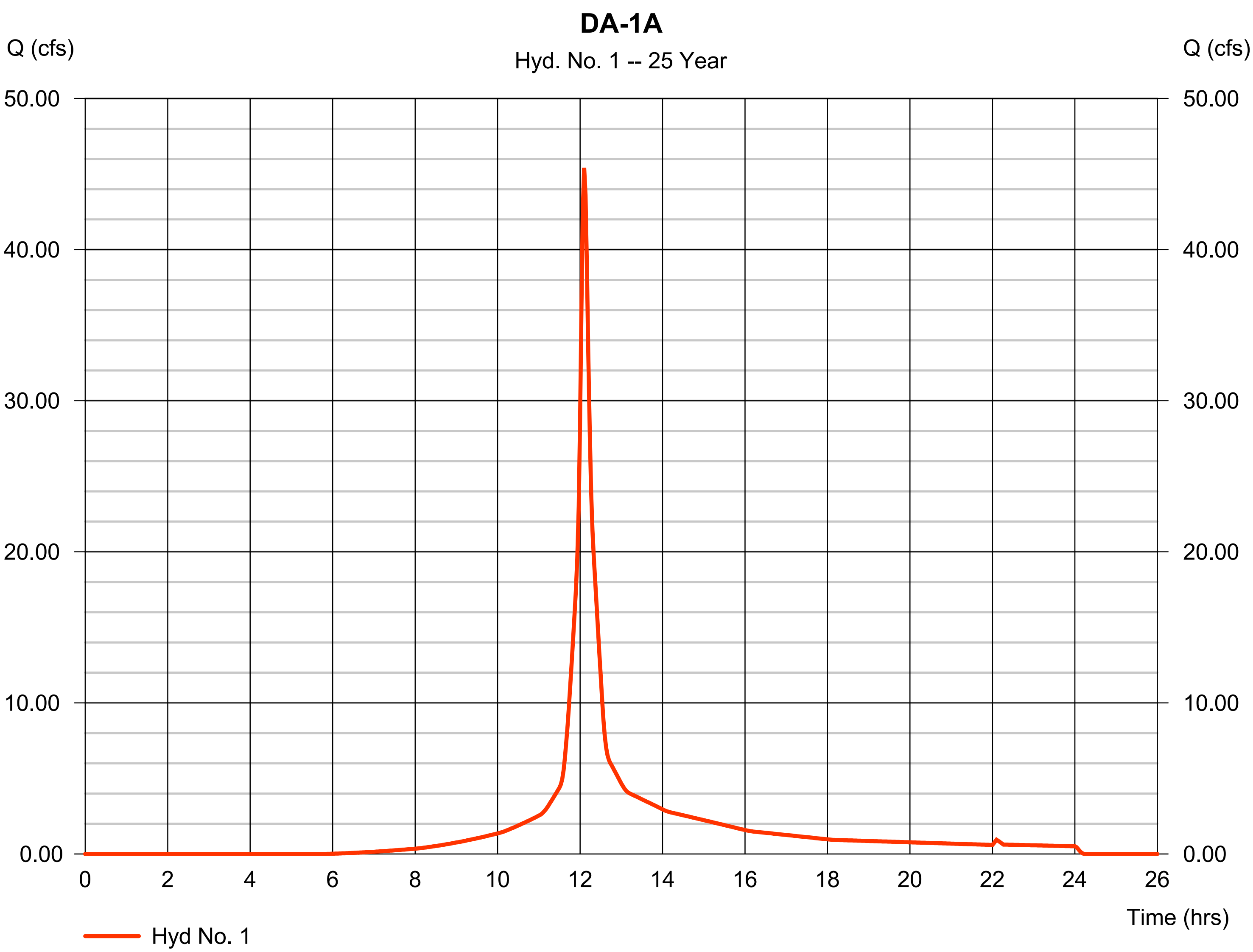
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 | Monday, 10 / 4 / 2021

Hyd. No. 1

DA-1A

Hydrograph type	= SCS Runoff	Peak discharge	= 45.41 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 156,851 cuft
Drainage area	= 8.500 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 9.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



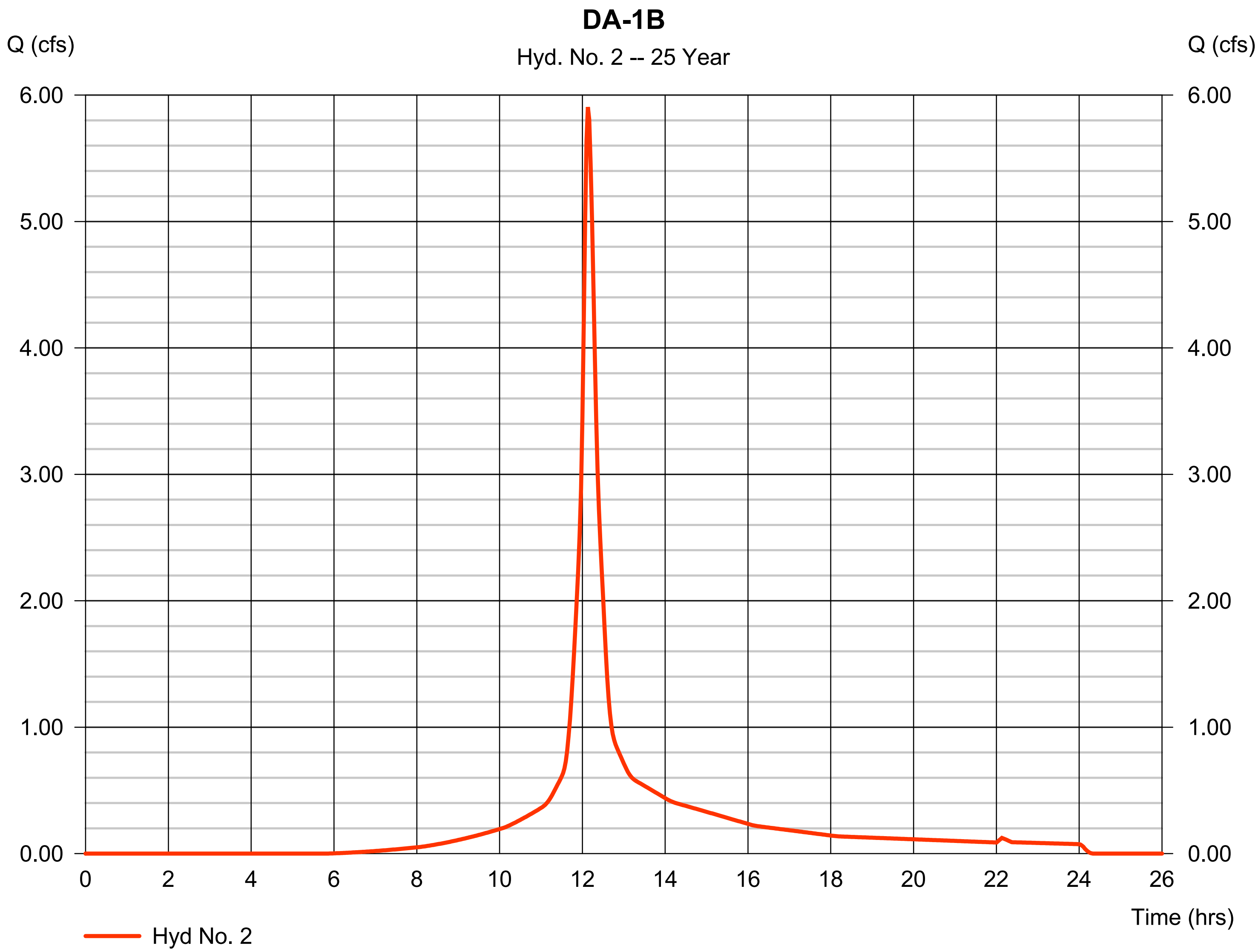
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 | Monday, 10 / 4 / 2021

Hyd. No. 2

DA-1B

Hydrograph type	= SCS Runoff	Peak discharge	= 5.905 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.13 hrs
Time interval	= 2 min	Hyd. volume	= 22,836 cuft
Drainage area	= 1.200 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 10.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



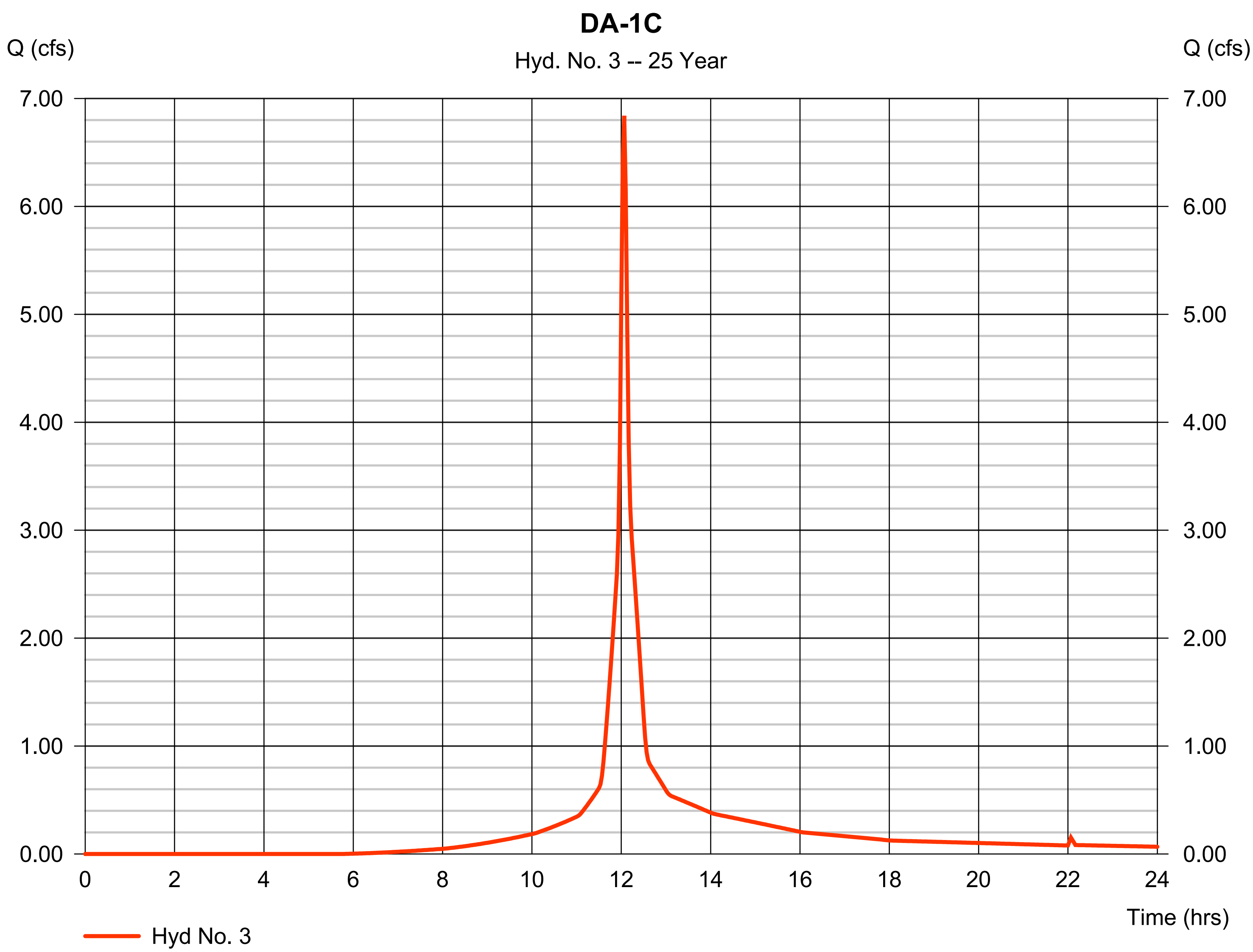
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 3

DA-1C

Hydrograph type	= SCS Runoff	Peak discharge	= 6.840 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 20,760 cuft
Drainage area	= 1.200 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 4.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

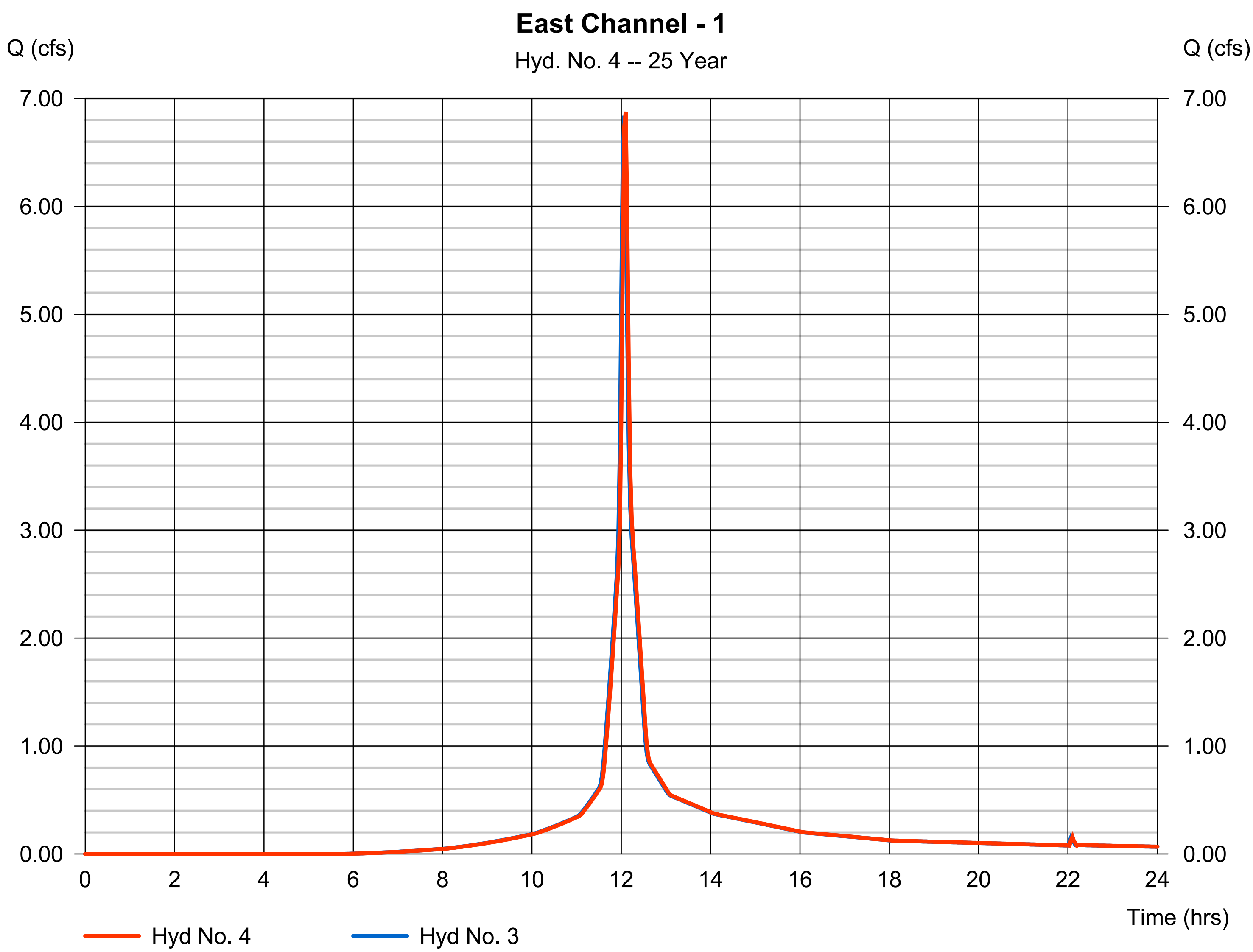
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 4

East Channel - 1

Hydrograph type	= Reach	Peak discharge	= 6.878 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 20,759 cuft
Inflow hyd. No.	= 3 - DA-1C	Section type	= Trapezoidal
Reach length	= 190.0 ft	Channel slope	= 1.0 %
Manning's n	= 0.009	Bottom width	= 8.0 ft
Side slope	= 3.0:1	Max. depth	= 4.0 ft
Rating curve x	= 4.136	Rating curve m	= 1.386
Ave. velocity	= 4.76 ft/s	Routing coeff.	= 1.3513

Modified Att-Kin routing method used.



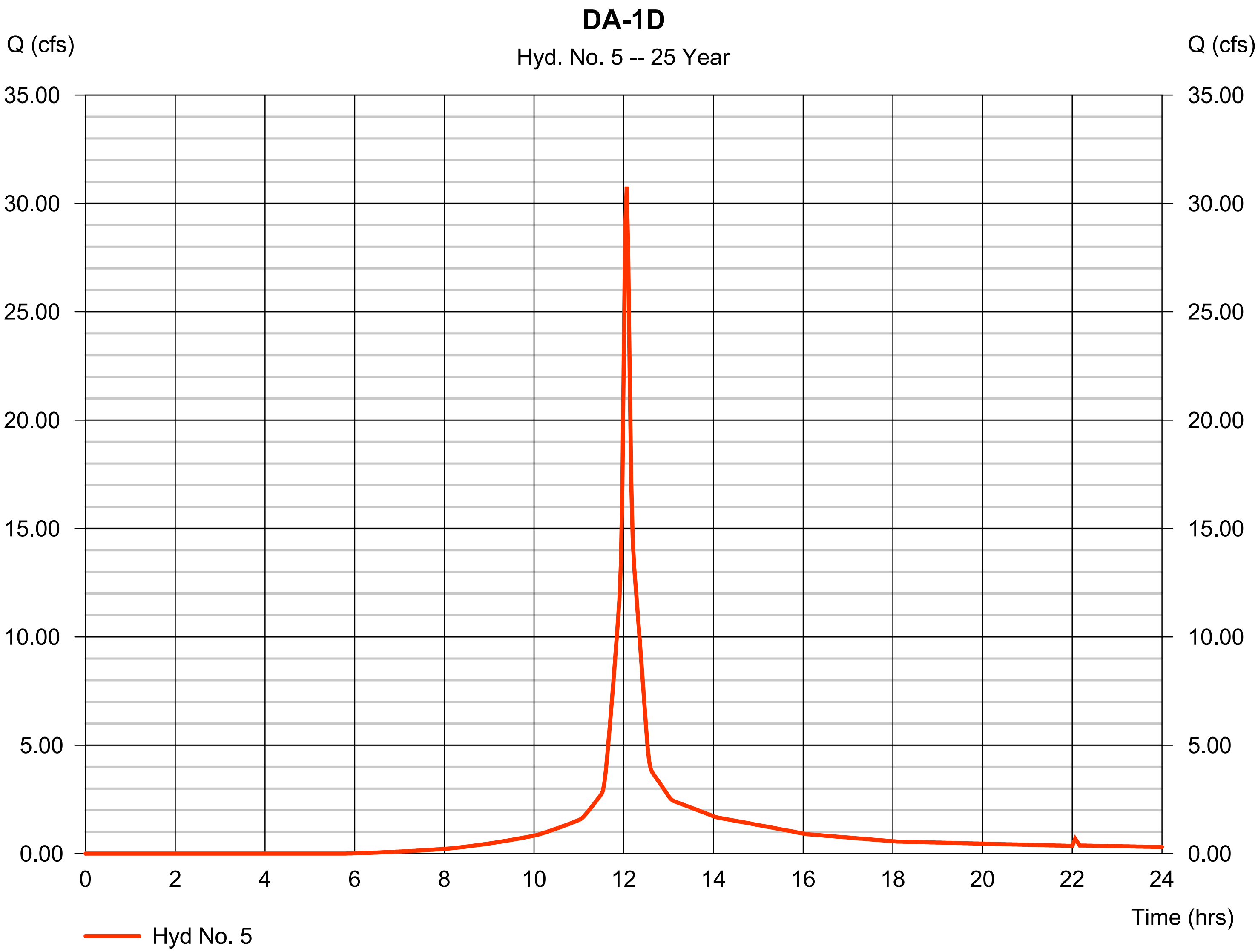
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 | Monday, 10 / 4 / 2021

Hyd. No. 5

DA-1D

Hydrograph type	= SCS Runoff	Peak discharge	= 30.78 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 93,418 cuft
Drainage area	= 5.400 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



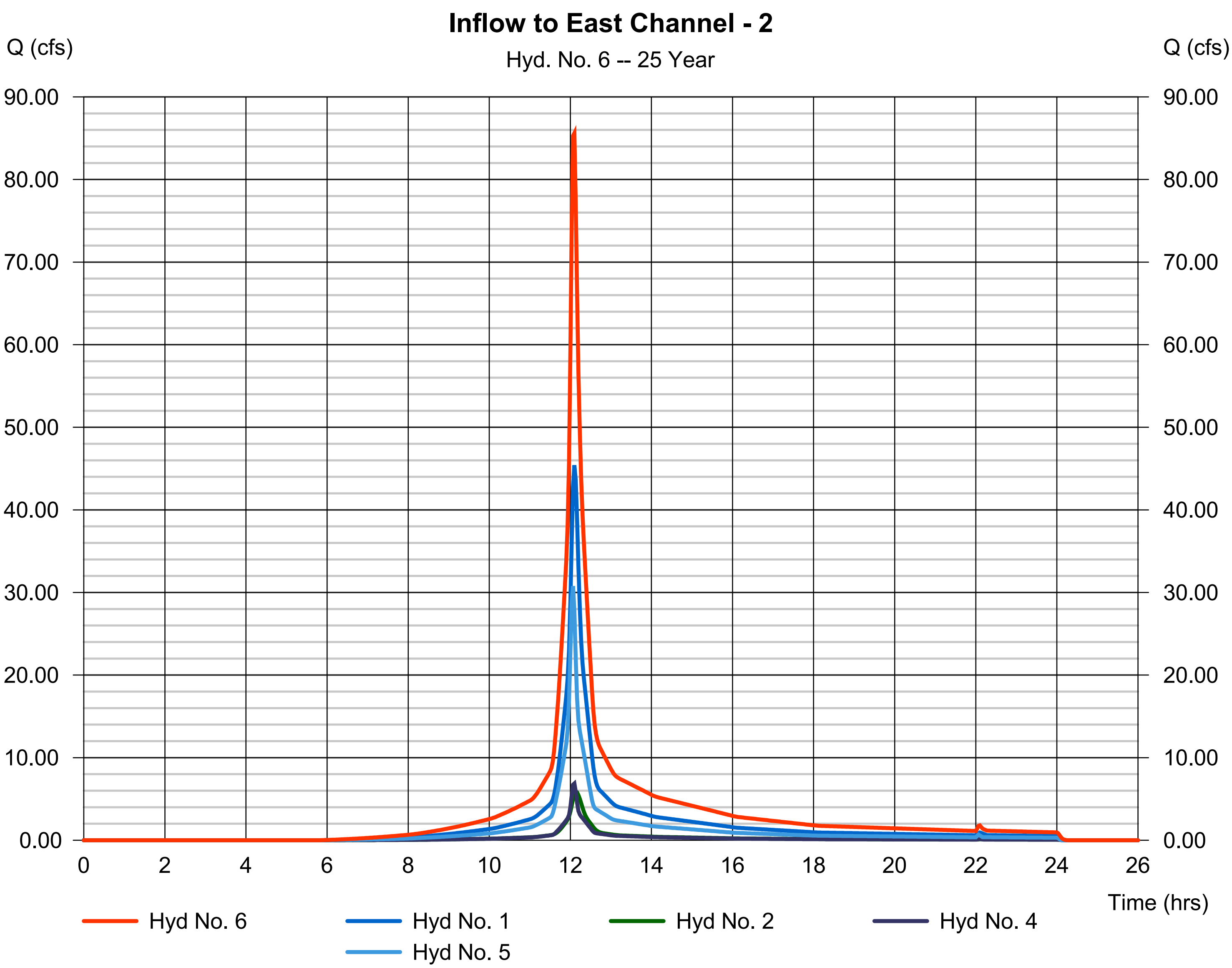
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 6

Inflow to East Channel - 2

Hydrograph type	= Combine	Peak discharge	= 85.61 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 293,864 cuft
Inflow hyds.	= 1, 2, 4, 5	Contrib. drain. area	= 15.100 ac



Hydrograph Report

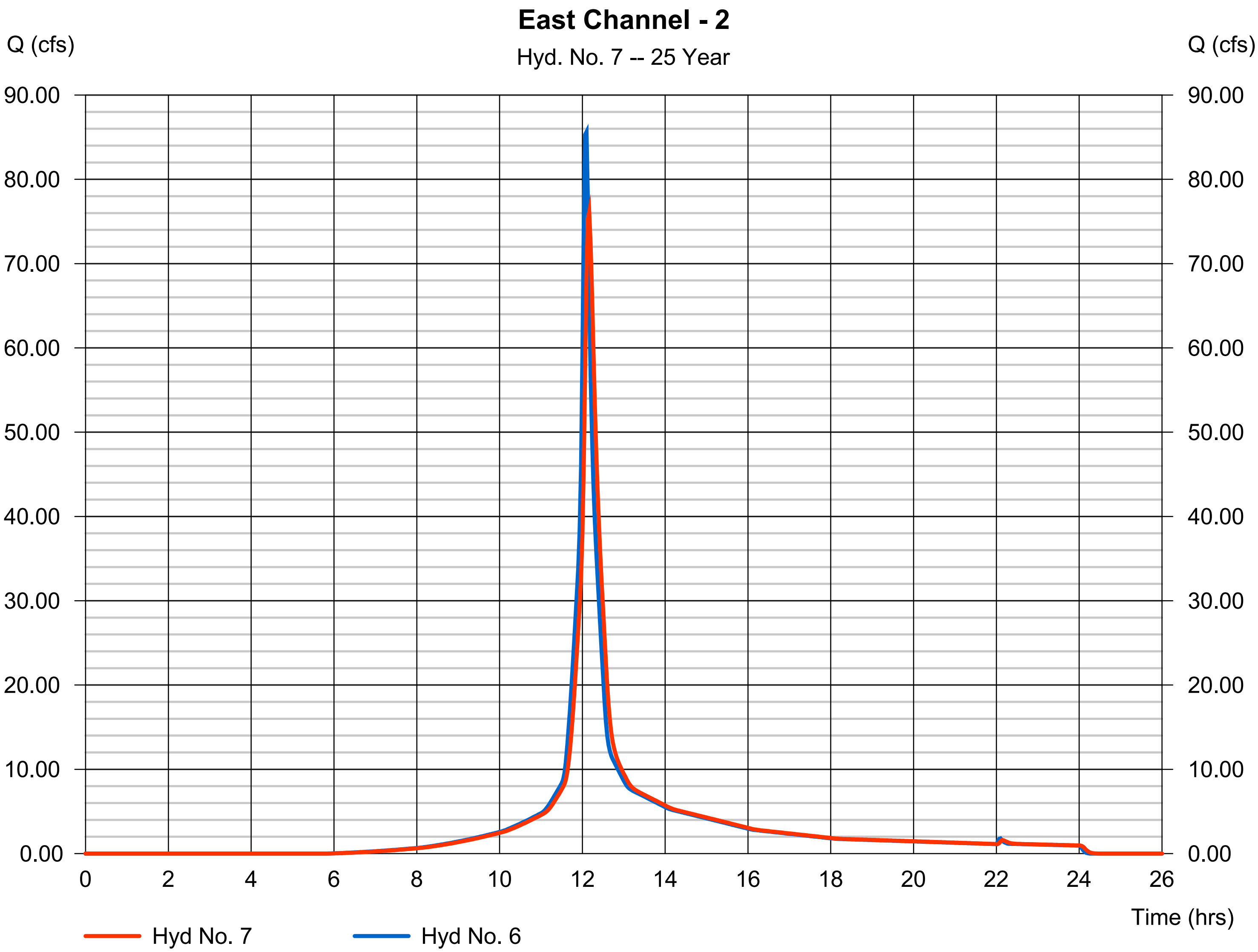
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 — Monday, 10 / 4 / 2021

Hyd. No. 7

East Channel - 2

Hydrograph type	= Reach	Peak discharge	= 76.07 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.17 hrs
Time interval	= 2 min	Hyd. volume	= 293,862 cuft
Inflow hyd. No.	= 6 - Inflow to East Channel - 2	Section type	= Trapezoidal
Reach length	= 1480.0 ft	Channel slope	= 1.0 %
Manning's n	= 0.027	Bottom width	= 8.0 ft
Side slope	= 3.0:1	Max. depth	= 4.0 ft
Rating curve x	= 1.379	Rating curve m	= 1.386
Ave. velocity	= 4.36 ft/s	Routing coeff.	= 0.3933

Modified Att-Kin routing method used.



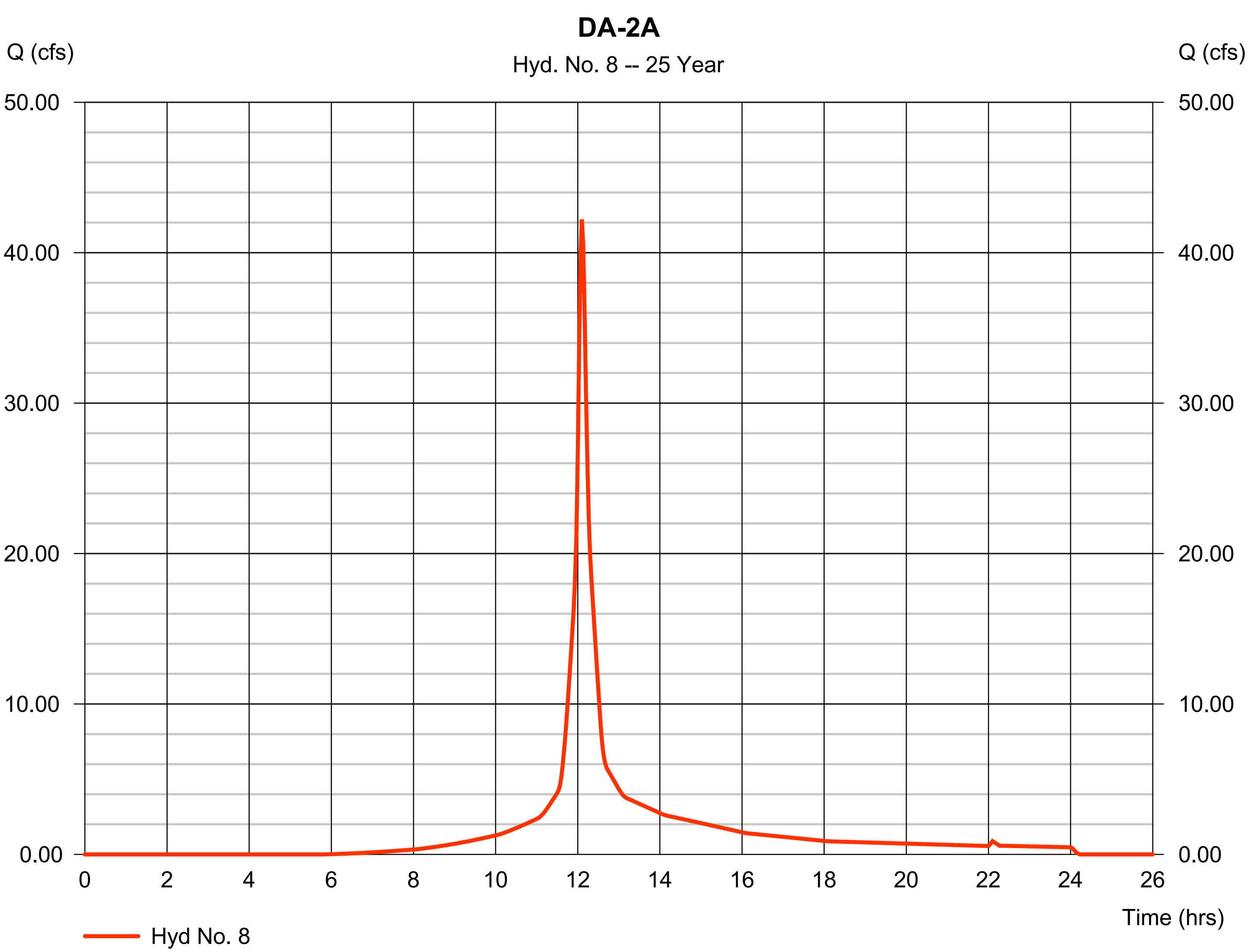
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 8

DA-2A

Hydrograph type	= SCS Runoff	Peak discharge	= 42.21 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 145,779 cuft
Drainage area	= 7.900 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 8.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



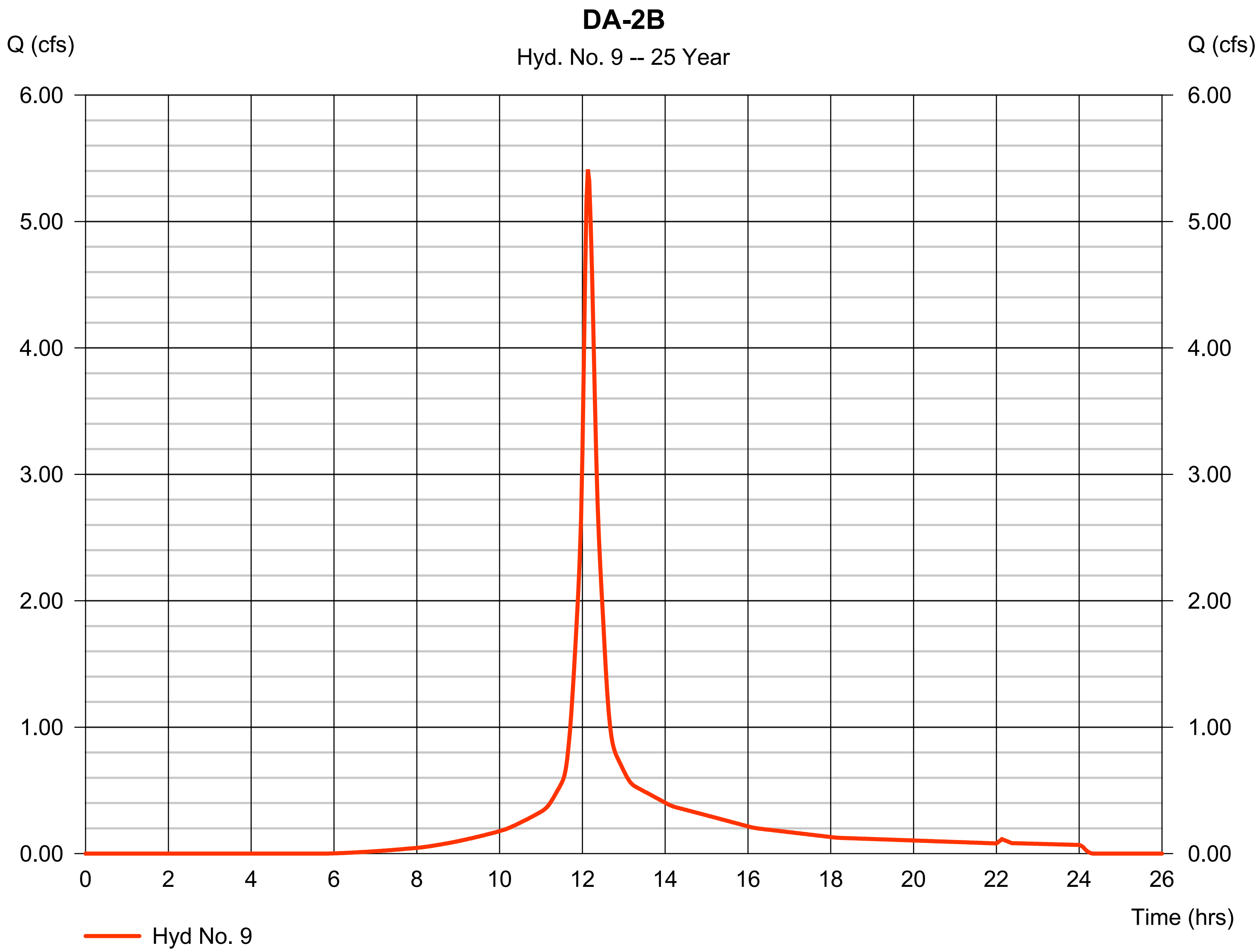
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 9

DA-2B

Hydrograph type	= SCS Runoff	Peak discharge	= 5.413 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.13 hrs
Time interval	= 2 min	Hyd. volume	= 20,933 cuft
Drainage area	= 1.100 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 10.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



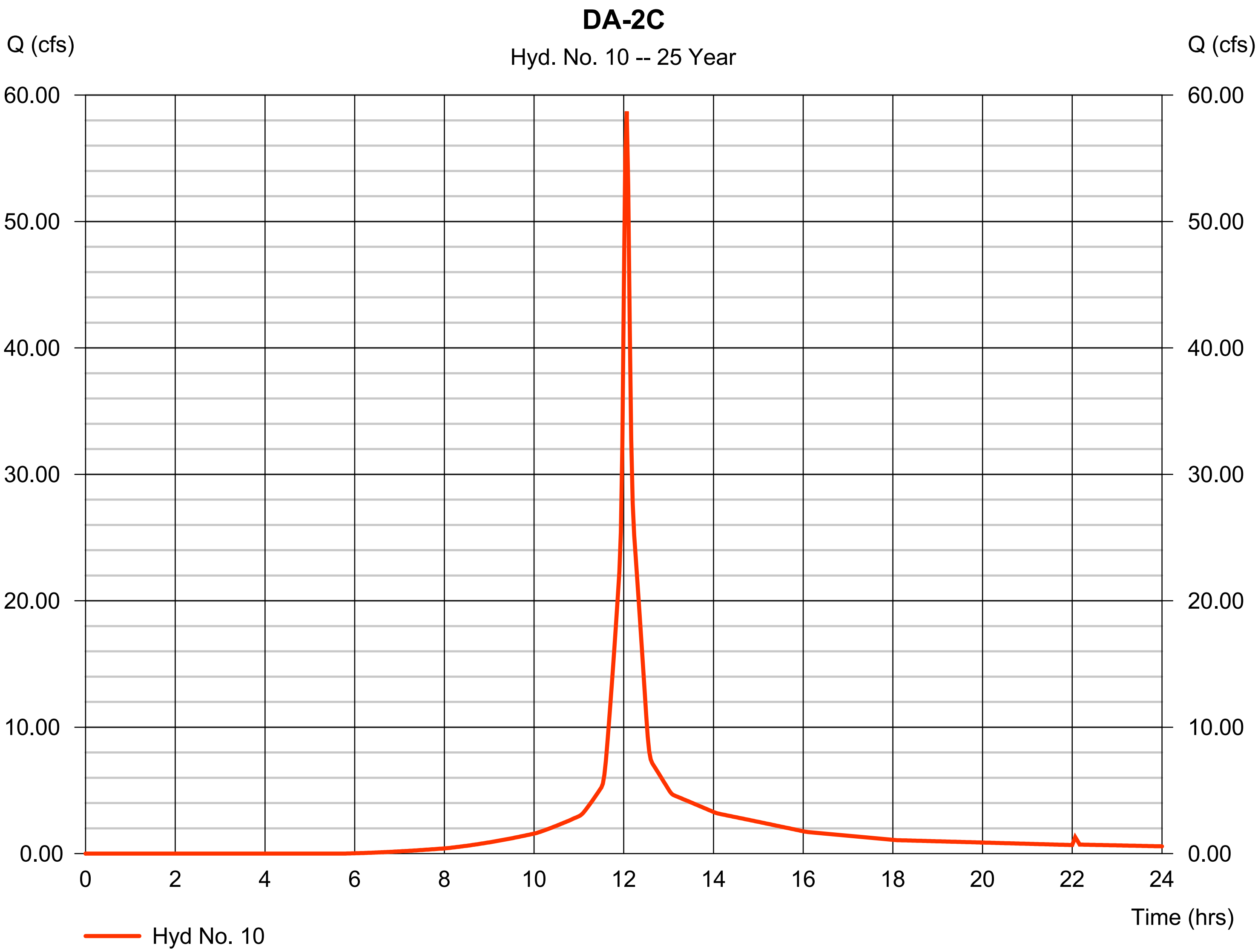
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 10

DA-2C

Hydrograph type	= SCS Runoff	Peak discharge	= 58.71 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 178,187 cuft
Drainage area	= 10.300 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 4.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

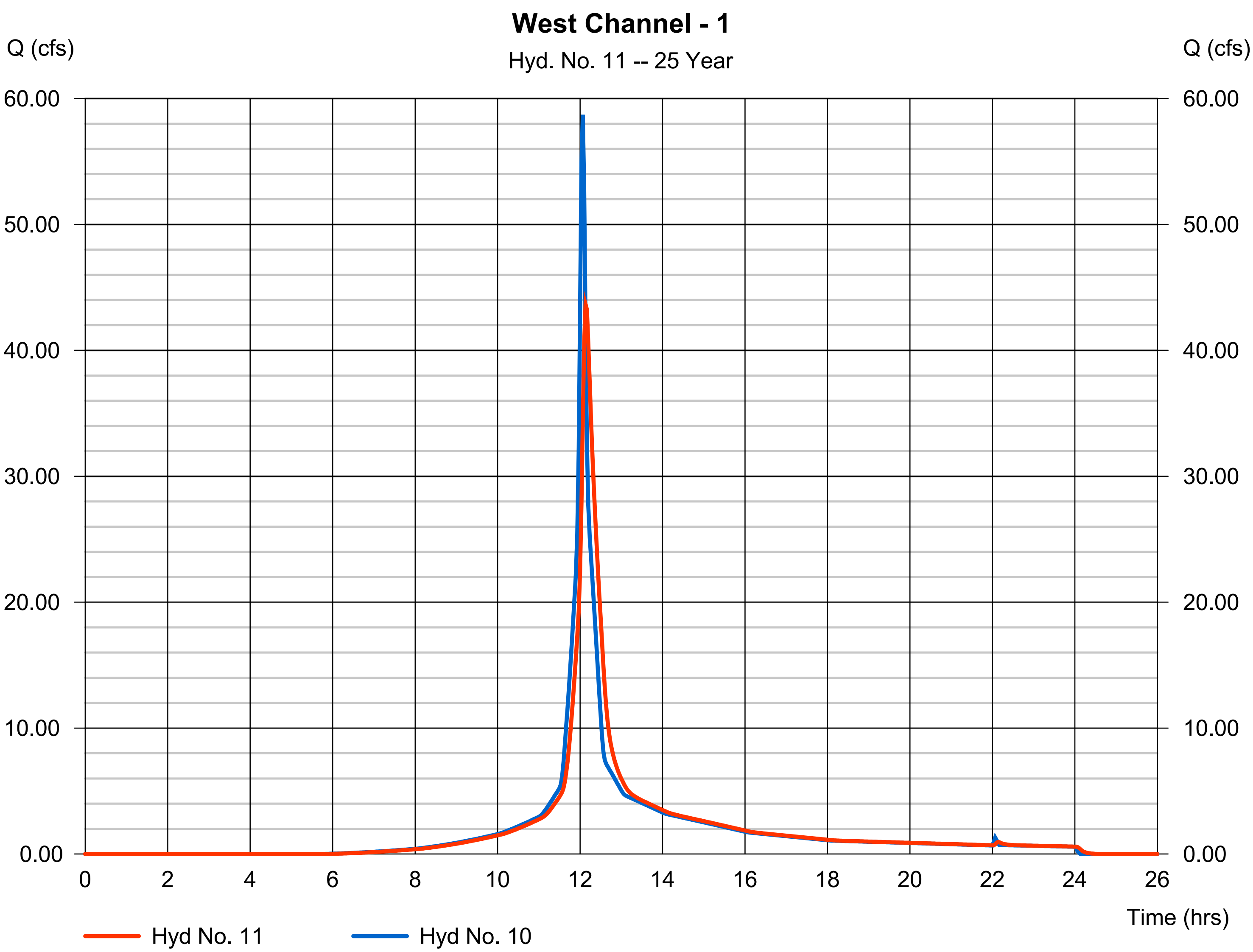
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 11

West Channel - 1

Hydrograph type	= Reach	Peak discharge	= 43.66 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.13 hrs
Time interval	= 2 min	Hyd. volume	= 178,183 cuft
Inflow hyd. No.	= 10 - DA-2C	Section type	= Trapezoidal
Reach length	= 2285.0 ft	Channel slope	= 1.0 %
Manning's n	= 0.027	Bottom width	= 8.0 ft
Side slope	= 3.0:1	Max. depth	= 4.0 ft
Rating curve x	= 1.379	Rating curve m	= 1.386
Ave. velocity	= 3.92 ft/s	Routing coeff.	= 0.2498

Modified Att-Kin routing method used.



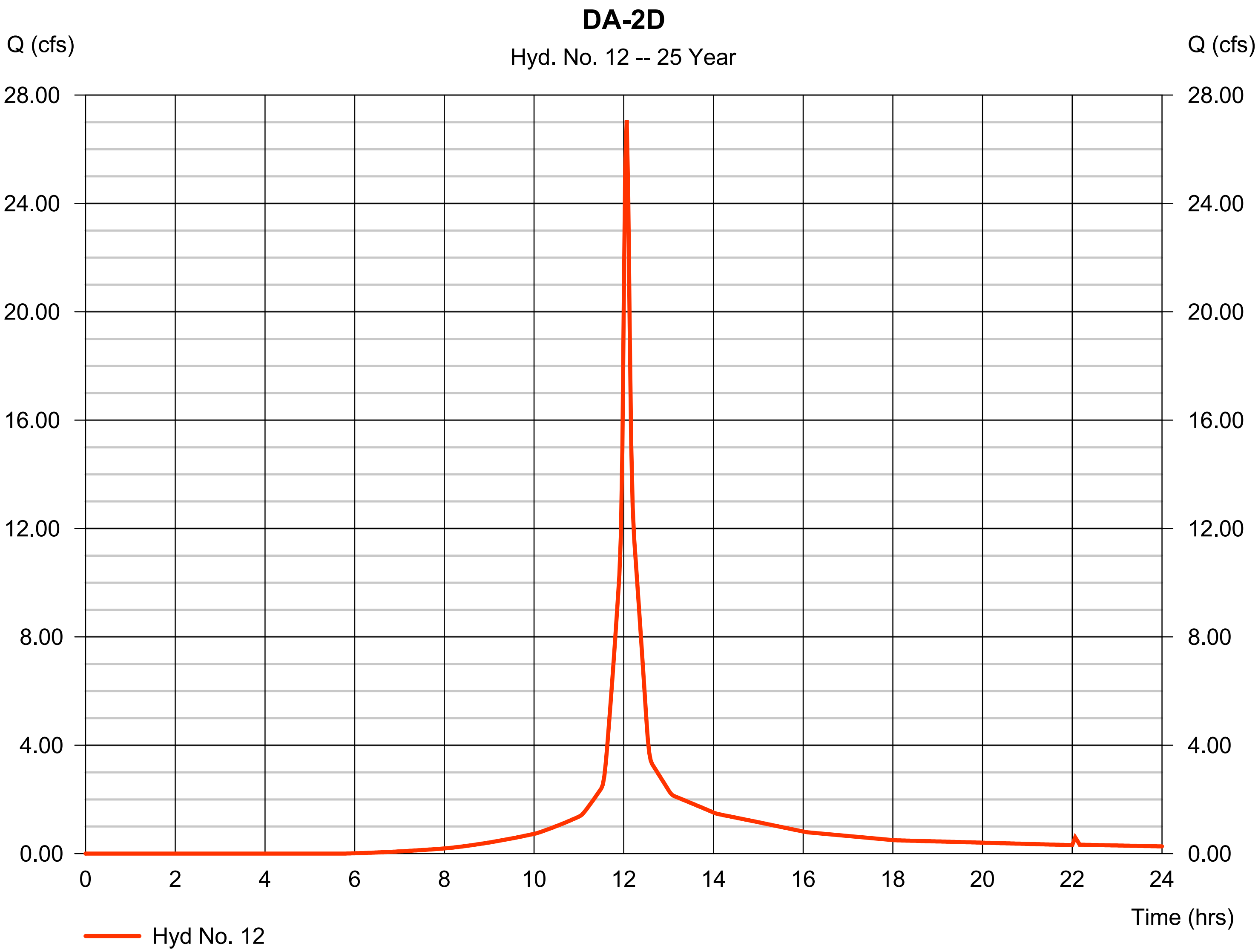
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 12

DA-2D

Hydrograph type	= SCS Runoff	Peak discharge	= 27.07 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 82,156 cuft
Drainage area	= 4.749 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



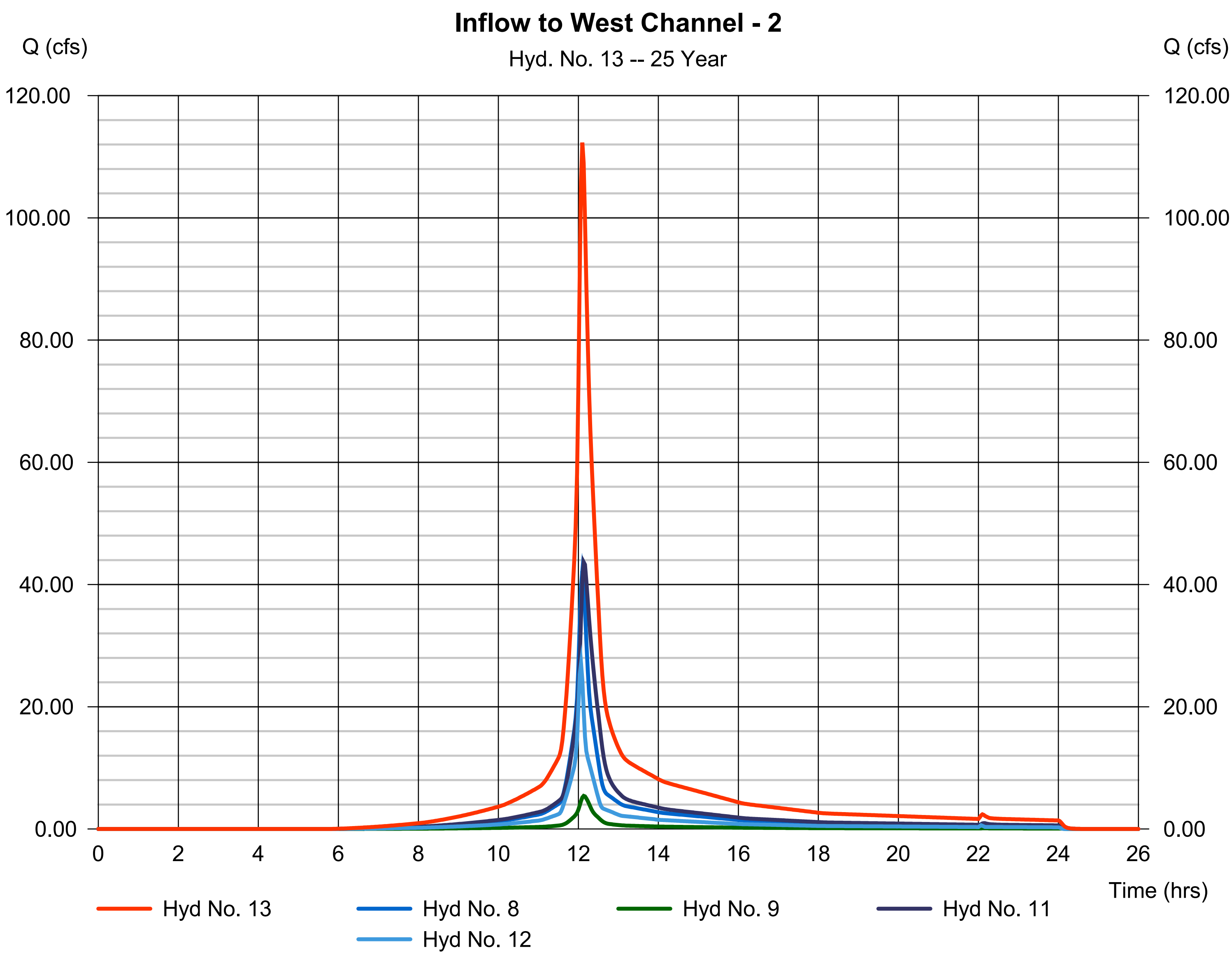
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 13

Inflow to West Channel - 2

Hydrograph type	= Combine	Peak discharge	= 112.33 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 427,051 cuft
Inflow hyds.	= 8, 9, 11, 12	Contrib. drain. area	= 13.749 ac



Hydrograph Report

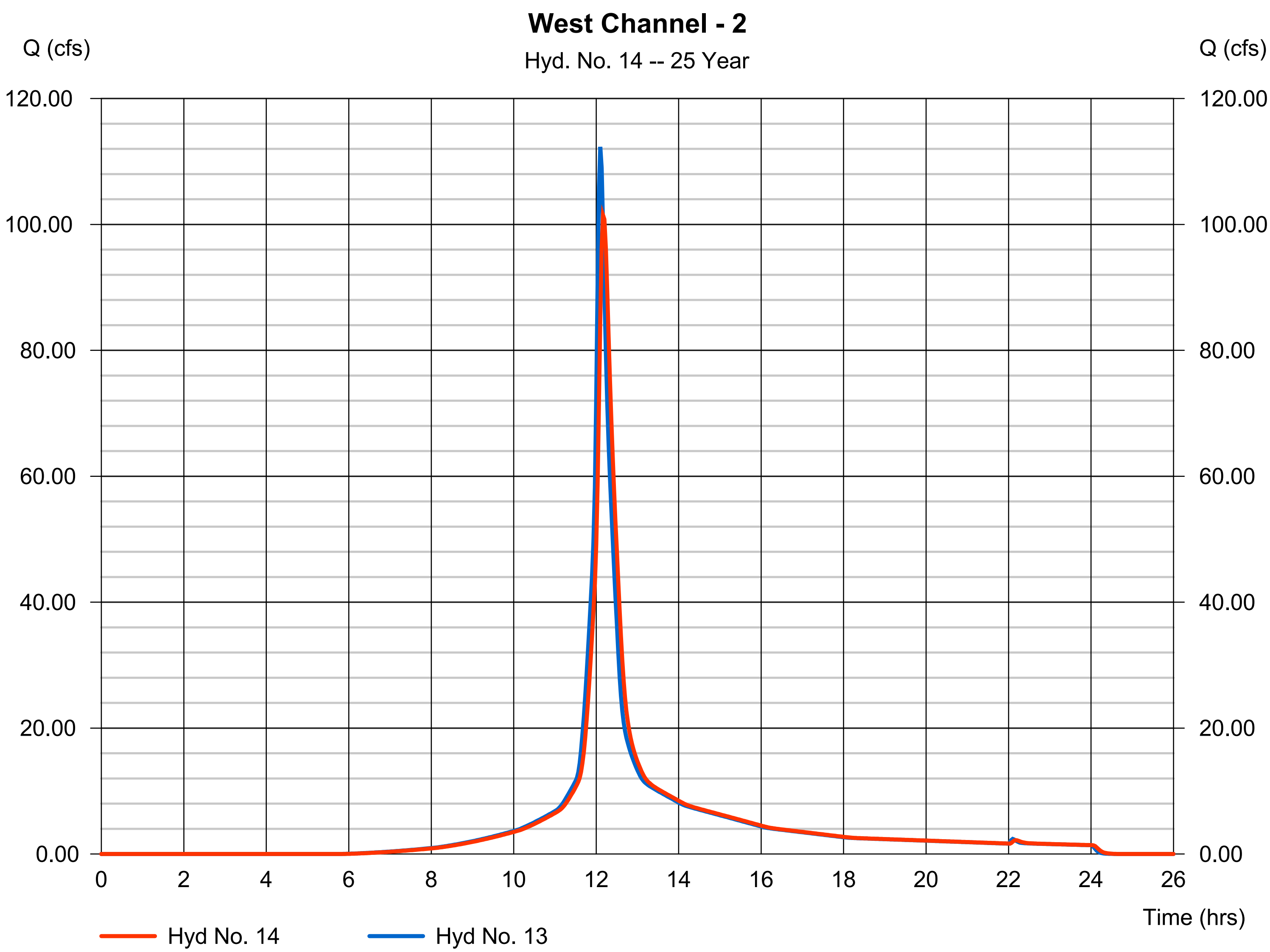
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 — Monday, 10 / 4 / 2021

Hyd. No. 14

West Channel - 2

Hydrograph type	= Reach	Peak discharge	= 101.45 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.17 hrs
Time interval	= 2 min	Hyd. volume	= 427,048 cuft
Inflow hyd. No.	= 13 - Inflow to West Channel - 2	Section type	= Trapezoidal
Reach length	= 1335.0 ft	Channel slope	= 1.0 %
Manning's n	= 0.033	Bottom width	= 8.0 ft
Side slope	= 3.0:1	Max. depth	= 4.0 ft
Rating curve x	= 1.128	Rating curve m	= 1.386
Ave. velocity	= 4.07 ft/s	Routing coeff.	= 0.4042

Modified Att-Kin routing method used.



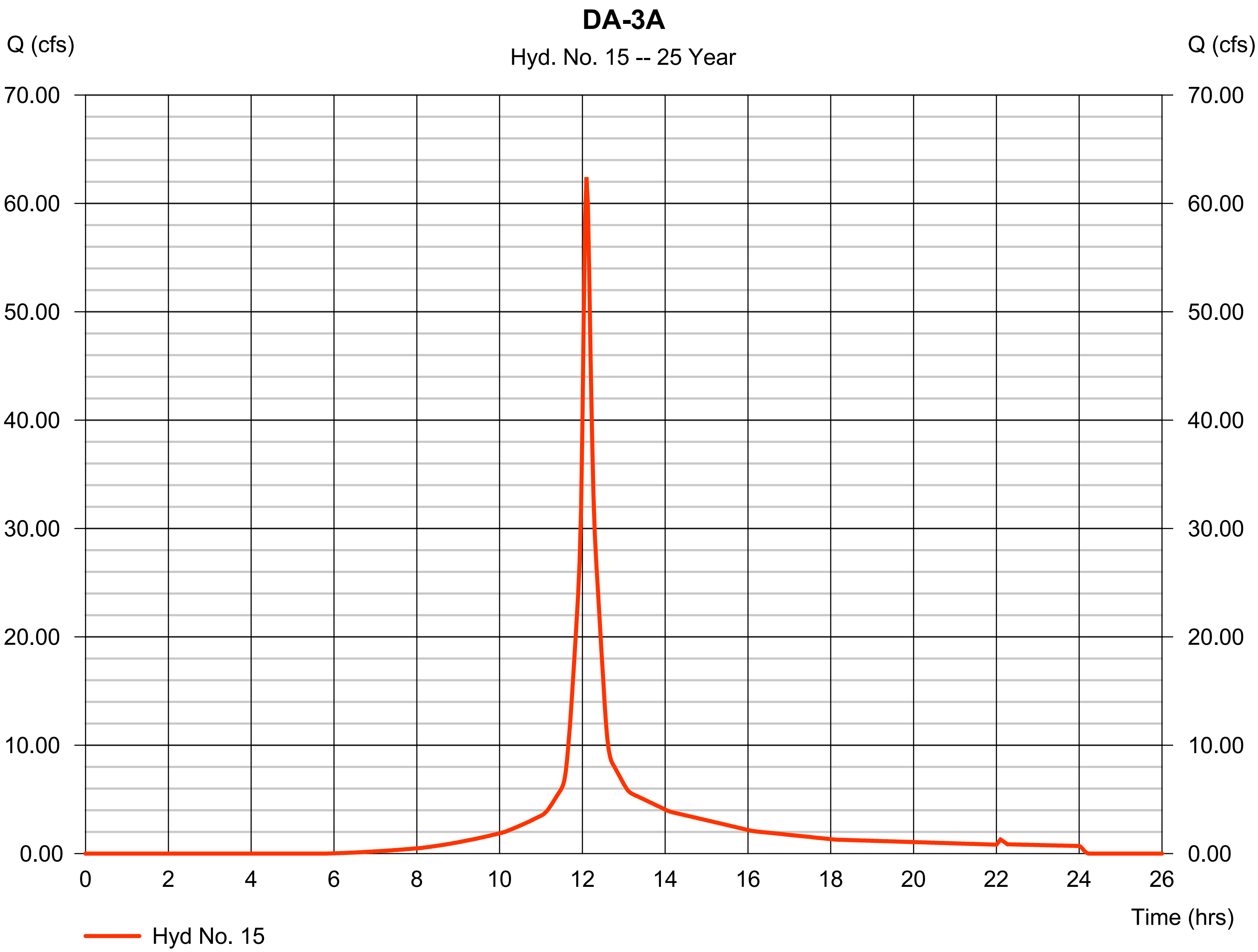
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 15

DA-3A

Hydrograph type	= SCS Runoff	Peak discharge	= 62.43 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 215,624 cuft
Drainage area	= 11.685 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 7.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



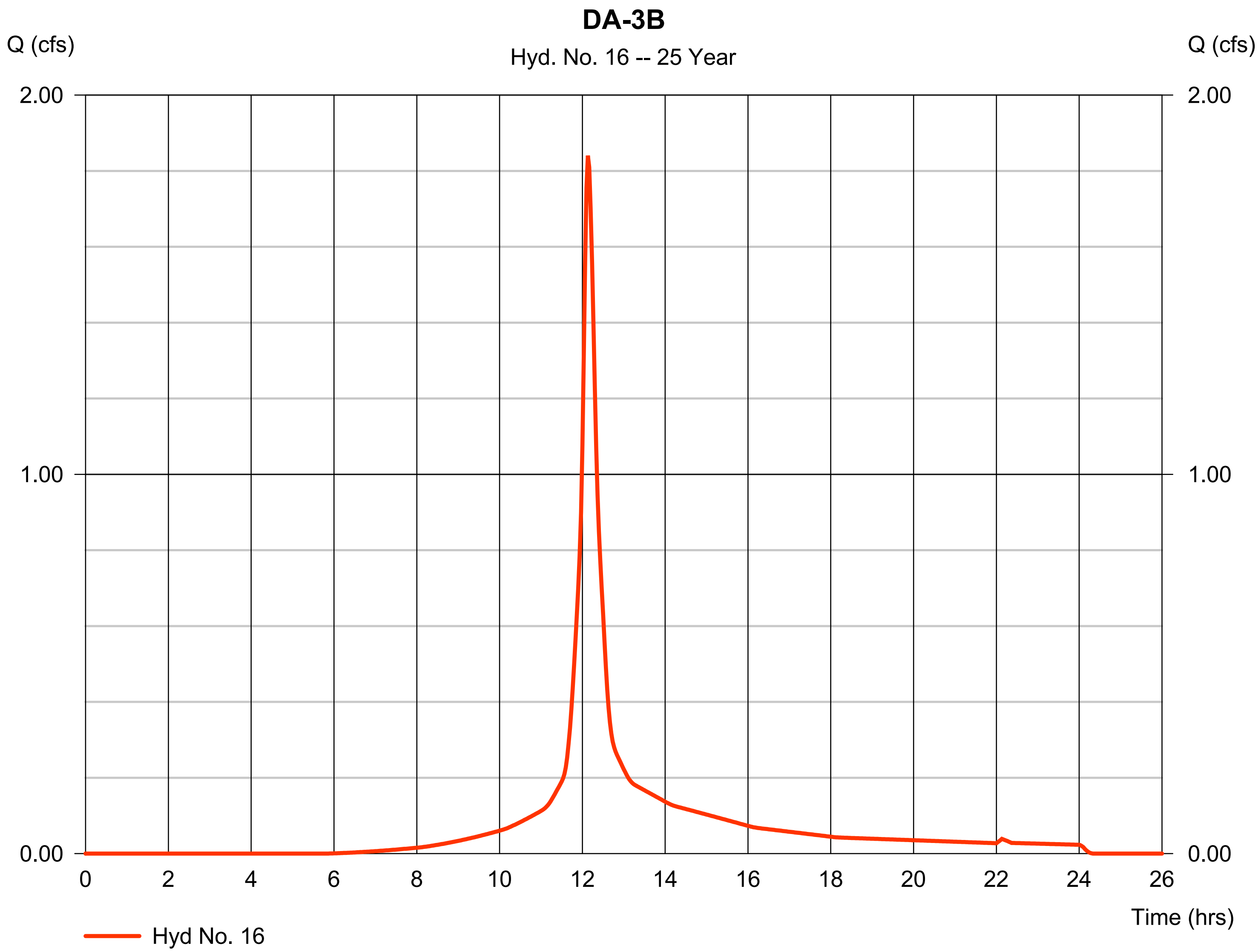
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Hyd. No. 16

DA-3B

Hydrograph type	= SCS Runoff	Peak discharge	= 1.840 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.13 hrs
Time interval	= 2 min	Hyd. volume	= 7,117 cuft
Drainage area	= 0.374 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 10.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



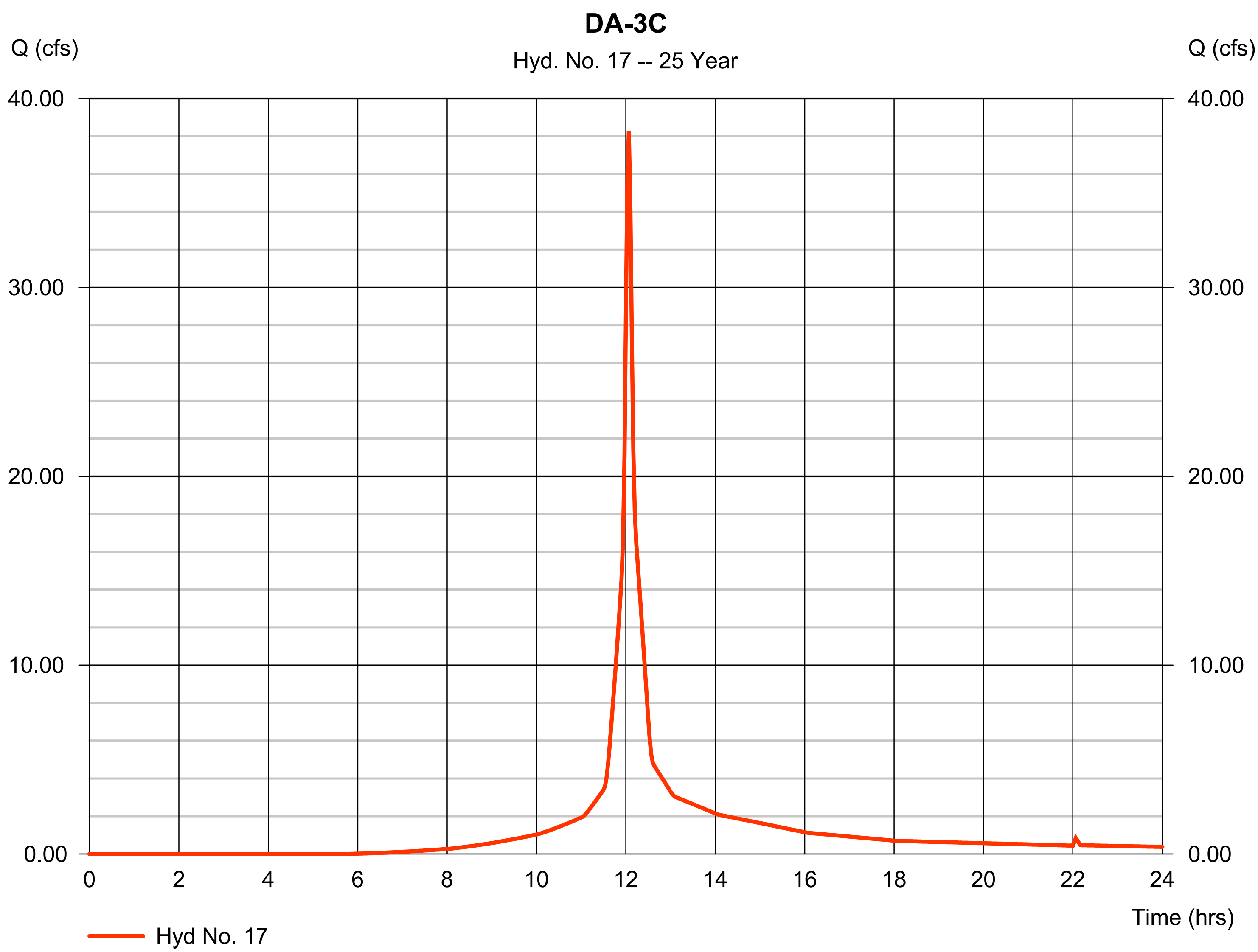
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 — Monday, 10 / 4 / 2021

Hyd. No. 17

DA-3C

Hydrograph type	= SCS Runoff	Peak discharge	= 38.28 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 116,185 cuft
Drainage area	= 6.716 ac	Curve number	= 80
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



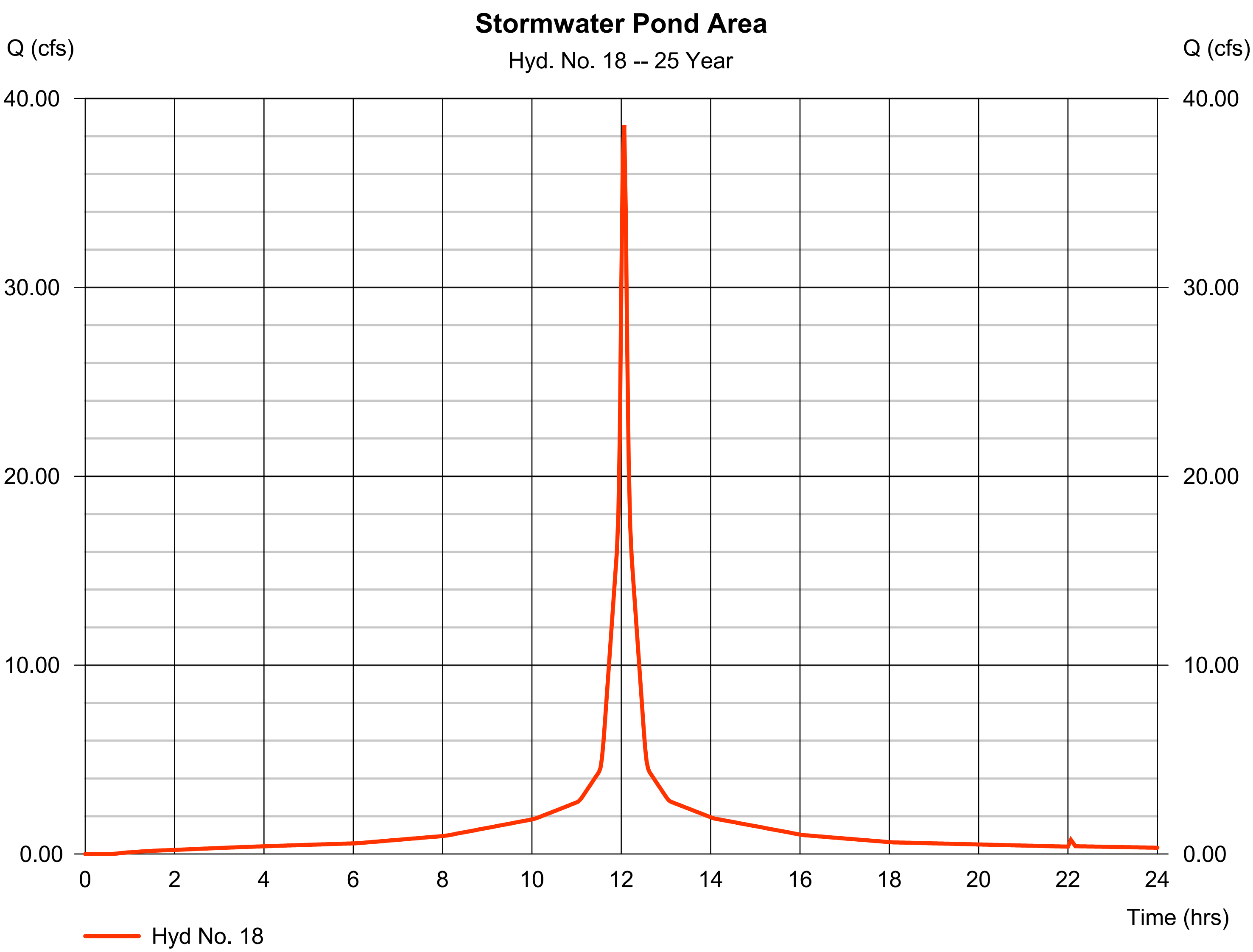
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 — Monday, 10 / 4 / 2021

Hyd. No. 18

Stormwater Pond Area

Hydrograph type	= SCS Runoff	Peak discharge	= 38.60 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 134,400 cuft
Drainage area	= 5.500 ac	Curve number	= 98
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 4.00 min
Total precip.	= 7.42 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



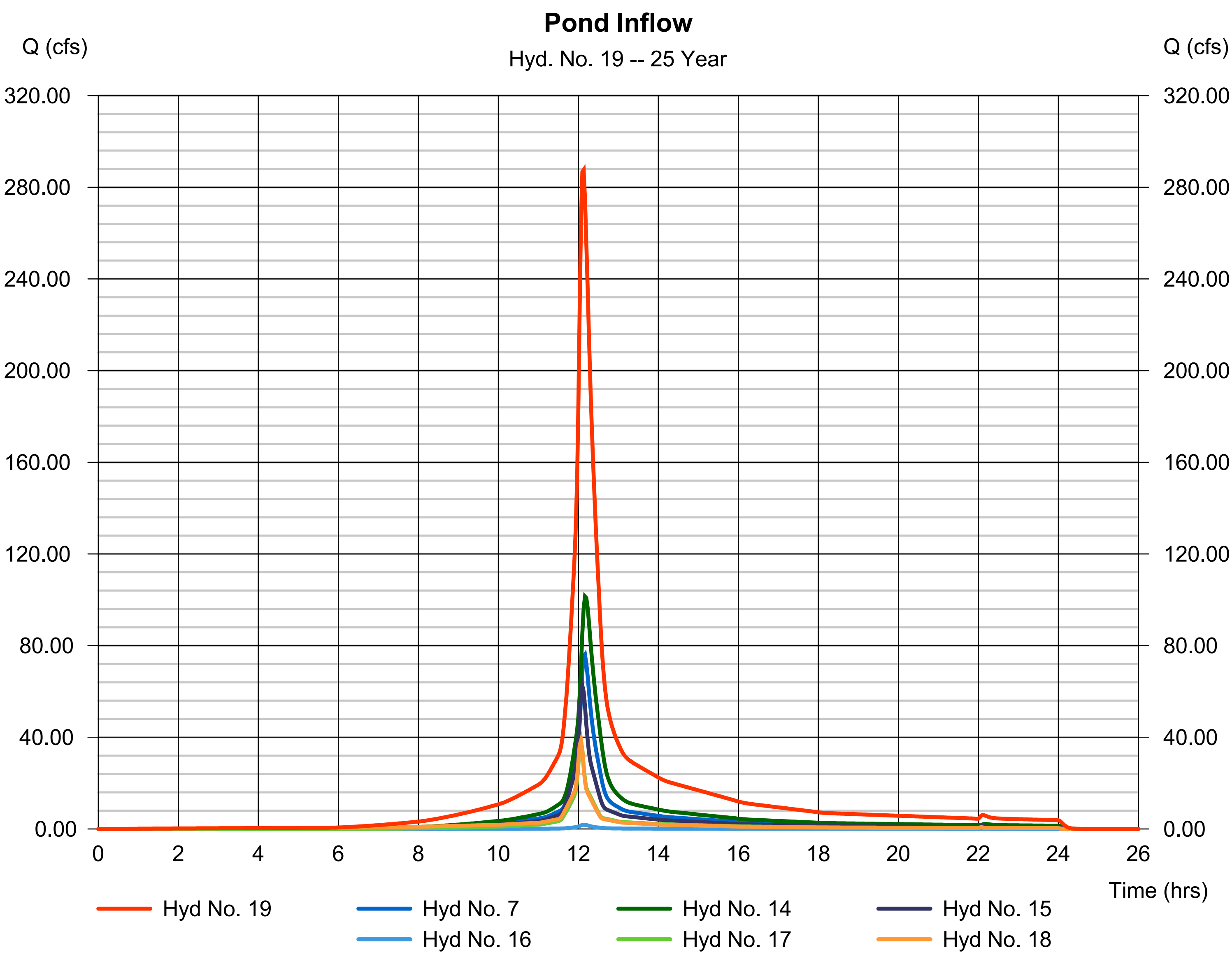
Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 — Monday, 10 / 4 / 2021

Hyd. No. 19

Pond Inflow

Hydrograph type	= Combine	Peak discharge	= 287.57 cfs
Storm frequency	= 25 yrs	Time to peak	= 12.13 hrs
Time interval	= 2 min	Hyd. volume	= 1,194,238 cuft
Inflow hyds.	= 7, 14, 15, 16, 17, 18	Contrib. drain. area	= 24.275 ac



Hydrograph Report

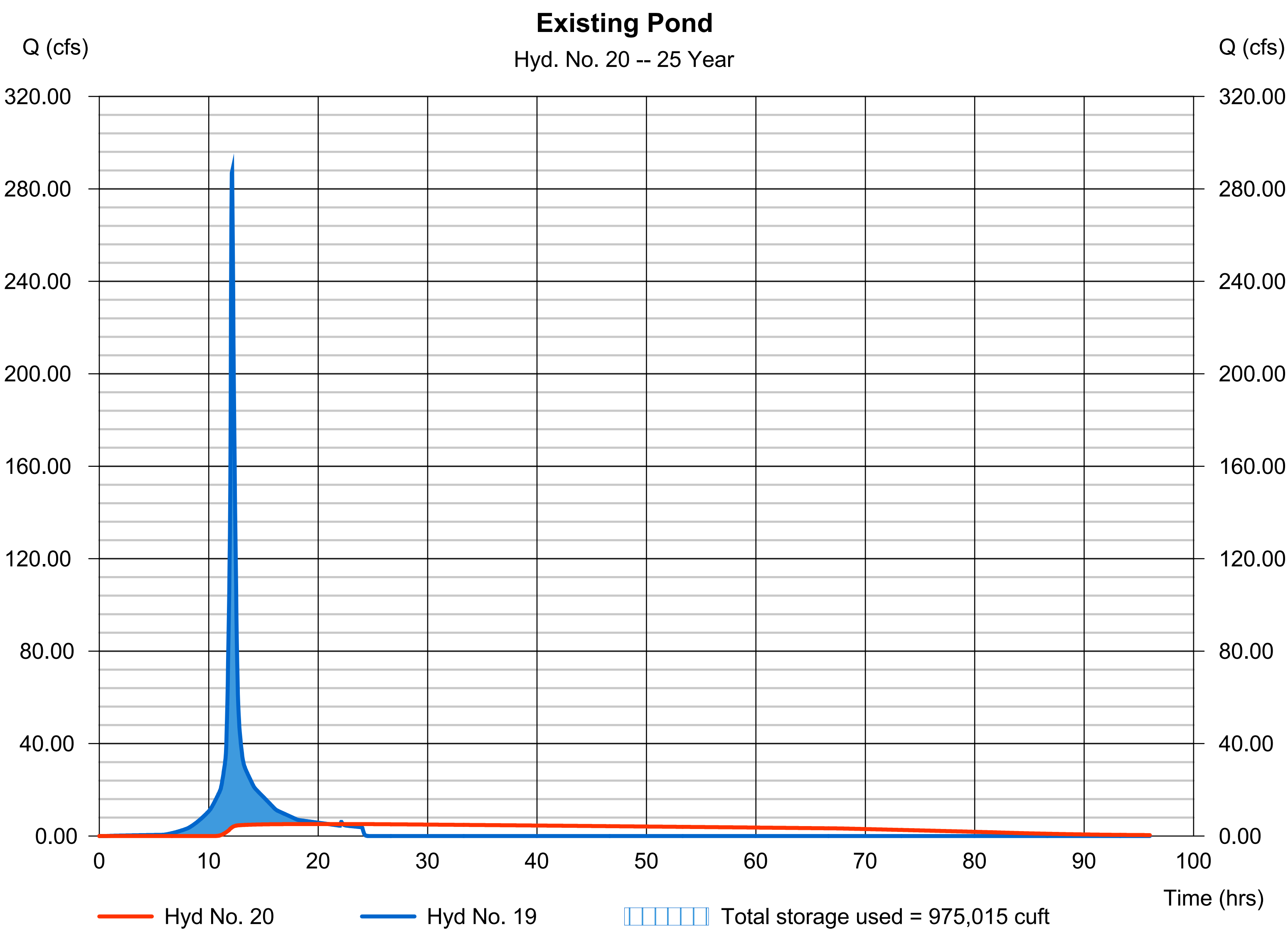
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 — Monday, 10 / 4 / 2021

Hyd. No. 20

Existing Pond

Hydrograph type	= Reservoir	Peak discharge	= 5.198 cfs
Storm frequency	= 25 yrs	Time to peak	= 20.87 hrs
Time interval	= 2 min	Hyd. volume	= 1,066,999 cuft
Inflow hyd. No.	= 19 - Pond Inflow	Max. Elevation	= 446.59 ft
Reservoir name	= Detention Pond	Max. Storage	= 975,015 cuft

Storage Indication method used.



Pond Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® by Autodesk, Inc. v2020 Monday, 10 / 4 / 2021

Pond No. 1 - Detention Pond

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 438.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	438.00	90,680	0	0
2.00	440.00	100,759	191,331	191,331
4.00	442.00	111,280	211,930	403,262
6.00	444.00	122,252	233,422	636,683
8.00	446.00	133,639	255,780	892,464
10.00	448.00	145,428	278,956	1,171,420
12.00	450.00	157,640	302,956	1,474,376
14.00	452.00	170,219	327,744	1,802,120
16.00	454.00	183,212	353,316	2,155,436

Culvert / Orifice Structures

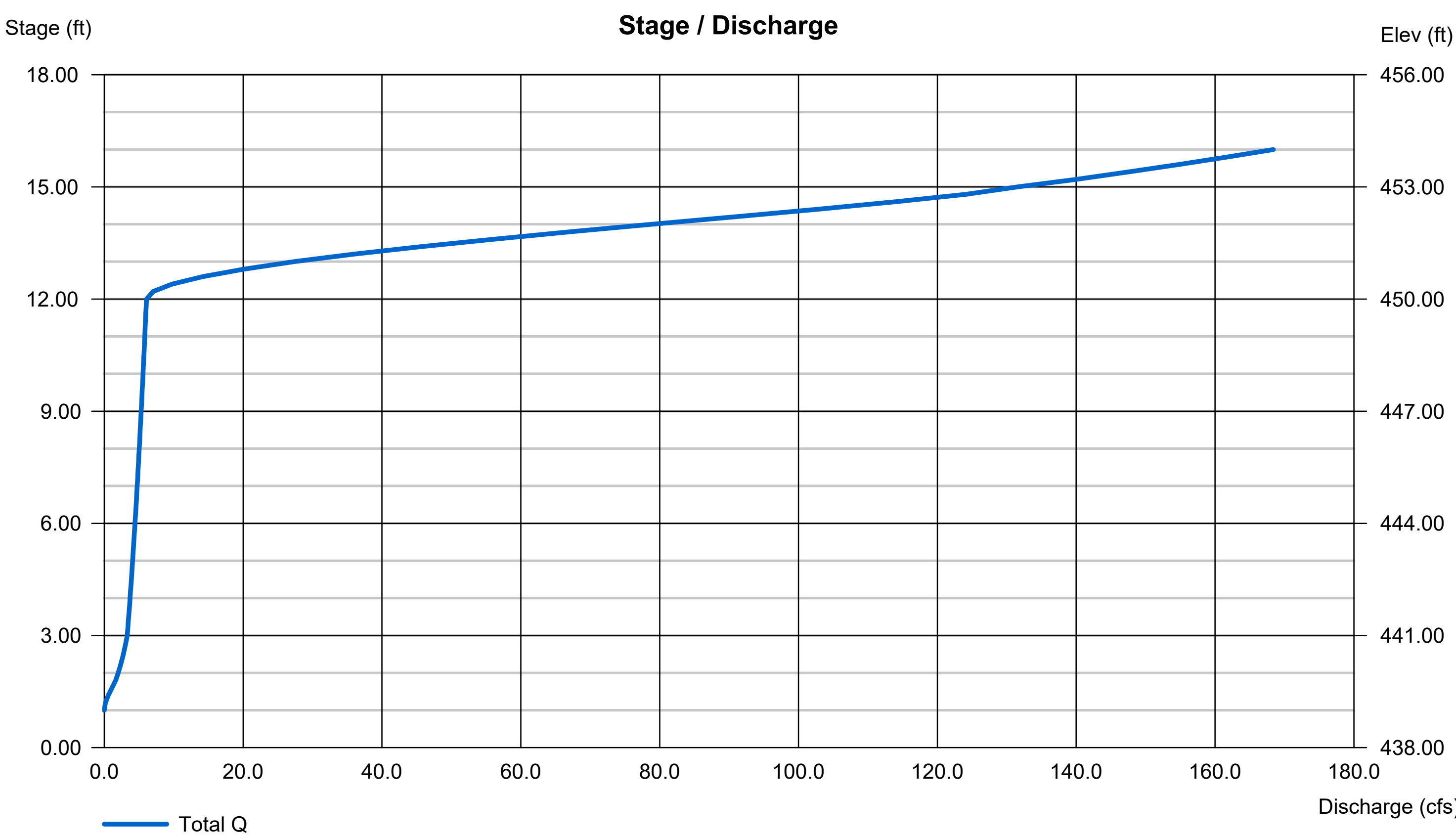
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 10.00	36.00	0.00	0.00
Span (in)	= 10.00	36.00	0.00	0.00
No. Barrels	= 1	3	0	0
Invert El. (ft)	= 439.00	450.00	0.00	0.00
Length (ft)	= 130.00	50.00	0.00	0.00
Slope (%)	= 2.00	2.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Contour)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	69.8703	13.1000	0.8658	--------
3	0.0000	0.0000	0.0000	--------
5	79.2597	14.6000	0.8369	--------
10	88.2351	15.5000	0.8279	--------
25	102.6072	16.5000	0.8217	--------
50	114.8193	17.2000	0.8199	--------
100	127.1596	17.8000	0.8186	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

Precip. file name: Sample.pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	0.00	0.00	0.00	0.00	0.00	7.42	0.00	9.99
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX IV.D3

HYDRAULIC ANALYSIS

- **Overland Flow Velocity Analysis**
- **Drainage Swale Flow Analysis**
- **Downchute Flow Analysis**
- **Perimeter Channel Flow Analysis (Hydraflow Express Output Files)**
- **Containment and Diversion Berm Analysis**
- **Hydraulic Analysis References**

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Brett DeVries 10/14/21

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OVERLAND FLOW VELOCITY ANALYSIS

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
FINAL COVER
OVERLAND FLOW VELOCITY

Required:

Calculate the peak velocity on final cover sideslopes and topslopes. Compare calculated peak velocities to permissible non-erodible flow velocity for final cover.

Method:

1. Determine the time of concentration (t_C) and sheet flow velocity on final cover using the Manning's Kinematic Solution.
2. Determine the shallow concentrated flow velocity on final cover using a derivation of Manning's Equation.
3. Compare peak velocity to permissible non-erodible velocity.

References:

1. Texas Department of Transportation, *Bridge Division Hydraulic Manual* , November 2004.
2. Natural Resouces Conservation Service, *Urban Hydrology for Small Watersheds* , *Technical Release 55* , Junes 1986.

Solution:

Calculate the expected peak overland flow velocity on the final cover, using the above methods, for both Case 1 - 175-foot Final Cover Sideslope and Case 2 - 125-foot Final Cover Topslope.

Note: The sideslope length is the greatest spacing between drainage swales on final cover, and the topslope length is the greatest flow length on the final cover topslope.

Case 1: 175-foot Final Cover Sideslope:

1. Determine the time of concentration (t_C) and sheet flow velocity on final cover sideslopes using the Manning's Kinematic Solution.

Sheet Flow Velocity:

Sheet Flow Length =	100	ft
Slope =	0.2857	ft/ft

Sheet Flow Time of Concentration Equation:

$$t_c = \frac{0.007(nL)^{0.8}}{(P_{25,24})^{0.5}S^{0.4}}$$

Where:

t_c =	sheet flow time of concentration (hr)
n =	Manning's roughness coefficient
L =	slope length
$P_{25,24}$ =	25-year, 24-hour rainfall depth (in)
S =	slope (ft/ft)

Sheet Flow Velocity Equation:

$$V = \frac{L}{60t_c}$$

Where:

V =	sheet flow velocity (fps)
t_c =	sheet flow time of concentration (min)
L =	sheet flow length (ft)

Calculate t_c:

n =	0.15	(surface roughness for short grass)
L =	100	
$P_{25,24}$ =	7.42	
S =	0.2857	

t_c =	0.037	hr
	2.22	min

Calculate the sheet flow velocity:

L =	100
t_c =	2.22

V =	0.75	fps

2. Determine the shallow concentrated flow velocity on the sideslopes using a derivation of Manning's Equation.

Shallow Concentrated Flow Velocity:

Shallow Concentrated Flow Length = 75 ft
Slope = 0.2857 ft/ft

Rational Method Equation:

$$Q = CiA$$

Where:
- Q = flow rate (cfs)
- C = runoff coefficient
- i = rainfall intensity (in/hr)
- A = drainage area (ac) (assume unit width for flow area)

Intensity Equation:

$$i = b / (t_c + d)^e$$

Where:
- i = rainfall intensity (in/hr)
- b = Constant for Limestone County = 103.67
- d = Constant for Limestone County = 14.4
- e = Constant for Limestone County = 0.812
- t_c = time of concentration (min) (noted below)

Time of Concentration Equation:

$$t_c = \frac{L}{V} = 0.87$$ min (see note below)

Note: (t_c is solved through trial and error by manually adjusting the value for the time of concentration until the ratio of length to velocity and t_c to reach the peak flow rate, as calculated using the Rational Method, are equal)

Calculate peak flow rate for unit width of flow:

C =	0.7		
t_c =	0.87	min	(see note above)
i =	11.33	in/hr	
A =	0.0017	ac	(Unit width of flow, w = 1 ft. Therefore, A = L/43560)

Q =	0.014	cfs

Calculate approximate depth of flow derived from Manning's Method Equation (see attached derivation, page 6A-E-69):

$$d = \left(\frac{Qn}{1.49 S^{0.5}} \right)^{0.6}$$

Q =	0.014	cfs
n =	0.025	(Manning's n for channel flow, conservative)
S =	0.2857	ft/ft

d =	0.010	ft	=	0.11	in

Calculate shallow concentrated flow velocity:

$$V = \frac{Q}{A} = \frac{Q}{d}$$

V =	1.43	fps

3. Compare peak velocity to permissible non-erodible velocity.

Case 1 Conclusion:

The peak velocity between drainage swales on the final cover sideslopes is associated with the shallow concentrated flow component of overland flow. The calculated sideslope shallow concentrated flow velocity is less than the permissible non-erodible velocity of 5.0 ft/s on final cover, as discussed Section 4.1.2.2 of the report.

Case 2: 125-foot Final Topslope:

1. Determine the time of concentration (t_C) and sheet flow velocity on final cover topslopes using the Manning's Kinematic Solution.

Sheet Flow Velocity:

Sheet Flow Length =	100	ft
Slope =	0.03	ft/ft

Sheet Flow Time of Concentration Equation:

$$t_c = \frac{0.007(nL)^{0.8}}{(P_{25,24})^{0.5} S^{0.4}}$$ **(as described above)**

Sheet Flow Velocity Equation:

$$V = \frac{L}{60t_c}$$ **(as described above)**

Calculate t_c:

n =	0.15	(surface roughness for short grass)
L =	100	
$P_{25,24}$ =	7.42	
S =	0.03	

t_c =	0.091	hr
	5.47	min

Calculate the sheet flow velocity:

L =	100
t_c =	5.47

V =	0.30	fps

2. Determine the shallow concentrated flow velocity on the topslopes using a derivation of Manning's Equation.

Shallow Concentrated Flow Velocity:

Shallow Concentrated Flow Length =	25	ft
Slope =	0.0300	ft/ft

Rational Method Equation:

$$Q = CiA$$ **(as described above)**

Where:

Q =	flow rate (cfs)
C =	runoff coefficient
i =	rainfall intensity (in/hr)
A =	drainage area (ac) (assume unit width for flow area)

Intensity Equation:

$$i = b / (t_c + d)^e$$ **(as described above)**

Time of Concentration Equation:

$$t_c = \frac{L}{V} = 1.18$$ min (see note below)

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
FINAL COVER
OVERLAND FLOW VELOCITY

Note: (t_c is solved through trial and error by manually adjusting the value for the time of concentration until the ratio of length to velocity and t_c to reach the peak flow rate, as calculated using the Rational Method, are equal)

Calculate peak flow rate for unit width of flow:

C =	0.35		
t_c =	1.18	min	(see note above)
i =	11.15	in/hr	
A =	0.0006	ac	(Unit width of flow, w = 1 ft. Therefore, A = L/43560)

Q =	0.002	cfs

Calculate approximate depth of flow derived from Manning's Method Equation (see attached derivation, page 6A-E-69):

$$d = \left(\frac{Qn}{1.49 S^{0.5}} \right)^{0.6}$$

Q =	0.002	cfs
n =	0.025	(Manning's n for channel flow, conservative)
S =	0.03	ft/ft

d =	0.006	ft	=	0.08	in

Calculate shallow concentrated flow velocity:

$$V = \frac{Q}{A} = \frac{Q}{d}$$

V =	0.35	fps

3. Compare peak velocity to permissible non-erodible velocity.

Case 2 Conclusion:

The peak velocity on the final cover topslope is associated with the shallow concentrated flow component of overland flow. The calculated topslope shallow concentrated flow velocity is less than the permissible non-erodible velocity of 5.0 ft/s on final cover, as discussed in Section 4.1.2.1 of the plan.

DRAINAGE SWALE FLOW ANALYSIS

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
DRAINAGE SWALE FLOW ANALYSIS

Required: Calculate the flow velocity and normal depth for sizing drainage swales installed on final cover.

Method:

1. Determine peak discharge rate associated with the 25 - year, 24 - hour storm event for the swale contributing drainage areas using the Rational Method (see Section 4.1.2.2 of report).
2. Determine Mannings "n" and runoff coefficient "C".
3. Using the specified channel geometry, evaluate the peak velocity and flow depth using Hydraflow Express program.
4. Compare the worst case flow velocity with the permissible velocity of 5 fps.

Solution: **Rational Method Calculations for Typical Swale Contributing Areas**

Drainage Area [2]	Runoff Coef. C[3]	Rainfall Int. I, (in/hr)[4]	Area (acres)	Peak Discharge (cfs)
SW-1	0.70	7.7	3.4	18.4
SW-2	0.70	7.7	2.2	11.9
SW-3	0.70	7.7	1.6	8.7
SW-4	0.70	7.7	2.5	13.8
SW-5	0.70	7.7	2.4	13.1
SW-6	0.70	7.7	1.8	9.5
SW-7	0.35	7.7	0.9	2.5

$$I = \frac{b}{(t_c + d)^e}$$

Where, I = Rainfall intensity, in/hr
b= 103.67
d= 14.4
e= 0.812
t_c = 10 min

(b, d, e are associated with a 25 - year, 24 - hour storm for McClennan Co.)

Typical Swale Summary Calculations[1]

Drainage Area [2]	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n[3]	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)
SW-1	18.4	0.01	0.027	2	3.5	0.0	1.30	3.95
SW-2	11.9	0.01	0.027	2	3.5	0.0	1.11	3.50
SW-3	8.7	0.01	0.027	2	3.5	0.0	0.99	3.22
SW-4	13.8	0.01	0.027	2	3.5	0.0	1.17	3.65
SW-5	13.1	0.01	0.027	2	3.5	0.0	1.15	3.59
SW-6	9.5	0.01	0.027	2	3.5	0.0	1.02	3.31
SW-7	2.5	0.01	0.027	2	3.5	0.0	0.62	2.35

Conclusions:

From above drainage swale summary calculations, the greatest calculated flow velocity in a sideslope swale is 3.95 fps , which is less than the permissible velocity of 7 fps. Therefore, drainage swales installed on the final cover sideslope will be constructed with a minimum depth of 2.3 feet. Drainage swales will be constructed with a minimum 1-foot of freeboard above calculated peak flow depth. See Drawing IV.D5 for drainage swale details.

Notes:

1. Calculations were performed using the Hydraflow Express program developed by Autodesk, Inc. (Version 2020).
2. Contributing drainage areas are depicted on Drawing IV.D2-B.
3. Refer to Hydraulic Calculation References for Mannings "n" and runoff coefficient, C, references.
4. Rainfal Intensity (I) calculated for tc = 10 min, using equation for rainfall intensity shown above. Refer to Hydraulic Calculation References for coefficient b,d, and e references.

Channel Report

SW-1, Lower Northeast Sideslope Swale (Worst Case)

Trapezoidal

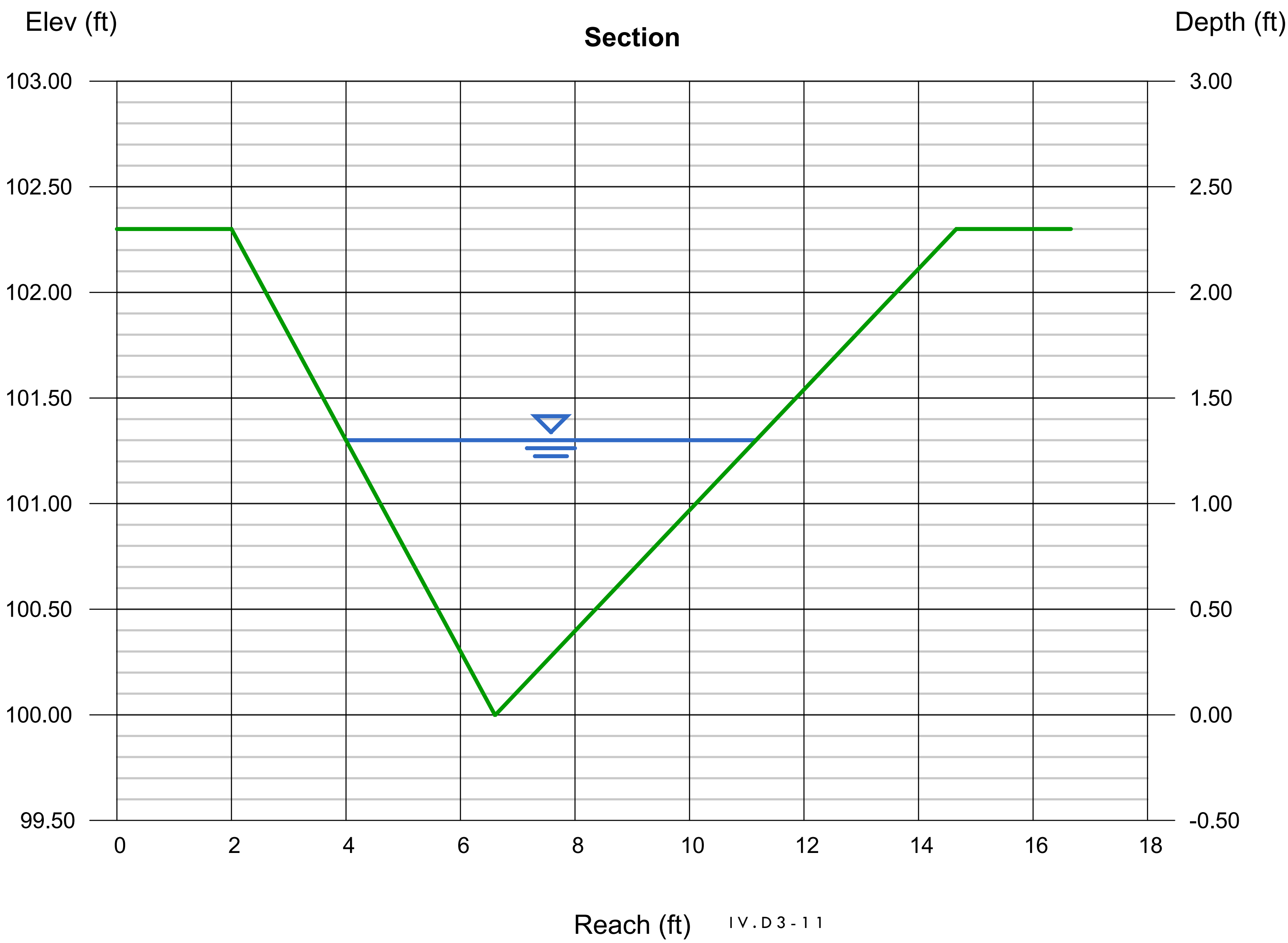
Bottom Width (ft)	=	0.01
Side Slopes (z:1)	=	2.00, 3.50
Total Depth (ft)	=	2.30
Invert Elev (ft)	=	100.00
Slope (%)	=	1.00
N-Value	=	0.027

Calculations

Compute by:		Known Q
Known Q (cfs)	=	18.40

Highlighted

Depth (ft)	=	1.30
Q (cfs)	=	18.40
Area (sqft)	=	4.66
Velocity (ft/s)	=	3.95
Wetted Perim (ft)	=	7.65
Crit Depth, Yc (ft)	=	1.23
Top Width (ft)	=	7.16
EGL (ft)	=	1.54

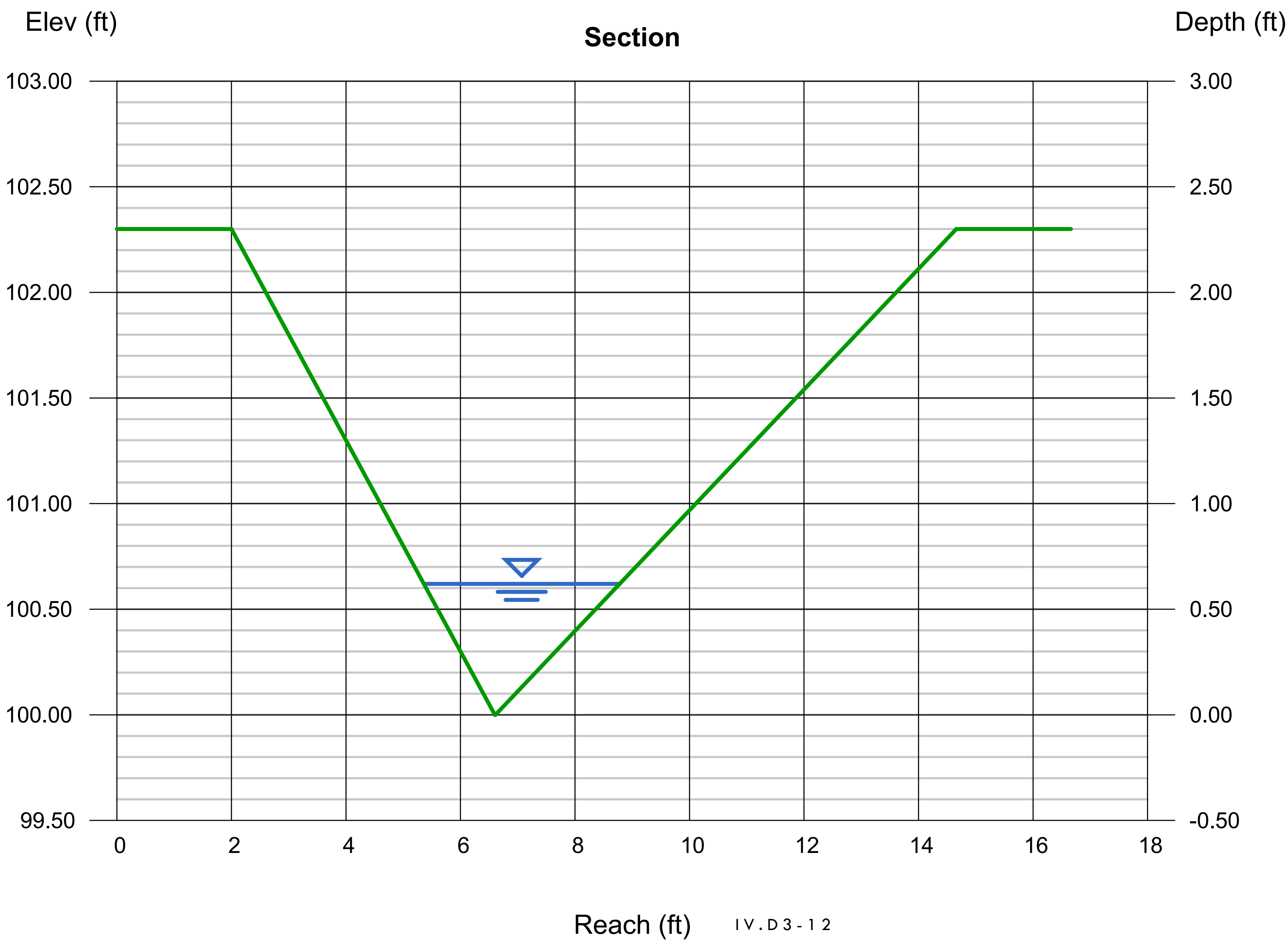


Channel Report

SW-7, West Topslope Swale (Worst Case)

Trapezoidal	
Bottom Width (ft)	= 0.01
Side Slopes (z:1)	= 2.00, 3.50
Total Depth (ft)	= 2.30
Invert Elev (ft)	= 100.00
Slope (%)	= 1.00
N-Value	= 0.027
Calculations	
Compute by:	Known Q
Known Q (cfs)	= 2.50

Highlighted	
Depth (ft)	= 0.62
Q (cfs)	= 2.500
Area (sqft)	= 1.06
Velocity (ft/s)	= 2.35
Wetted Perim (ft)	= 3.65
Crit Depth, Yc (ft)	= 0.56
Top Width (ft)	= 3.42
EGL (ft)	= 0.71



DOWNCHUTE FLOW ANALYSIS

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
DOWNCHUTE FLOW ANALYSIS

Required: Calculate the peak flow depth for sizing downchutes installed on final cover.

Method:

1. Determine peak discharge rate associated with the 25 - year, 24 - hour storm event for downchute contributing drainage areas using the Rational Method (see Section 4.1.2.2 of report).
2. Determine Mannings "n" and runoff coefficient "C".
3. Using the specified channel geometry, evaluate the peak velocity and flow depth using Hydraflow Express program.

Solution:

$$I = \frac{b}{(t_c + d)^e}$$

Where, I = Rainfall intensity, in/hr

b= 103.67
d= 14.4
e= 0.812
t_c = 10 min

(b, d, e are associated with a 25 - year, 24 - hour storm for McLennan Co.)

Rational Method Calculations for Typical Swale Contributing Areas

	Drainage Area [2]	Runoff Coef. C[3]	Rainfall Int. I, (in/hr)[4]	Area (acres)	Peak Discharge (cfs)
East	DC-1	0.70	7.7	9.7	52.8
	DC-2	0.70	7.7	9.0	48.5
West	DC-3	0.70	7.7	5.2	27.9

Typical Swale Summary Calculations[1]

Drainage Area [2]	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n[3]	Sideslope (left)	Sideslope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)
DC-1	52.8	0.2857	0.033	2	2	15.0	0.32	10.55
DC-2	48.5	0.2857	0.033	2	2	15.0	0.30	10.36
DC-3	27.9	0.2857	0.033	2	2	15.0	0.22	8.21

Conclusions: Based on the greatest contributing drainage areas shown on Drawing 2, downchutes installed on final cover will be constructed 2 feet deep (assuming 1-foot of freeboard), with a 15-foot bottom width, and 2H:1V sideslopes. Gabions, rip rap, or dissipation blocks will be installed at the toe of the landfill berm with the perimeter channels to dissipate the peak velocity. Typical details for downchutes are depicted on Drawing 5.4.

Notes:

1. Calculations were performed using the Hydraflow Express program developed by Autodesk, Inc. (Version 2020).
2. Contributing drainage areas are depicted on Drawing IV.D2-B.
3. Refer to Hydraulic Calculation References for Mannings "n" and runoff coefficient, C, references.
4. Rainfal Intensity (I) calculated for tc = 10 min, using equation for rainfall intensity shown above. Refer to Hydraulic Calculation References for coefficient b,d, and e references.

Channel Report

Hydraflow Express Extension for Autodesk® Civil 3D® by Autodesk, Inc. Thursday, Sep 30 2021

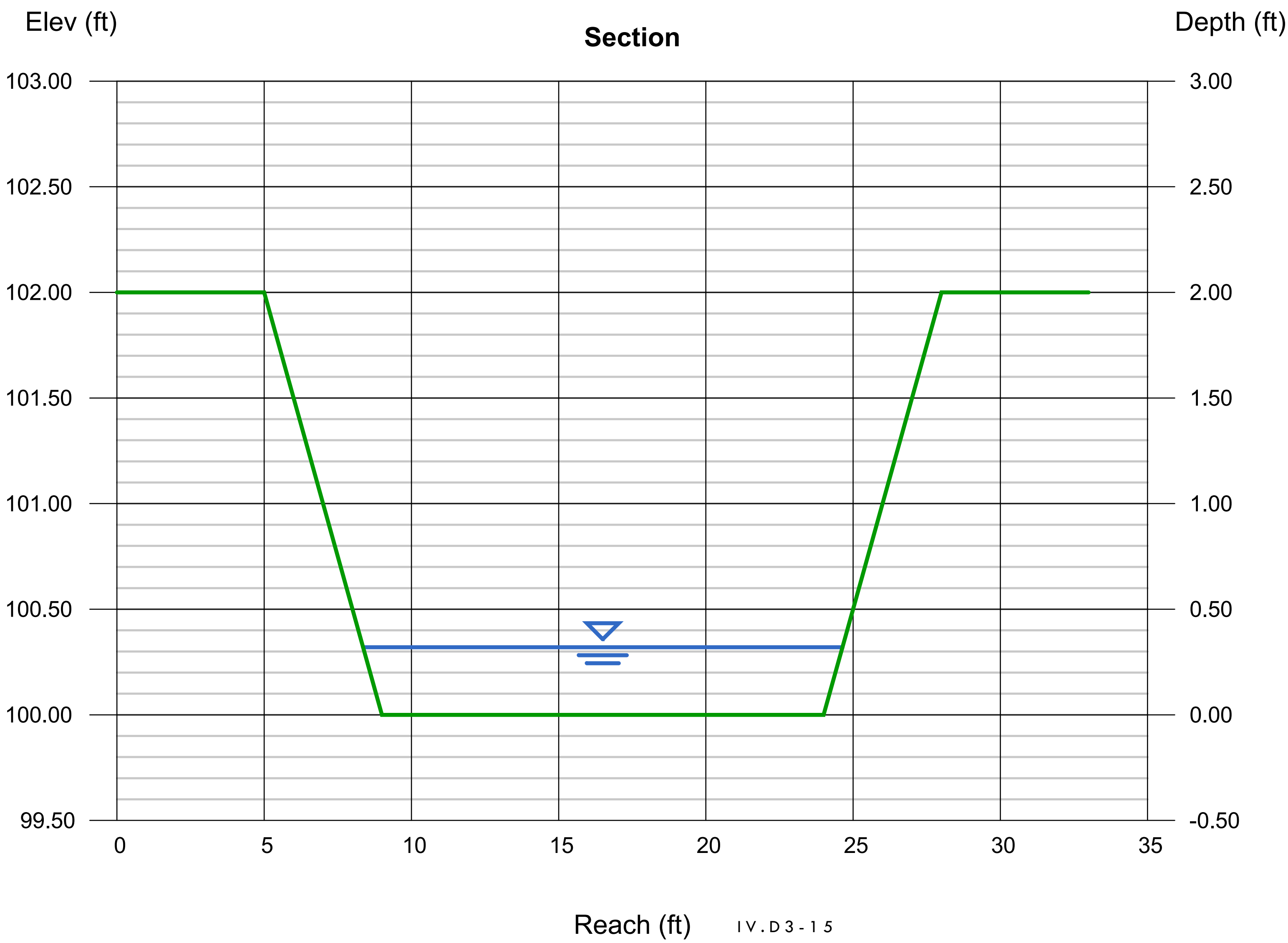
DC-1, Drainage Area 1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 15.00	Depth (ft)	= 0.32
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 52.80
Total Depth (ft)	= 2.00	Area (sqft)	= 5.00
Invert Elev (ft)	= 100.00	Velocity (ft/s)	= 10.55
Slope (%)	= 28.57	Wetted Perim (ft)	= 16.43
N-Value	= 0.033	Crit Depth, Yc (ft)	= 0.71
		Top Width (ft)	= 16.28
		EGL (ft)	= 2.05

Calculations

Compute by: Known Q

Known Q (cfs) = 52.80



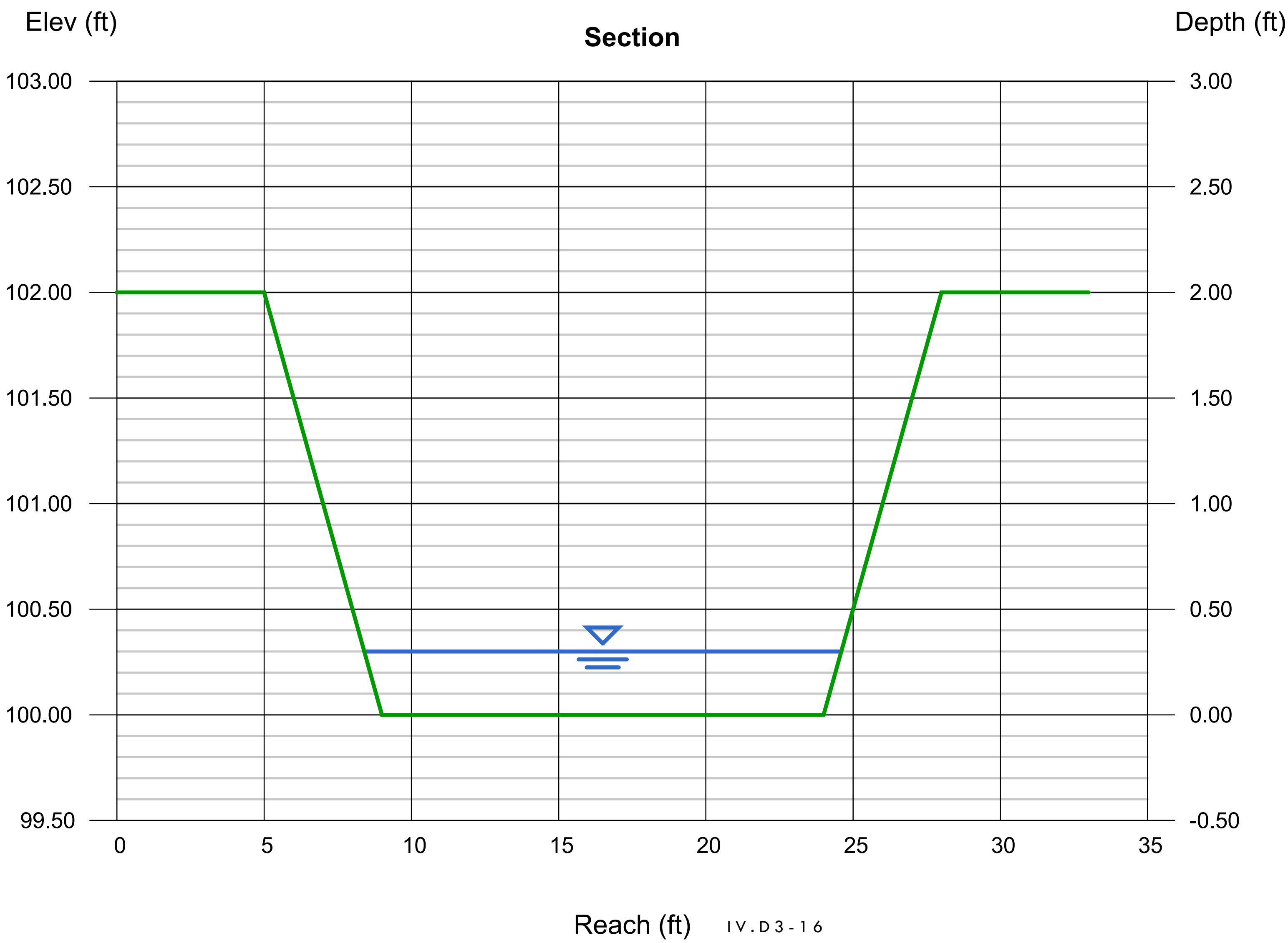
Channel Report

DC-2, Drainage Area 2

Trapezoidal
Bottom Width (ft) = 15.00
Side Slopes (z:1) = 2.00, 2.00
Total Depth (ft) = 2.00
Invert Elev (ft) = 100.00
Slope (%) = 28.57
N-Value = 0.033

Calculations
Compute by: Known Q
Known Q (cfs) = 48.50

Highlighted
Depth (ft) = 0.30
Q (cfs) = 48.50
Area (sqft) = 4.68
Velocity (ft/s) = 10.36
Wetted Perim (ft) = 16.34
Crit Depth, Yc (ft) = 0.67
Top Width (ft) = 16.20
EGL (ft) = 1.97

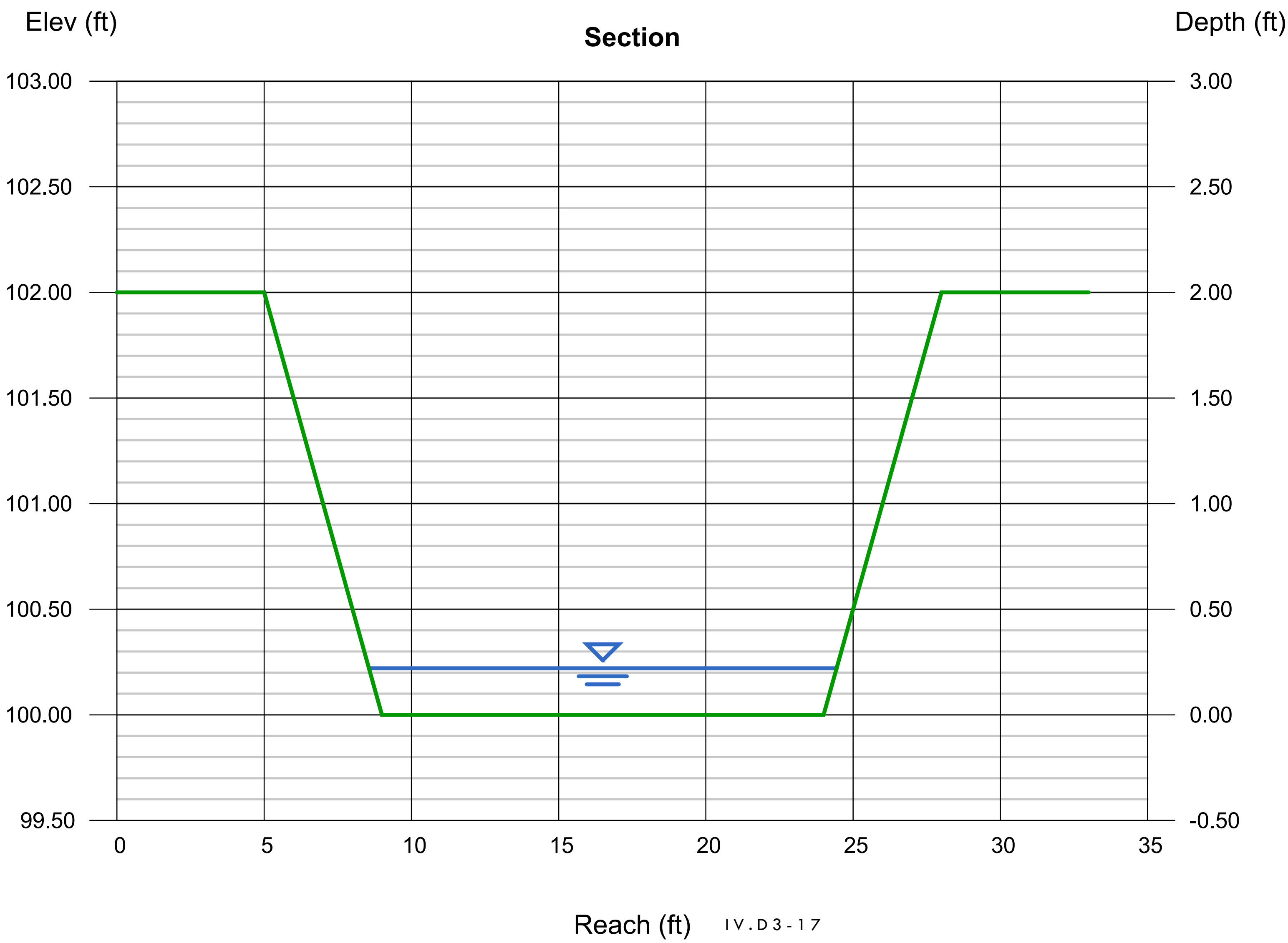


Channel Report

DC-3, Drainage Area 3

Trapezoidal	
Bottom Width (ft)	= 15.00
Side Slopes (z:1)	= 2.00, 2.00
Total Depth (ft)	= 2.00
Invert Elev (ft)	= 100.00
Slope (%)	= 28.57
N-Value	= 0.033
Calculations	
Compute by:	Known Q
Known Q (cfs)	= 27.90

Highlighted	
Depth (ft)	= 0.22
Q (cfs)	= 27.90
Area (sqft)	= 3.40
Velocity (ft/s)	= 8.21
Wetted Perim (ft)	= 15.98
Crit Depth, Yc (ft)	= 0.47
Top Width (ft)	= 15.88
EGL (ft)	= 1.27



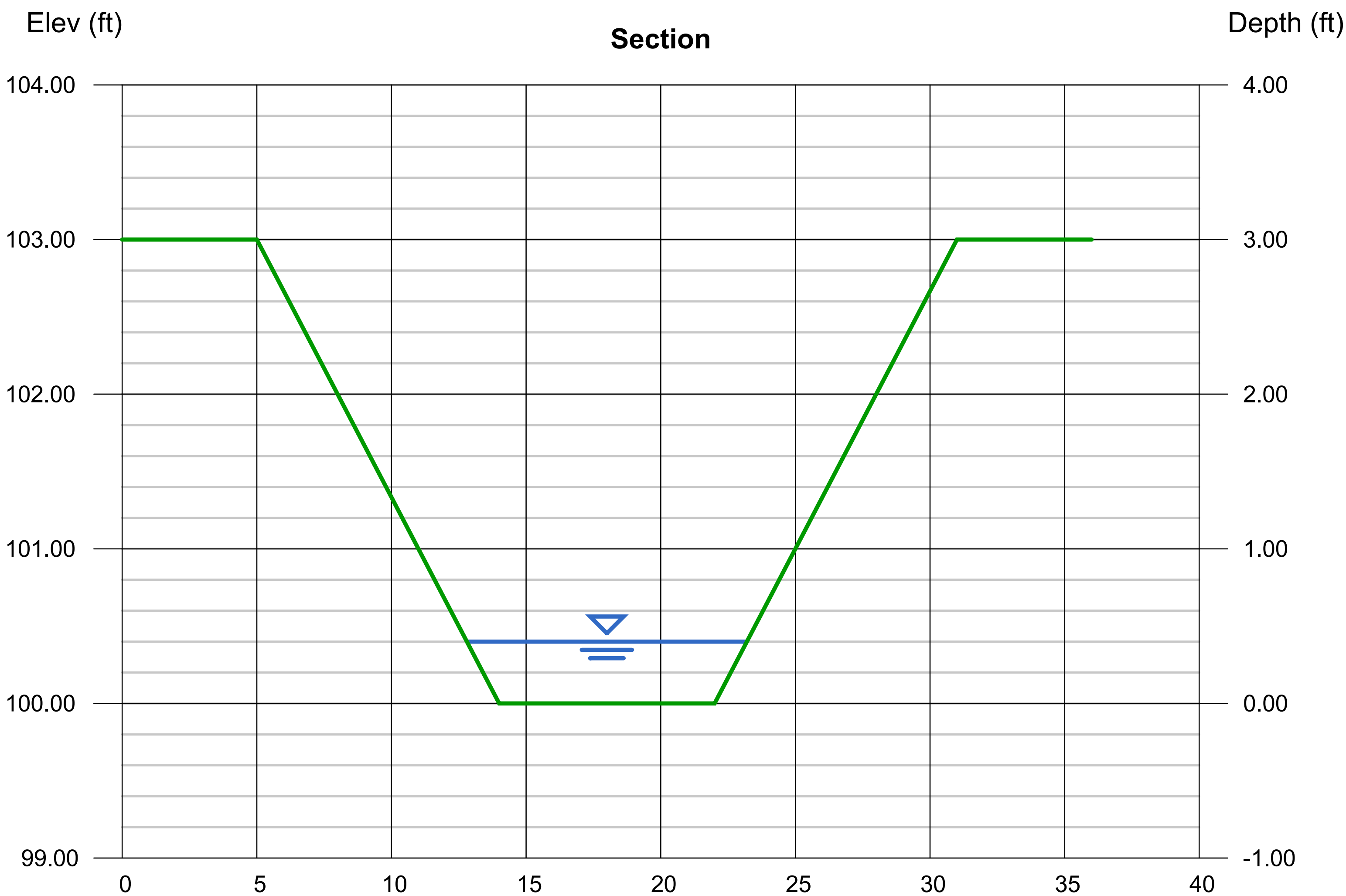
PERIMETER CHANNEL FLOW ANALYSIS
(HYDRAFLOW EXPRESS OUTPUT FILES)

Channel Report

Hydraflow Express Extension for Autodesk® Civil 3D® by Autodesk, Inc. — Monday, Oct 4 2021

East Channel - 1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 8.00	Depth (ft)	= 0.40
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 9.860
Total Depth (ft)	= 3.00	Area (sqft)	= 3.68
Invert Elev (ft)	= 100.00	Velocity (ft/s)	= 2.68
Slope (%)	= 1.00	Wetted Perim (ft)	= 10.53
N-Value	= 0.027	Crit Depth, Yc (ft)	= 0.35
		Top Width (ft)	= 10.40
Calculations		EGL (ft)	= 0.51
Compute by:	Known Q		
Known Q (cfs)	= 9.86		

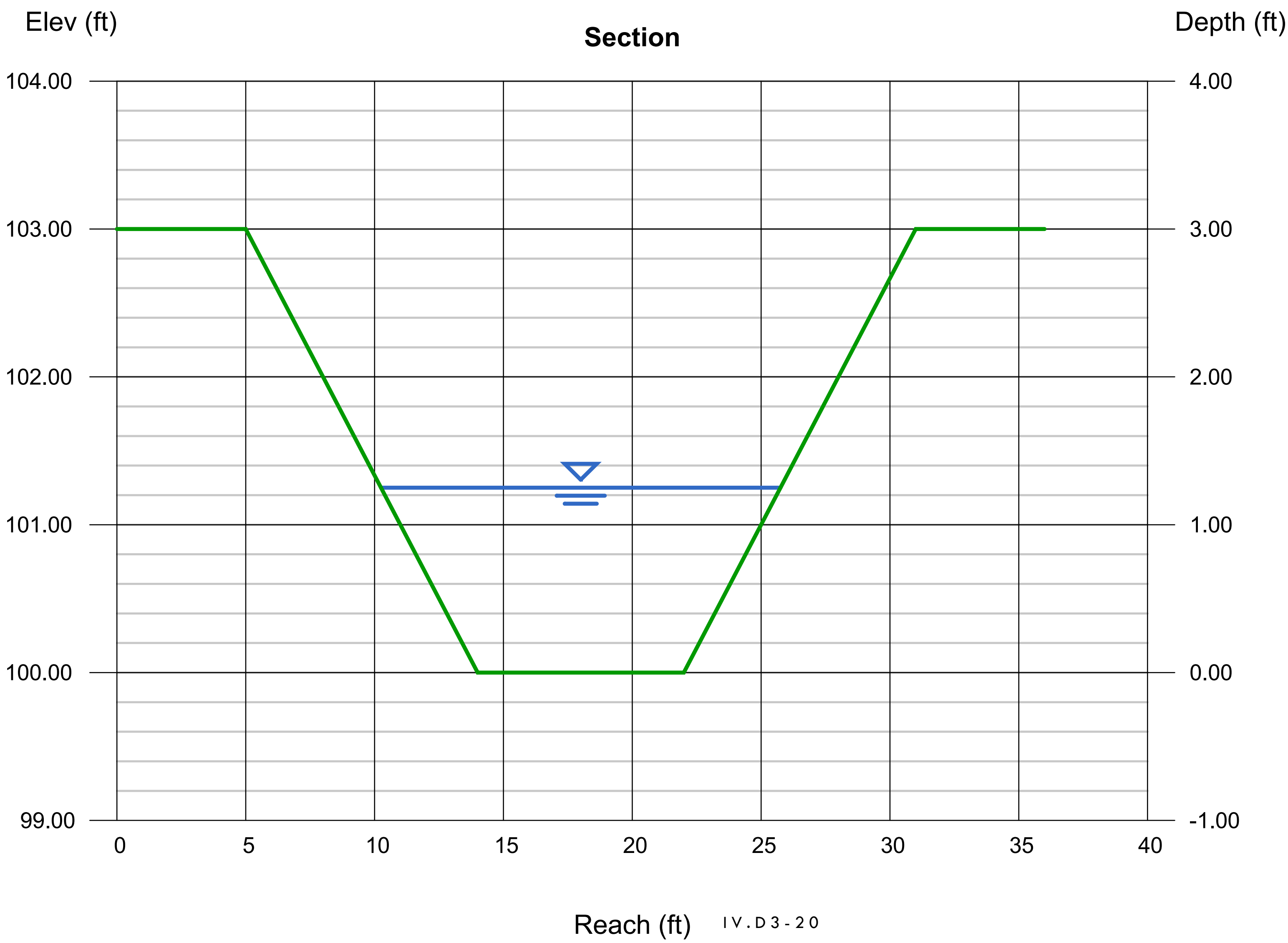


Reach (ft)

Channel Report

East Channel - 2

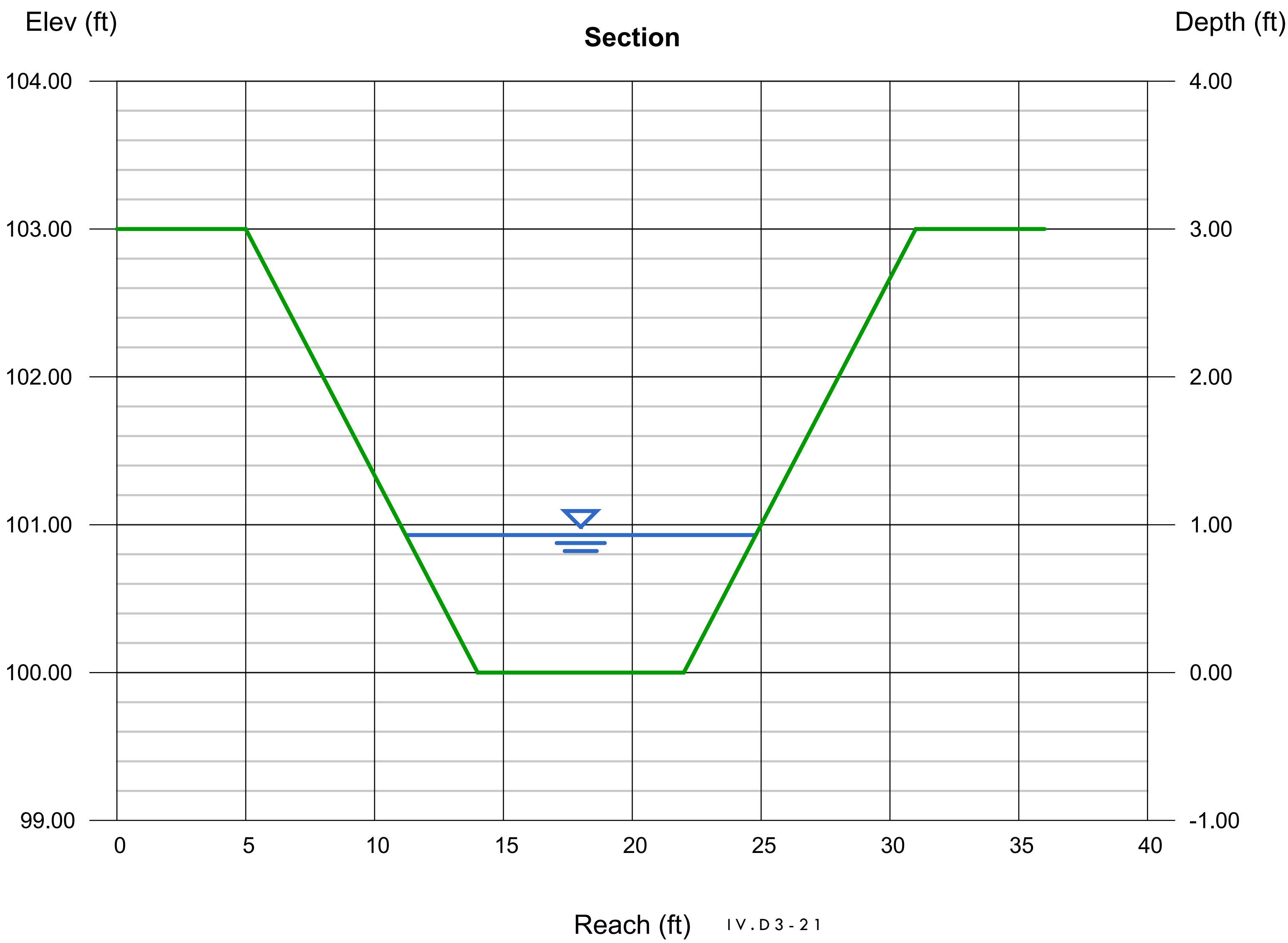
Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 8.00	Depth (ft)	= 1.25
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 76.07
Total Depth (ft)	= 3.00	Area (sqft)	= 14.69
Invert Elev (ft)	= 100.00	Velocity (ft/s)	= 5.18
Slope (%)	= 1.00	Wetted Perim (ft)	= 15.91
N-Value	= 0.027	Crit Depth, Yc (ft)	= 1.21
		Top Width (ft)	= 15.50
Calculations		EGL (ft)	= 1.67
Compute by:	Known Q		
Known Q (cfs)	= 76.07		



Channel Report

West Channel - 1

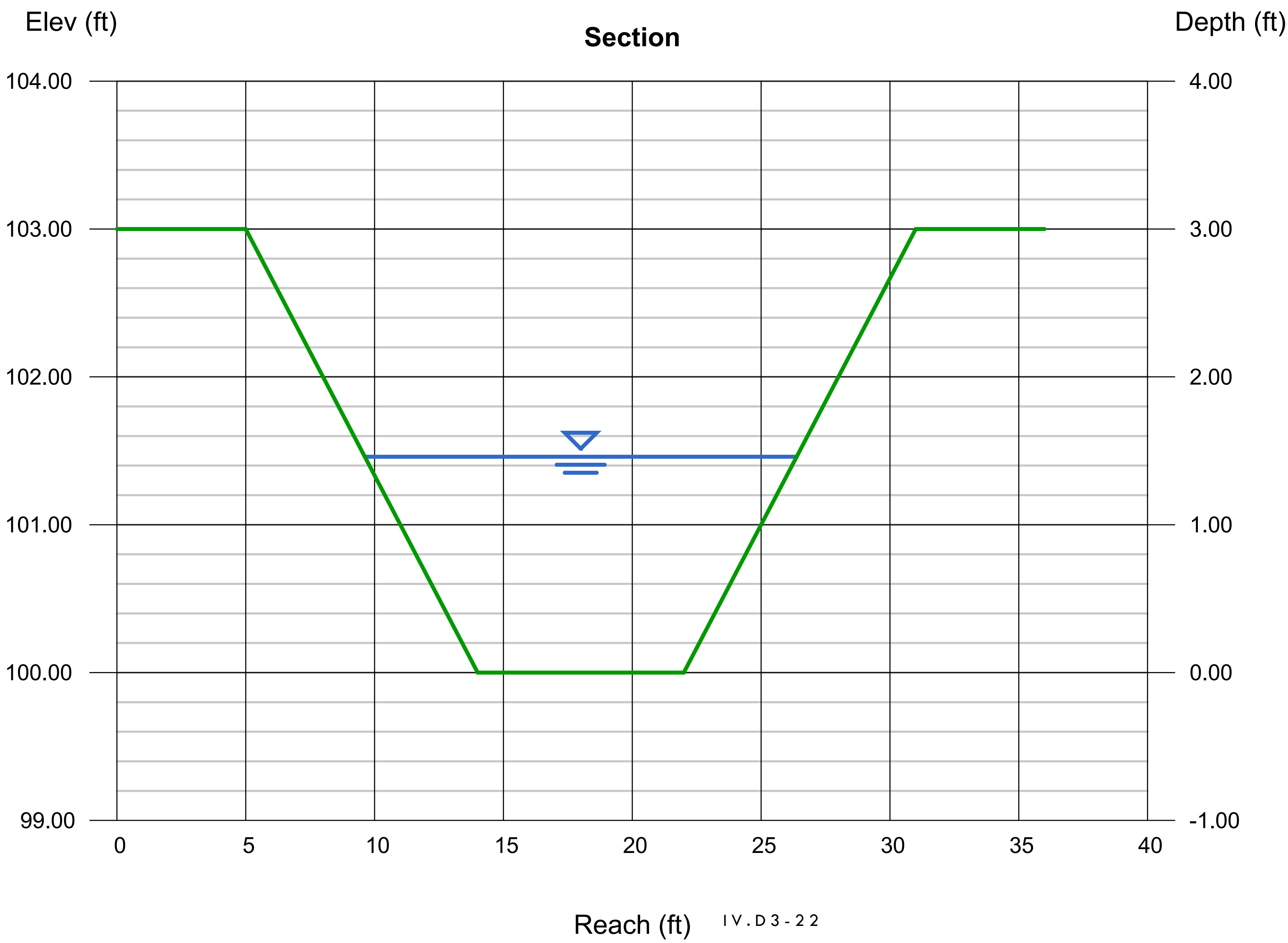
Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 8.00	Depth (ft)	= 0.93
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 43.66
Total Depth (ft)	= 3.00	Area (sqft)	= 10.03
Invert Elev (ft)	= 100.00	Velocity (ft/s)	= 4.35
Slope (%)	= 1.00	Wetted Perim (ft)	= 13.88
N-Value	= 0.027	Crit Depth, Yc (ft)	= 0.87
		Top Width (ft)	= 13.58
Calculations		EGL (ft)	= 1.22
Compute by:	Known Q		
Known Q (cfs)	= 43.66		



Channel Report

West Channel - 2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 8.00	Depth (ft)	= 1.46
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 101.45
Total Depth (ft)	= 3.00	Area (sqft)	= 18.07
Invert Elev (ft)	= 100.00	Velocity (ft/s)	= 5.61
Slope (%)	= 1.00	Wetted Perim (ft)	= 17.23
N-Value	= 0.027	Crit Depth, Yc (ft)	= 1.43
		Top Width (ft)	= 16.76
Calculations		EGL (ft)	= 1.95
Compute by:	Known Q		
Known Q (cfs)	= 101.45		



CONTAINMENT AND DIVISION BERM ANALYSIS

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
CONTAINMENT AND DIVERSION BERM ANALYSIS

Required:

1. Determine the height of the containment and diversion berms required for run-on control over exposed CCR waste.

Procedure:

Containment and Diversion Berm Calculations

A. Determine the 25-year, 24-hour flow rates for the containment and diversion berm run-on drainage areas by the Rationa

B. Calculate the capacity of the containment and diversion berm swales at various slopes.

C. Calculate the height of the containment and diversion berm required for the flow rate of run-on surface or contact water

References:

1. National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation Frequency Data Server, 25-year, 24-hour rainfall depth
2. Texas Department of Transportation, "Bridge Division Hydraulic Manual", 2004.

1. Containment and Diversion Berm

As shown on Drawing IV.D7, several scenarios were analyzed to determine the adequacy of the berm configuration.

Hydraulic calculations are summarized in Tables 1 and 2.

The diversion berms were analyzed using the Rational Method.

$$Q = CIA$$

Where:
C = run-off coefficient (intermediate cover and exposed CCR) = 0.5
I = intensity (in/hr)
A = drainage area (ac)

$$I = b / (t_c + d)^e$$

b =	=	103.67	From Rainfall Intensity-Duration Frequency Coefficients for McLennan County:
d =	=	14.39	
e =	=	0.8123	

Note: b, d, e are associated with a 25 - year, 24 - hour storm for McLennan Co. Consistent with TxDOT guidance, a minimum time of 10 minutes was used to calculate the rainfall intensity.

I =	7.74	in/hr

Diversion Berm Summary (Table 1)

Area (ac)	Flow Rate (cfs)
0.5	1.9
1.0	3.9
2.0	7.7
5.0	19.4
8.0	31.0

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
TABLE 2 - CONTAINMENT AND DIVERSION BERM SUMMARY SHEET

For 3% Diversion Berm Area Slope

Drainage Area	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude Number	Berm Depth (ft)	Flow Top Width (ft)
0.5	1.9	0.01	0.025	2	33.3	0	0.3	1.6	0.8	1.3	9.3
1.0	3.9	0.01	0.025	2	33.3	0	0.4	1.9	0.8	1.4	12.2
2.0	7.7	0.01	0.025	2	33.3	0	0.5	2.2	0.8	1.5	15.8
5.0	19.4	0.01	0.025	2	33.3	0	0.6	2.8	0.9	1.6	22.3
8.0	31.0	0.01	0.025	2	33.3	0	0.8	3.1	0.9	1.8	26.6

Note: Calculations were performed using the Hydraflow Express program developed by Autodesk, Inc. (Version 2020).

For 3.5H:1V Diversion Berm Area Slope

Drainage Area	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude Number	Berm Depth (ft)	Flow Top Width (ft)
0.5	1.9	0.01	0.025	2	3.5	0	0.5	2.4	0.8	1.5	3.0
1.0	3.9	0.01	0.025	2	3.5	0	0.7	2.9	0.8	1.7	3.9
2.0	7.7	0.01	0.025	2	3.5	0	0.9	3.4	0.9	1.9	5.0
5.0	19.4	0.01	0.025	2	3.5	0	1.3	4.2	0.9	2.3	7.1
8.0	31.0	0.01	0.025	2	3.5	0	1.5	4.8	1.0	2.5	8.5

Note: Calculations were performed using the Hydraflow Express program developed by Autodesk, Inc. (Version 2020).

HYDRAULIC ANALYSIS REFERENCE

Hydraulic Design Manual

Revised September 2019

Table 4-10: Runoff Coefficients for Urban Watersheds

Type of drainage area	Runoff coefficient
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.30-0.70
Residential:	
Single-family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.35-0.40
Apartment dwelling areas	0.30-0.70
Industrial:	
Light areas	0.30-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.30-0.40
Railroad yards	0.30-0.40
Unimproved areas:	
Sand or sandy loam soil, 0-3%	0.15-0.20
Sand or sandy loam soil, 3-5%	0.20-0.25
Black or loessial soil, 0-3%	0.18-0.25
Black or loessial soil, 3-5%	0.25-0.30
Black or loessial soil, > 5%	0.70-0.80
Deep sand area	0.05-0.15
Steep grassed slopes	0.70
Lawns:	
Sandy soil, flat 2%	0.05-0.10
Sandy soil, average 2-7%	0.10-0.15
Sandy soil, steep 7%	0.15-0.20
Heavy soil, flat 2%	0.13-0.17
Heavy soil, average 2-7%	0.18-0.22

Table 4-10: Runoff Coefficients for Urban Watersheds

Type of drainage area	Runoff coefficient
Heavy soil, steep 7%	0.25-0.35
Streets:	
Asphaltic	0.85-0.95
Concrete	0.90-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.95
Roofs	0.75-0.95

Rural and Mixed-Use Watershed

Table 4-11 shows an alternate, systematic approach for developing the runoff coefficient. This table applies to rural watersheds only, addressing the watershed as a series of aspects. For each of four aspects, the designer makes a systematic assignment of a runoff coefficient "component." Using Equation 4-22, the four assigned components are added to form an overall runoff coefficient for the specific watershed segment.

The runoff coefficient for rural watersheds is given by:

$$C = C_r + C_i + C_v + C_s$$

Equation 4-22.

Where:

C = runoff coefficient for rural watershed

C_r = component of coefficient accounting for watershed relief

C_i = component of coefficient accounting for soil infiltration

C_v = component of coefficient accounting for vegetal cover

C_s = component of coefficient accounting for surface type

The designer selects the most appropriate values for C_r, C_i, C_v, and C_s from Table 4-11.

Procedure for using the Rational Method

The rational formula estimates the peak rate of runoff at a specific location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration. The rational formula is:

$$Q = \frac{CIA}{Z}$$

Equation 4-20.

Where:

Q = maximum rate of runoff (cfs or m^3/sec.)

C = runoff coefficient

I = average rainfall intensity (in./hr. or mm/hr.)

A = drainage area (ac or ha)

Z = conversion factor, 1 for English, 360 for metric

Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in in./hr. for a specific rainfall duration and a selected frequency. The duration is assumed to be equal to the time of concentration. For drainage areas in Texas, you may compute the rainfall intensity using Equation 4-21, which is known as a rainfall intensity-duration-frequency (IDF) relationship (power-law model).

$$I = \frac{b}{(t_c + d)^e}$$

Equation 4-21.

Where:

I = design rainfall intensity (in./hr.)

tc = time of concentration (min) as discussed in Section 11

e, b, d = coefficients for specific frequencies listed by county in the EBDLKUP-2015v2.1.xlsx spreadsheet lookup tool (developed by Cleveland et al. 2015). These coefficients are based on rainfall frequency-duration data contained in the Atlas of Depth-Duration Frequency (DDF) of Precipitation of Annual Maxima for Texas (TxDOT 5-1301-01-1). Also see video/tutorial on the use of the EBDLKUP-2015v2.1.xlsx spreadsheet tool.

Rainfall Intensity-Duration-Frequency Coefficients for Texas

Based on United States Geological Survey (USGS) Scientific Investigations Report 2004–5041
"Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas"

1. Select English or SI Units

English

2. Select or Enter a County

McLennan

3. Enter a Time of Conc.
Select Units

10 min

Coefficient	50% (2-year)	20% (5-year)	10% (10-year)	4% (25-year)	2% (50-year)	1% (100-year)
e	0.8233	0.813	0.8121	0.8123	0.8136	0.8146
b (in.)	56.42	71.84	85.78	103.67	122.99	144.44
d (min)	13.34	13.04	13.60	14.39	14.87	15.43
Intensity (in./hr)	4.22	5.61	6.58	7.74	9.00	10.35

(Spreadsheet Release Date: August 31, 2015; data table reshuffle by Asquith July 14, 2016)

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Conservation
Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

TR-55

To show bookmarks which navigate through the document.

Click the show/hide navigation pane button , and then

click the bookmarks tab. It will navigate you to the contents,

chapters, rainfall maps, and printable forms.

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Final Cover: n= 0.15

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \quad \text{[eq. 3-3]}$$

where:

- T_t = travel time (hr),
- n = Manning's roughness coefficient (table 3-1)
- L = flow length (ft)
- P_2 = 2-year, 24-hour rainfall (in)
- s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation.

Design Hydrology and Sedimentology for Small Catchments

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where the value of I is

Retardance	I
A	10.000
B	7.643
C	5.601
D	4.436
E	2.876

This relationship can be used in computer programs to make hydraulic computations for vegetated waterways. The relationships should not be used outside the range of the curves shown in Fig. 4.14.

The graphs of Fig. 4.15 are solutions to Manning's equation using the curves in Fig. 4.14. They can be used as a design aid for solving Manning's equation for all retardance classes.

Example Problem 4.11 Vegetated channel 1

Design a channel to carry 25 cfs on a 4% slope. Use a parabolic channel. The soil is easily eroded, and the grass may be mowed to 2.5 in. or it may be uncut.

Solution: Select Bermuda grass. Bermuda grass is in retardance B if unmowed and retardance D if mowed. The permissible velocity is selected from Table 4.5 as 6 fps. First design for the mowed condition

$$A = Q/v = 25/6 = 4.17\ \text{ft}^2.$$

Table 4.4 Guide to Selection of Vegetal Retardance[a]

Stand	Length of vegetation (in.)	Retardance class
Good	>30	A
	11–24	B
	6–10	C
	2–6	D
	<2	E
Fair	>30	B
	11–24	C
	6–10	D
	2–6	D
	<2	E

[a]Soil Conservation Service (1979) engineering field manual.

Table 4.5 Permissible velocities for Vegetated Channels (Ree, 1949)

	Permissible velocity (fps)					
	Erosion-resistant soils (% slope)			Easily eroded soils (% slope)		
Cover	0–5	5–10	Over 10	0–5	5–10	Over 10
Bermuda grass	8	7	6	6	5	4
Buffalo grass Kentucky bluegrass Smooth brome Blue grama Tall fescue	7	6	5	5	4	3
Lespedeza sericea Weeping lovegrass Kudzu Alfalfa Crabgrass	3.5	NR[a]	NR	2.5	NR	NR
Grass mixture	5	4	NR	4	3	NR
Annuals for temporary protection	3.5	NR	NR	2.5	NR	NR

[a]Not recommended.

APPENDIX IV.D4

SOIL LOSS ANALYSIS

STATE OF TEXAS
BRETT J. DeVRIES
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PROFESSIONAL ENGINEER

10/14/21

SCS Engineers
TBPE Reg. # F-3407

SANDY CREEK ENERGY STATION
SOLID WASTE DISPOSAL FACILITY
SOIL LOSS ANALYSIS

<u>Required:</u> Determine expected soil loss for the landfill topslope and sideslope with final cover consistent with 30 TAC §330.305(d)(2).

<u>Method:</u>

Expected soil loss is calculated using the Universal Soil Loss Equation (USLE)/Revised Universal Soil Loss Equation (RUSLE). The annual soil loss calculated for final cover conditions is compared to the permissible soil loss of 3 tons/acre/year, as referenced from the TCEQ's "Surface Water Drainage and Erosional Stability Guidance for Municipal Solid Waste Landfill", dated May, 2018.

<u>References:</u>

1. SCS National Engineering Handbook, *Section 3 - Sedimentation, Chapter 3 - Erosion*.
2. TNRCC, Use of the USLE in Final Cover/Configuration Design, 1993.
2. USDA, *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), 1997.*
3. United States Department of Agriculture, Soil Conservation Service, *Soil Survey of Limestone County, Texas.*
3. United States Department of Agriculture, Soil Conservation Service, *Soil Survey of Hill County*, Texas.
4. Reference: USDA, *Predicting Rainfall Erosion Losses, A Guide to Conservation Planning*, Agriculture Handbook Number 537, 1978.
5. TCEQ, *Surface Water Drainage and Erosional Stability Guidance for Municipal Solid Waste Landfill, May 2018.*

<u>Solution:</u> 1. Soil loss equation: A = RKLSCP

Where:

A =	Soil Loss (tons/ac/yr)
R =	Rainfall/Runoff Erosivity actor
K =	Soil Erodibility Factor
L =	Slope Length Factor
S =	Slope Steepness Factor
C =	Cover Management Factor
P =	Support Practice Factor

The rainfall factor, R, is a product of rainfall energy and maximum 30-min intensity.
Average annual R values for Eastern United States is presented in Figure 2-1 of USDA 1997.
Values of the R Factor (see page IV.D4-4), the R factor for the Site is:

R = 295

The soil erodibility, K, factor represents the resistance of a soil surface to erosion as a function of the soil's physical and chemical properties. As shown in soil surveys for McLennan County for the applicable on-site soils (see page IV.D4-5), the weighted average K factor for the area is:

K = 0.289

Solution (Cont.): The effect of topography on soil erosion are determined by the slope length factor, L, and slope steepness factor, S. The slopes of interest are represented by either of the following: (1) topslope above and sideslope below the first drainage swale placed on final cover or (2) sideslope area between consecutive drainage swales on final cover.

Topslope Conditions			Sideslope Conditions		
slope =	3	%	slope =	28.57	%
length, l =	125	ft	length, l =	175	ft

Topographic factor, combined slope length and slope steepness factors LS, is based on a low rill/interill erosion ratio (see page IV.D4-12).

Topslope, LS = 0.65 Sideslope, LS = 5.395

The cover and cropping management factor, C, represents the percentage of soil loss that would occur if the surface were partially protected by some combination of cover and management practices. Using of Table 2 - Factor C for Permanent Pasture, Range, and Idle Land (see page IV.D4-13) for 90% ground cover yields the following C value.

C = 0.006

The erosion control practice factor, P, measures the effect of control practices that reduce the erosion potential of the runoff by influencing drainage patterns, runoff concentration, and runoff velocity. Use of Table 3, for Countouring, Countouring, Stripcropping and Terracing (see page IV.D4-14), the P factor is determined to be:

P = 0.90

2. Soil loss calculations:

Slope Condition	R	K	LS	C	P	A (tons/ac /yr)
3% slope 125 ft length	295	0.289	0.650	0.006	0.90	0.30
28.57% slope 175 ft length	305	0.289	5.395	0.006	0.90	2.57

Conclusions:

From review of the annual soil loss, a value of less than 3 tons/acre/year is achieved, consistent with TCEQ's guidance document for addressing erosional stability during all phases of landfill operation.

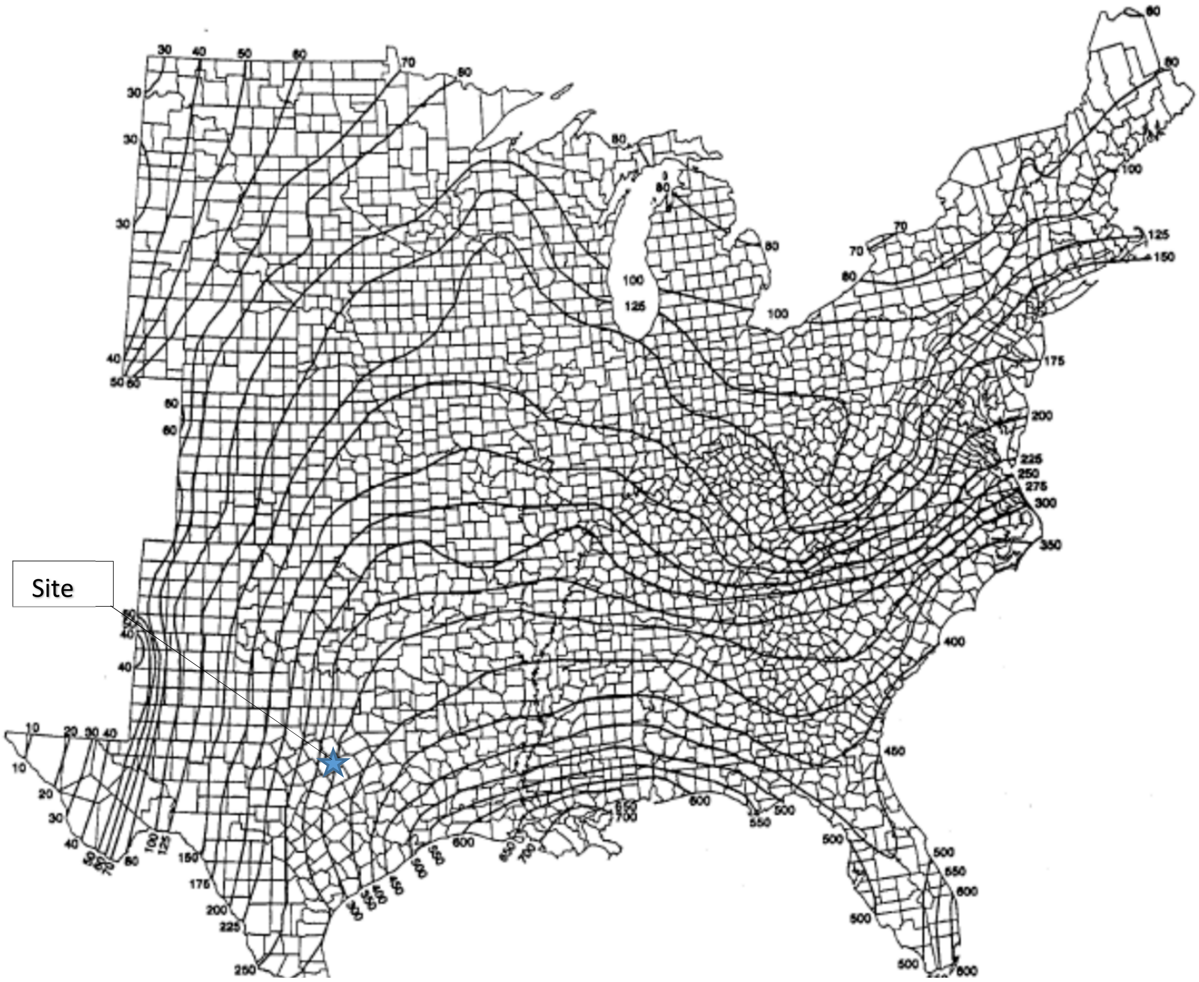

Figure 1. Isoerodent Map of Average Annual Rainfall Runoff Erosivity Factor, R.

Reference: USDA, Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), Agricultural Research Service, Agriculture Handbook Number 703, 1997.

Soil Map—McLennan County, Texas

Map Scale: 1:4,700 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 50, 100, 200, 300

Feet: 0, 200, 400, 800, 1200

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

K Factors for Site Soils

(Table from McLennan County Soil Survey, USDA, NRCS, September 1997

Table 14.--Physical and Chemical Properties of the Soils--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permea- bility	Available water capacity	Soil reaction	Salinity	Shrink- swell potential	Erosion factors K	Erosion factors T	Wind erodi- bility group	Organic matter
	In	Pct	g/cc	In/hr	In/in	pH	mmhos/cm					Pct
BrB-------------	0-5	10-18	1.45-1.60	0.6-2.0	0.11-0.20	5.6-7.3	<2	Low-------	0.43	5	5	1-2
Bremond	5-24	40-50	1.35-1.50	<0.06	0.14-0.18	5.6-7.3	<2	High------	0.32			
	24-55	30-50	1.40-1.65	<0.06	0.15-0.18	6.1-8.4	<2	High------	0.32			
	55-80	27-50	1.40-1.65	<0.06	0.15-0.18	6.6-8.4	2-8	High------	0.32			
BuA-------------	0-24	40-60	1.35-1.50	<0.06	0.12-0.18	6.1-8.4	<2	Very high	0.32	5	4	1-3
Burleson	24-40	40-60	1.40-1.55	<0.06	0.12-0.18	6.1-8.4	0-4	Very high	0.32			
	40-80	35-60	1.40-1.55	<0.06	0.12-0.18	7.4-8.4	0-4	Very high	0.32			
CaB-------------	0-15	2-12	1.40-1.60	2.0-6.0	0.06-0.10	5.6-7.3	<2	Low-------	0.20	5	2	<1
Chazos	15-40	35-50	1.35-1.50	0.06-0.2	0.10-0.18	5.6-6.5	<2	Moderate	0.32			
	40-55	20-40	1.35-1.55	0.06-0.2	0.10-0.18	5.6-7.3	<2	Moderate	0.32			
	55-80	27-45	1.40-1.60	0.06-0.2	0.10-0.18	6.1-8.4	<2	Moderate	0.32			
CfB-------------	0-5	40-60	1.30-1.55	<0.06	0.12-0.15	6.1-8.4	0	Very high	0.32	2	4	1-3
Crawford	5-38	40-60	1.30-1.55	<0.06	0.12-0.15	6.1-8.4	0-2	Very high	0.32			
	38-48	---	---	0.2-2.0	---	---	---	----------	----			
CrB-------------	0-9	5-20	1.50-1.60	0.6-2.0	0.11-0.20	5.6-7.3	<2	Low-------	0.43	4	5	.5-2
Crockett	9-24	40-55	1.35-1.60	<0.06	0.08-0.14	5.6-7.3	<4	High------	0.32			
	24-36	35-55	1.40-1.65	<0.06	0.08-0.14	6.1-8.4	<4	High------	0.32			
	36-55	20-50	1.50-1.70	<0.06	0.11-0.15	6.1-8.4	<4	Moderate	0.32			
	55-80	30-60	1.50-1.70	<0.06	0.11-0.15	6.1-8.4	<4	High------	0.32			
DeB-------------	0-14	35-57	1.18-1.32	0.06-0.2	0.12-0.18	7.9-8.4	<2	High------	0.32	3	4	1-4
Denton	14-22	35-55	1.28-1.50	0.06-0.2	0.12-0.18	7.9-8.4	<2	High------	0.32			
	22-36	20-37	1.40-1.65	0.6-2.0	0.11-0.14	7.9-8.4	<2	Moderate	0.43			
	36-52	12-35	1.40-1.65	0.6-2.0	0.08-0.12	7.9-8.4	<2	Moderate	0.43			
	52-60	---	---	0.06-2.0	---	---	---	----------	----			
DsC-------------	0-7	2-12	1.30-1.60	6.0-20	0.05-0.08	5.1-7.3	0	Low-------	0.20	5	2	.3-1
Desan	7-65	2-12	1.30-1.60	6.0-20	0.05-0.08	5.1-7.3	0	Low-------	0.17			
	65-80	12-25	1.35-1.65	0.6-2.0	0.12-0.16	5.1-6.5	0	Low-------	0.24			
DuB-------------	0-8	3-12	1.30-1.60	6.0-20	0.05-0.10	5.6-7.3	<2	Low-------	0.20	5	2	<1
Dutek	8-30	3-12	1.30-1.60	6.0-20	0.05-0.10	5.6-7.3	<2	Low-------	0.20			
	30-58	18-35	1.30-1.65	0.6-2.0	0.12-0.17	4.5-6.5	<2	Low-------	0.24			
	58-80	5-20	1.30-1.60	2.0-20	0.05-0.10	4.5-6.5	<2	Low-------	0.20			
EcB-------------	0-4	40-60	1.35-1.55	0.2-0.6	0.05-0.12	7.4-8.4	0-2	Moderate	0.15	1	8	2-11
Eckrant	4-15	40-60	1.35-1.60	0.2-0.6	0.05-0.12	7.4-8.4	0-2	Moderate	0.10			
	15-40	---	---	0.06-2.0	---	---	---	----------	----			
EdD-------------	0-4	20-40	1.30-1.50	0.6-2.0	0.10-0.13	7.9-8.4	<2	Low-------	0.24	1	8	<2
Eddy	4-8	20-40	1.30-1.50	0.6-2.0	0.03-0.07	7.9-8.4	<2	Low-------	0.24			
	8-20	---	---	0.06-2.0	---	---	---	----------	----			
EeD*:												
Eddy-----------	0-4	20-40	1.30-1.50	0.6-2.0	0.10-0.13	7.9-8.4	<2	Low-------	0.24	1	8	<2
	4-10	20-40	1.30-1.50	0.6-2.0	0.03-0.07	7.9-8.4	<2	Low-------	0.24			
	10-20	---	---	0.06-2.0	---	---	---	----------	----			
Urban land.												
EsE-------------	0-4	40-50	1.35-1.55	<0.06	0.12-0.18	6.6-8.4	<2	High------	0.32	3	4	1-3
Ellis	4-28	40-60	1.35-1.55	<0.06	0.12-0.18	6.6-8.4	<2	High------	0.32			
	28-60	40-60	1.40-1.65	<0.06	0.10-0.15	6.6-8.4	<2	High------	0.32			

See footnote at end of table.

Table 14.--Physical and Chemical Properties of the Soils--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permea- bility	Available water capacity	Soil reaction	Salinity	Shrink- swell potential	Erosion factors K	Erosion factors T	Wind erodi- bility group	Organic matter
	In	Pct	g/cc	In/hr	In/in	pH	mmhos/cm					Pct
FaB-------------- Fairlie	0-5	35-50	1.35-1.50	<0.06	0.14-0.20	7.4-8.4	0-2	High------	0.32	4	4	1-4
	5-32	40-60	1.40-1.55	<0.06	0.14-0.20	7.4-8.4	0-2	High------	0.32			
	32-42	40-60	1.40-1.60	<0.06	0.14-0.20	7.4-8.4	0-2	High------	0.32			
	42-60	---	---	0.06-2.0	---	---	---	----------	----			
FbB*:												
Fairlie---------	0-14	35-50	1.35-1.50	<0.06	0.14-0.20	7.4-8.4	0-2	High------	0.32	4	4	1-4
	14-32	40-60	1.40-1.55	<0.06	0.14-0.20	7.4-8.4	0-2	High------	0.32			
	32-45	40-60	1.40-1.60	<0.06	0.14-0.20	7.4-8.4	0-2	High------	0.32			
	45-60	---	---	0.06-2.0	---	---	---	----------	----			
Urban land.												
FeE2------------- Ferris	0-6	40-65	1.40-1.50	<0.06	0.15-0.18	7.9-8.4	0-2	Very high	0.32	4	4	.5-2
	6-38	40-65	1.40-1.50	<0.06	0.12-0.18	7.9-8.4	0-2	Very high	0.32			
	38-60	40-75	1.45-1.65	<0.06	0.11-0.15	7.9-8.4	0-2	High------	0.32			
Fr--------------- Frio	0-4	30-50	1.25-1.45	0.2-0.6	0.14-0.20	7.9-8.4	<2	Moderate	0.32	5	4	1-4
	4-42	30-50	1.25-1.45	0.2-0.6	0.14-0.20	7.9-8.4	<2	Moderate	0.32			
	42-80	35-50	1.30-1.55	0.2-0.6	0.14-0.20	7.9-8.4	<2	Moderate	0.32			
Ga--------------- Gaddy	0-8	5-15	1.35-1.50	6.0-20	0.07-0.11	7.4-8.4	0	Low-------	0.17	5	2	0-.5
	8-80	5-35	1.50-1.70	6.0-20	0.06-0.10	7.9-8.4	0	Low-------	0.17			
GhD-------------- Gholson	0-8	5-20	1.35-1.55	2.0-6.0	0.11-0.17	6.1-7.3	<2	Low-------	0.37	5	3	<2
	8-48	20-35	1.50-1.65	0.6-2.0	0.15-0.19	6.1-7.8	<2	Low-------	0.37			
	48-72	5-20	1.50-1.65	2.0-6.0	0.12-0.16	6.6-8.4	<2	Low-------	0.37			
	72-80	5-20	1.50-1.65	2.0-6.0	0.07-0.15	6.6-8.4	<2	Low-------	0.32			
Go--------------- Gowen	0-12	27-30	1.35-1.50	0.6-2.0	0.15-0.20	6.6-8.4	0-2	Moderate	0.28	5	6	1-4
	12-80	20-35	1.40-1.60	0.6-2.0	0.15-0.20	6.6-8.4	0-2	Moderate	0.28			
HeB-------------- Heiden	0-6	40-60	1.30-1.50	<0.06	0.15-0.20	7.9-8.4	0-2	Very high	0.32	5	4	1-4
	6-35	40-60	1.35-1.55	<0.06	0.14-0.18	7.9-8.4	0-2	Very high	0.32			
	35-55	40-60	1.40-1.60	<0.06	0.12-0.18	7.9-8.4	0-2	Very high	0.32			
	55-80	40-60	1.45-1.65	<0.06	0.11-0.15	7.9-8.4	0-2	Very high	0.32			
HeC-------------- Heiden	0-6	40-60	1.30-1.50	<0.06	0.15-0.20	7.9-8.4	0-2	Very high	0.32	5	4	1-4
	6-22	40-60	1.35-1.55	<0.06	0.14-0.18	7.9-8.4	0-2	Very high	0.32			
	22-52	40-60	1.40-1.60	<0.06	0.12-0.18	7.9-8.4	0-2	Very high	0.32			
	52-80	40-60	1.45-1.65	<0.06	0.11-0.15	7.9-8.4	0-2	Very high	0.32			
HeD-------------- Heiden	0-6	40-60	1.30-1.50	<0.06	0.15-0.20	7.9-8.4	0-2	Very high	0.32	5	4	1-4
	6-14	40-60	1.35-1.55	<0.06	0.14-0.18	7.9-8.4	0-2	Very high	0.32			
	14-50	40-60	1.40-1.60	<0.06	0.12-0.18	7.9-8.4	0-2	Very high	0.32			
	50-80	40-60	1.45-1.65	<0.06	0.11-0.15	7.9-8.4	0-2	Very high	0.32			
HgB-------------- Heiden	0-6	40-60	1.30-1.50	<0.06	0.11-0.18	7.9-8.4	0-2	High------	0.20	5	4	1-4
	6-38	40-60	1.35-1.55	<0.06	0.14-0.18	7.9-8.4	0-2	Very high	0.32			
	38-55	40-60	1.40-1.60	<0.06	0.12-0.18	7.9-8.4	0-2	Very high	0.32			
	55-80	40-60	1.45-1.65	<0.06	0.11-0.15	7.9-8.4	0-2	Very high	0.32			
HoB-------------- Houston Black	0-6	50-60	1.20-1.40	<0.06	0.15-0.20	7.4-8.4	0-2	Very high	0.32	5	4	1-5
	6-35	50-60	1.25-1.50	<0.06	0.12-0.18	7.4-8.4	0-2	Very high	0.32			
	35-80	45-65	1.30-1.55	<0.06	0.10-0.16	7.4-8.4	0-4	Very high	0.32			
KrC-------------- Krum	0-6	35-55	1.35-1.55	0.2-0.6	0.15-0.20	7.4-8.4	0-2	High------	0.32	5	4	1-3
	6-42	40-60	1.25-1.50	0.2-0.6	0.12-0.18	7.9-8.4	0-2	High------	0.32			
	42-80	35-60	1.30-1.55	0.2-0.6	0.07-0.18	7.9-8.4	0-2	High------	0.32			

See footnote at end of table.

Table 14.--Physical and Chemical Properties of the Soils--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permea- bility	Available water capacity	Soil reaction	Salinity	Shrink- swell potential	Erosion factors K	Erosion factors T	Wind erodi- bility group	Organic matter
	In	Pct	g/cc	In/hr	In/in	pH	mmhos/cm					Pct
LaD-------------- Lamar	0-6	20-35	1.25-1.40	0.6-2.0	0.12-0.15	7.9-8.4	<2	Moderate	0.32	5	4L	1-3
	6-44	20-35	1.30-1.50	0.6-2.0	0.12-0.15	7.9-8.4	<2	Moderate	0.32			
	44-80	20-35	1.35-1.60	0.6-2.0	0.12-0.15	7.9-8.4	<2	Moderate	0.32			
LeB-------------- Lewisville	0-20	28-45	1.20-1.40	0.6-2.0	0.16-0.20	7.9-8.4	<2	High------	0.32	5	4L	1-3
	20-52	30-45	1.20-1.45	0.6-2.0	0.14-0.18	7.9-8.4	<2	High------	0.37			
	52-80	30-50	1.30-1.50	0.6-2.0	0.14-0.18	7.9-8.4	<2	High------	0.37			
LoB-------------- Lott	0-12	35-50	1.20-1.40	0.2-0.6	0.15-0.20	7.9-8.4	<2	High------	0.32	4	4L	1-3
	12-52	35-50	1.25-1.45	0.2-0.6	0.15-0.20	7.9-8.4	<2	Moderate	0.32			
	52-80	16-35	1.30-1.60	0.6-2.0	0.15-0.20	7.9-8.4	<2	Moderate	0.32			
LoD-------------- Lott	0-16	35-50	1.20-1.40	0.2-0.6	0.15-0.20	7.9-8.4	<2	High------	0.32	4	4L	1-3
	16-44	35-50	1.25-1.45	0.2-0.6	0.15-0.20	7.9-8.4	<2	Moderate	0.32			
	44-60	16-35	1.30-1.60	0.6-2.0	0.15-0.20	7.9-8.4	<2	Moderate	0.32			
MaA-------------- Mabank	0-10	10-25	1.50-1.65	0.6-2.0	0.11-0.15	5.6-7.3	0-2	Low-------	0.43	5	3	1-2
	10-65	35-50	1.45-1.65	<0.6	0.12-0.18	5.6-8.4	0-2	High------	0.32			
	65-80	35-50	1.45-1.65	<0.6	0.12-0.18	5.6-8.4	2-8	High------	0.32			
MbA*:												
Mabank----------	0-7	10-25	1.50-1.65	0.6-2.0	0.11-0.15	6.1-7.3	0-2	Low-------	0.43	5	3	1-2
	7-60	35-50	1.45-1.65	<0.6	0.12-0.18	5.6-8.4	0-2	High------	0.32			
	60-80	35-50	1.45-1.65	<0.6	0.12-0.18	5.6-8.4	2-8	High------	0.32			
Bremond---------	0-8	10-18	1.45-1.60	0.6-2.0	0.11-0.20	5.6-7.3	<2	Low-------	0.43	5	5	1-2
	8-60	40-50	1.35-1.50	<0.06	0.14-0.18	5.6-7.3	<2	High------	0.32			
	60-80	27-50	1.40-1.65	<0.06	0.15-0.18	6.6-8.4	2-8	High------	0.32			
McE-------------- McLennan	0-7	35-40	1.20-1.40	0.2-0.6	0.15-0.20	7.9-8.4	<2	Moderate	0.32	4	4L	<2
	7-32	35-50	1.20-1.50	0.2-0.6	0.15-0.20	7.9-8.4	<2	Moderate	0.32			
	32-80	35-65	1.30-1.60	0.2-0.6	0.08-0.15	7.9-8.4	<2	High------	0.32			
MnB-------------- Minwells	0-8	10-20	1.40-1.55	2.0-6.0	0.10-0.15	6.1-7.8	<2	Low-------	0.24	5	3	.1-1
	8-38	35-45	1.35-1.60	0.06-0.2	0.11-0.16	6.1-7.8	<2	Moderate	0.32			
	38-60	20-35	1.35-1.60	0.2-0.6	0.10-0.16	6.6-8.4	<2	Moderate	0.32			
	60-80	3-25	1.35-1.60	2.0-6.0	0.01-0.09	6.6-8.4	<2	Low-------	0.15			
MnC2------------- Minwells	0-4	10-20	1.40-1.55	2.0-6.0	0.10-0.15	6.1-7.8	<2	Low-------	0.24	5	3	.1-1
	4-28	35-45	1.35-1.60	0.06-0.2	0.11-0.16	6.1-7.8	<2	Moderate	0.32			
	28-60	20-35	1.35-1.60	0.2-0.6	0.10-0.16	6.6-8.4	<2	Moderate	0.32			
	60-80	3-25	1.35-1.60	2.0-6.0	0.01-0.09	6.6-8.4	<2	Low-------	0.15			
OgB-------------- Oglesby	0-18	40-50	1.25-1.45	0.06-0.2	0.13-0.18	6.6-7.8	<2	High------	0.32	1	4	1-3
	18-35	---	---	0.06-2.0	---	---	---	----------	----			
Ov--------------- Ovan	0-20	40-55	1.40-1.50	0.06-0.2	0.15-0.20	7.9-8.4	0-2	High------	0.32	5	4	1-3
	20-80	40-55	1.40-1.50	<0.06	0.15-0.20	7.9-8.4	0-2	High------	0.32			
PcB-------------- Payne	0-8	20-30	1.40-1.60	0.2-0.6	0.15-0.20	6.1-7.3	<2	Moderate	0.37	5	6	1-3
	8-30	35-55	1.40-1.55	<0.06	0.12-0.18	6.1-7.8	<2	Moderate	0.32			
	30-72	35-55	1.45-1.60	<0.06	0.12-0.18	7.9-8.4	<2	Moderate	0.32			
Pg*, Pr*. Pits												
PvB-------------- Purves	0-9	40-55	1.25-1.45	0.2-0.6	0.12-0.18	7.9-8.4	0-2	High------	0.32	1	4	1-4
	9-15	35-55	1.25-1.45	0.2-0.6	0.08-0.18	7.9-8.4	0-2	High------	0.15			
	15-35	---	---	0.06-2.0	---	---	---	----------	----			

See footnote at end of table.

Table 14.--Physical and Chemical Properties of the Soils--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permea- bility	Available water capacity	Soil reaction	Salinity	Shrink- swell potential	Erosion factors K	Erosion factors T	Wind erodi- bility group	Organic matter
	In	Pct	g/cc	In/hr	In/in	pH	mmhos/cm					Pct
QuC-------------- Queeny	0-12	22-35	1.25-1.42	0.6-2.0	0.14-0.19	7.9-8.4	0-2	Moderate	0.32	2	4L	1-3
	12-20	---	---	0.01-0.6	---	---	---	----------	----			
	20-60	---	---	0.2-2.0	---	---	---	----------	----			
ReF*:												
Real------------	0-6	22-40	1.25-1.55	0.6-2.0	0.05-0.10	7.9-8.4	0	Low--------	0.15	2	8	1-4
	6-14	22-40	1.25-1.55	0.6-2.0	0.05-0.10	7.9-8.4	0	Low--------	0.10			
	14-40	---	---	0.2-2.0	---	---	---	----------	----			
Rock outcrop.												
RgB-------------- Riesel	0-16	5-15	1.40-1.60	2.0-6.0	0.04-0.10	6.1-7.3	<2	Low--------	0.10	4	8	.5-2
	16-48	35-55	1.35-1.50	0.06-0.2	0.05-0.12	5.6-7.3	<2	Moderate	0.17			
	48-55	35-55	1.40-1.55	0.06-0.2	0.05-0.16	5.6-7.3	<2	Moderate	0.17			
	55-80	3-12	1.45-1.65	6.0-20	0.03-0.05	6.6-8.4	<2	Low--------	0.10			
SaB-------------- San Saba	0-18	45-60	1.30-1.45	<0.06	0.12-0.16	7.4-8.4	0-2	High------	0.32	2	4	1-4
	18-38	45-60	1.30-1.50	<0.06	0.12-0.16	7.4-8.4	0-2	High------	0.32			
	38-48	---	---	0.06-2.0	---	---	---	----------	----			
SgB-------------- Sanger	0-6	40-60	1.40-1.55	<0.06	0.12-0.18	7.9-8.4	0-2	High------	0.32	4	4	1-3
	6-34	40-60	1.40-1.55	<0.06	0.12-0.18	7.9-8.4	0-2	High------	0.32			
	34-66	40-60	1.40-1.55	<0.06	0.12-0.18	7.9-8.4	0-2	High------	0.32			
	66-80	40-60	1.40-1.60	<0.06	0.12-0.18	7.9-8.4	0-2	High------	0.32			
Sh--------------- Ships	0-10	60-80	1.20-1.40	<0.06	0.12-0.18	7.9-8.4	<2	Very high	0.32	5	4	.5-3
	10-74	60-80	1.20-1.40	<0.06	0.12-0.18	7.9-8.4	<2	Very high	0.32			
	74-80	35-80	1.25-1.50	<0.06	0.12-0.18	7.9-8.4	<2	Very high	0.32			
SsB-------------- Slidell	0-20	40-60	1.25-1.55	<0.06	0.15-0.18	7.4-8.4	0-2	High------	0.32	5	4	1-4
	20-37	40-60	1.25-1.55	<0.06	0.15-0.18	7.4-8.4	0-2	High------	0.32			
	37-72	40-60	1.35-1.55	<0.06	0.13-0.18	7.4-8.4	0-2	High------	0.32			
StC*:												
Stephen---------	0-8	40-55	1.35-1.55	0.2-0.6	0.10-0.15	7.9-8.4	<2	Moderate	0.32	2	4	1-4
	8-12	---	---	0.06-2.0	---	---	---	----------	----			
	12-28	---	---	0.06-2.0	---	---	---	----------	----			
Eddy------------	0-5	20-40	1.30-1.50	0.6-2.0	0.10-0.13	7.9-8.4	<2	Low--------	0.24	1	8	.5-2
	5-9	20-40	1.30-1.50	0.6-2.0	0.03-0.07	7.9-8.4	<2	Low--------	0.24			
	9-20	---	---	0.06-2.0	---	---	---	----------	----			
SuD*:												
Stephen---------	0-10	40-55	1.35-1.55	0.2-0.6	0.10-0.15	7.9-8.4	<2	Moderate	0.32	2	4	1-4
	10-15	---	---	0.06-2.0	---	---	---	----------	----			
	15-30	---	---	0.06-2.0	---	---	---	----------	----			
Urban land.												
SyB-------------- Styx	0-8	3-15	1.40-1.60	2.0-6.0	0.05-0.10	5.1-7.3	<2	Low--------	0.17	5	2	.5-2
	8-27	3-15	1.40-1.60	2.0-6.0	0.05-0.10	5.1-7.3	<2	Low--------	0.17			
	27-80	25-35	1.30-1.65	0.6-2.0	0.12-0.16	5.1-6.5	<2	Low--------	0.24			
SzB-------------- Sunev	0-19	20-40	1.30-1.50	0.6-2.0	0.11-0.16	7.9-8.4	<2	Moderate	0.28	5	4L	1-3
	19-80	20-40	1.40-1.60	0.6-2.0	0.11-0.16	7.9-8.4	<2	Low--------	0.28			
Tn--------------- Tinn	0-5	40-60	1.40-1.50	0.06-0.2	0.15-0.20	7.4-8.4	0-2	Very high	0.32	5	4	1-4
	5-80	40-60	1.40-1.50	<0.06	0.13-0.18	7.4-8.4	0-2	Very high	0.32			

See footnote at end of table.

Table 14.--Physical and Chemical Properties of the Soils--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permea- bility	Available water capacity	Soil reaction	Salinity	Shrink- swell potential	Erosion factors K	Erosion factors T	Wind erodi- bility group	Organic matter
	In	Pct	g/cc	In/hr	In/in	pH	mmhos/cm					Pct
To-------------- Tinn	0-8	40-60	1.40-1.50	0.06-0.2	0.15-0.20	7.4-8.4	0-2	Very high	0.32	5	4	1-4
	8-80	40-60	1.40-1.50	<0.06	0.13-0.18	7.4-8.4	0-2	Very high	0.32			
Ur*. Urban land												
Wd-------------- Weswood	0-6	8-26	1.20-1.35	0.6-2.0	0.12-0.20	7.9-8.4	0-2	Low-------	0.43	5	6	1-4
	6-60	10-20	1.30-1.55	0.6-2.0	0.12-0.20	7.9-8.4	0-2	Low-------	0.43			
	60-80	27-45	1.30-1.55	0.2-0.6	0.13-0.18	7.9-8.4	0-2	Moderate	0.32			
We-------------- Weswood	0-8	27-35	1.20-1.35	0.6-2.0	0.12-0.20	7.9-8.4	0-2	Low-------	0.43	5	6	1-4
	8-60	10-20	1.30-1.55	0.6-2.0	0.12-0.20	7.9-8.4	0-2	Low-------	0.43			
	60-80	27-45	1.30-1.55	0.2-0.6	0.13-0.18	7.9-8.4	0-2	Moderate	0.32			
WnA------------- Wilson	0-8	27-35	1.35-1.50	0.2-0.6	0.10-0.17	5.6-7.3	0	Moderate	0.43	5	6	.5-2
	8-47	35-50	1.50-1.60	<0.06	0.12-0.15	5.6-7.8	0-4	High------	0.37			
	47-80	35-60	1.50-1.60	<0.06	0.12-0.15	6.6-8.4	2-8	High------	0.37			
Ya-------------- Yahola	0-12	10-18	1.30-1.55	2.0-6.0	0.15-0.20	7.4-8.4	<2	Low-------	0.32	5	4L	.5-1
	12-28	5-18	1.40-1.70	2.0-6.0	0.11-0.20	7.9-8.4	<2	Low-------	0.32			
	28-80	5-18	1.50-1.70	2.0-6.0	0.07-0.20	7.9-8.4	<2	Low-------	0.32			
Yg*: Yahola----------	0-10	10-18	1.30-1.60	2.0-6.0	0.11-0.15	7.4-8.4	<2	Low-------	0.20	5	3	.5-1
	10-42	5-18	1.40-1.70	2.0-6.0	0.11-0.20	7.9-8.4	<2	Low-------	0.32			
	42-80	5-18	1.50-1.70	2.0-6.0	0.07-0.20	7.9-8.4	<2	Low-------	0.32			
Gaddy-----------	0-8	5-15	1.35-1.50	6.0-20	0.07-0.11	7.4-8.4	0	Low-------	0.17	5	2	0-.5
	8-80	5-35	1.50-1.70	6.0-20	0.06-0.10	7.9-8.4	0	Low-------	0.17			

* See description of the map unit for composition and behavior characteristics of the map unit.

Soil Type	Percent Area	K Factor
HeB	31.8%	0.32
HeD	47.1%	0.32
Ov	0.6%	0.32
RgB	20.5%	0.17
	100.0%	

Weighted Average: **0.2893**

Table 4-1.
Values for topographic factor, LS, for low ratio of rill to interrill erosion.[1]

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	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

[1]Such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

Reference: USDA, Predicting Soil Erosion by Water: A guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), Agricultural Research Service, Agriculture Handbook Number 703, 1997.

TABLE 10.—*Factor* **C** *for permanent pasture, range, and idle land*[1]

Vegetative canopy		Cover that contacts the soil surface						
			Percent ground cover					
Type and height[2]	Percent cover[3]	Type[4]	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

Final
Cover (use 0.06)

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

Reference: USDA, Predicting Rainfall Erosion Losses, A Guide to Conservation Planning, Agriculture Handbook Number 537, 1978.

Table 3 P Factors for Contouring, Contour Stripcropping and Terracing

Land Slope	P values	
%	Contouring†	Terracing†
2.0 to 7	0.50	0.50
8.0 to 12	0.60	0.60
13.0 to 18	0.80	0.80
19.0 to 24	0.90	0.90

(This table appeared in SCS (5), p.9)

† Contouring and terracing columns are suitable for MSWLF cover. Contour stripcropping is not suitable for the type of vegetative cover normally practiced at municipal landfills.

Table 4 Guide for Assigning Soil Loss Tolerance Values (T) to Solid Having Different Rooting Depths

Rooting Depth	Soil Loss Tolerance Values Annual Soil Loss - (Tons/Acre)
Inches	Non-Renewable Soil a/
10 - 20	1
20 - 40	2
40 - 50	3
50 - 60	4
60 +	< 5

(This table appears in SCS (6) p.4)

a/ Soils with unfavorable substrata such as rock or soft rock that cannot be renewed by economical means. Most of the MSWLF covers with constructed, or recompacted clay cap and/or flexible membrane should use this performance criteria.