ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS
TCEQ PERMIT NO. MSW-1614B

MAJOR PERMIT AMENDMENT APPLICATION

VOLUME 5 OF 7

Prepared for

Pine Hill Farms Landfill TX, LP

May 2024

CHARLES R. MARSH
105073

05/20/2024

Prepared by

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Project No. 0120-076-11-106

This document is intended for permitting purposes only.

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MAJOR PERMIT AMENDMENT APPLICATION

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

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1 INTRODUCTION

This section addresses §330.63(c)

This Surface Water Drainage Plan is prepared as part of a permit amendment application for the Royal Oaks Landfill consistent with Title 30 Texas Administrative Code (TAC) Chapter 330. This plan addresses surface water drainage design and erosion control. Permit level plans and details are presented for the proposed drainage system in this appendix. This appendix also includes a demonstration consistent with Title 30 TAC §330.305(a) that the proposed landfill development will not adversely alter permitted drainage patterns. Parts I/II, Section 11.1 includes information pertaining to the sites compliance with floodplain location restrictions. The 100-year floodplain as defined by the Federal Emergency Management Agency (FEMA) is shown in Figure 4.6.

This appendix includes the design of the final cover erosion layer and drainage structures (i.e., chutes and swales), perimeter drainage channels, detention ponds, as well as hydrologic and hydraulic calculations. Consistent with Title 30 TAC §330.63(c) and §330.305(b) and (c), these facilities are designed to convey run-off produced from the 25-year storm event. In addition, an Erosion Control Plan for all phases of landfill development is included in Appendix IIIF-F. All drainage facilities will be constructed and maintained in accordance with this plan.

This appendix also includes (Section 4) a demonstration that shows that the proposed landfill development will not adversely alter the existing permitted drainage patterns. As noted in Section 4, the proposed condition represents the proposed configuration of the site after the landfill has been completely developed. Consistent with Title 30 TAC §330.63(c)(1)(C), §330.63(c)(1)(D)(iii), and §330.305(a), the proposed completion condition is compared to the existing permitted condition to demonstrate that the continued development of the Royal Oaks Landfill will not adversely alter the existing permitted drainage patterns.

To provide a complete and relevant comparison between the permitted and post-project conditions, the existing permitted landfill layout was evaluated using the latest precipitation data, different hydrograph methodology, and updated offsite drainage area information. These updates are discussed further in Section 4.

2 STORMWATER MANAGEMENT

2.1 Drainage System Layout

Stormwater runoff collected in swales located on the top dome and sideslopes of the landfill will be conveyed to drainage letdown structures (chutes) down the slopes to the perimeter channel system. The perimeter channels will be constructed before fill is placed above existing grade in each adjacent landfill sector. The perimeter drainage system will be constructed as the site is developed. Additional details regarding the existing condition of the perimeter drainage system and the sequence of development for the drainage system is listed below.

- Currently the site drains toward the south through perimeter channels on the west and south sides, and toward the east through perimeter channels on the north and east sides of the fill area as previously (or currently) permitted.
- Consistent with the natural drainage patterns, the currently developed areas drain toward the south and east portion of the permit boundary as previously (or currently) permitted.
- The final stage in the perimeter drainage system construction is shown on the landfill completion plan on Drawings I/IIA.3 and IIIF.1. A detailed drawing of the perimeter channels located along the permit boundary is provided on Drawings IIIF.4 through IIIF.6.

As shown on Drawing IIIF.1 – Drainage Structure Plan, runoff generated from within the permit boundary will discharge south to Keys Creek and east to Barbers Branch, which eventually discharges into Ragsdale Creek. Stormwater discharge from the west and south sides of the landfill will be attenuated by a detention pond located at the south side of the permit boundary before flowing off the permit boundary to Keys Creek. Stormwater from the north and east side of the landfill will be routed through proposed channels and attenuated by a detention ponds on the northeast and east sides of the landfill, respectively, and discharged into Barbers Branch from the east at two discharge locations.

The facility has been designed to prevent discharge of pollutants into waters of the State or waters of the United States, as defined by the Texas Water Code and the Federal Clean Water Act, respectively. The Royal Oaks Landfill has a current Texas Pollution Discharge Elimination System (TPDES) multi-sector general permit

(MSGP) for industrial activity as stipulated under Section 402 of the Clean Water Act and under Chapter 26 of the Texas Water Code, the TPDES program. A copy of the multi-sector permit is included in Parts I/II, Appendix I/IIG. Any stormwater that has become contaminated by contact with the working face or with leachate will be handled in accordance with Appendix IIIC – Leachate and Contaminated Water Management Plan. The facility maintains a current Stormwater Pollution Prevention Plan prepared consistent with the provisions of TPDES MSGP TXR050000.

2.2 Erosion and Sedimentation Control Plan

The Royal Oaks Landfill will use various interim and permanent erosion and sedimentation controls during all phases of site development to provide effective erosion stability for the external sideslopes and top dome surfaces. The interim controls will be used around active areas and external embankment sideslopes and top dome surfaces. These controls will include temporary letdown structures, soil berms, and seeding of intermediate cover areas to minimize the erosion potential. These interim controls will be used during all phases of landfill development to provide effective erosion stability for the external sideslopes and top dome surfaces until final cover is installed. Refer to Appendix IIIF-F – Erosion Control Plan for All Phases of Landfill Operation for more information.

Permanent controls include swales and chutes that will be constructed upon completion of the final cover installation. As part of the final cover construction, an erosion layer capable of sustaining vegetation will be constructed. Areas that receive final cover will be vegetated in accordance with Appendix IIIJ – Closure Plan upon completion of final cover placement. Final cover vegetation will protect the erosion layer soil against erosive runoff velocities. A soil loss and sheet flow velocity demonstration for the erosion layer is included in Appendix IIIF-D. The erosion layer will include a vegetation layer that provides for 95 percent ground coverage, to keep soil loss below the required design values. If there are areas that do not maintain at least 95 percent vegetative coverage, vegetation in these areas will be reestablished to maintain at least 95 percent vegetative cover.

Erosion will be controlled by vegetation in drainage structures with flow velocities less than or equal to 5 feet per second (fps). For drainage structures with flow velocities greater than 5 fps, rock riprap, gabions, or other surface reinforcing materials as designed will be used for surface reinforcement.

During site development, non-structured and structural best management practices (BMPs) will be employed to control erosion and sedimentation ponds will be installed to prevent sediment discharge from the site. BMPs may include the use of temporary rock riprap, silt fences, straw bales, check dams, interceptor swales and berms, temporary and permanent seeding and sodding, surface roughening, matting and mulching, sediment traps, and surface wetting for dust control (refer to Appendix IIIF-F for more information).

Runoff volume (25-year, 24-hour storm event) from the active fill area (i.e., working face of the landfill operation) will be contained by the containment berm (refer to Part III, Appendix IIIC – Leachate and Contaminated Water Management Plan for details) to prevent potential discharge of contaminated runoff from the site.

2.3 Stormwater System Maintenance Plan

In accordance with Title 30 TAC §330.305(e)(1), the constructed stormwater systems such as channels, drainage swales, and chutes will be repaired and restored in the event of wash-out or failure from extreme storm events. Stormwater BMPs installed during all phases of landfill development will also be replaced or repaired in the event of failure. Excessive sediment will be removed, as needed, so that the drainage structures, such as the perimeter channels and detention ponds, function as designed. Site inspections by landfill personnel will be performed weekly or within 24 hours after any significant rainfall event of 0.5 inches or more, or as soon as the areas are accessible. Documentation of the inspection will be included in the Site Operating Record.

The following items will be evaluated during the inspections as further discussed in Appendix IIIF-F and Part IV – SOP:

- Erosion of daily and intermediate cover areas, final cover areas, perimeter ditches, chutes, swales, detention ponds, berms, and other drainage features.
- Settlement of intermediate cover areas, final cover areas, perimeter ditches, chutes, swales, and other drainage features.
- Silt and sediment build-up in perimeter ditches, chutes, swales, and detention ponds. Removed silt and sediment used as daily cover or to replenish intermediate cover soils.
- Obstructions in drainage features.
- Presence of erosion or sediment discharge at offsite stormwater discharge locations.
- Presence of sediment discharges along the site boundary in areas which have been disturbed by site activities.

Maintenance activities will be performed to correct damaged or deficient items noted during the site inspections. These activities will be performed once repairs can safely be performed. The time frame for correction of damaged or deficient items will vary based on weather, ground conditions, and other site-specific conditions.

Maintenance activities will consist of the following, as needed:

- Vegetation reestablishment.
- Placement, grading, and stabilization of additional soils in eroded areas or in areas which have settled.
- Replacement or repair of riprap or other surface lining materials.
- Placement of additional riprap in eroded areas.
- Removal of obstructions from drainage features.
- Removal of silt and sediment build-up from drainage features.
- Repairs to erosion and sedimentation controls.
- Installation of additional erosion and sedimentation controls.

3 DRAINAGE SYSTEM DESIGN

3.1 Methodology

Drainage calculations for the final cover system erosion control structures and perimeter drainage system are based on the peak flow rates resulting from the 25-year frequency rainfall event for the area. The United States Army Corps of Engineers (USACE) HEC-HMS computer program was used to compute peak flow rates produced from the design storm. The hydraulic methods employed in this study are consistent with those presented in the TCEQ *Guidelines for Preparing a Surface Water Drainage Report for Municipal Solid Waste Facility (RG-417, May 2018)* and TxDOT *Bridge Division Hydraulic Manual*, July 2019.

Water surface profiles were determined for the perimeter channels using the Channel Analysis Program (HYDROCALC HYDRAULICS Version 2.0.1 for Windows, Dodson & Associates, 1996-2010) that is based on Manning's formula for uniform flow. The perimeter channels are designed to collect and route runoff from the 25-year frequency storm event to the detention ponds.

3.2 Hydrologic Analysis

3.2.1 Description of Computer Program

HEC-HMS was developed by the USACE Hydrologic Engineering Center to simulate the surface runoff response of a watershed. The HEC-HMS model represents a watershed as a network of hydrologic and hydraulic components. The modeling process results in the computation of stream-flow hydrographs at desired locations in the watershed. The hydrologic analysis for the post-development condition is presented in Appendix IIIF-A. The hydrologic analysis for the permitted landfill completion condition is included in Appendix IIIF-E.

3.2.2 Watershed Subareas and Schematization

The landfill areas that contribute flow to each detention pond were delineated into subareas to derive peak flow rates for the design of the perimeter channel and final cover drainage letdowns. Hydrographs are developed for each subarea and appropriately combined and routed through the swales and perimeter channels.

The subareas are shown on Drawing IIIF.2 – Post-Development Drainage Area Plan as well as in Appendix IIIF-E for the permitted completion condition.

Offsite areas (areas outside the permit boundary) incorporated into the hydrologic analyses as appropriate have been delineated using topography obtained from the United States Geological Survey 7.5-Minute Quadrangle for Jacksonville West, Jacksonville East, Mount Selman, and Tecula. The offsite drainage area delineation is shown on Figure 4.3 for the post-development discharge analysis. The offsite areas are also included in the hydrologic analysis for the permitted landfill completion condition, as shown in Appendix IIIF-E.

3.2.3 Time Step

The time step, or the program computation interval, is the time interval at which the flow rates for the hydrographs are generated by the program. Time step used for a design storm event hydrograph generation is 5 minutes.

3.2.4 Hypothetical Precipitation

The hypothetical storm data used in the hydrologic analyses was obtained from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 point precipitation frequency estimates for the project area. For the design storm event analysis, a return period (frequency) of 25 years and a duration of 24 hours is used. The precipitation is assumed to be evenly distributed over the entire area modeled for each time interval.

3.2.5 Precipitation Losses

Precipitation losses (the precipitation that does not contribute to the runoff) are calculated using the Soil Conservation Service (SCS) Curve Number (CN) method. CN is a function of soil cover, land use, and antecedent moisture conditions. A CN of 86 was selected to represent the final cover sideslopes, and a CN of 84 was selected for final cover top dome surfaces. A CN of 99 was used for the detention pond areas. Further discussion on selection of CN values is provided in Appendices IIIF-A and IIIF-E for post-development and updated permitted landfill completion conditions, respectively.

3.2.6 Hydrograph Information

Two different types of hydrograph generation methods have been used in the drainage analyses: distributed runoff methods and the Snyder unit hydrograph method using the Espey "10-Minute" method for parameter estimation. Muskingum-Cunge and pond storage discharge methods were used for hydrograph routings. Example hydrograph development information for both distributed runoff and Snyder unit hydrograph methods is provided in Appendix IIIF-A.

Distributed Runoff Methods

The distributed runoff method (e.g., kinematic wave method) is applicable to small-water catchments with uniformly sloped overland flow plains that drain into channels. Landfill final cover areas consist of relatively short (typically 120 feet on 4H:IV sideslopes) overland flow lengths that drain into landfill final cover swales. Distributed runoff estimation methods are applicable to landfill final cover areas because of the following:

- These methods were developed for uniform slopes that drain to collection channels. For a landfill final cover area, this translates to an overland flow segment of final cover that drains to a swale.
- These methods were developed for a network of relatively small drainage areas. Typically, to design the various perimeter channels, landfill drainage areas need to be subdivided to determine a peak flow at several points.
- These methods are also inherently conservative because it is based on watershed dimensions as opposed to other methods that use empirical information. Also, this method is conservative because flow attenuation is not accounted for.
- This method is also more conservative than the rational method because watershed lag time is computed as a function of real flow time without any limitations such as using a minimum time of concentration (i.e., 10 minutes), which is common practice for the rational method.

The kinematic wave method has been used for estimating peak runoff rates from the landfill final cover areas. A hydrograph from each drainage area with channelized flow (e.g., landfill final cover areas to swales) was developed using the kinematic wave method to simulate both overland and channelized flow. This method utilizes a simplified form of the energy equation and is based on the characteristics of the drainage area, swale, or channel. This method uses physical (measurable) characteristics (e.g., flow lengths, slopes, surface roughness coefficients, channel cross sections) of a watershed to estimate peak discharges.

Snyder Unit Hydrograph Method

The Snyder unit hydrograph method has been used mainly for non-landfill drainage areas (e.g., offsite drainage areas). The method is applicable to drainage areas with a wide range of characteristics. Several different methods have been developed to estimate Snyder unit hydrograph parameters (watershed lag and peaking coefficient). Espey “10-Minute” method was used in this project to estimate Snyder unit hydrograph parameters. The Espey “10-Minute” method was developed using flow records from 41 different watersheds in Texas and other states. The main advantage of the Espey “10-Minute” method is that it is one of the most widely used and accepted methods for determining hydrograph input values for small-size drainage areas.

Hydrograph Routing

The Muskingum-Cunge Method was used for routing of the flood wave through the drainage channels. This method is capable of accounting for hydrograph attenuation based on physical channel properties such as length, bottom slope, channel shape, and channel roughness.

Hydrographs at pond outlets were generated by routing the combined incoming flow hydrographs through the ponds. Pond routings were performed by using storage/elevation relationships for each pond by defining pond surface area versus depth. Additionally, discharge structure (low level outlet and spillway) characteristics of each pond are used for pond routing.

3.3 Hydraulic Analysis

3.3.1 Swale and Channel Analysis

Drainage structure details are illustrated on Drawings IIIF.7 through IIIF.12. The swales and channels are designed to convey the peak flow rate generated by the design storm event. These swales and channels will also reduce maintenance at the site after closure by minimizing erosion.

Hydraulic analyses of the swales and channels are conducted using Manning's uniform flow formula. The uniform flow assumption is applicable to long prismatic channels of uniform slope, as proposed at the site.

The general form of Manning's equation is

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

in which

V = *Velocity of flow, fps (feet per second)*
n = *Manning's "n" (unitless)*
$R = \frac{A}{P}$ = *Hydraulic radius, ft (feet)*
S = *Friction slope for nonuniform flow or channel slope for uniform flow, ft/ft*
A = *Area of water perpendicular to direction of flow, sf (square feet)*
P = *Wetted perimeter, ft.*

Using the relationship

$$Q = VA$$

Manning's equation can be written as

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

The uniform flow assumption equates the channel slope to the friction slope; therefore, the slope of the channel can be used for “S” in Manning's formula for computation of uniform flow.

Typical values for Manning's “*n*” are presented in the 2019 TXDOT Bridge Division *Hydraulic Manual* (“Suggested Manning’s Roughness Coefficients” Table, Chapter 6, Section 1). A value of 0.030 is used for “*n*” for swales, a value of 0.040 is used for gabion-lined chutes, and a value of 0.030 is used for perimeter channels. These values represent typical roughness coefficients to the proposed drainage structures, after vegetation has become established.

3.3.2 Drainage Letdown Structure (or Chute) Analysis

A typical chute detail is illustrated on Drawing IIIF.9. The final cover drainage letdown structures are designed to convey the flow rate generated by the design storm event. Hydraulic analysis of the letdown structures is conducted under the principles of tumbling flow. Tumbling flow is a function of channel slope, discharge, spacing and sizing of energy dissipating elements. The tumbling flow regime consists of a series of hydraulic jumps and overfalls that maintain critical velocity down the chute. The spacing and sizing of the energy dissipators controls the velocity and flow of the water in the chutes, thereby reducing erosive conditions at slope transitions with the perimeter road low water crossings and chute/perimeter channel confluences.

Appendix IIIF-C presents calculations for the energy dissipators.

4 DRAINAGE PATTERNS

Consistent with Title 30 TAC §330.63(c)(1)(C), §330.63(c)(1)(D)(iii), and §330.305(a), this section provides a demonstration showing that the proposed landfill development will not adversely alter the existing permitted landfill completion condition drainage patterns. The appendices containing the two drainage conditions analyzed are listed below.

- Appendix IIIF-A (Post-Development Condition Hydrologic Calculations) – This appendix contains analysis and supporting calculations for the proposed configuration of the site after development of the expanded landfill is complete.
- Appendix IIIF-E (Updated Permitted Condition Hydrologic Calculations) – This appendix contains excerpts from the 1996 permit document that establish the currently-permitted drainage patterns and peak flow rates for the permit boundary area. Section 4.3.1 includes a discussion of analyses performed to facilitate a comparison between the existing permitted and post-development conditions.

The following three sections discuss: (1) regional drainage associated with the site; (2) site drainage patterns; (3) effect of the proposed development on peak flows, volumes, and velocities discharged from the site.

4.1 Regional Drainage Information

As shown on Figure 4.1, the 144.3-acre Royal Oaks Landfill permit boundary is located approximately 2.5 miles north of the City of Jacksonville and 0.5 miles east of Heath Lane, and is located within the Ragsdale Creek Watershed, which is a part of the Neches River Basin. As shown on Figure 4.2, the permit boundary is located near the headwaters of Barber Branch and Keys Creek. The site drains to Barber Branch on the east side of the permit boundary and to Keys Creek on the south side of the permit boundary. Barber Branch and Keys Creek discharge to Ragsdale Creek approximately 7 miles southeast of the landfill which joins with Mud Creek 10 miles southeast of the permit boundary.

4.2 Site Drainage Patterns

The existing permitted, updated permitted, and post-development site drainage patterns are shown on Figures 4.4 and 4.5. As shown on Figures 4.4 and 4.5, the proposed drainage patterns are consistent with the currently permitted and updated permitted drainage patterns. As shown on these two figures, most of the permit area discharges from the south and east corners of the permit boundary.

As shown on Figure 4.4, the total drainage area of the permit boundary is unchanged by the proposed expansion. However, changes to precipitation data, drainage area delineations and hydrologic methodology led to the development of the updated permitted condition. Supplementing the existing permitted condition analysis with an updated hydrologic model allows for a direct comparison to be made between the permitted and post-project conditions. As shown in the onsite drainage area information on Figures 4-4 and 4-5, the updated permitted and proposed onsite drainage delineations are consistent.

4.3 Effect of Site Development on Drainage from the Site

The purpose of this section is to evaluate the peak flow rates, runoff volumes, and peak flow velocities of the updated permitted and post-development hydrologic conditions. A summary of peak flow rates, runoff volumes, and peak flow velocities entering and exiting the permit boundary is provided in Table 4.1 and Figure 4.5 – Site Drainage Patterns, Runon/Runoff. Section 4.3.1 discusses the updated permitted landfill completion condition drainage analysis and how its input and methodology compares to the post-development condition.

Sections 4.3.2 through 4.3.5 discuss the impact of the proposed landfill conditions on peak flow rates, runoff volumes, and peak flow velocities entering and exiting the permit boundary.

4.3.1 Comparison of Updated Permitted and Post-Development Analyses

4.3.1.1 Purpose of Updated Permitted Condition

As shown in Figures 4.4 and 4.5, the drainage analysis included in TCEQ Permit No. 1614A (for the purpose of this appendix, this case will be designated the "existing permitted condition") was developed in 1996 by HMA Environmental Services, Inc. In 2005, WCG developed a permit modification to revise the final contour plan. This modification only revised the landfill sideslopes and topslopes and did not significantly alter the peak flows; therefore, the flow rates associated with the original 1996 drainage analysis are considered the existing permitted condition. These documents utilized different hydrologic methodologies, precipitation data, and offsite areas than what is included in current guidance documents to develop surface water drainage systems. In order to develop a direct comparison between the existing permitted and post-development conditions, a separate HEC-HMS analysis was developed for an updated permitted condition. This analysis is included in Appendix IIIF-E. To comply with Title 30 TAC §330.63(c)(1)(C), the proposed landfill completion condition is compared to the updated permitted condition of the landfill to demonstrate that the continued development of the landfill will not adversely alter the existing permitted drainage patterns. This comparison is only meaningful if both the post-development and existing permitted conditions are based on consistent drainage information and methodology. A discussion of the model parameters used in the updated permitted condition is included in Section 4.3.1.2.

Additionally, runoff volume and velocity calculations for all discharge locations were not included in the existing permitted drainage calculations at all discharge locations. These calculations were prepared as a part of this application and are included in Appendix IIIF-E.

4.3.1.2 Model Parameter Comparison

Updates to the existing permitted condition are listed below.

- The existing permitted condition utilizes a combination of the rational method for the final cover areas, culverts and channels and a HEC-1 model utilizing the SCS unit dimensions hydrograph for the stormwater detention ponds and comparison of discharge points. A HEC-HMS model was developed for the updated permitted condition to analyze all drainage areas and develop comparisons at discharge points.
- An additional discharge point on the east side of the site was added to the updated permitted condition due to increased definition of onsite topography.
- Offsite Areas O1 through O6 were delineated using the USGS topography dated 2022.
- To be consistent with methods utilized in recently approved TCEQ applications, precipitation loss, hydrograph development, channel routing, and pond storage routing methods were updated as follows:
  - Curve numbers for all drainage methods were updated to a composite curve number for most non-landfill drainage areas, 84 for landfill top dome surfaces, 86 for landfill side slope surfaces, and 99 for ponds based on tabulated curve numbers for the land uses of these areas (see Appendix IIIF-E).
  - Hydrographs are developed in the updated permitted landfill completion condition using distributed runoff methods or Snyder's unit hydrograph, as discussed in Section 3.2.6.

  - The channel routing mechanism was updated to the Muskingum-Cunge Method for all channels in the updated permitted condition.
  - Pond routing is accomplished using the storage routing method, with storage/elevation data, and spillway and low-water outlet information input into HEC-HMS for ponds P2 and P3. The existing P1 pond utilizes a storage/elevation/discharge rating curve for pond routing.
- The drainage area delineation for the currently permitted final cover drainage letdowns has been updated to model top dome surfaces and sideslope areas separately to better represent the final cover drainage areas. This update provides more accurate flow rates for the top dome area drainage letdown structures.

4.3.1.3 Comparison of Peak Flows at the Permit Boundary

As shown in Figure 4.5, all peak discharges for the existing condition are different from those in the updated permitted condition due to adjustments in offsite drainage areas changes in methodology and using HEC-HMS. The discharge at locations DP2, DP4, and DP5 are higher in the updated permitted condition when compared to the existing permitted condition, and this is attributable to the change in different hydrologic methodologies.

4.3.2 Peak Flow Rates

As shown on Figure 4.5 and in Table 4-1, the peak flow rates entering the permit boundary from 01, 02, 03, 04, 05, and 06 are identical for the updated permitted and post-development conditions. Stormwater that enters the site from an off-site area and stormwater that is generated from within the permit boundary discharges at five separate locations along the permit boundary (DP1, DP2, DP3, DP4, and DP5 as shown on Figure 4.5). At these discharge points, the peak flow rates from the 25-year frequency storm event that are discharged from the site for the post-development condition are all equal to or less than the updated permitted conditions. Reductions in the peak flow rates is due to the additional detention provided by the east ponds (P2 and P3) and different chute/swale configurations on the final cover.

4.3.3 Volumes

As shown in Table 4-1, the volumes entering the permit boundary are consistent for the updated permitted and post-development landfill conditions. Volume increases are minimal (a maximum increase of 1.23-ac-ft at DP4), and the reduced peak flow rate results in a better-regulated release of the increased storm volume. DP2 and DP5 have a decrease in runoff volume. Runoff volume calculations are provided in Appendices IIIF-A and IIIF-E.

4.3.4 Velocities

A summary of the 25-year frequency storm peak flow velocities that enter and exit the site are shown on Table 4-1. As shown, the velocities at each discharge point are equal or lower for the post-development condition compared to the updated permitted conditions. This is due to the lower flow rates, given that the cross-sectional area at each drainage outfall remains unchanged. Velocity calculations are provided in Appendices IIIF-A and IIIF-E for the post-development and permitted conditions, respectively.

4.4 Summary

From the hydrologic evaluations of the updated permitted and proposed conditions, the existing drainage conditions at the permit boundary will not be adversely altered by the proposed development. Given that: (1) total design stormwater peak discharge rate at the permit boundary is less than the updated permitted total stormwater peak discharge rate (and the post-development peak flows entering the site are equal to the updated permitted peak flows entering the site), (2) total volume of stormwater entering and leaving the permit boundary is not significantly altered, (3) there is no increase in velocity at the permit boundary, and (4) the stormwater discharge outfall locations are consistent with the permitted configuration, it is concluded that the proposed landfill development will not adversely alter permitted drainage patterns consistent with Title 30 TAC 330.63(c)(1)(C), §330.63(c)(1)(D)(iii), and §330.305(a).

Table 4-1
Flow Rates, Drainage Areas, Hydrograph Time to Peak Values, Runoff Volumes, and Velocities for the 25-Year Design Storm Event

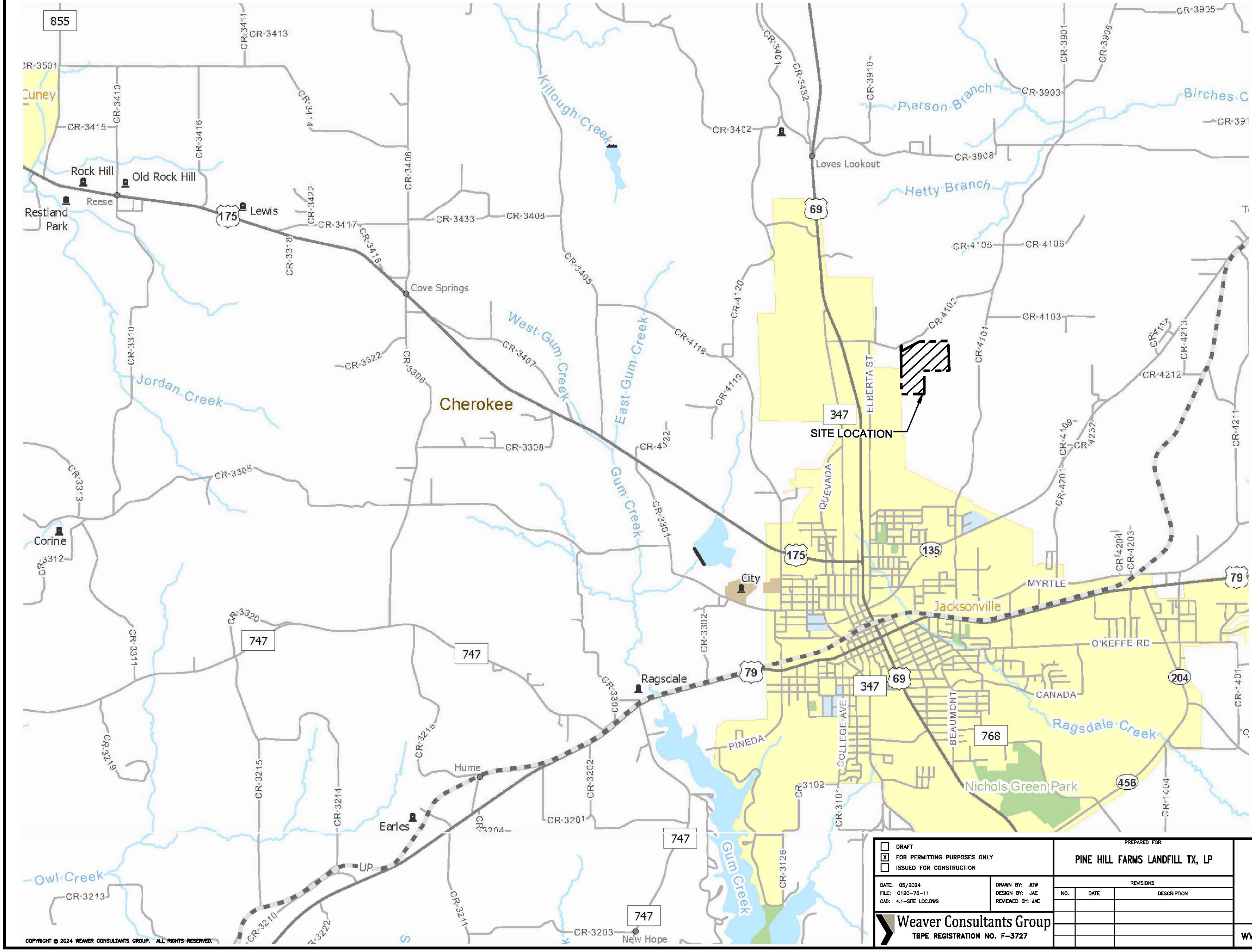
Stormwater Discharge Point[1]	Existing Permitted Condition[4]					Updated Permitted Condition[4]					Post-Development Condition				
	Flow Rate (cfs)	Drainage Area (acres)	Time to Peak (hrs)	Runoff Volume[3] (ac-ft)	Velocity at Permit Boundary (fps)	Flow Rate (cfs)	Drainage Area (acres)	Time to Peak (hrs)	Runoff Volume [2] (ac-ft)	Velocity at Permit Boundary[2] (fps)	Flow Rate (cfs)	Drainage Area (acres)	Time to Peak (hrs)	Runoff Volume[2] (ac-ft)	Velocity at Permit Boundary[2] (fps)
01	367	--	--	--	--	318.9	166.84	12.58	55.89	8.16	318.9	166.84	12.58	55.89	8.16
02	16	--	--	--	--	40.7	15.24	12.33	4.25	3.07	40.7	15.24	12.33	4.25	3.07
03	53	--	--	--	--	64.9	14.76	12.25	6.64	6.63	64.9	14.76	12.25	6.64	6.63
04	15	--	--	--	--	34.5	9.00	12.33	3.87	7.54	34.5	9.00	12.33	3.87	7.54
05	15	--	--	--	--	8.2	1.93	12.33	0.81	1.51	8.2	1.93	12.33	0.81	1.51
06	13	--	--	--	--	40.1	10.93	12.33	4.60	2.90	40.1	10.93	12.33	4.60	2.90
DP1	454	--	13.00	--	--	338.5	202.64	12.58	74.08	3.54	338.5	204.40	12.58	74.98	3.54
DP2	41	--	--	--	--	103.6	26.42	12.08	12.21	1.64	103.4	25.85	12.08	11.94	1.64
DP3	--	--	--	--	--	42.1	10.77	12.33	4.67	5.16	42.1	10.77	12.33	4.67	5.16
DP4	111	--	12.50	--	--	126.6	46.31	12.33	22.71	8.22	121.1	46.29	12.33	23.94	8.12
DP5	67	--	12.50	--	--	84.8	76.89	12.25	34.56	3.65	82.3	75.71	12.25	34.55	3.62

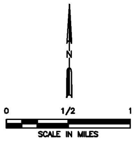
[1] Stormwater discharge points are shown on Figure 4.5. The volume shown is the total volume of runoff for the hydrograph duration.

[2] Runoff volume and velocity calculations are provided in Appendix IIIF-A and IIIF-E.

[3] Discharge points DP3 was not included in the current permitted conditions.

[4] A "--" in the existing permitted condition indicate information that was not provided in the Drainage Analysis developed by HMA Environmental Services, Inc. Refer to Section 4.3.1.1 for a discussion on the existing permitted condition and updated permitted condition.





LEGEND

- • Unincorporated Community
- ✱ County Seat
- ⊕ Border Crossing
- ▲ Cemetery
- ▬ Cemetery (Inside City)
- ⊞ Deep Draft Port
- ⊞ Shallow Draft Port
- ▬ Railroad
- — Dam
- — River or Stream
- — TXDOT District
- ▬ Lakes
- ▬ Education
- ▬ Military
- ▬ Airport Runway
- ▬ Airport
- ▬ Prison
- ▬ Parks and Other Public Land

▨ LANDFILL PROPERTY

NOTES:

1. REPRODUCED FROM 2018 TEXAS DEPARTMENT OF TRANSPORTATION COUNTY MAPS, CHEROKEE COUNTY, TEXAS.

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105073
05/20/2024

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☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120-76-11
CAD: 4.1-SITE LOC.DWG

DRAWN BY: JDW
DESIGN BY: JAE
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT SITE LOCATION MAP

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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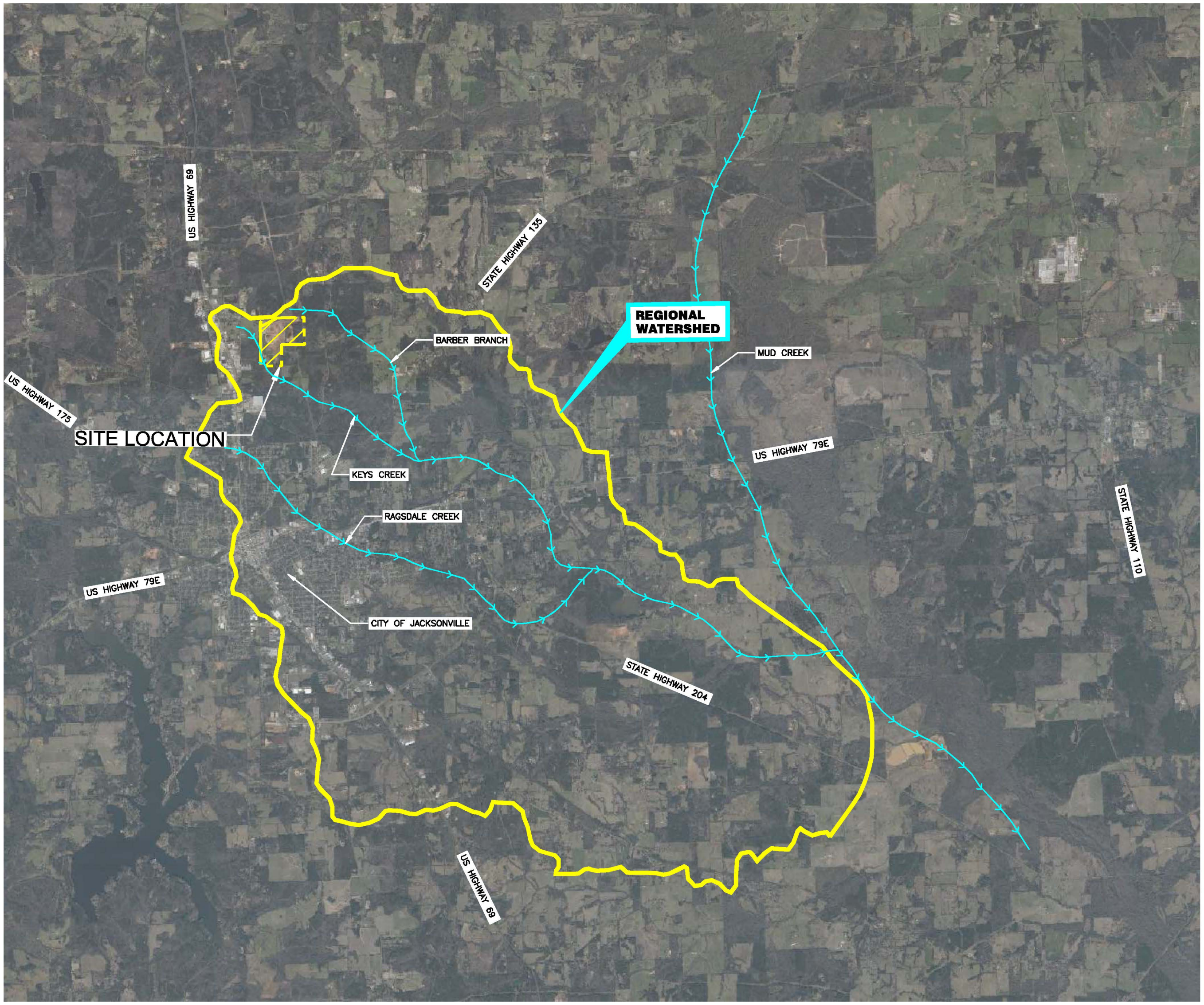
FIGURE 4.1

O:\0120\76\EXPANSION 2023\PART III\IIIF\FIGURES\4.1 – SITE LOCATION.dwg, byoung, 1:2



N

0 3000 6000

SCALE IN FEET

LEGEND

CREEK FLOW LINE

NOTES:

1. REGIONAL WATERSHED MAP REPRODUCED FROM THE TEXAS PARKS & WILDLIFE, TEXAS WATERSHED VIEWER.

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DATE: 05/2024
FILE: 0120-76-11
CAD: 4.2-REGIONAL WATERSHED.DWG

DRAWN BY: JDW
DESIGN BY: JAE
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT REGIONAL WATERSHED MAP

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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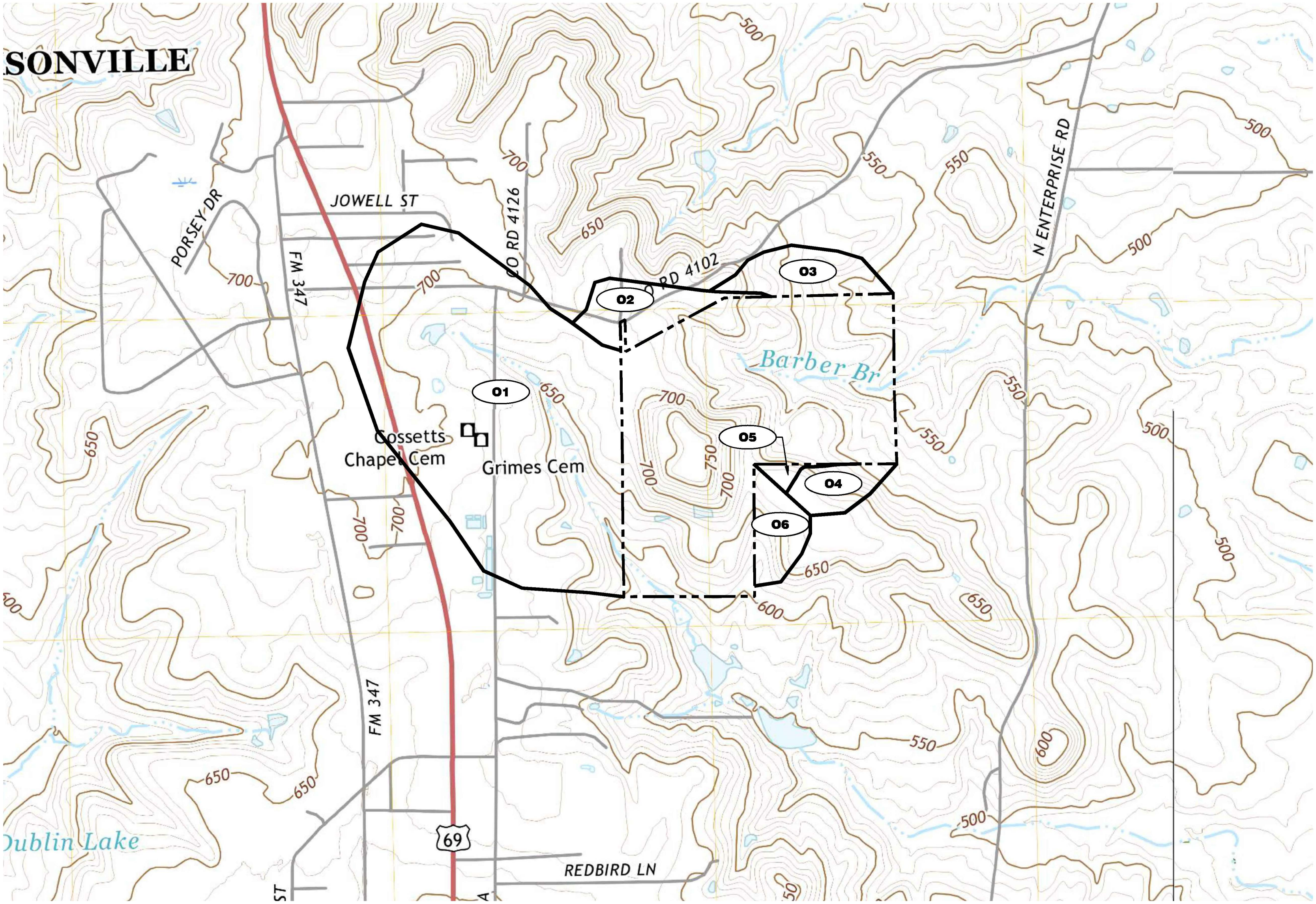
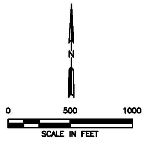
FIGURE 4.2

O:\0120\76\EXPANSION 2023\PART III\IIIF\FIGURES\4.2-REGIONAL WATERSHED.dwg, byoung, 1:2





LEGEND

— - — - —	LANDFILL PROPERTY
———	DRAINAGE AREA BOUNDARY
(O1)	DRAINAGE AREA DESIGNATION

DRAINAGE AREA NO.	AREA (ACRES)
O1	166.84
O2	15.24
O3	14.76
O4	9.00
O5	1.93
O6	10.93

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JACKSONVILLE WEST, TX
2022

JACKSONVILLE EAST, TX
2022

MOUNT SELMAN, TX
2022

TECULA, TX
2022

NOTES:

1. REPRODUCED FROM 7.5 MINUTE, JACKSONVILLE WEST, JACKSONVILLE EAST, MOUNT SELMAN, AND TECULA TEXAS QUADRANGLE USGS MAP DATED 2022.

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DATE: 05/2024
FILE: 0120-76-11
CAD: 4.3 OFFSITE DRAINAGE.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

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PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT OFFSITE DRAINAGE AREA MAP

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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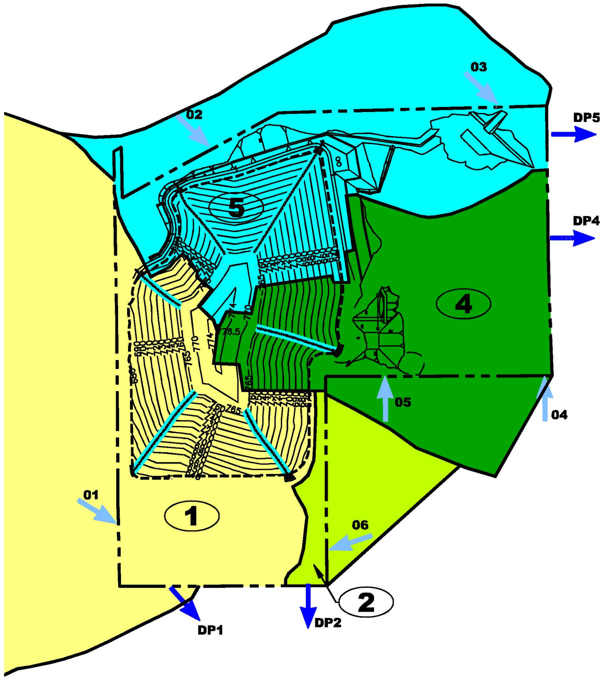
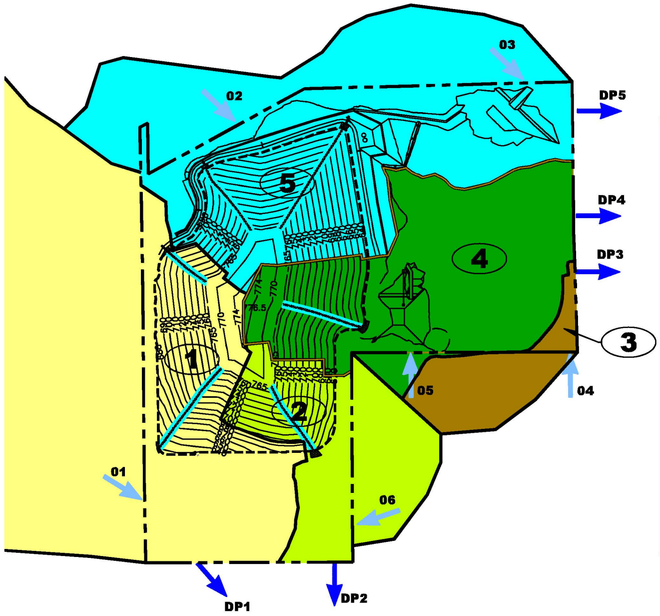
FIGURE 4.3

`O:\0120\76\EXPANSION 2023\PART III\IIIF\FIGURES\4.4 DRAINAGE PATTERNS.dwg, byoung, 1:2`



EXISTING PERMITTED DRAINAGE PATTERNS[1,2]



UPDATED PERMITTED DRAINAGE PATTERNS[1]

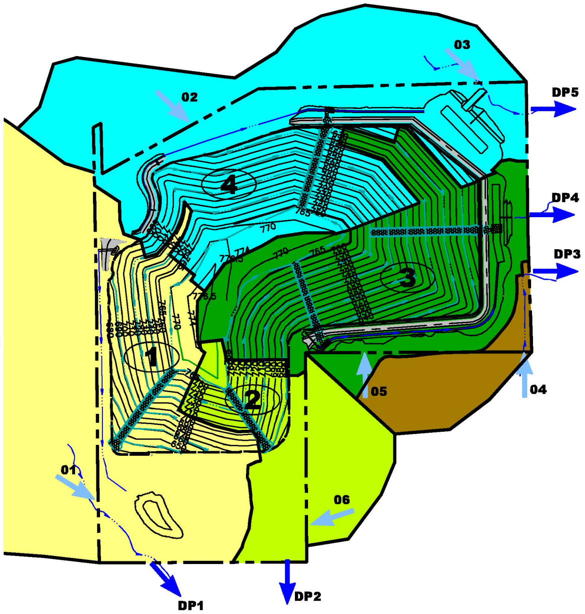
DISCHARGE POINT AREAS

1 = 202.6 ACRES
2 = 26.4 ACRES
3 = 10.8 ACRES
4 = 46.3 ACRES
5 = 76.9 ACRES

TOTAL = 363 ACRES

OFF-SITE AREAS

01 = 166.8 ACRES
02 = 15.2 ACRES
03 = 14.8 ACRES
04 = 9.0 ACRES
05 = 1.9 ACRES
06 = 10.9 ACRES



POST-DEVELOPMENT DRAINAGE PATTERNS

DISCHARGE POINT AREAS

1 = 204.4 ACRES
2 = 25.8 ACRES
3 = 10.8 ACRES
4 = 46.3 ACRES
5 = 75.7 ACRES

TOTAL = 363 ACRES

OFF-SITE AREAS

01 = 166.8 ACRES
02 = 15.2 ACRES
03 = 14.8 ACRES
04 = 9.0 ACRES
05 = 1.9 ACRES
06 = 10.9 ACRES

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105073
05/20/2024

LEGEND

— · — · —	PERMIT BOUNDARY
——100——	ELEVATION OF FINAL COVER SYSTEM
———	DRAINAGE AREA BOUNDARY
①	DRAINAGE AREA DESIGNATION
→	UPLAND DRAINAGE ENTERING THE SITE
→	STORMWATER DISCHARGE POINT

NOTES:

1. REFER TO SECTION 4.3.1 FOR A DISCUSSION ON THE EXISTING PERMITTED CONDITION AND UPDATED PERMITTED CONDITION.
2. TOTAL ACREAGES FOR OFFSITE AREAS AND AT DISCHARGE POINTS WERE NOT PROVIDED IN THE EXISTING PERMIT.

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DATE: 05/2024
FILE: 0120-76-11
CAD: 4.4 DRAINAGE PATTERNS.DWG

DRAWN BY: JDW
DESIGN BY: JAE
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
SITE DRAINAGE PATTERNS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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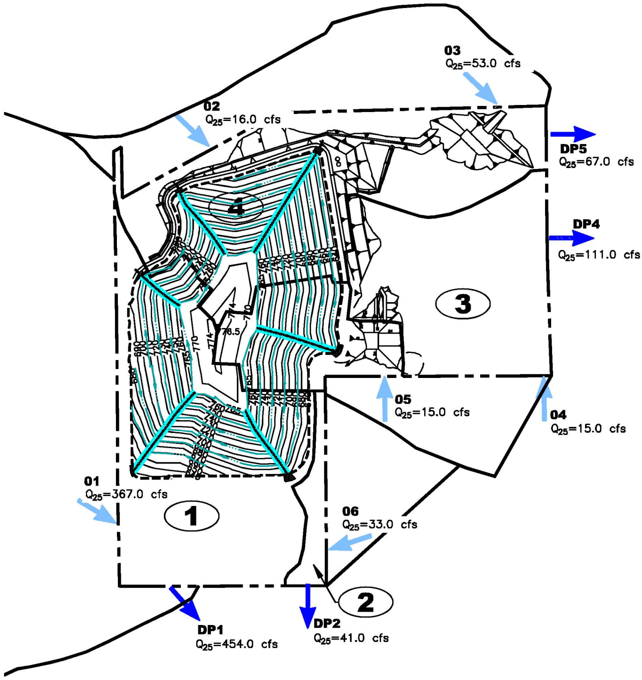
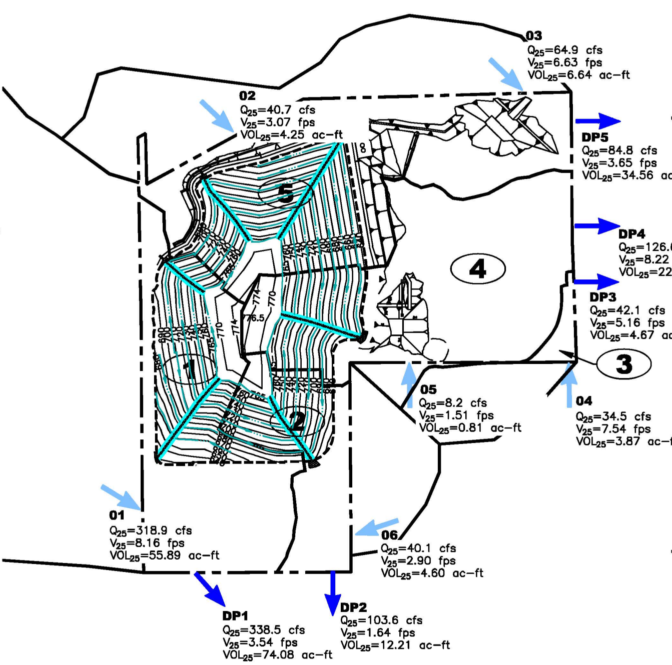
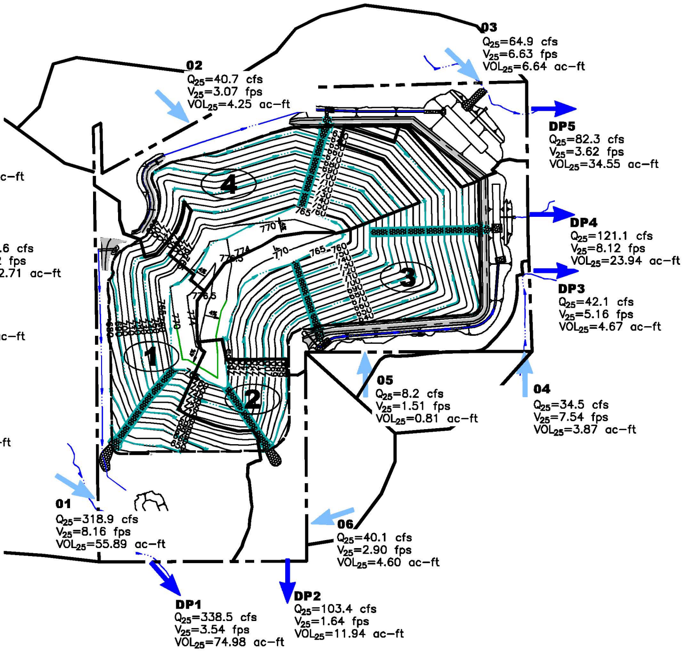
FIGURE 4.4



EXISTING PERMITTED DRAINAGE PATTERNS[1]



UPDATED PERMITTED DRAINAGE PATTERNS[1]



POST–DEVELOPMENT DRAINAGE PATTERNS

LEGEND

— - — - —	PERMIT BOUNDARY
——100——	ELEVATION OF FINAL COVER SYSTEM
———	DRAINAGE AREA BOUNDARY
(1)	DRAINAGE AREA DESIGNATION
→	UPLAND DRAINAGE ENTERING THE SITE
→	STORMWATER DISCHARGE POINT

NOTES:

1. REFER TO SECTION 4.3.1 FOR A DISCUSSION ON THE EXISTING PERMITTED CONDITION AND UPDATED PERMITTED CONDITION.

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DATE: 05/2024
FILE: 0120–76–11
CAD: 4.5 RUN–ON–RUN–OFF.DWG

DRAWN BY: JDW
DESIGN BY: JAE
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
SITE DRAINAGE PATTERNS
RUN–ON/RUNOFF
ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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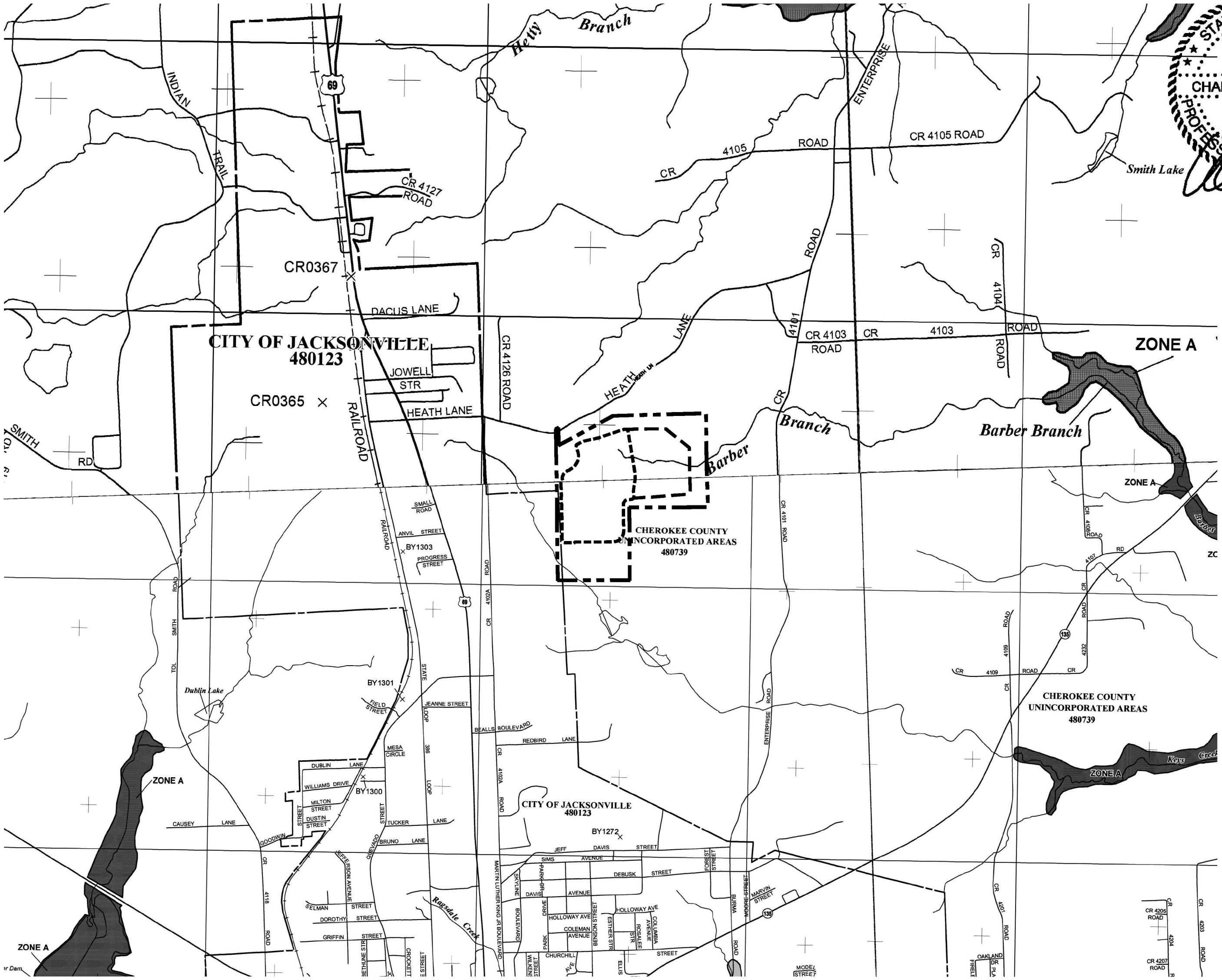
FIGURE 4.5

O:\0120\76\EXPANSION 2023\PART III\IIIF\FIGURES\4.5–RUN–ON RUN–OFF.dwg, byoung, 1:2



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105073
05/20/2024

LEGEND

— — —	PERMIT BOUNDARY
- - - -	AUTHORIZED LIMITS OF WASTE
— — —	PROPOSED LIMITS OF WASTE
■	SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.
■	FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

■	OTHER FLOOD AREAS
ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.
☐	OTHER AREAS
ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.
▨	COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS
▨	OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

———	Floodplain boundary
— — —	Floodway boundary
- —— —— -	Zone D boundary
••••••••	CBRS and OPA boundary
▬	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
~~ 513 ~~~~	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

(A)——(A)	Cross section line
(23)- - - -(23)	Transect line
97°07'30", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
$^{42}75^{000m}$N	1000-meter Universal Transverse Mercator grid , zone 15
6000000 FT	5000-foot grid : Texas State Plane coordinate system, central zone (FIPSZONE 4203), Lambert Conformal Conic
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

NOTE:

1. REPRODUCED FROM FEMA FIRM NUMBER 48073C0175D FOR CHEROKEE COUNTY, TEXAS AND INCORPORATED AREAS, EFFECTIVE DATE JANUARY 2012.

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DATE: 05/2024
FILE: 0120-076-11
CAD: 4.6 FEMA MAP.DWG

DRAWN BY: RAA
DESIGN BY: SSM
REVIEWED BY: RJS

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL COMPANY, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
FLOOD INSURANCE RATE MAP (FIRM)

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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FIGURE 4.6

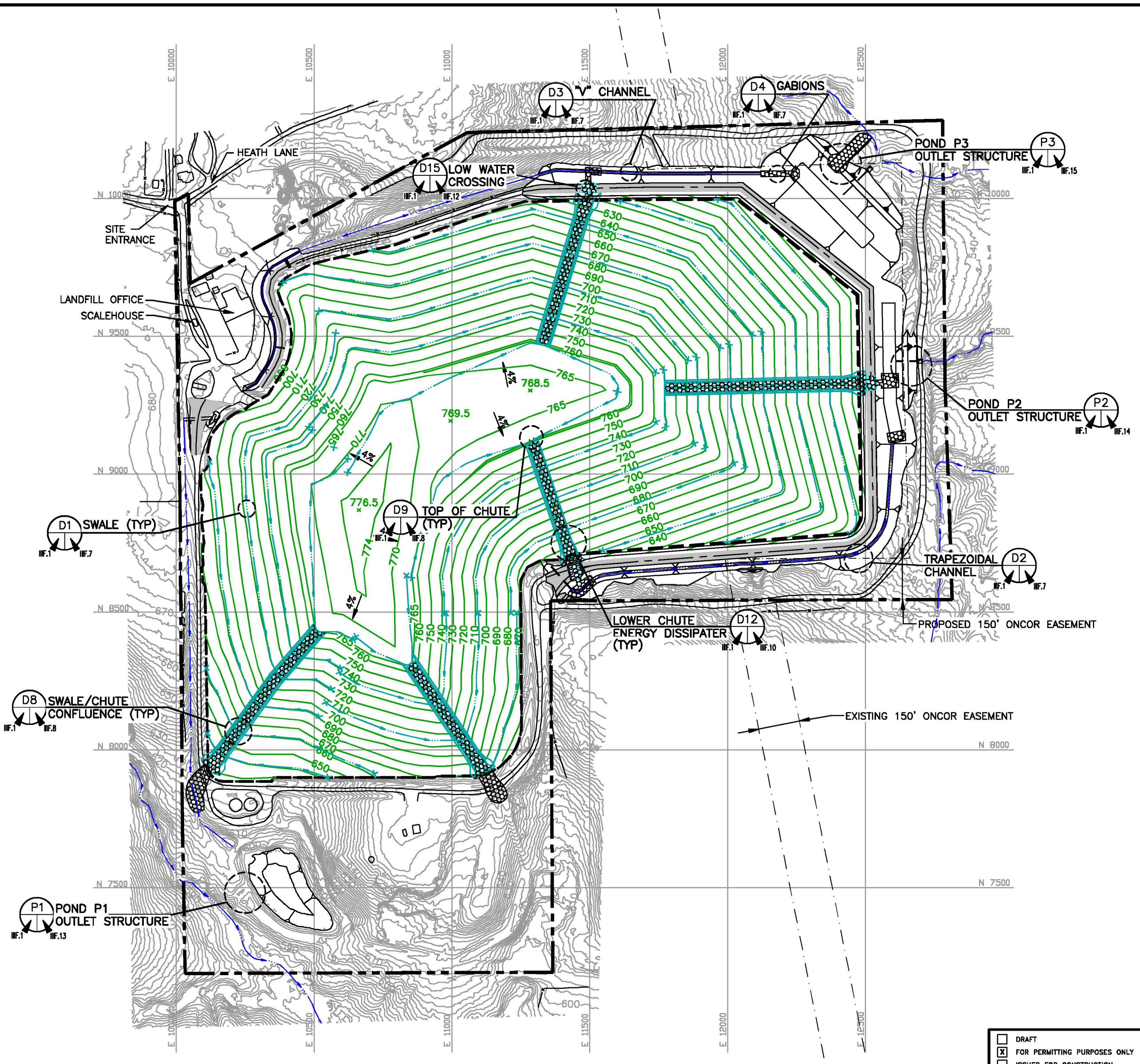
O:\0120\76\EXPANSION 2023\PART III\IIIF\FIGURES\4.6-FEMA MAP.dwg, byoung, 1:2

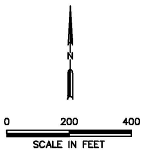
DRAWINGS

IIIF.1 – Drainage Structure Plan
IIIF.2 – Post-Project Drainage
IIIF.3 –Offsite Drainage Area Map
IIIF.4 – Perimeter Drainage Plan
IIIF.5 – Channels 1 and 2 Plan and Profile
IIIF.6 – Channels 1 and 2 Sections
IIIF.7 – Drainage Details
IIIF.8 – Drainage Details
IIIF.9 – Drainage Details
IIIF.10 – Drainage Details
IIIF.11 – Drainage Details
IIIF.12 – Drainage Details
IIIF.13 – Pond P1 Plan
IIIF.14 – Pond P2 Plan
IIIF.15 – Pond P3 Plan

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

05/20/2024





LEGEND

▬ ▬ · ▬	PERMIT BOUNDARY
▬ ▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
🟩	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
▬	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. REFER TO APPENDIX IIIF–SURFACE WATER DRAINAGE PLAN FOR DRAINAGE DESIGN INFORMATION.
3. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT–MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.0 FT–MSL.
4. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
5. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

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105073
05/20/2024

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DATE: 05/2024
FILE: 0120–76–11
CAD: IIIF–1–COMPLETION PLAN.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
DRAINAGE STRUCTURE PLAN

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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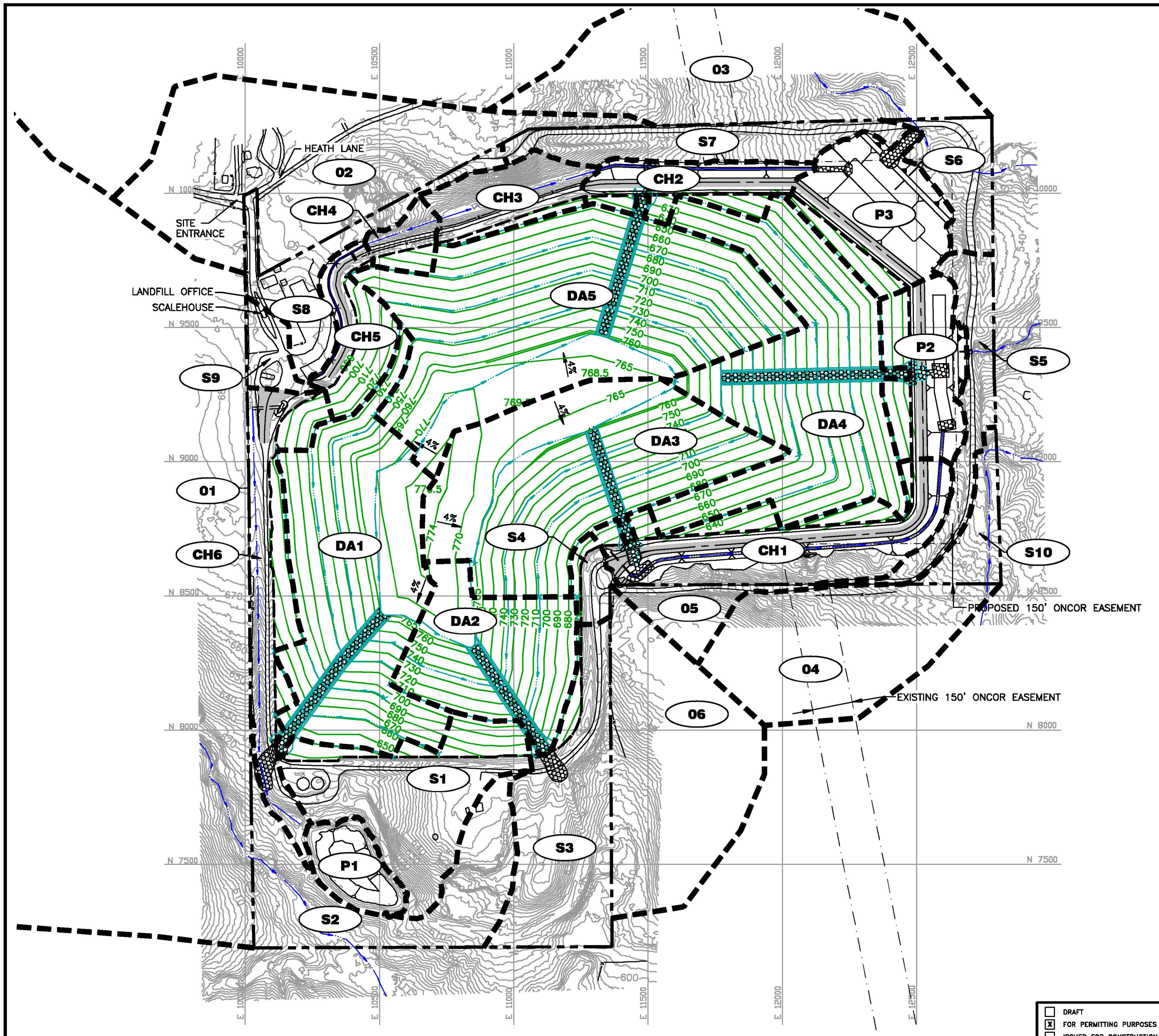
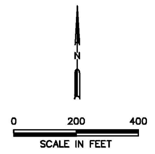
DRAWING IIIF.1





CHARLES R. MARSH
105073
05/20/2024

LEGEND

	PERMIT BOUNDARY
	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
	DRAINAGE SWALE
	DRAINAGE LETDOWN
	CHANNEL CENTERLINE
	DRAINAGE AREA BOUNDARY
DA4	DRAINAGE AREA DESIGNATION

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT-MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.0 FT-MSL.
3. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
4. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

DRAINAGE AREA NO.	AREA (ACRES)	DRAINAGE AREA NO.	AREA (ACRES)
DA1	14.07	CH1	7.55
DA2	6.99	CH2	3.09
DA3	14.33	CH3	2.98
DA4	13.99	CH4	1.14
DA5	20.05	CH5	2.79
S1	7.59	CH6	5.77
S2	6.92	P1	2.01
S3	7.93	P2	4.23
S4	0.94	P3	5.52
S5	3.32	01	166.84
S6	2.63	02	15.24
S7	4.07	03	14.76
S8	3.44	04	9.00
S9	1.19	05	1.93
S10	1.77		

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DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-2-DRAINAGE AREAS.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT POST PROJECT DRAINAGE AREAS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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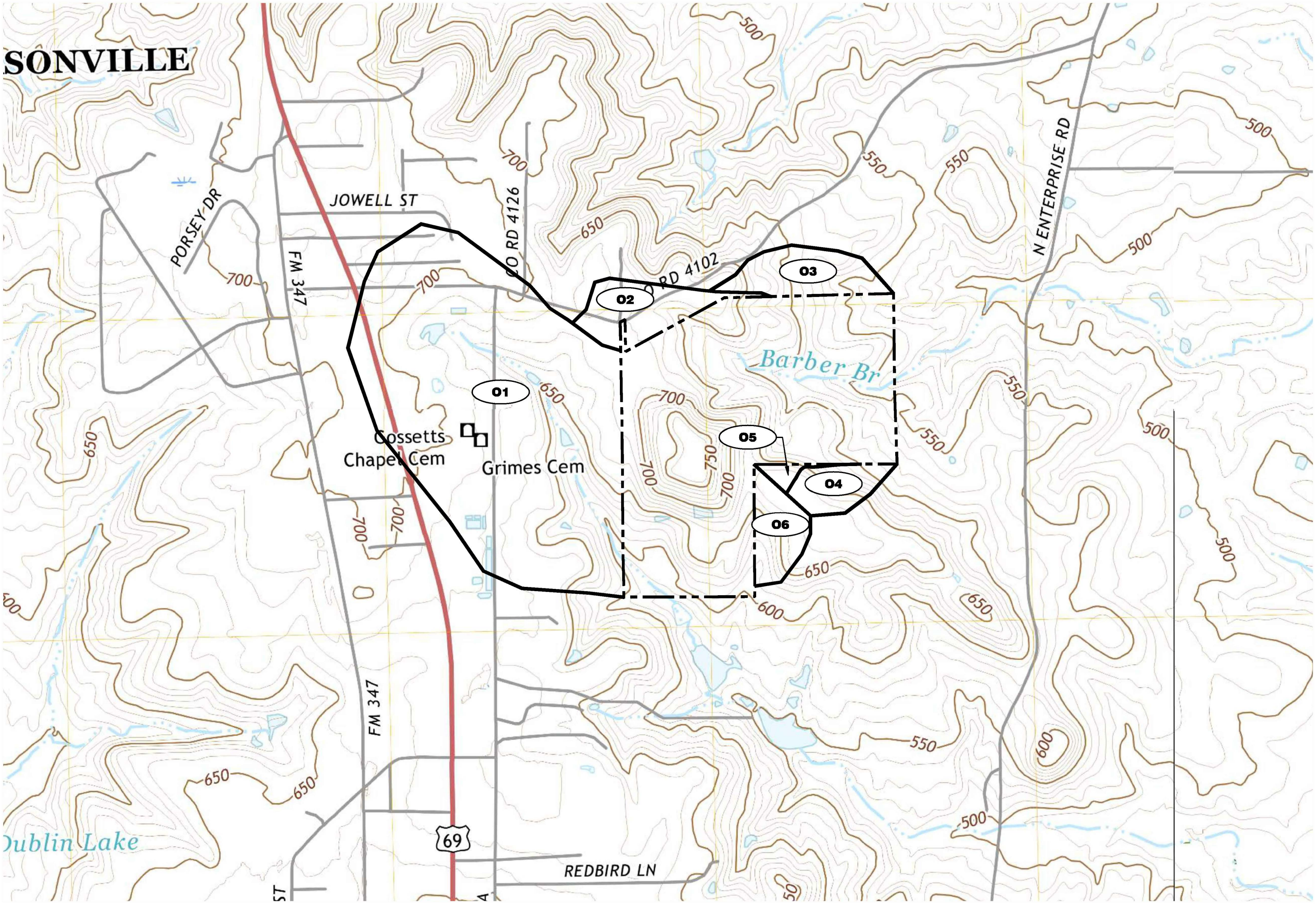
DRAWING IIIF.2

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.2 DRAINAGE AREAS.dwg, byoung, 1:2



LEGEND

— · —	LANDFILL PROPERTY
▬	DRAINAGE AREA BOUNDARY
O1	DRAINAGE AREA DESIGNATION

DRAINAGE AREA NO.	AREA (ACRES)
O1	166.84
O2	15.24
O3	14.76
O4	9.00
O5	1.93
O6	10.93

CHARLES R. MARSH
105073
05/20/2024

JACKSONVILLE WEST, TX
2022

JACKSONVILLE EAST, TX
2022

MOUNT SELMAN, TX
2022

TECULA, TX
2022

NOTES:

1. REPRODUCED FROM 7.5 MINUTE, JACKSONVILLE WEST, JACKSONVILLE EAST, MOUNT SELMAN, AND TECULA TEXAS QUADRANGLE USGS MAP DATED 2022.

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DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-3 OFFSITE DRAINAGE.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT OFFSITE DRAINAGE AREA MAP

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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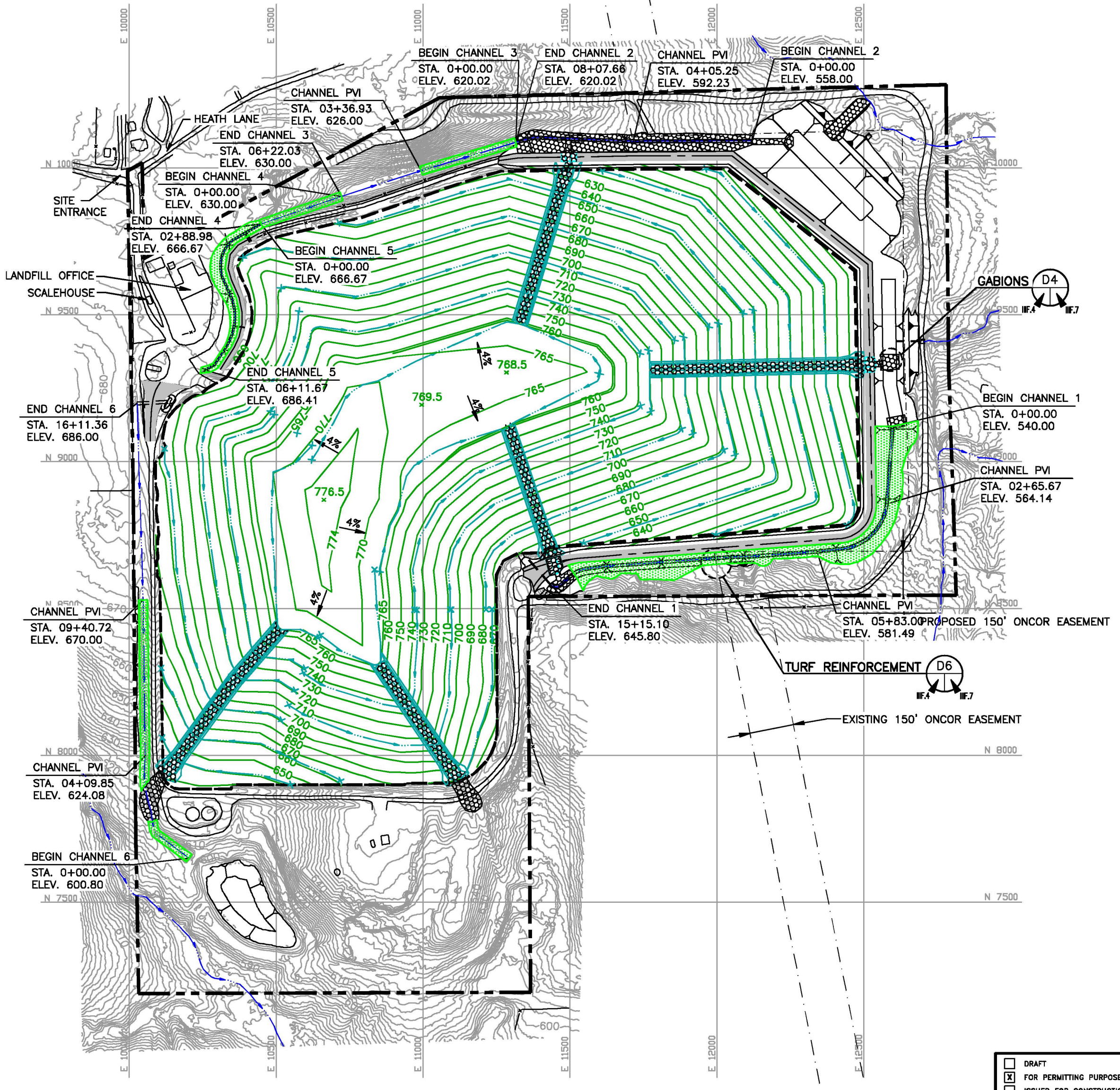
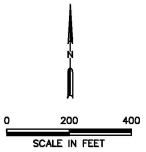
DRAWING IIIF.3

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.3 OFFSITE DRAINAGE.dwg, byoung, 1:2





LEGEND

- ▬ · ▬ PERMIT BOUNDARY
- ▬ ▬ LIMIT OF WASTE
- E 10500 SITE GRID
- 610 EXISTING CONTOUR (SEE NOTE 1)
- 624 PROPOSED FINAL COVER CONTOUR
- DRAINAGE SWALE
- ▨ DRAINAGE LETDOWN
- CHANNEL CENTERLINE
- ▨ GABIONS
- 🟩 TURF REINFORCEMENT MAT

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. REFER TO APPENDIX IIIF–SURFACE WATER DRAINAGE PLAN FOR DRAINAGE DESIGN INFORMATION.
3. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT-MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.0 FT-MSL.
4. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
5. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

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FILE: 0120-76-11
CAD: IIIF-4-CHANNEL PLAN.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

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PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

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MAJOR PERMIT AMENDMENT PERIMETER CHANNEL PLAN

ROYAL OAKS LANDFILL
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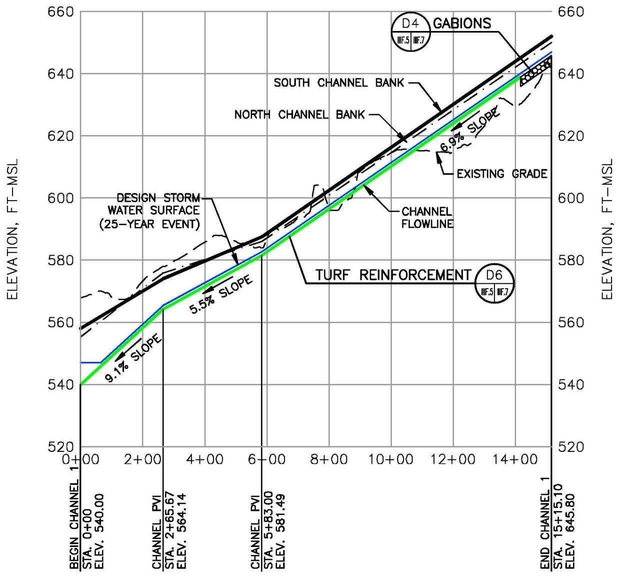
DRAWING IIIF.4

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.4-CHANNEL PLAN.dwg, byoung, 1:2

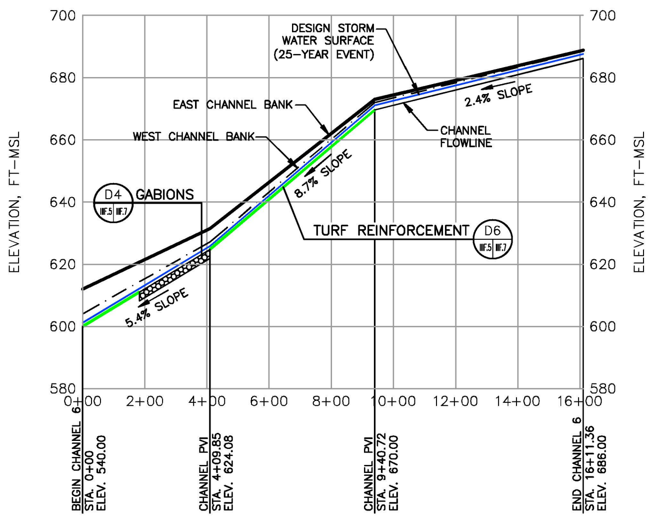


CHANNEL 1 (1 IIIF.4 IIIF.5)

0 200 400 SCALE IN FEET (HORIZONTAL)
0 20 40 SCALE IN FEET (VERTICAL)

25–YEAR CHANNEL 1 INFORMATION						
CHANNEL STATION		BOTTOM WIDTH (FT)	PEAK INFLOW (CFS)	SLOPE (%)	FLOW DEPTH (FT.)	VELOCITY (FT/S)
FROM	TO					
0+00	2+65.67	10	163.2	9.1	0.99	12.74
2+65.67	5+83.00	10	163.2	5.5	1.14	10.70
5+83.00	15+15.00	10	163.2	6.9	1.07	11.58

NOTE: NORMAL DEPTH CALCULATION DOES NOT ACCOUNT FOR BACK WATER WHICH WILL INCREASE FLOW DEPTH (SEE PROFILE) AND DECREASE VELOCITY.



CHANNEL 6 (6 IIIF.4 IIIF.5)

0 200 400 SCALE IN FEET (HORIZONTAL)
0 20 40 SCALE IN FEET (VERTICAL)

25–YEAR CHANNEL 6 INFORMATION						
CHANNEL STATION		BOTTOM WIDTH (FT)	PEAK INFLOW (CFS)	SLOPE (%)	FLOW DEPTH (FT.)	VELOCITY (FT/S)
FROM	TO					
0+00	4+09.85	6	33.5	5.4	0.61	9.64
4+09.85	9+40.72	10	33.5	8.7	0.40	12.42
9+40.72	16+11.36	10	33.5	2.4	0.58	4.77

NOTE: NORMAL DEPTH CALCULATION DOES NOT ACCOUNT FOR BACK WATER WHICH WILL INCREASE FLOW DEPTH (SEE PROFILE) AND DECREASE VELOCITY.

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NOTES:

1. REFER TO DRAWING IIIF.4 FOR PROFILE LOCATIONS.
2. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
3. HYDRAULIC CALCULATIONS INCLUDED IN APPENDIX IIIF–B.
4. GABIONS SHALL BE USED FOR VELOCITIES OF 13 FT/SEC OR HIGHER.
5. CULVERT CALCULATIONS INCLUDED IN APPENDIX IIIF–B.

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DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

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MAJOR PERMIT AMENDMENT
PERIMETER CHANNEL PLAN

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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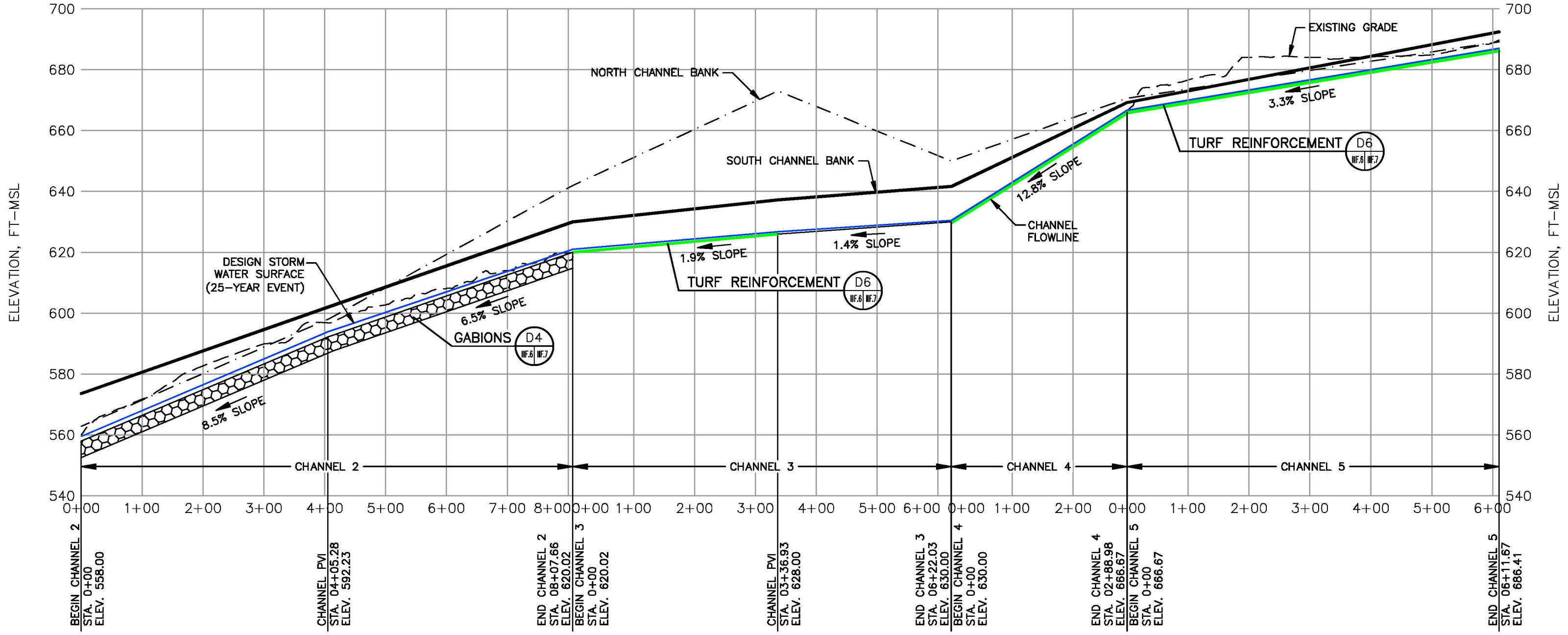
DRAWING IIIF.5

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.5–6 PROFILES.dwg, byoung, 1:2



CHANNEL 2 THROUGH 5

1 IIIF.4 IIIF.6

0 100 200
SCALE IN FEET (HORIZONTAL)

0 10 20
SCALE IN FEET (VERTICAL)

25-YEAR CHANNEL 2 INFORMATION

CHANNEL STATION		BOTTOM WIDTH (FT)	PEAK INFLOW (CFS)	SLOPE (%)	FLOW DEPTH (FT.)	VELOCITY (FT/S)
FROM	TO					
0+00	4+05.25	10	285.1	8.5	1.37	14.74
4+05.25	8+07.66	10	285.1	6.5	1.47	13.45

NOTE: NORMAL DEPTH CALCULATION DOES NOT ACCOUNT FOR BACK WATER WHICH WILL INCREASE FLOW DEPTH (SEE PROFILE) AND DECREASE VELOCITY.

25-YEAR CHANNEL 3 INFORMATION

CHANNEL STATION		BOTTOM WIDTH (FT)	PEAK INFLOW (CFS)	SLOPE (%)	FLOW DEPTH (FT.)	VELOCITY (FT/S)
FROM	TO					
0+00	3+36.93	15	90.9	1.8	1.12	6.06
0+62.45	6+22.03	30	90.9	1.4	0.66	4.28

NOTE: NORMAL DEPTH CALCULATION DOES NOT ACCOUNT FOR BACK WATER WHICH WILL INCREASE FLOW DEPTH (SEE PROFILE) AND DECREASE VELOCITY.

25-YEAR CHANNEL 4 INFORMATION

CHANNEL STATION		BOTTOM WIDTH (FT)	PEAK INFLOW (CFS)	SLOPE (%)	FLOW DEPTH (FT.)	VELOCITY (FT/S)
FROM	TO					
0+00	2+88.98	10	49.3	12.80	0.45	9.63

NOTE: NORMAL DEPTH CALCULATION DOES NOT ACCOUNT FOR BACK WATER WHICH WILL INCREASE FLOW DEPTH (SEE PROFILE) AND DECREASE VELOCITY.

25-YEAR CHANNEL 5 INFORMATION

CHANNEL STATION		BOTTOM WIDTH (FT)	PEAK INFLOW (CFS)	SLOPE (%)	FLOW DEPTH (FT.)	VELOCITY (FT/S)
FROM	TO					
0+00	1+24.29	0	25.7	3.3	0.60	5.48

NOTE: NORMAL DEPTH CALCULATION DOES NOT ACCOUNT FOR BACK WATER WHICH WILL INCREASE FLOW DEPTH (SEE PROFILE) AND DECREASE VELOCITY.

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NOTES:

1. REFER TO DRAWING IIIF.4 FOR PROFILE LOCATIONS.
2. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
3. HYDRAULIC CALCULATIONS INCLUDED IN APPENDIX IIIF-B.
4. GABIONS SHALL BE USED FOR VELOCITIES OF 13 FT/SEC OR HIGHER.
5. CULVERT CALCULATIONS INCLUDED IN APPENDIX IIIF-B.

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DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

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MAJOR PERMIT AMENDMENT
PERIMETER CHANNEL PROFILE

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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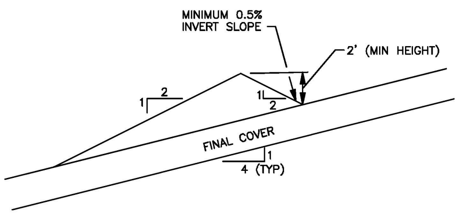
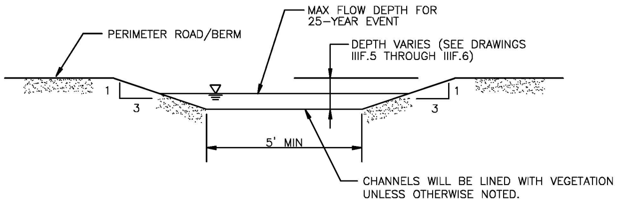
DRAWING IIIF.6

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.5-6 PROFILES.dwg, byoung, 1:2



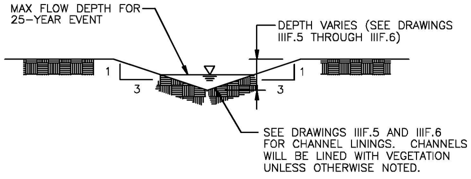
SWALE (TYP) D1 IIIF.1 IIIF.7

0 4 8
SCALE IN FEET



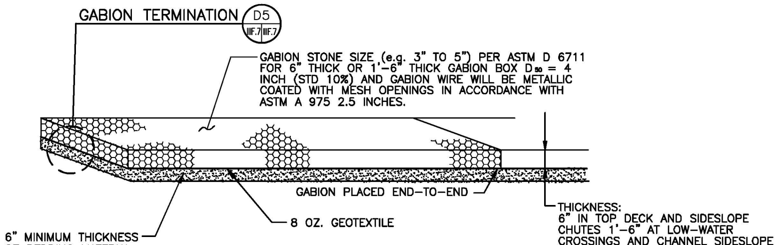
TRAPEZOIDAL CHANNEL (TYP) D2 IIIF.1 IIIF.7

0 2 4
SCALE IN FEET



"V" CHANNEL (TYP) D3 IIIF.1 IIIF.7

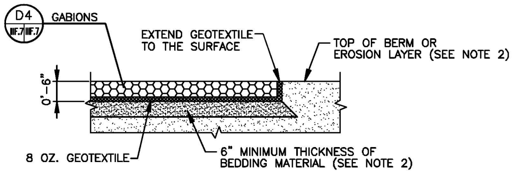
0 2 4
SCALE IN FEET



GABIONS D4 IIIF.7

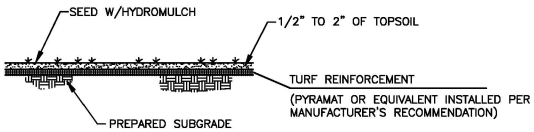
IIIF.1,IIIF.4,IIIF.5,IIIF.6,IIIF.7,IIIF.8,IIIF.9

0 2 4
SCALE IN FEET



GABION TERMINATION D5 IIIF.7 IIIF.7

0 2 4
SCALE IN FEET



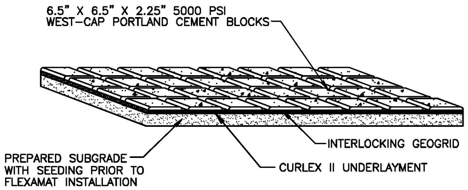
TURF REINFORCEMENT D6 IIIF.7

NOT TO SCALE
(SEE NOTE 2)

IIIF.4,IIIF.5,IIIF.6

NOTES:

1. REFER TO DRAWING IIIF.1-DRAINAGE STRUCTURE PLAN FOR LOCATION OF DETAILS.
2. BEDDING MATERIAL WILL CONSIST OF CLAYEY SOILS COMPACTED TO PROVIDE FIRM BASE THAT WILL BE OVERLAIN BY 8 oz/sy GEOTEXTILE PRIOR TO PLACEMENT OF GABIONS.



FLEXAMAT D7 IIIF.9 IIIF.7

0 2 4
SCALE IN FEET

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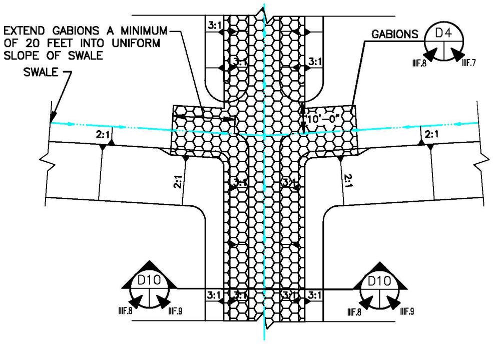
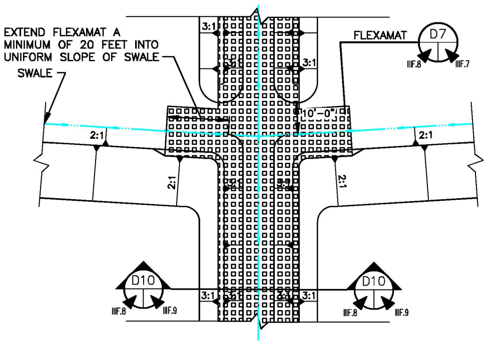
FIGURE IIIF.7

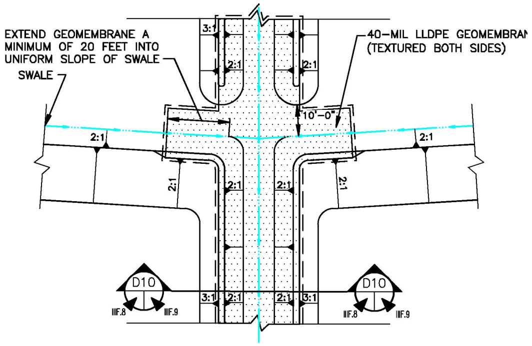
O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.7-DRAINAGE DETAILS.dwg, byoung, 1:2



GABION/GROUTED RIPRAP OPTION



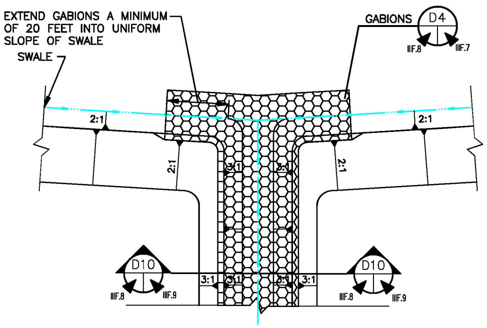
FLEXAMAT OPTION



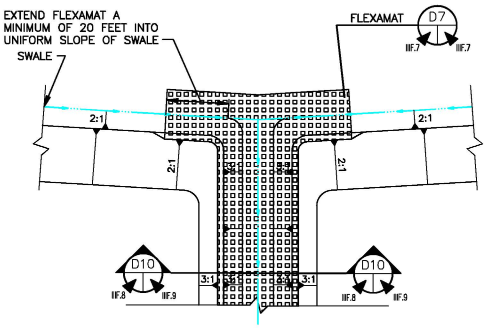
GEOMEMBRANE LINER OPTION

SWALE/CHUTE CONFLUENCE (TYP) D8 IIIF.1 IIIF.9

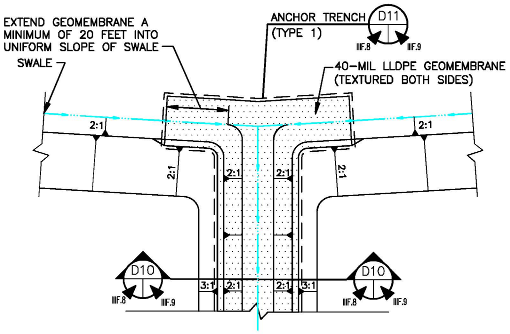
0 20 40
SCALE IN FEET



GABION/GROUTED RIPRAP OPTION



FLEXAMAT OPTION



GEOMEMBRANE LINER OPTION

TOP OF CHUTE (TYP) D9 IIIF.1 IIIF.8

0 20 40
SCALE IN FEET

NOTES:

1. REFER TO DRAWING IIIF.1 STORMWATER MANAGEMENT PLAN FOR LOCATION OF DETAILS.
2. SEE APPENDIX IIIF-C FOR BOTTOM WIDTHS OF EACH INDIVIDUAL CHUTE.

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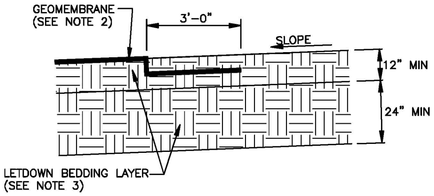
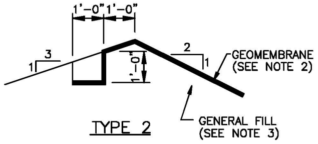
FIGURE IIIF.8

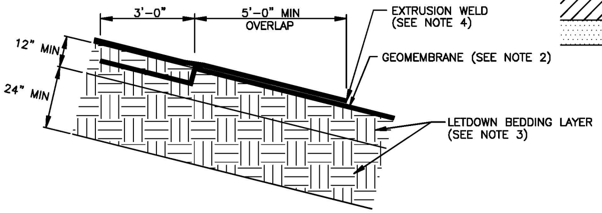
O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.8-DRAINAGE DETAILS.dwg, byoung, 1:2



TYPE 1



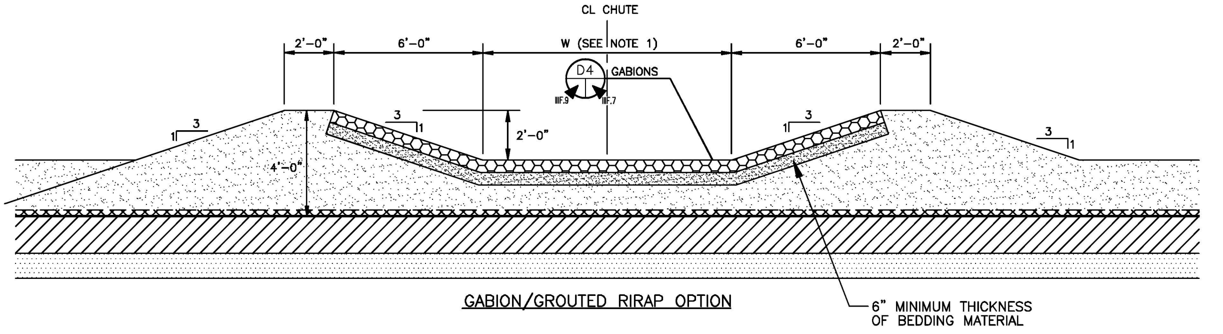
TYPE 2



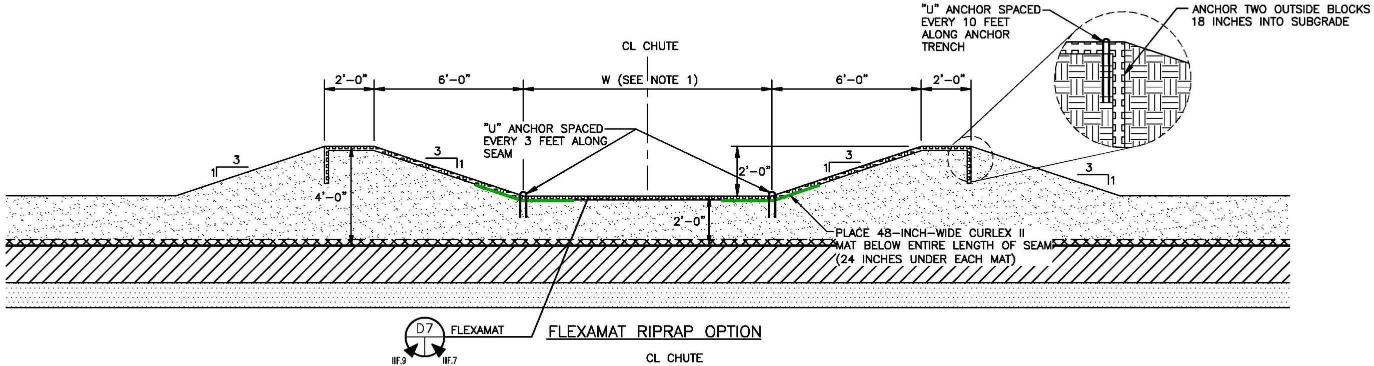
TYPE 3

ANCHOR TRENCH D11 IIIF.8 IIIF.9

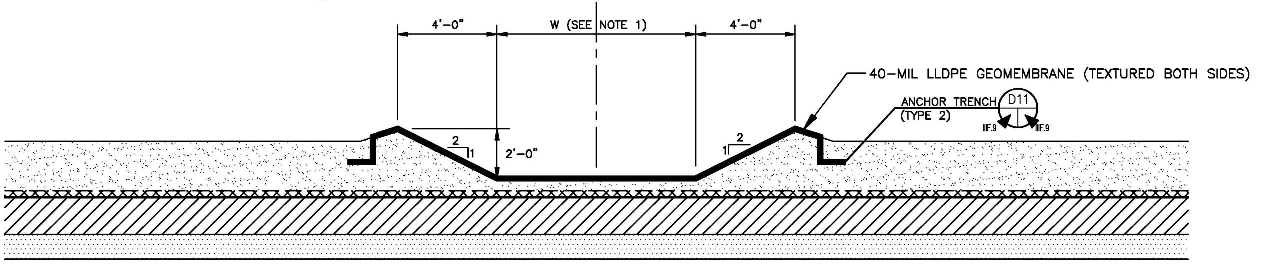
0 2 4
SCALE IN FEET



GABION/GROUTED RIRAP OPTION



FLEXAMAT RIPRAP OPTION



GEOMEMBRANE OPTION

UPPER CHUTE SECTION (TYP) D10 IIIF.8 IIIF.9

0 2.5 5
SCALE IN FEET

NOTES:

1. SEE APPENDIX IIIF-C FOR CHUTE HYDRAULIC CALCULATIONS.
2. 60 MIL HDPE GEOMEMBRANE TEXTURED BOTH SIDES SHALL BE USED FOR GEOMEMBRANE LETDOWN LINING.
3. SOIL PLACED UNDER GEOMEMBRANE LETDOWN AND CONCRETE DISSIPATER SHALL NOT CONTAIN TOPSOIL THAT WILL BE USED FOR VEGETATION LAYER.
4. EXTRUSION WELD UPSTREAM PANEL OVER DOWNSTREAM PANEL USING 1'-0" LONG EXTRUSION WELD WITH A SPACING OF 1'-0" BETWEEN EACH WELD.

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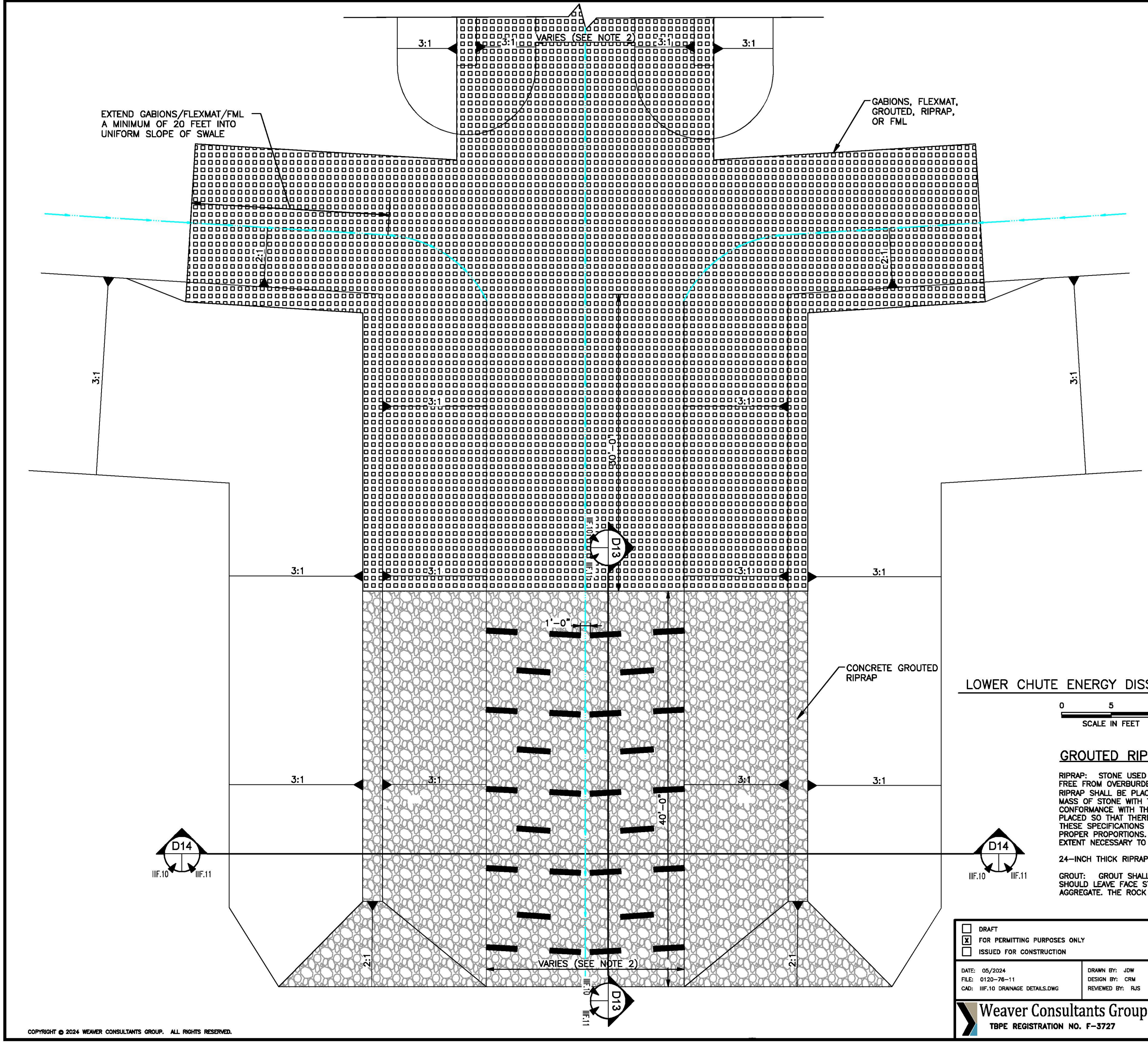
FIGURE IIIF.9

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.9-DRAINAGE DETAILS.dwg, byoung, 1:2



LOWER CHUTE ENERGY DISSIPATER (TYP)

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105073
05/20/2024

NOTES:

1. REFER TO DRAWING IIIF.1 STORMWATER MANAGEMENT PLAN FOR LOCATION OF DETAILS.
2. SEE APPENDIX IIIF-C FOR CHUTE HYDRAULIC CALCULATIONS.

GROUTED RIPRAP SPECIFICATION

RIPRAP: STONE USED FOR RIPRAP SHALL BE HARD, DURABLE, ANGULAR IN SHAPE; RESISTANT TO WEATHERING AND TO WATER ACTION; FREE FROM OVERBURDEN, SPOIL, SHALE AND ORGANIC MATERIAL; AND SHALL MEET THE GRADATION REQUIREMENTS SPECIFIED. STONE RIPRAP SHALL BE PLACED ON THE PREPARED SUBGRADE/FILTER FABRIC IN A MANNER WHICH WILL PRODUCE A REASONABLY WELL-GRADED MASS OF STONE WITH THE MINIMUM PARTICLE PERCENTAGE OF VOIDS. THE ENTIRE MASS OF STONE SHALL BE PLACED SO AS TO BE IN CONFORMANCE WITH THE LINES, GRADES, AND THICKNESS SHOWN ON THE PLANS. THE LARGER STONES SHALL BE WELL DISTRIBUTED AND PLACED SO THAT THERE WILL BE NO LARGE ACCUMULATIONS OF EITHER THE LARGER OR SMALLER SIZES OF STONE. IT IS THE INTENT OF THESE SPECIFICATIONS TO PRODUCE A FAIRLY COMPACT RIPRAP PROTECTION IN WHICH ALL SIZES OF MATERIAL ARE PLACED IN THEIR PROPER PROPORTIONS. HAND PLACING OR REARRANGING OF INDIVIDUAL STONES BY MECHANICAL EQUIPMENT MAY BE REQUIRED TO THE EXTENT NECESSARY TO SECURE THE RESULTS SPECIFIED.

24-INCH THICK RIPRAP GRADATION: (D_{15} = 9-INCH, D_{50} = 15-INCH, D_{MAX} = 24-INCH).

GROUT: GROUT SHALL CONSIST OF 3,500 PSI CONCRETE USING A MAXIMUM AGGREGATE SIZE OF 3/4 INCH. THE FINISHED GROUT SHOULD LEAVE FACE STONES EXPOSED APPROXIMATELY 6 INCHES. THE SURFACE OF THE GROUT SHOULD EXPOSE A MATRIX OF COARSE AGGREGATE. THE ROCK SHOULD BE WET IMMEDIATELY PRIOR TO COMMENCING THE GROUTING OPERATION.

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CAD: IIIF.10 DRAINAGE DETAILS.DWG

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DESIGN BY: CRM
REVIEWED BY: RJS

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DRAINAGE DETAILS

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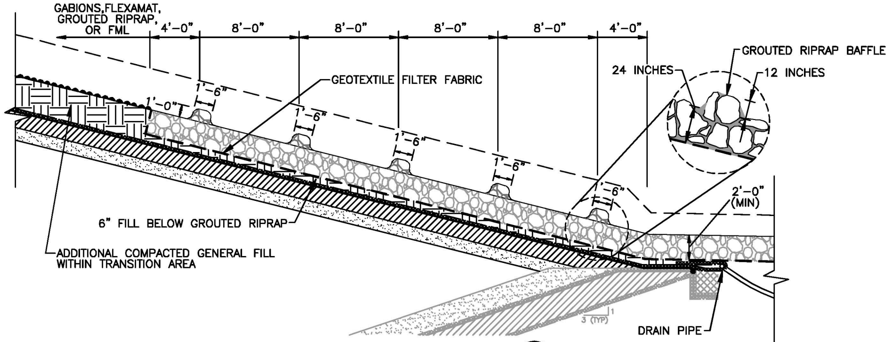
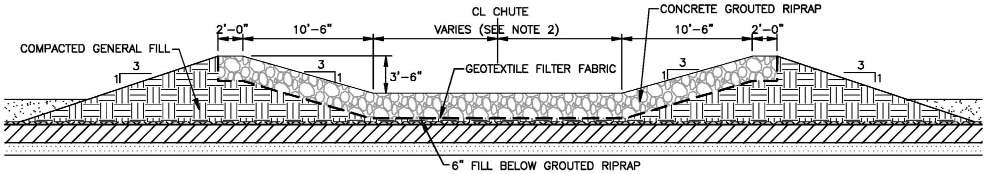
FIGURE IIIF.10

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.10-DRAINAGE DETAILS.dwg, byoung, 1:2



LOWER CHUTE ENERGY DISSIPATOR SECTION (TYP) D13 IIIF.10 IIIF.11

0 5 10
SCALE IN FEET



LOWER CHUTE SECTION (TYP) D14 IIIF.10 IIIF.11

0 5 10
SCALE IN FEET

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NOTES:

1. REFER TO DRAWING IIIF.1 STORMWATER MANAGEMENT PLAN FOR LOCATION OF DETAILS.
2. SEE APPENDIX IIIF–C FOR CHUTE HYDRAULIC CALCULATIONS.

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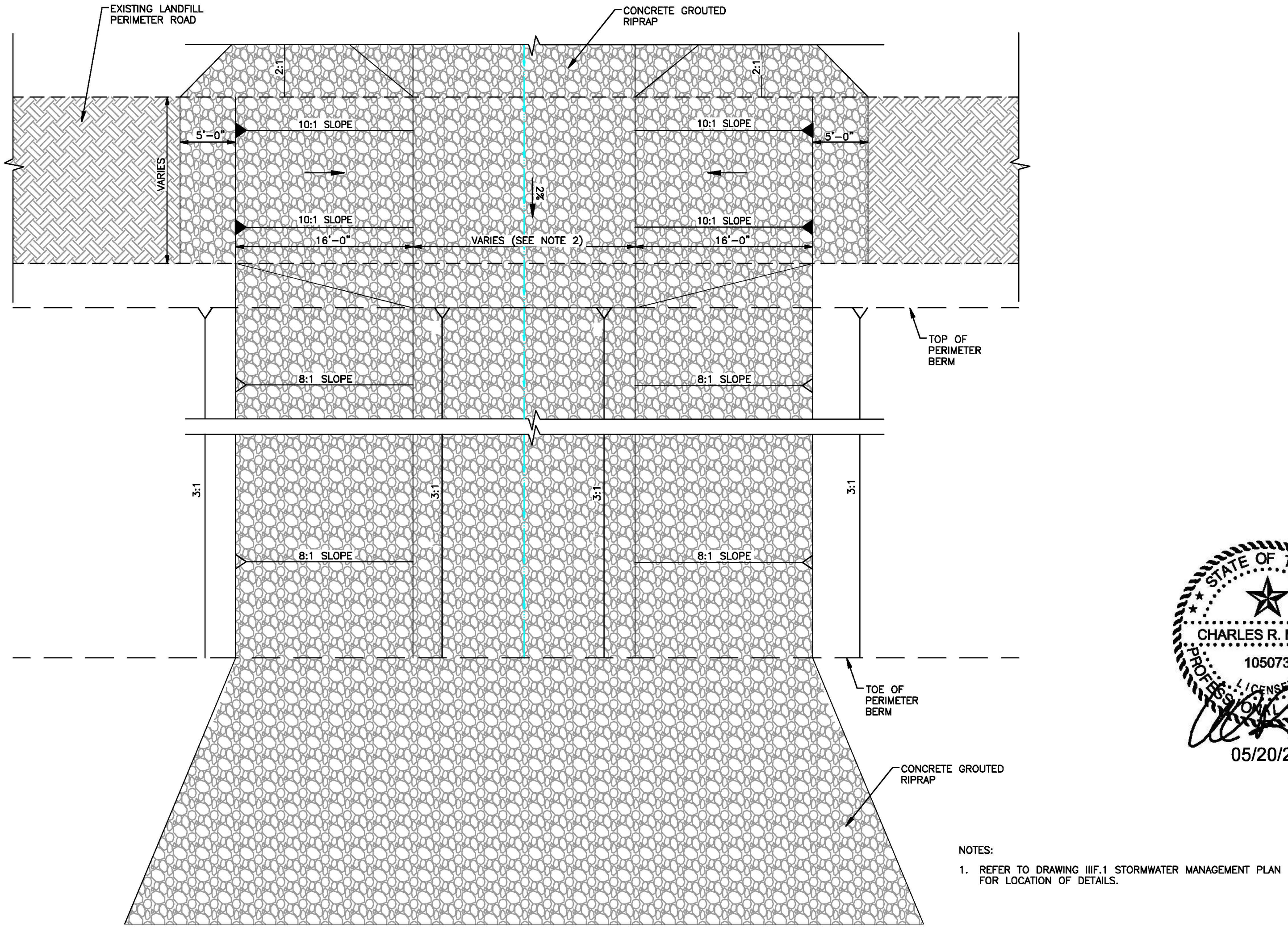
FIGURE IIIF.11



LOW WATER CROSSING (TYP)

D15
IIIF.1
IIIF.12

0 5 10
SCALE IN FEET

NOTES:

1. REFER TO DRAWING IIIF.1 STORMWATER MANAGEMENT PLAN FOR LOCATION OF DETAILS.

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105073
05/20/2024

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☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF.12 DRAINAGE DETAILS.DWG

DRAWN BY: JDW
DESIGN BY: CRM
REVIEWED BY: RJS

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

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PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
DRAINAGE DETAILS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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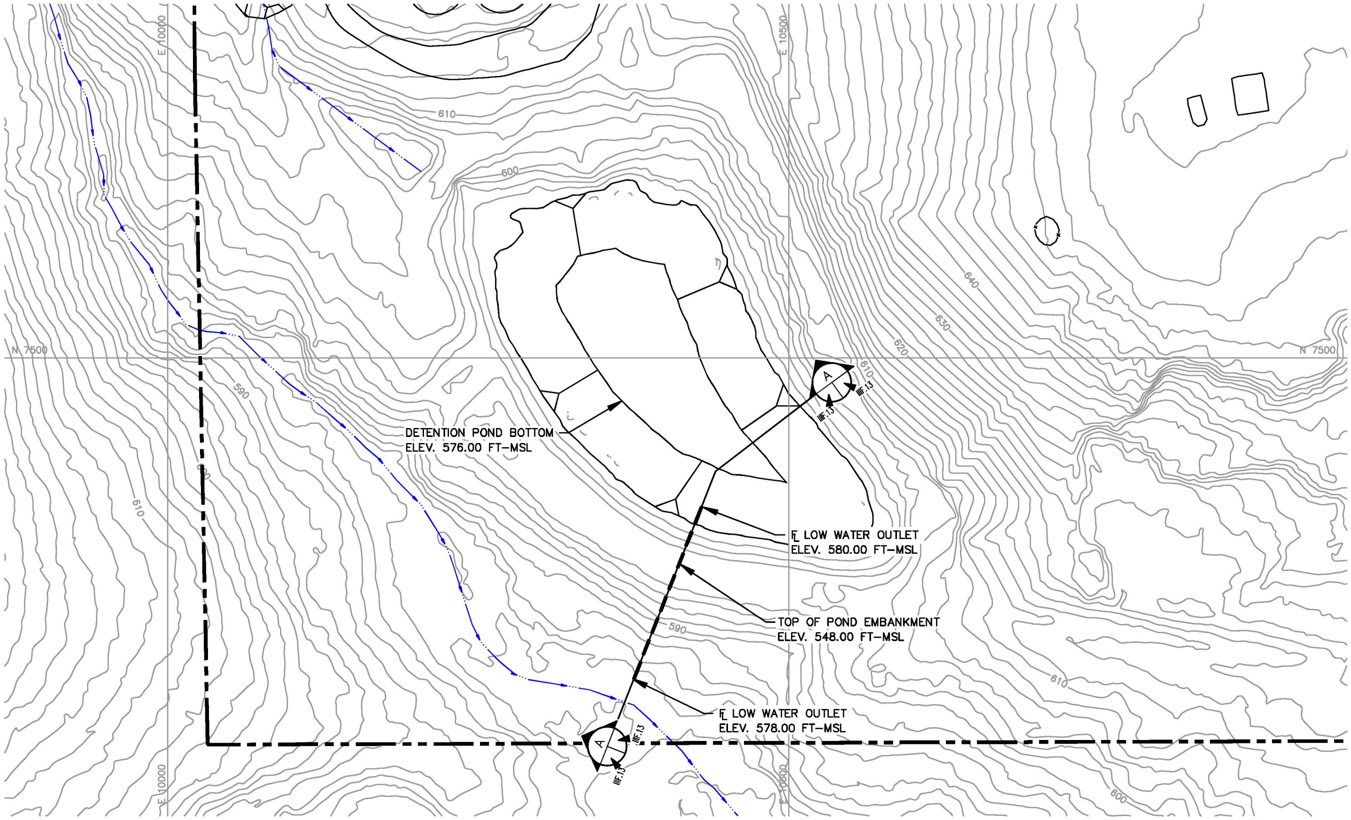
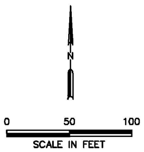
FIGURE IIIF.12



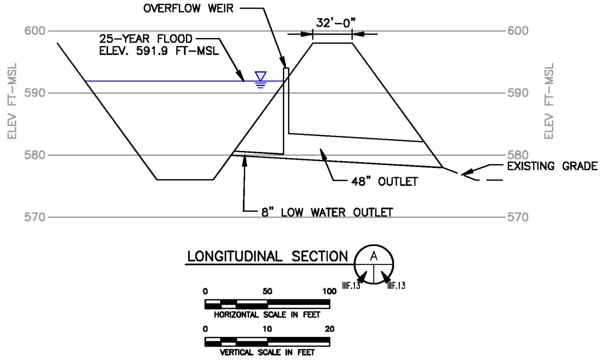


LEGEND

▬ · ▬	PERMIT BOUNDARY
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. REFER TO APPENDIX IIIF–SURFACE WATER DRAINAGE PLAN FOR DRAINAGE DESIGN INFORMATION.



LONGITUDINAL SECTION A

CHARLES R. MARSH
105073

05/20/2024

DETENTION POND DESIGN SUMMARY

POND BOTTOM	534.00 FT–MSL
TOP OF EMBANKMENT	550.00 FT–MSL
SPILLWAY ELEVATION	544.00 FT–MSL
25–YEAR PEAK STAGE	591.90 FT–MSL
25–YEAR STORAGE VOLUME	10.2 AC–FT
LOW WATER OUTLET	(1)10" RCP
OUTLET UPSTREAM ELEVATION	534.00
OUTLET DOWNSTREAM ELEVATION	531.97

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☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120–76–11
CAD: IIIF–13–POND P1 PLAN.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

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PINE HILL FARMS LANDFILL TX, LP

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NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
POND P1 PLAN

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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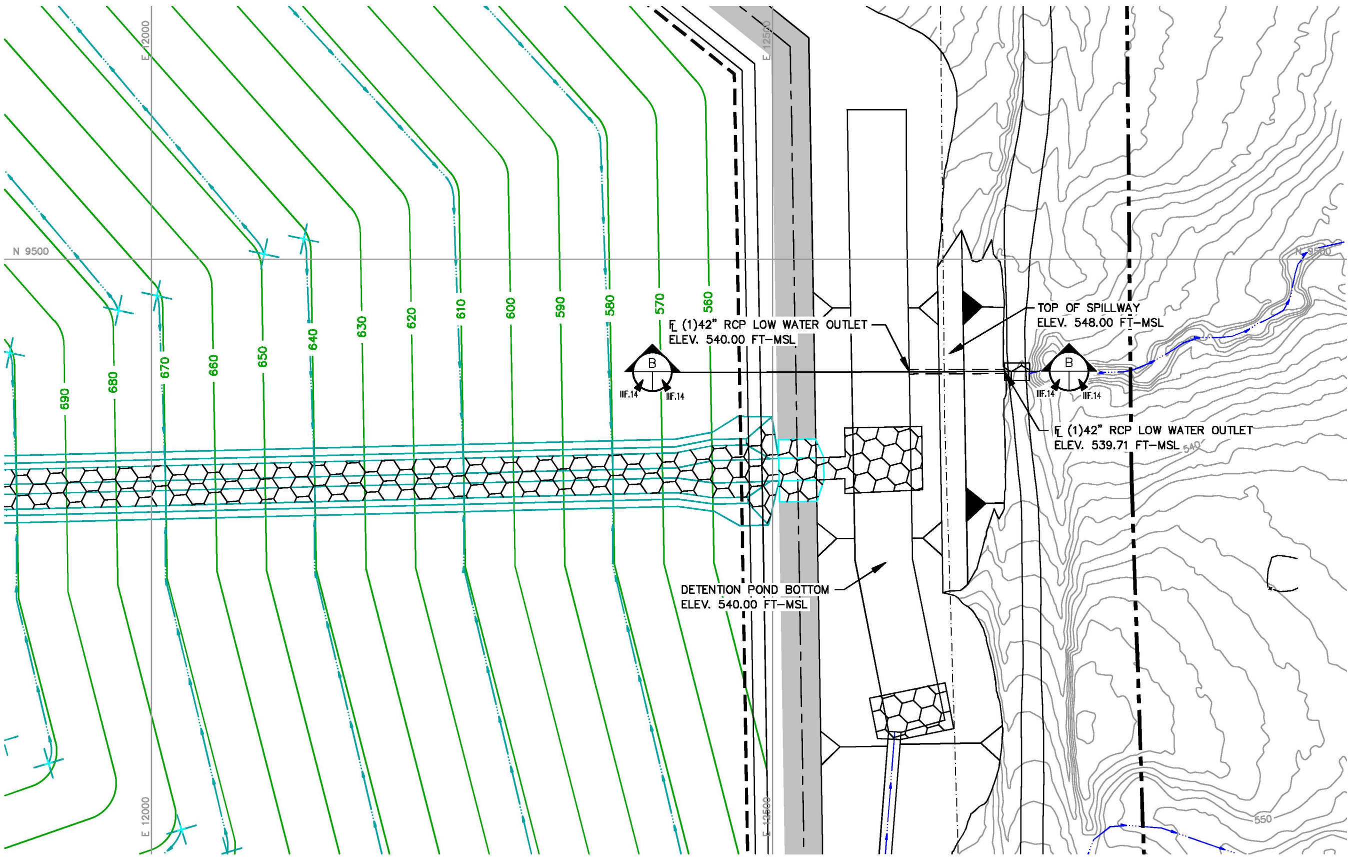
DRAWING IIIF.13



N

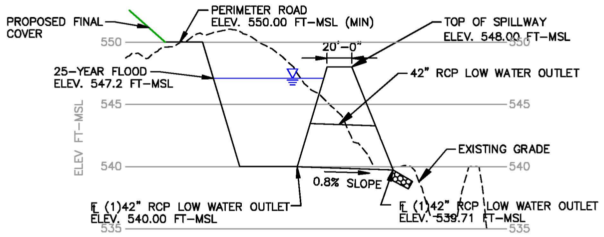
0 50 100
SCALE IN FEET

LEGEND

▬ ▪ ▬	PERMIT BOUNDARY
▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
▬	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
▬	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. REFER TO APPENDIX IIIF–SURFACE WATER DRAINAGE PLAN FOR DRAINAGE DESIGN INFORMATION.



LONGITUDINAL SECTION B
IIIF.15 IIIF.15

0 50 100
HORIZONTAL SCALE IN FEET

0 5 10
VERTICAL SCALE IN FEET

DETENTION POND DESIGN SUMMARY

POND BOTTOM	540.00 FT–MSL
TOP OF EMBANKMENT	550.00 FT–MSL
SPILLWAY ELEVATION	548.00 FT–MSL
25–YEAR PEAK STAGE	547.2 FT–MSL
25–YEAR STORAGE VOLUME	5.9 AC–FT
LOW WATER OUTLET	(1)42" RCP
OUTLET UPSTREAM ELEVATION	540.00 FT–MSL
OUTLET DOWNSTREAM ELEVATION	539.71 FT–MSL

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105073

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DATE: 05/2024
FILE: 0120–76–11
CAD: IIIF–14–POND P2 PLAN.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
POND P2 PLAN

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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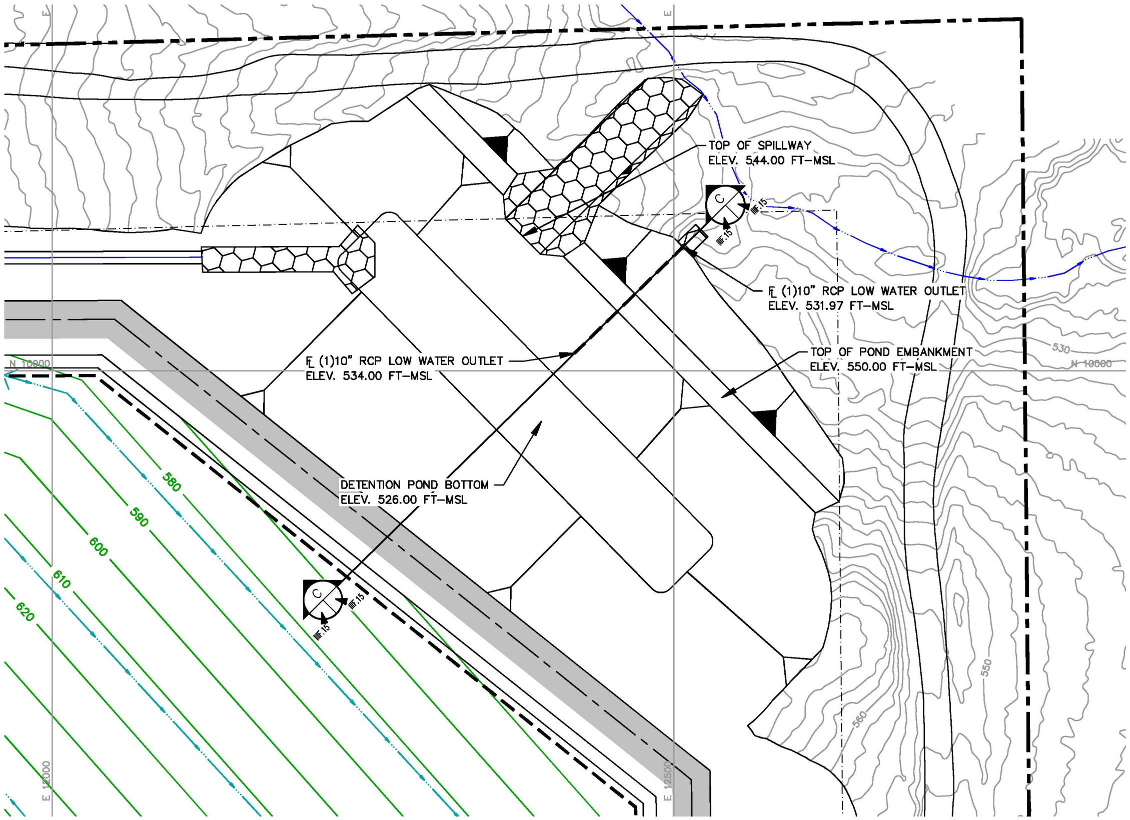
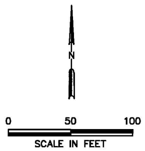
DRAWING IIIF.14

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.14-POND P2 PLAN.dwg, byoung, 1:2



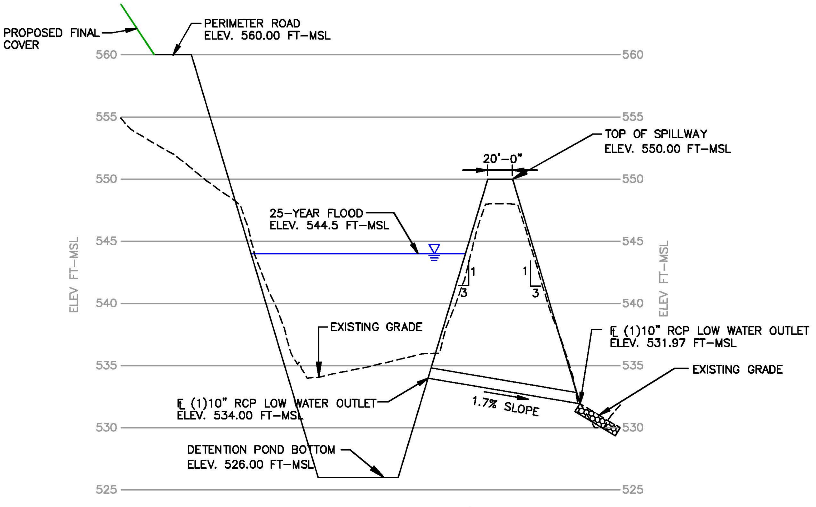


LEGEND

▬ · ▬	PERMIT BOUNDARY
▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
	DRAINAGE SWALE
	DRAINAGE LETDOWN
	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. REFER TO APPENDIX IIIF-SURFACE WATER DRAINAGE PLAN FOR DRAINAGE DESIGN INFORMATION.



LONGITUDINAL SECTION C IIIF.15 IIIF.15

0 50 100
HORIZONTAL SCALE IN FEET

0 5 10
VERTICAL SCALE IN FEET

DETENTION POND DESIGN SUMMARY

POND BOTTOM	526.00 FT-MSL
TOP OF EMBANKMENT	550.00 FT-MSL
SPILLWAY ELEVATION	544.00 FT-MSL
25-YEAR PEAK STAGE	544.5 FT-MSL
25-YEAR STORAGE VOLUME	21.8 AC-FT
LOW WATER OUTLET	(1)10" RCP
OUTLET UPSTREAM ELEVATION	534.00 FT-MSL
OUTLET DOWNSTREAM ELEVATION	531.97 FT-MSL

CHARLES R. MARSH
105073
05/20/2024

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DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-15-POND P3 PLAN.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT POND P3 PLAN

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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DRAWING IIIF.15

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF.15-POND P3 PLAN.dwg, byoung, 1:2

APPENDIX IIIF-A

POST-DEVELOPMENT CONDITION
HYDROLOGIC CALCULATIONS

Includes pages IIIF-A-1 through IIIF-A-102

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105073

05/20/2024

CONTENTS

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED PROFESSIONAL ENGINEER

05/20/2024

HYPOTHETICAL STORM DATA

Hypothetical Storm Data

Precipitation data taken from NOAA Atlas 14 rainfall data.

Time	5 min	15 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr
25-Year Event	0.895	1.78	3.29	4.26	4.87	5.92	6.87	7.88

NOAA Atlas 14 - Precipitation-Frequency Atlas of the United States, Volume 11, Version 2.0: Texas (*U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Weather Service, 2018*) was used to identify precipitation values for storm durations ranging from 5 minutes to 24 hours.

PRECIPITATION LOSS DATA

Prep By: VG
Date: 5/6/2024

ROYAL OAKS LANDFILL
0120-076-11-106
PRECIPITATION LOSS DATA

Chkd By:BPY/CRM
Date: 5/6/2024

Required: Determine the SCS curve numbers for both on-site and off-site drainage areas for use in the HEC-HMS analysis.

References:

1. U.S. Army Corps of Engineers, Hydrologic Engineering Center, *HEC-HMS Hydrologic Modeling System 4.9,* January 2022.
2. United States Department of Agriculture, National Resource Conservation Service, Web Soil Survey for Cherokee County, Texas (http://websoilsurvey.nrcs.usda.gov).
3. The Hydrologic Evaluation of Landfill Performance (HELP) Model - Engineering Documentation for version 3. EPA/600/R-94/168b, September 1994.

Note: Approximate non landfill areas within the permit boundary on SCS map (page IIIF-A-6).

Solution: Based on the soil survey information found in Ref. 2, hydrologic groups A, B, C, and D soils are found within the permit boundary. (See pages IIIF-A-6 trough IIIF-A9)

All non-landfill on-site and offsite drainage areas and drainage channels were considered pasture land in fair condition. A curve number was selected using the table on page IIIF-A-12.

Hydrologic Group	A	B	C	D
CN	49	69	79	84

Composite calculations for offsite and non-landfill drainage areas are shown on page IIIF-A-6.

The final cover system was assumed to be in place and the erosion layer will control precipitation loss. A curve number that is corrected for the surface slope of the erosion layer may be computed first using the chart on page IIIF-A-12 to select an un-adjusted curve number. Calculate the adjusted curve number using equation 34 from Ref. 3 (see page IIIF-A-11).

$$CN_{II} = 100 - (100 - CN_{II\,o}) * (L^{*\,2} / S^{*}) \wedge (CN_{II\,o}^{-0.81})$$

Use: $CN_{II\,o} = 84$, $L^{*} = (500/500)$, $S^{*} = (.04/.04)$ for top dome surfaces
Use: $CN_{II\,o} = 84$, $L^{*} = (120/500)$, $S^{*} = (.25/.04)$ for side slopes

Calculate: CN = 84 for top dome surfaces
Calculate: CN = 86 for side slopes

- Use curve number calculated for side slopes for the entire final cover area, inculding top dome areas, conservatively.

The pond areas are assumed to collect all precipitation for their areas:

Use: CN = 99

The initial abstraction is:

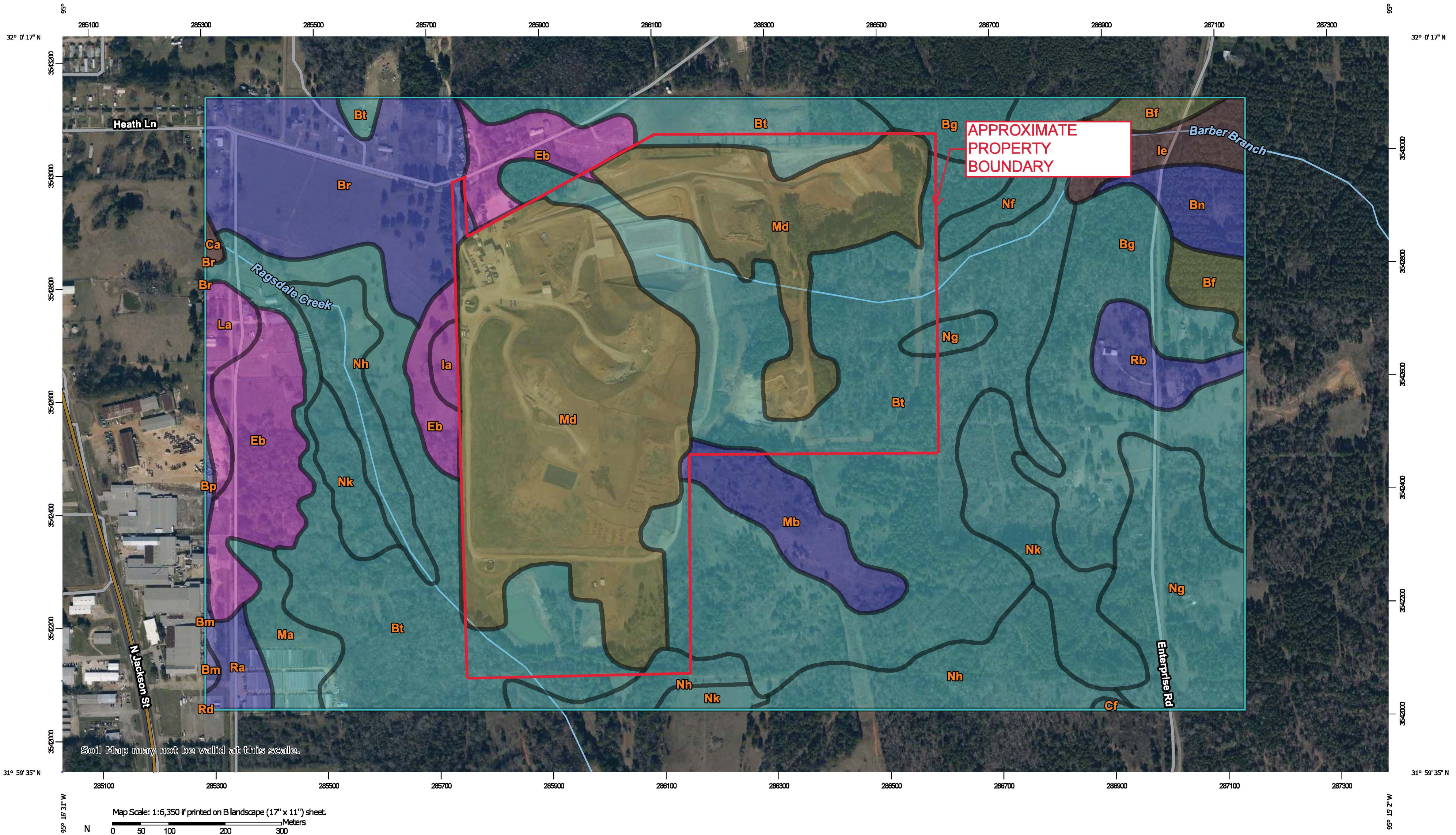
Use: I = 0.0"

- All drainage areas were modeled to assume no inital abstractions.

ROYAL OAKS LANDFILL
0120-076-11-106
COMPOSITE CURVE NUMBER SUMMARY

Drainage Area	Hydraulic Soil Group Area (ac)				Total Area (ac)	Composite CN
	A	B	C	D		
	CN = 49	CN = 69	CN = 79	CN = 84		
S1	0.00	0.00	2.11	7.40	9.51	83
S2	0.00	0.00	3.36	3.56	6.92	82
S3	0.00	0.30	4.07	4.09	8.46	81
S4	0.00	0.03	0.09	0.95	1.07	83
S5	0.00	0.00	3.32	0.00	3.32	79
S6	0.00	0.00	1.08	1.55	2.63	82
S7	0.00	0.05	2.89	1.13	4.07	80
S8	0.00	0.88	0.37	2.19	3.44	80
S9	0.00	0.00	0.00	1.19	1.19	84
S10	0.00	0.00	1.77	0.00	1.77	79
O1	43.62	67.68	48.23	7.31	166.84	67
O2	7.03	5.64	2.57	0.00	15.24	61
O3	0.00	0.00	14.70	0.06	14.76	79
O4	0.00	1.79	7.21	0.00	9.00	77
O5	0.00	0.67	1.26	0.00	1.93	76
O6	0.00	3.37	7.56	0.00	10.93	76

Hydrologic Soil Group—Cherokee County, Texas
(Royal Oaks Landfill - Hydrologic Soil Group Map)



Map Scale: 1:6,350 if printed on B landscape (17" x 11") sheet.

N

0 50 100 200 300 Meters

0 300 600 1200 1800 Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

MAP LEGEND

Area of Interest (AOI)

- ⬜ Area of Interest (AOI)

Soils

Soil Rating Polygons

- 🟪 A
- 🟩 A/D
- 🟦 B
- 🟫 B/D
- 🟦 C
- 🟨 C/D
- 🟥 D
- ⬜ Not rated or not available

Soil Rating Lines

- 〰 A
- 〰 A/D
- 〰 B
- 〰 B/D
- 〰 C
- 〰 C/D
- 〰 D
- 〰 Not rated or not available

Soil Rating Points

- ■ A
- ■ A/D
- ■ B
- ■ B/D
- ■ C
- ■ C/D
- ■ D
- □ Not rated or not available

Water Features

- 〰 Streams and Canals

Transportation

- ┼┼┼ Rails
- 〰 Interstate Highways
- 〰 US Routes
- 〰 Major Roads
- 〰 Local Roads

Background

- ▨ Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cherokee County, Texas
Survey Area Data: Version 21, Aug 24, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Dec 18, 2019—Feb 1, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Bf	Sacul fine sandy loam, 8 to 15 percent slopes	C/D	5.9	1.2%
Bg	Sacul fine sandy loam, strongly sloping, eroded	C	39.5	8.0%
Bm	Bowie fine sandy loam, 1 to 3 percent slopes	B	0.4	0.1%
Bn	Bowie fine sandy loam, 3 to 8 percent slopes	B	6.0	1.2%
Bp	Lilbert loamy fine sand, 1 to 3 percent slopes	B	0.7	0.1%
Br	Lilbert loamy fine sand, 3 to 8 percent slopes	B	32.6	6.6%
Bt	Trawick-Bub complex, 8 to 40 percent slopes	C	168.3	34.0%
Ca	Alazan very fine sandy loam, 0 to 1 percent slopes	B/D	0.4	0.1%
Cf	Cuthbert fine sandy loam, 8 to 15 percent slopes	C	0.3	0.1%
Eb	Betis loamy fine sand, 3 to 8 percent slopes	A	27.9	5.6%
Ia	Bienville loamy fine sand, 1 to 3 percent slopes	A	1.6	0.3%
Ie	Iulus fine sandy loam, 0 to 1 percent slopes, frequently flooded	B/D	7.3	1.5%
La	Darco loamy fine sand, 1 to 3 percent slopes	A	4.3	0.9%
Ma	Elrose fine sandy loam, 1 to 3 percent slopes	C	6.8	1.4%
Mb	Elrose fine sandy loam, 3 to 8 percent slopes	B	10.8	2.2%
Md	Angelina	C/D	92.6	18.7%
Nf	Nacogdoches fine sandy loam, sloping	C	3.8	0.8%
Ng	Nacogdoches fine sandy loam, sloping, eroded	C	24.4	4.9%
Nh	Trawick fine sandy loam, 8 to 20 percent slopes	C	29.4	5.9%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Nk	Trawick fine sandy loam, strongly sloping, eroded	C	22.4	4.5%
Ra	Ruston fine sandy loam, 1 to 3 percent slopes	B	3.8	0.8%
Rb	Ruston fine sandy loam, 3 to 8 percent slopes	B	6.5	1.3%
Rd	Briley loamy fine sand, 1 to 3 percent slopes	B	0.0	0.0%
Totals for Area of Interest			**495.5**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition where

CN_{II_o} = AMC-II curve number for mild slope (unadjusted for slope)

C_O = regression constant for a given level of vegetation

C_I = regression constant for a given level of vegetation

C_2 = regression constant for a given level of vegetation

IR = infiltration correlation parameter for given soil type

The relationship between CN_{II}, the vegetative cover and default soil texture is shown graphically in Figure 8. Table 7 gives values of C_0, C_1 and C_2 for the five types of vegetative cover built into the HELP program.

4.2.3 Adjustment of Curve Number for Surface Slope

A regression equation was developed to adjust the AMC-II curve number for surface slope conditions. The regression was developed based on kinematic wave theory where

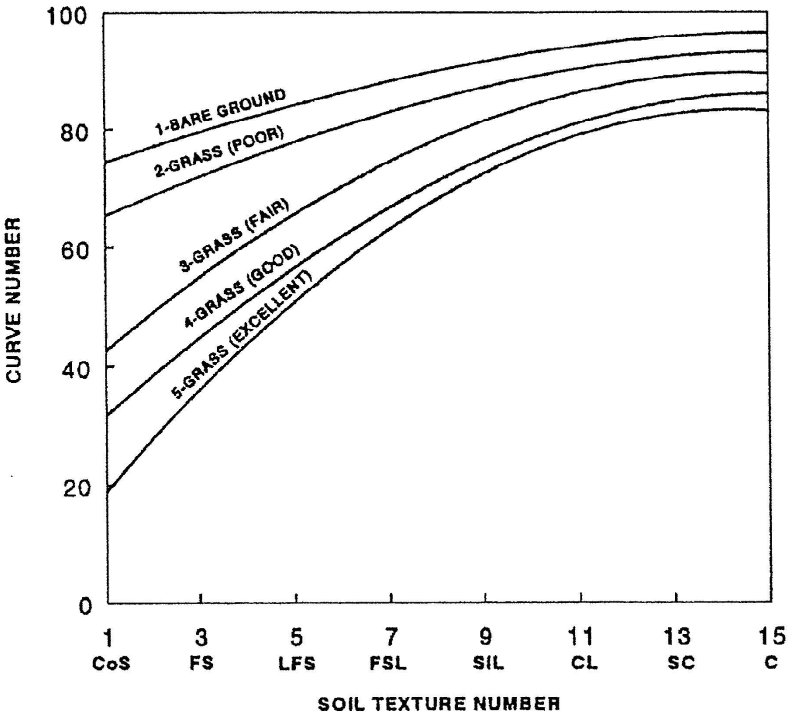


Figure 8. Relation between SCS Curve Number and Default Soil Texture Number for Various Levels of Vegetation

loam, and clayey loam as specified by saturated hydraulic conductivity, capillary drive, porosity, and maximum relative saturation, Two levels of vegetation were described--a good stand of grass (bluegrass sod) and a poor stand of grass (clipped range). Slopes of 0.04,0.10,0.20,0.35, and 0.50 ft/ft and slope lengths of 50, 100, 250, and 500 ft were used. Rainfalls of 1.1 inches, l-hour duration and 2nd quartile Huff distribution and of 3.8 inches, 6-hour duration and balanced distribution were modeled.

The resulting regression equation used for adjusting the AMC-II curve number computed for default soils and vegetation placed at mild slopes, CN_{II_o}, is:

$$CN_{II} = 100 - (100 - CN_{II_o}) \cdot \left(\frac{L^{*2}}{S^*} \right)^{CN_{II_o}^{-0.81}} \tag{34}$$

where

L^* = standardized dimensionless length, (L/500 ft)

S^* = standardized dimensionless slope, (S/0.04)

This same equation is used to adjust user-specified AMC-II curve numbers for surface slope conditions by substituting the user value for CN_{II_o} in Equation 34.

4.2.4 Adjustment of Curve Number for Frozen Soil

When the HELP program predicts frozen conditions to exist, the value of CN_{II} is increased, resulting in a higher calculated runoff. Knisel et al. (1985) found that this type of curve number adjustment in the CREAMS model resulted in improved predictions of annual runoff for several test watersheds. If the CN_{II} for unfrozen soil is less than or equal to 80, the CN_{II} for frozen soil conditions is set at 95. When the unfrozen soil CN_{II} is greater than 80, the CN_{II} is reset to be 98 on days when the program has determined the soil to be frozen. This adjustment results in an increase in CN_I and consequently a decrease in S_{mx} and S' (Equations 19, 26, and 30).

From Equations 19 and 21, it is apparent that as S' approaches zero, Q approaches P. In other words, as S' decreases, the calculated runoff becomes closer to being equal to the net rainfall which is most often, when frozen soil conditions exist, predominantly snowmelt. This will result in a decrease in infiltration under frozen soil conditions, which has been observed in numerous studies.

4.2.5 Summary of Daily Runoff Computation

The HELP model determines daily runoff by the following procedure:

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

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	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)		98	98	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).					

---

[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.

HYDROGRAPH DEVELOPMENT INFORMATION

HYDROGRAPH DEVELOPMENT INFORMATION

Landfill Areas

Direct runoff methods, (i.e., kinematic wave) have been used for the majority of the landfill final cover areas. The kinematic wave method has been used to model the 4 percent topslope areas and 25 percent side slope areas before the flow is intercepted by the drainage swales. The kinematic wave method is a physically based method using slope, surface roughness, catchment lengths and areas. This method does not consider attenuation for flood wave; as a consequence, this method provides for a conservative analysis. The following typical parameters for the kinematic wave method have been developed for landfill areas.

Kinematic wave parameters for overland flow:

Slope:	Varies from 0.04 to 0.25 ft/ft landfill slopes
N:	0.30 Manning's friction coefficient (based on using a value between dense grass (N = 0.24) and Bermuda grass (N = 0.41) listed in Soil Conservation Services TR-55)
L:	Represents a typical distance between swales for overland flow for each drainage area. For example, as shown on Sheet IIIF-A-23, the swale spacing on 4H:1V sideslopes is 120 feet.

Percentage of drainage area represented by this element is 100 percent.

Kinematic Wave routing for channels:

- Channel length (ft): The length of the channel section.
- Channel slope (ft/ft): Varies from 0.005 to 0.1283 (0.005 for swales).
- Channel roughness coefficient: 0.03 for grass lined channels and swales.
- Channel type: A trapezoidal channel was used with varying width and 2:1 side slopes ("V" ditch with varying side slopes for swales).

Non-Landfill Final Cover Areas

Hydrographs for the majority of non-landfill final cover areas within and near the permit boundary (e.g., pond areas) were developed using the Snyder unit hydrograph method. Espey “10-Minute” method has been used to estimate Snyder parameters. Snyder parameter estimations are provided on pages IIIF-A-20 through IIIF-A-24.

As discussed in Section 2 of Appendix IIIF, hydrographs for the areas outside of the permit boundary (O1 and O2) and larger areas inside the permit boundary (S1 through S10) were developed using the Snyder unit hydrograph method. The percent imperviousness ranges from 2 percent to 25 percent, for the majority of the non-landfill on-site and off-site areas, which represents the majority of the watershed as undeveloped. Pond areas are assumed to be 99 percent impervious, and areas with significant channel surface or paved surfaces were assigned higher percentages of impervious area, as shown on IIIF-A-20.

Drainage Areas

The drainage areas used for this analysis are shown on Sheets IIIF-A-28 and 29. The routing scheme for the post-development condition is shown in the HEC-HMS output file presented on pages IIIF-A-31 through IIIF-A-91.

DISTRIBUTED RUNOFF METHOD
KINEMATIC WAVE EXAMPLE

ROYAL OAKS LANDFILL
0120-076-11-106
KINEMATIC WAVE PARAMETERS

Drainage area "DA5" is used in this example (refer to Sheet IIIF-A-17 for location of drainage area).

Watershed Specific Parameters:

A =	20.16	acres	Watershed Area (acres)
A =	0.0315	sq-miles	Watershed Area (sq-miles)
CN=	84		SCS Curve Number (see sheet IIIF-A-4 for more information)

Kinematic Wave parameter for overland flow:

L=	120	ft	Typical overland flow (ft)
S=	0.25	ft/ft	Landfill slope (ft/ft)
N=	0.30		Manning's Coefficient

Percentage of the drainage area represented by this element is 100 percent

Kinematic Wave routing data for the swale:

L=	1077	ft	Typical swale length (ft)
S=	0.005	ft/ft	Swale bottom slope (ft/ft)
N=	0.03		Manning's Coefficient
Channel=	TRAP		Swale Type*

* A trapezoidal channel with no bottom width was used to simulate a triangular channel.

0 200 400
SCALE IN FEET

LEGEND

▬ · ▬	PERMIT BOUNDARY
▬ ▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
─‹─	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
─·─	CHANNEL CENTERLINE
▬ ▬	DRAINAGE AREA BOUNDARY
🟥	KINEMATIC WAVE SLOPE LENGTHS
DA5	DRAINAGE AREA DESIGNATION

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT–MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.0 FT–MSL.
3. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
4. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED PROFESSIONAL ENGINEER
05/20/2024

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DATE: 05/2024
FILE: 0120–76–11
CAD: IIIF–A–18 KINEMATIC WAVE.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT KINEMATIC WAVE PATTERNS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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DRAWING IIIF–A–18

O:\0120\76\EXPANSION 2023\PART III\IIIF-A\IIIF-A-18 KINEMATIC WAVE PATTERN.dwg, byoung, 1:2

ESPEY 10-MINUTE METHOD PARAMETERS

Prep By: VG
Date: 5/6/2024

Chkd By: BPY/CRM
Date: 5/6/2024

ROYAL OAKS LANDFILL
0120-076-11-06
ESPEY 10 MINUTE CALCULATION
POST-DEVELOPMENT CONDITION

Snyder's Hydrograph Coefficients (Espey's 10 Minute Method)

<u>Post-Development Expansion Conditions</u>

Area No.	Area (acres)	Max. Flow Length (L) (ft)	S (ft/ft)	I (%)	Manning "n"	Φ[1]	T_r[2] (min)	T_{lag}[3] (min)	T_{lag} (hr)	Area[4] (sq mi)	q_p[5] (cfs/sq mi)	C_p[6]
O1	166.84	4,242	0.0316	2	0.04	0.87	35.6	33.1	0.55	0.2607	729.1	0.63
O2	15.24	990	0.0444	10	0.04	0.84	16.6	14.1	0.23	0.0238	1818.1	0.67
O3	14.76	1,771	0.0802	10	0.04	0.84	16.4	13.9	0.23	0.0231	1848.0	0.67
O4	9.00	987	0.0871	2	0.04	0.87	19.8	17.3	0.29	0.0141	1538.7	0.69
O5	1.93	670	0.0970	2	0.04	0.87	17.6	15.1	0.25	0.0030	1852.7	0.73
O6	10.93	935	0.0684	2	0.04	0.87	20.7	18.2	0.30	0.0171	1450.4	0.69
S1	7.59	1,052	0.0570	10	0.04	0.84	15.8	13.3	0.22	0.0119	1969.3	0.68
S2	6.92	1,041	0.0768	10	0.04	0.84	14.6	12.1	0.20	0.0108	2146.3	0.68
S3	7.93	968	0.0558	5	0.04	0.86	18.3	15.8	0.26	0.0124	1677.9	0.69
S4	0.94	298	0.0940	5	0.04	0.86	12.3	9.8	0.16	0.0015	2807.2	0.71
S5	3.32	1,382	0.0687	5	0.04	0.86	18.9	16.4	0.27	0.0052	1682.9	0.72
S6	2.63	486	0.0494	5	0.04	0.86	16.1	13.6	0.23	0.0041	2010.8	0.71
S7	4.07	1,328	0.0956	10	0.04	0.84	14.6	12.1	0.20	0.0064	2189.2	0.69
S8	3.44	908	0.0463	25	0.04	0.75	11.4	8.9	0.15	0.0054	2876.0	0.67
S9	1.19	286	0.0035	25	0.03	0.75	16.7	14.2	0.24	0.0019	1996.9	0.74
S10	1.77	675	0.0711	2	0.04	0.87	19.1	16.6	0.28	0.0028	1707.7	0.74

[1] Conveyance efficiency coefficient from Dodson & Associates Inc., *ProHec-1 Program Documentation* , 1995, pages 6-19 and 6-20.

[2] $T_r = 3.1(L^{0.23})(S^{-0.25})(I^{-0.18})(\Phi^{1.57})$

[3] $T_{lag} = T_r - \Delta t/2$

[4] From area summary sheet

[5] $q_p = 31600(A^{-0.04})(T_r^{-1.07})$

[6] $C_p = 49.375(A^{-0.04})(T_r^{-1.07})(T_{lag})$

T_r = surface runoff to unit hydrograph peak (min)
L = distance along main channel from study point to watershed boundary (ft)
S = main channel slope (ft/ft)
I = impervious cover within the watershed (%)
T_{lag} = watershed lag time (min)
Δt= computation interval (minutes)
q_p = unit hydrograph peak discharge (cfs/sq mi)
C_p = Snyder's peaking coefficient

ESPEY 10 MINUTE SAMPLE CALCULATION

Snyder Unit Hydrograph uses lag time (T_{lag}) and peaking coefficient accounting for flood wave and watershed storage conditions.

Drainage area "S3" in the post-project condition is used in this example.

Estimated Watershed specific parameters

A =	7.93	acres	watershed area
L =	968	feet	maximun flow length with this watershed
S =	0.0558	feet/feet	watershed slope
I =	5	percent (%)	watershed imperviousness
n =	0.04		Manning's coefficient

Calculate Tr: time beginning of surface runoff to the unit hydrograph peak in minutes

$T_r = 3.1(L^{0.23})(S^{-0.25})(I^{-0.18})(\Phi^{1.57})$

Estimate : conveyance efficiency coefficient

Φ = for 2 percent impervious cover and n = 0.04

$\Phi = 0.86$

$T_r = 3.1(1382^{.23})(0.0687^{-0.25})(5^{-0.18})(0.86^{1.57})$

$T_r = 18.3$ min

Calculate T_{lag}: watershed lag time

$T_{lag} = Tr - (\Delta t/2)$ — Δt is calculation interval, and 5 minutes is used in the HEC - HMS modeling in this project

$T_{lag} = 15.8$ minutes

$T_{lag} = 0.26$ hours

$A = A/640$

$A = 0.0124$ square miles

Calculate q_p: peak discharge of unit hydrograph per unit area (cfs/sq. mi).

$q_p = 31600(A^{-0.04})(T_r^{-1.07})$

$q_p = 31600(0.0124^{-0.04})(18.3^{-1.07})$

$q_p = 1677.9$ cfs/sq. mi

Calculate Peaking coefficient C_p:

$C_p = 49.375(A^{-0.04})(T_r^{-1.07})(T_{lag})$

$C_p = 49.375(0.0124^{-0.04})(18.3^{-1.07})(0.26)$

$C_p = 0.69$

compute the value of Snyder's peaking coefficient C_p for use in HEC-1 analyses. First, the watershed lag time T_L is determined by subtracting one-half of the computation interval from the time to rise ($T_L = T_r - \Delta t/2$). Then, C_p may be computed by substituting the known values of T_L and q_p into Snyder's equation for peak unit hydrograph flow rate and solving for C_p.

$$C_p = \frac{q_p \times T_L}{640} \qquad 6.30$$

Espey "10-Minute" Method for Estimating Snyder Parameters

In another study, Espey [1977] derived the following equation for computing the time from the beginning of surface runoff to the unit hydrograph peak:

$$T_r = 3.10\, L^{0.23} S^{-0.25} I^{-0.18}\, \Phi^{1.57} \qquad 6.31$$

in which:

T_r = time from beginning of surface runoff to unit hydrograph peak (minutes)

L = total distance along main channel from study point to watershed boundary (feet)

S = main channel slope between the reference point and a point 0.2L downstream from the upstream watershed boundary (feet per foot)

I = impervious cover within the watershed (percent)

Φ = description of conveyance efficiency of the watershed drainage system.

The conveyance efficiency coefficient Φ is determined using the relationships illustrated on Figure 6.12.

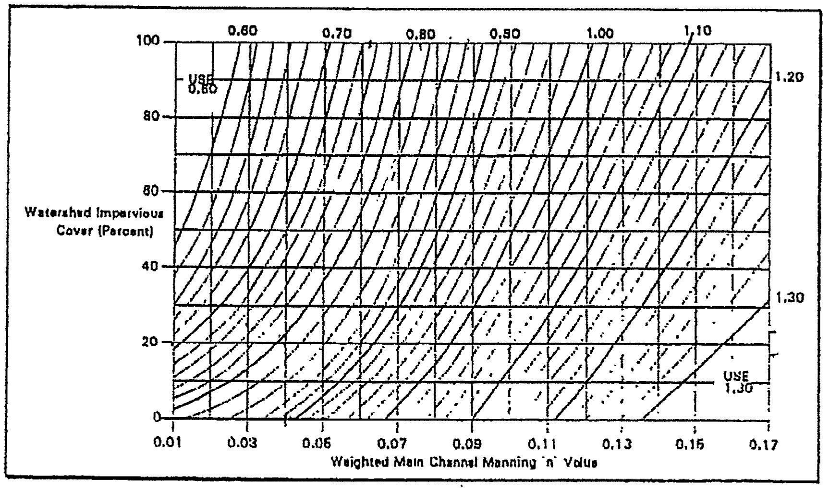


FIGURE 6.12 Determination of Conveyance Efficiency Coefficient Φ

This equation was derived from records for 41 watersheds in Texas, Tennessee, Mississippi, Pennsylvania, North Carolina, Colorado, Kentucky, and Indiana. The range in the watershed characteristics used to develop the equations for urban areas were:

Area : From 0.0128 square miles to 15.00 square miles

L : From 555 feet to 35,600 feet

S : From 0.0005 ft. per ft. to 0.0295 ft. per ft.

I: From 2% to 100%

Φ : From 0.60 to 1.30

Again, note that the time to rise T_r is not the same as the watershed lag time T_p. The difference between the two is that T_r is defined as the time from the beginning of effective rainfall to the peak of the unit hydrograph, while T_L is the time from the centroid of the effective rainfall to the peak of the unit hydrograph. For the purposes of HEC-1 analyses, however, T_L may be determined simply by subtracting one-half the computation time interval from the computed value of T_r ($T_R - \Delta t/2$).

The relationship developed by Espey to compute the peak flow rate of the unit hydrograph is as follows:

$$Q_u = 31600 \quad A^{0.96} T_r^{-1.07} \tag{6.32}$$

in which:

Q_u = unit hydrograph peak discharge (cfs)

A = drainage area (square miles)

T_r = time of rise from beginning of surface runoff to unit hydrograph peak (minutes)

Riverside County Method for Estimating Snyder Parameters

Three watershed lag equations have been derived for use in rural areas of Riverside County, California by the Riverside County Flood Control and Water Conservation District [Anonymous, 1963]. These equations differ slightly from those developed at the Tulsa District of the U.S. Army Corps of Engineers in that lag is defined as the time from the beginning of rainfall to the point on the unit hydrograph corresponding to one-half of the total runoff volume.

Each equation is applicable to a different topographic region:

$$T_L = 1.20\left(\frac{L \times L_{ca}}{\sqrt{S}}\right)^{0.38} \quad \text{(Mountain Areas)} \tag{6.33}$$

$$T_L = 0.72\left(\frac{L \times L_{ca}}{\sqrt{S}}\right)^{0.38} \quad \text{(Foothill Areas)} \tag{6.34}$$

$$T_L = 0.38\left(\frac{L \times L_{ca}}{\sqrt{S}}\right)^{0.38} \quad \text{(Valley Areas)} \tag{6.35}$$

in which:

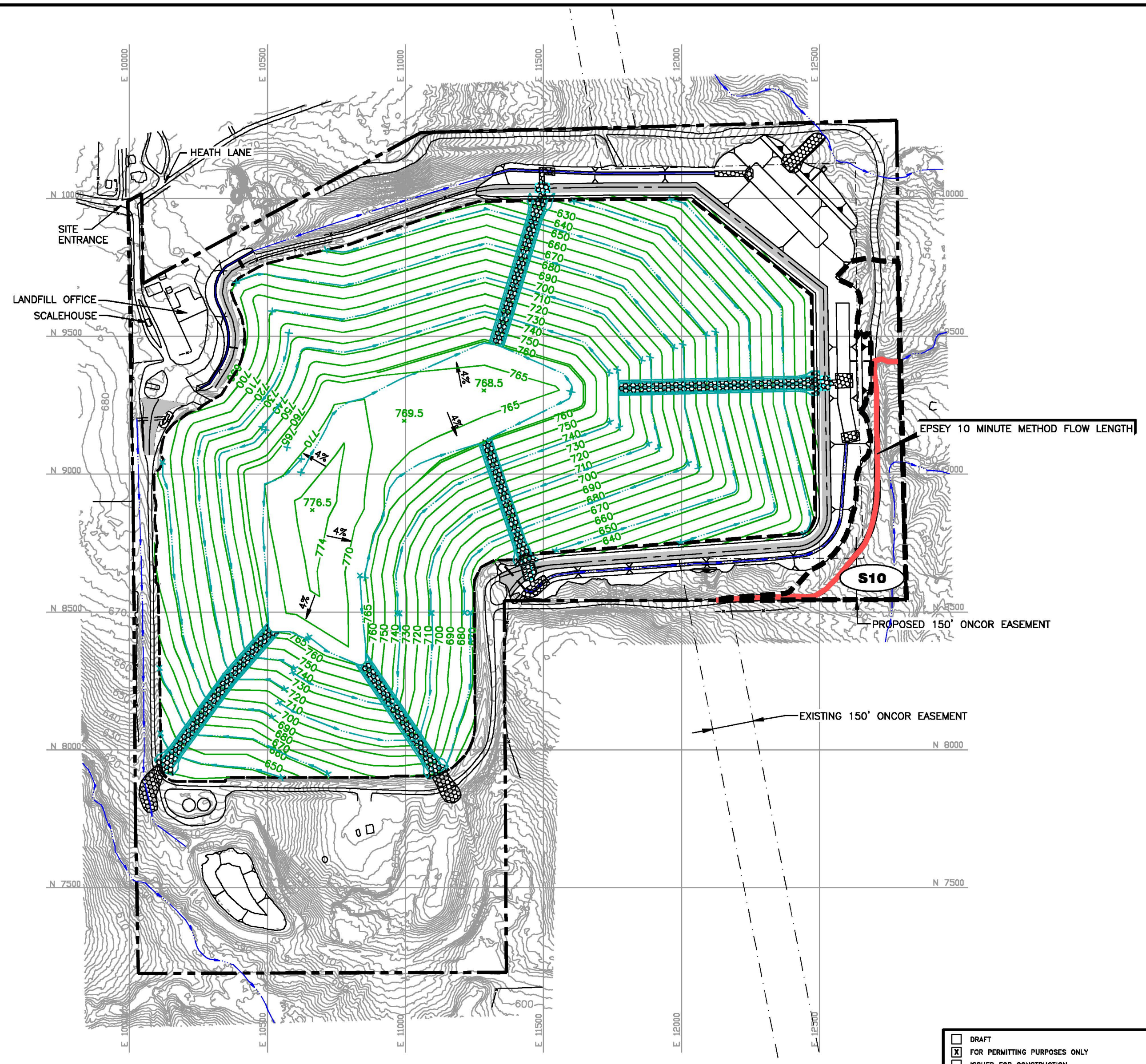
T_L = watershed lag in hours

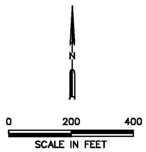
L = watershed length in miles

L_{ca} = length to centroid in miles

S = watershed slope in feet per mile.

The sizes of the watersheds studied in developing these equations ranged from 2.3 square miles to 645 square miles.





LEGEND

— · — · —	PERMIT BOUNDARY
— — —	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
←·	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
→·	CHANNEL CENTERLINE
■ ■ ■	DRAINAGE AREA BOUNDARY
🟥	EPSEY 10 MINUTE METHOD FLOW LENGTH
S10	DRAINAGE AREA DESIGNATION

NOTES:

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4. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

CHARLES R. MARSH
105073

05/20/2024

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DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT EPSEY"10-MINUTE" METHOD PARAMETERS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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DRAWING IIIF-A-24

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POND ROUTING INFORMATION

Pond Routing Information

The detention ponds and outlet structures will be designed to detain the 25-year storm and provide flood attenuation for the site. The following information was used to develop the existing condition.

Design information for the detention ponds low water outlet is summarized below:

	Initial Elevation (ft-msl)	Shape	Chart	Scale (ft)	Length (ft)	Diameter (ft)	Inlet Elevation (ft-msl)	Entrance Coefficient	Outlet Elevation (ft-msl)	Exit Coefficient	Manning's n
P1[1]	--	--	--	--	--	--	--	--	--	--	--
P2	540	Circular	1	1	77.0	3.50	540.00	0.5	539.71	0.8	0.015
P3	534	Circular	1	1	122.0	0.83	534.00	0.5	531.97	0.8	0.015

[1] See Appendix IIIF-B for the Pond P1 outlet structure information. See the elevation/storage/discharge function below for routing infromation.

Design information for the detention ponds spillway is summarized below:

	Spillway Elevation (ft-msl)	Length (ft)	Coefficient
P1	--	--	--
P2	548	262.00	2.6
P3	544	40.00	2.6

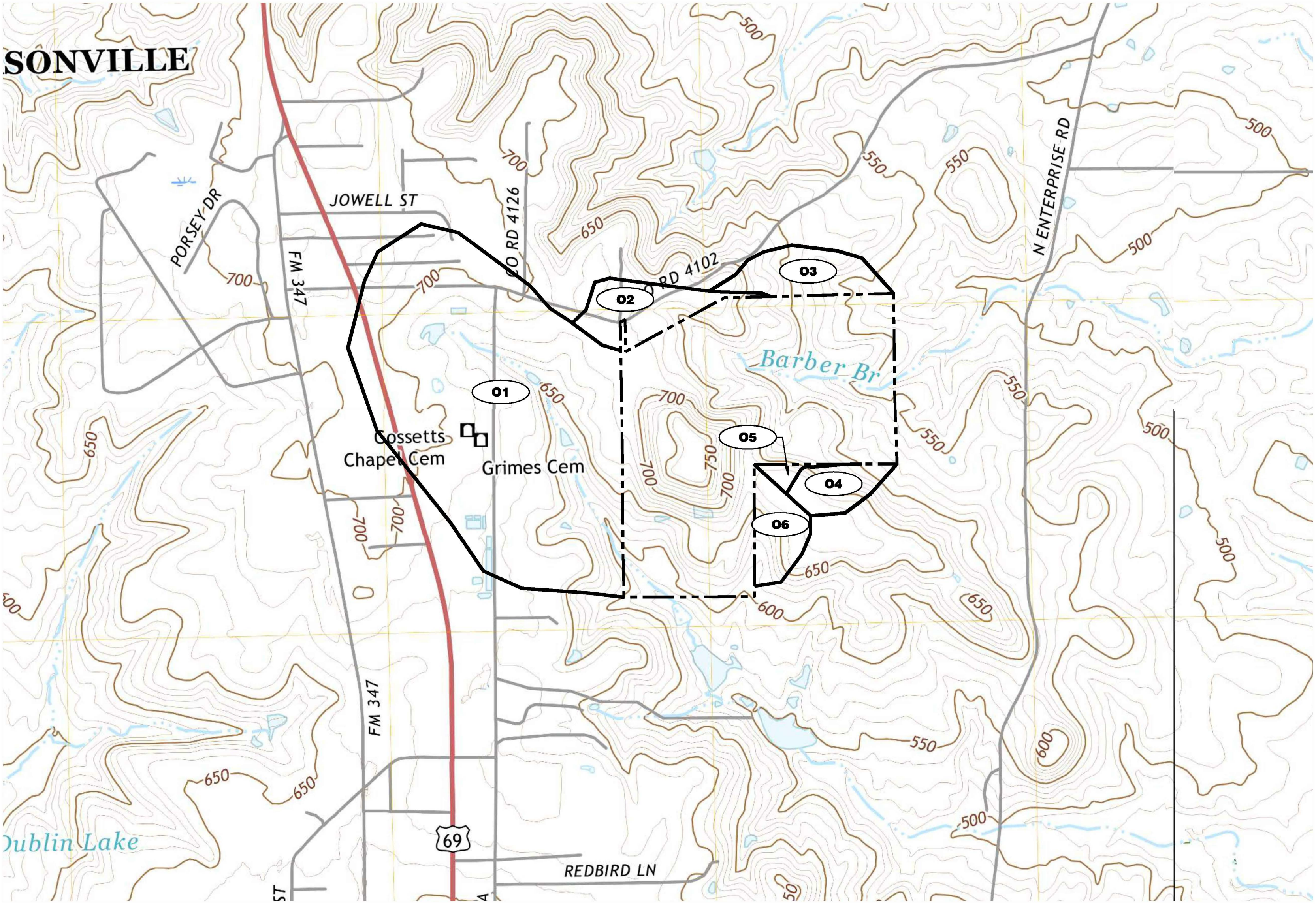
The elevation/area functions which are used to determine the volume of the detention ponds is summarized below.

Pond P2		Pond P3	
Elevation (ft-msl)	Area (ac)	Elevation (ft-msl)	Area (ac)
540.00	0.0000	526.00	0.0000
542.00	0.6870	534.00	0.0000
544.00	0.8540	535.00	1.1470
546.00	1.0297	540.00	1.5260
548.00	1.2160	545.00	1.9410
550.00	1.4310	550.00	2.3900
552.00	1.9680	--	--

The elevation/storage/discharge functions which are used to determine the volume of the detention ponds is summarized below.

Pond P1[1]		
Elevation (ft-msl)	Storage (ac-ft)	Discharge (ac)
580.00	0.00	0.0
582.00	1.16	1.8
584.00	2.54	2.7
586.00	4.14	3.4
588.00	5.96	3.9
590.00	8.03	4.4
592.00	10.36	4.9
594.00	12.95	5.3
595.00	14.37	41.4
596.00	15.88	107.4

POST-DEVELOPMENT HEC-HMS ANALYSIS
DRAINAGE AREAS



LEGEND

- LANDFILL PROPERTY
- DRAINAGE AREA BOUNDARY
- O1 DRAINAGE AREA DESIGNATION

DRAINAGE AREA NO.	AREA (ACRES)
O1	166.84
O2	15.24
O3	14.76
O4	9.00
O5	1.93
O6	10.93

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05/20/2024

JACKSONVILLE WEST, TX
2022

JACKSONVILLE EAST, TX
2022

MOUNT SELMAN, TX
2022

TECULA, TX
2022

NOTES:

1. REPRODUCED FROM 7.5 MINUTE, JACKSONVILLE WEST, JACKSONVILLE EAST, MOUNT SELMAN, AND TECULA TEXAS QUADRANGLE USGS MAP DATED 2022.

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DESIGN BY: VG
REVIEWED BY: JAE

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PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

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MAJOR PERMIT AMENDMENT
OFFSITE DRAINAGE AREA MAP

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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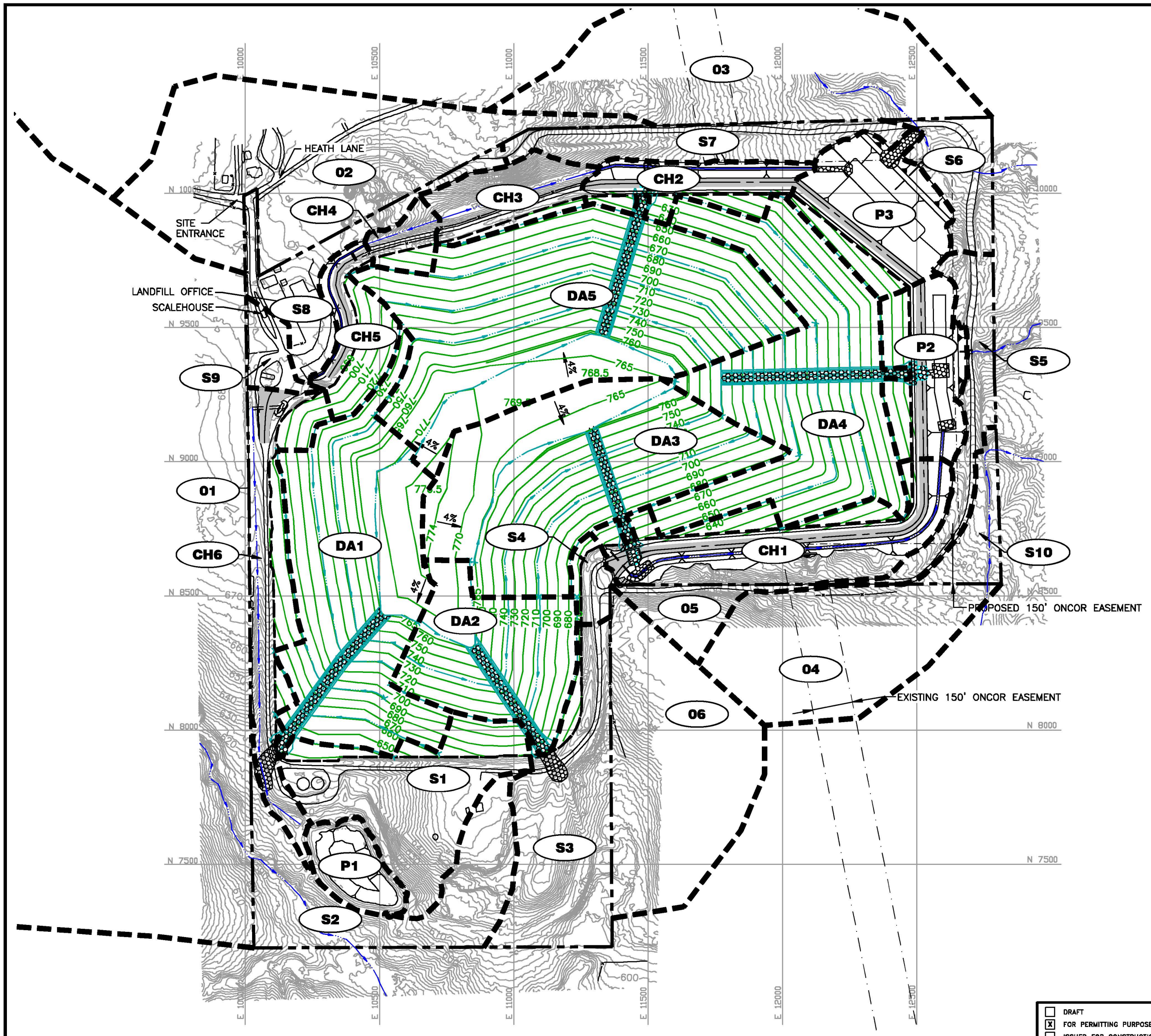

0 200 400
SCALE IN FEET

CHARLES R. MARSH
105073
05/20/2024

LEGEND

▬ · ▬	PERMIT BOUNDARY
▬ ▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
◄	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
— · —	CHANNEL CENTERLINE
■ ■ ■	DRAINAGE AREA BOUNDARY
DA4	DRAINAGE AREA DESIGNATION

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT-MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.0 FT-MSL.
3. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
4. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

DRAINAGE AREA NO.	AREA (ACRES)	DRAINAGE AREA NO.	AREA (ACRES)
DA1	14.07	CH1	7.55
DA2	6.99	CH2	3.09
DA3	14.33	CH3	2.98
DA4	13.99	CH4	1.14
DA5	20.05	CH5	2.79
S1	7.59	CH6	5.77
S2	6.92	P1	2.01
S3	7.93	P2	4.23
S4	0.94	P3	5.52
S5	3.32	01	166.84
S6	2.63	02	15.24
S7	4.07	03	14.76
S8	3.44	04	9.00
S9	1.19	05	1.93
S10	1.77	06	10.93

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DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
POST PROJECT DRAINAGE AREAS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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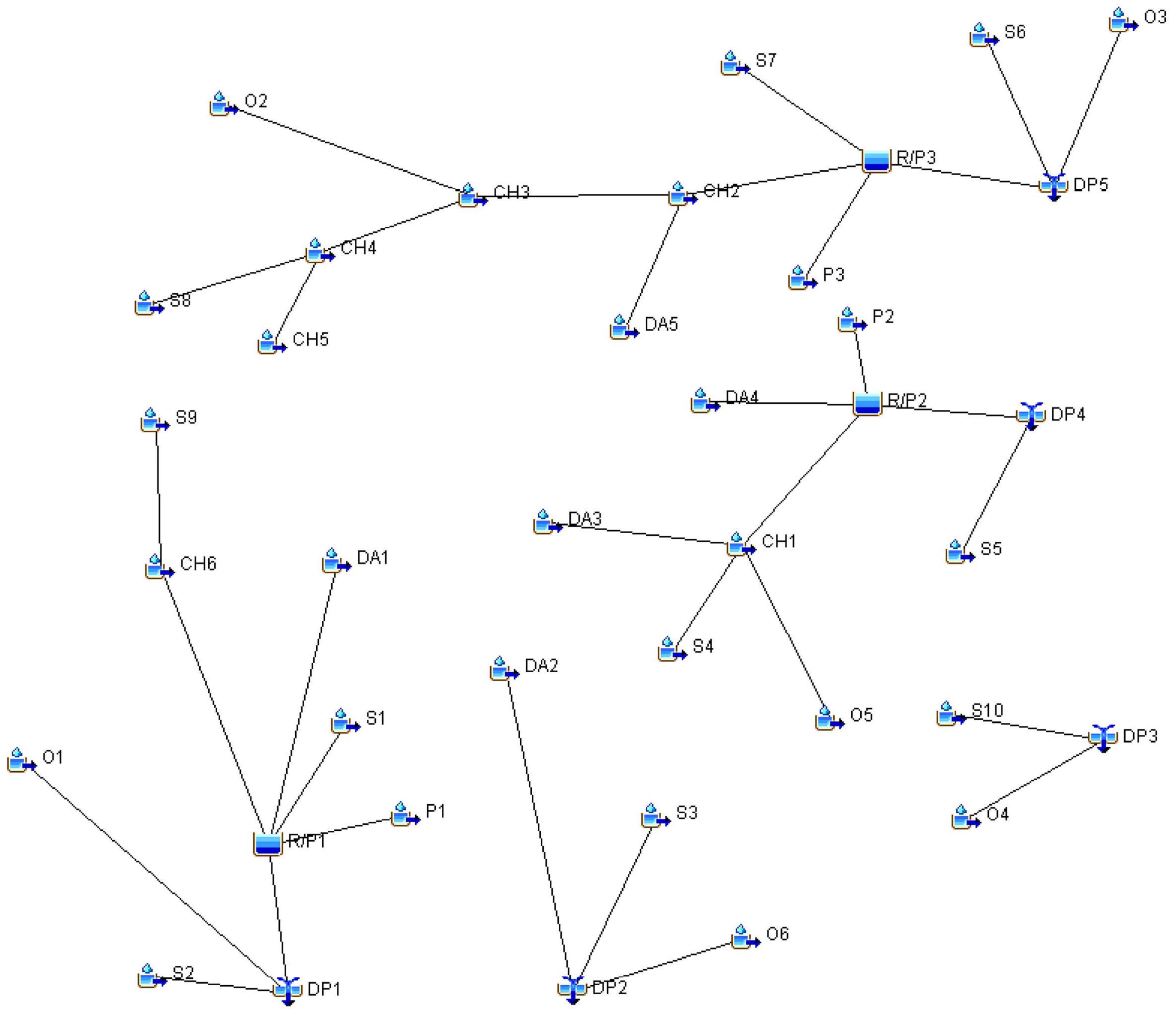
DRAWING IIIF-A-30

HEC-HMS OUTPUT – POST-DEVELOPMENT
25-YEAR, 24-HOUR STORM EVENT


S6
O3
S7
O2
R/P3
CH3
CH2
DP5
CH4
S8
P3
DA5
CH5
P2
DA4
R/P2
DP4
S9
DA3
CH1
S5
CH6
DA1
S4
DA2
S10
O5
DP3
S1
O1
P1
S3
O4
R/P1
O6
S2
DP1
DP2

Project: Royal_Oaks_Proposed
Simulation Run: 25-Year Run
Simulation Start: 28 December 2020, 24:00
Simulation End: 31 December 2020, 13:00

HMS Version: 4.10
Executed: 28 March 2024, 13:17

Global Parameter Summary - Subbasin

Area (MI2)

Element Name	Area (MI2)
O1	0.26
S9	0
Da1	0.02
Ch6	0.01
S1	0.01
P1	0
S2	0.01
O6	0.02
S3	0.01
Da2	0.01
Da3	0.02
O5	0
S4	0
Ch1	0.01
Da4	0.02
P2	0.01
S5	0.01
S8	0.01
Ch5	0
O2	0.02
Ch4	0
Ch3	0
Da5	0.03
Ch2	0
P3	0.01
S7	0.01
O3	0.02

S6	0
O4	0.01
S10	0

Downstream

Element Name	Downstream
O1	Dp1
S9	Ch6
Da1	R/p1
Ch6	R/p1
S1	R/p1
P1	R/p1
S2	Dp1
O6	Dp2
S3	Dp2
Da2	Dp2
Da3	Ch1
O5	Ch1
S4	Ch1
Ch1	R/p2
Da4	R/p2
P2	R/p2
S5	Dp4
S8	Ch4
Ch5	Ch4
O2	Ch3
Ch4	Ch3
Ch3	Ch2
Da5	Ch2
Ch2	R/p3
P3	R/p3
S7	R/p3
O3	Dp5
S6	Dp5
O4	Dp3
S10	Dp3

Loss Rate: Scs

Element Name	Percent Impervious Area	Curve Number
O1	0	67
S9	0	84
S1	0	83
P1	0	99
S2	0	82
O6	0	76
S3	0	81
O5	0	76
S4	0	83
P2	0	99
S5	0	79
S8	0	80
O2	0	61
P3	0	99
S7	0	80
O3	0	79
S6	0	82
O4	0	77
S10	0	79

Transform: Snyder

Element Name	Snyder Method	Snyder Tp	Snyder Cp
O1	Standard	0.55	0.63
S9	Standard	0.24	0.74
S1	Standard	0.22	0.68
S2	Standard	0.2	0.68
O6	Standard	0.3	0.69
S3	Standard	0.26	0.69
O5	Standard	0.25	0.73
S4	Standard	0.16	0.71
S5	Standard	0.27	0.72
S8	Standard	0.15	0.67
O2	Standard	0.23	0.67
S7	Standard	0.2	0.69
O3	Standard	0.23	0.67
S6	Standard	0.23	0.71
O4	Standard	0.29	0.69
S10	Standard	0.28	0.74

Transform: Kinematic Wave

Element Name	Transform
Da1	Kinematic Wave
Ch6	Kinematic Wave
Da2	Kinematic Wave
Da3	Kinematic Wave
Ch1	Kinematic Wave
Da4	Kinematic Wave
Ch5	Kinematic Wave
Ch4	Kinematic Wave
Ch3	Kinematic Wave
Da5	Kinematic Wave
Ch2	Kinematic Wave

Transform: Scs

Element Name	Lag	Unitgraph Type
P1	0.1	Standard
P2	0.1	Standard
P3	0.1	Standard

Global Results Summary

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
O1	0.26	318.89	29Dec2020, 12:35	4.02
S9	0	6.23	29Dec2020, 12:15	5.98
Da1	0.02	135.68	29Dec2020, 12:05	5.53
Ch6	0.01	33.47	29Dec2020, 12:10	5.04
S1	0.01	37.04	29Dec2020, 12:15	5.86
P1	0	18.87	29Dec2020, 12:05	7.76
R/p1	0.05	7.49	29Dec2020, 14:55	5.62
S2	0.01	34.66	29Dec2020, 12:15	5.75
Dp1	0.32	338.55	29Dec2020, 12:35	4.32
O6	0.02	40.14	29Dec2020, 12:20	5.05
S3	0.01	35.02	29Dec2020, 12:20	5.63
Da2	0.01	66.96	29Dec2020, 12:05	5.78
Da3	0.02	104.63	29Dec2020, 12:05	5.59
O5	0	8.18	29Dec2020, 12:20	5.05
S4	0	5.6	29Dec2020, 12:15	5.86
Ch1	0.04	163.16	29Dec2020, 12:05	5.54
Da4	0.02	123.17	29Dec2020, 12:05	4.88
P2	0.01	40.18	29Dec2020, 12:05	7.76
R/p2	0.07	106.86	29Dec2020, 12:20	5.54

S5	0.01	14.25	29Dec2020, 12:20	5.4
S8	0.01	19.41	29Dec2020, 12:10	5.51
Ch5	0	25.7	29Dec2020, 12:05	5.36
O2	0.02	40.73	29Dec2020, 12:20	3.35
Ch4	0.01	49.32	29Dec2020, 12:05	5.48
Ch3	0.04	90.95	29Dec2020, 12:05	4.26
Da5	0.03	182.49	29Dec2020, 12:05	4.98
Ch2	0.08	285.09	29Dec2020, 12:05	4.66
P3	0.01	52.36	29Dec2020, 12:05	7.76
S7	0.01	20.06	29Dec2020, 12:15	5.51
R/p3	0.09	42.27	29Dec2020, 13:05	4.74
O3	0.02	64.93	29Dec2020, 12:15	5.4
S6	0	12.72	29Dec2020, 12:15	5.75
Dp5	0.12	82.32	29Dec2020, 12:15	4.9
Dp4	0.07	121.11	29Dec2020, 12:20	5.53
Dp2	0.04	103.39	29Dec2020, 12:05	5.42
O4	0.01	34.48	29Dec2020, 12:20	5.16
S10	0	7.65	29Dec2020, 12:20	5.4
Dp3	0.02	42.13	29Dec2020, 12:20	5.2

Subbasin: O1

Area (MI2) : 0.26
Downstream : Dp1

Loss Rate: Scs

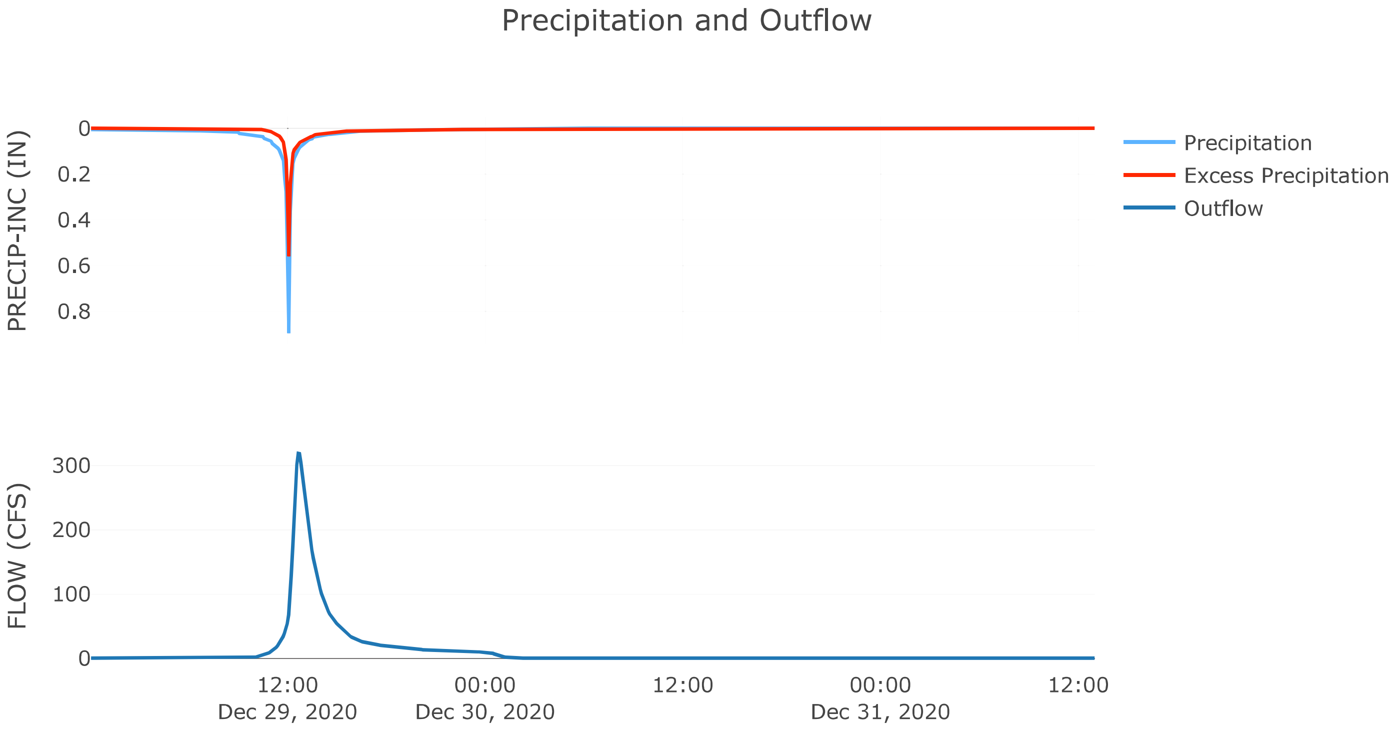
Percent Impervious Area	0
Curve Number	67

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.55
Snyder Cp	0.63

Results: O1

Peak Discharge (CFS)	318.89
Time of Peak Discharge	29Dec2020, 12:35
Volume (IN)	4.02
Precipitation Volume (AC - FT)	109.56
Loss Volume (AC - FT)	53.64
Excess Volume (AC - FT)	55.92
Direct Runoff Volume (AC - FT)	55.92
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
300
200
100
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: S9

Area (MI2) : 0
Downstream : Ch6

Loss Rate: Scs

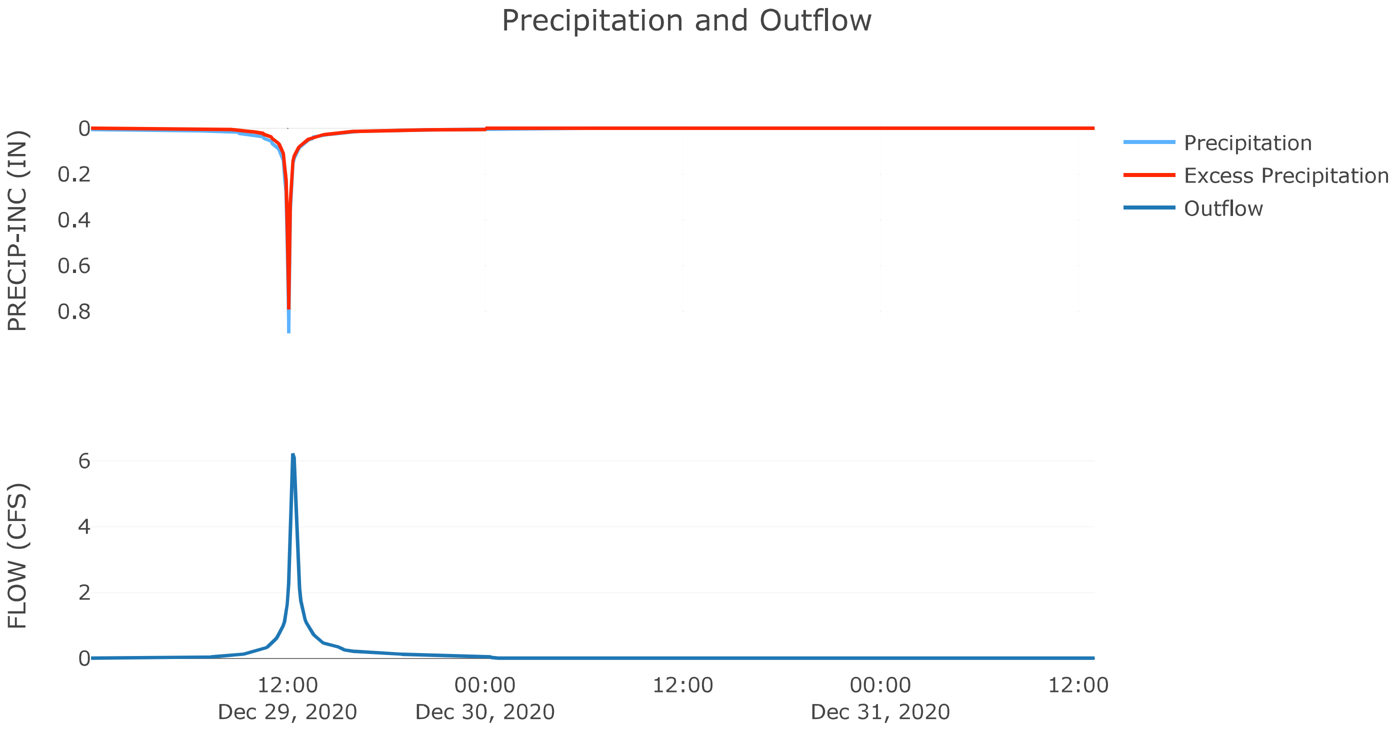
Percent Impervious Area	0
Curve Number	84

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.24
Snyder Cp	0.74

Results: S9

Peak Discharge (CFS)	6.23
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.98
Precipitation Volume (AC - FT)	0.8
Loss Volume (AC - FT)	0.19
Excess Volume (AC - FT)	0.61
Direct Runoff Volume (AC - FT)	0.61
Baseflow Volume (AC - FT)	0

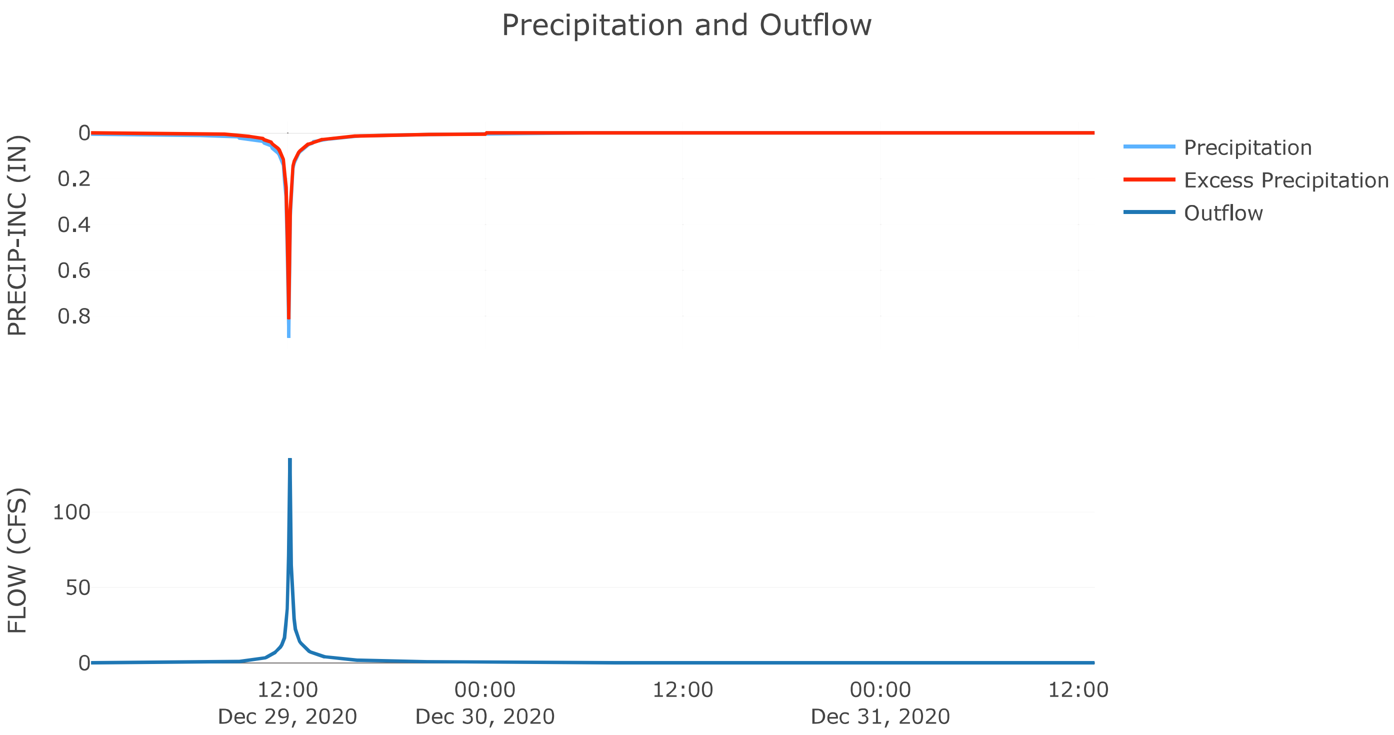

Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
6
4
2
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: DA1

Area (MI2) : 0.02
Downstream : R/p1
Transform : Kinematic Wave

Results: DA1

Peak Discharge (CFS)	135.68
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.53
Precipitation Volume (AC - FT)	9.25
Loss Volume (AC - FT)	1.95
Excess Volume (AC - FT)	7.29
Direct Runoff Volume (AC - FT)	6.48
Baseflow Volume (AC - FT)	0

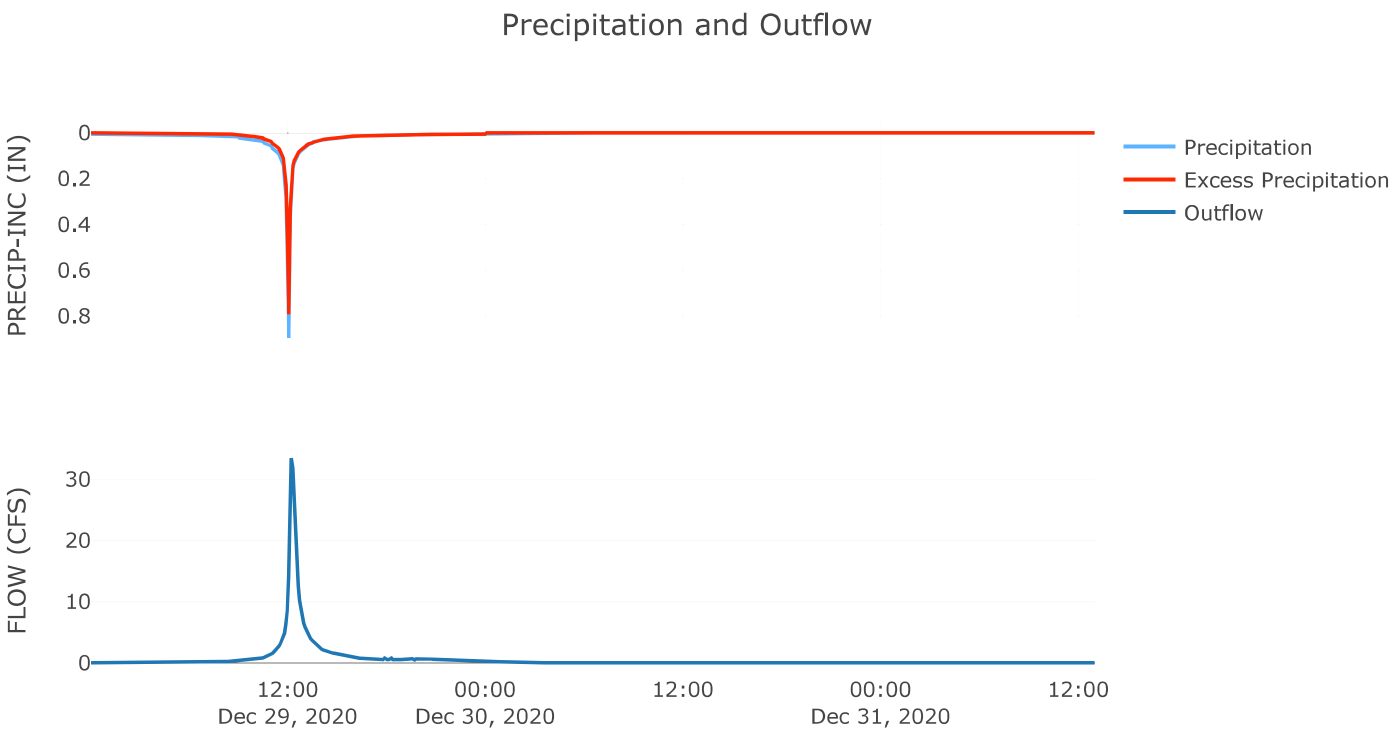


Subbasin: CH6

Area (MI2) : 0.01
Downstream : R/p1
Transform : Kinematic Wave

Results: CH6

Peak Discharge (CFS)	33.47
Time of Peak Discharge	29Dec2020, 12:10
Volume (IN)	5.04
Precipitation Volume (AC - FT)	4.58
Loss Volume (AC - FT)	1.1
Excess Volume (AC - FT)	3.48
Direct Runoff Volume (AC - FT)	2.93
Baseflow Volume (AC - FT)	0



Subbasin: S1

Area (MI2) : 0.01
Downstream : R/p1

Loss Rate: Scs

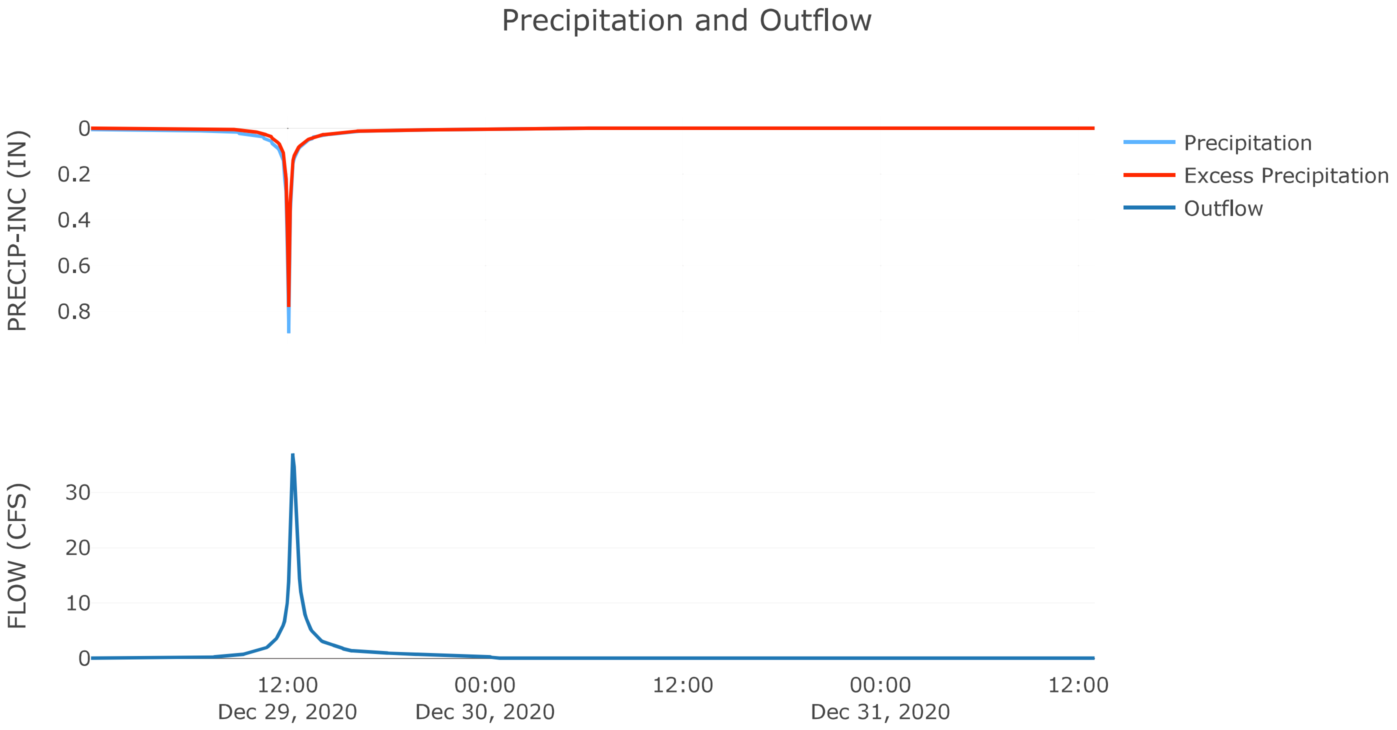
Percent Impervious Area	0
Curve Number	83

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.22
Snyder Cp	0.68

Results: S1

Peak Discharge (CFS)	37.04
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.86
Precipitation Volume (AC - FT)	5
Loss Volume (AC - FT)	1.28
Excess Volume (AC - FT)	3.72
Direct Runoff Volume (AC - FT)	3.72
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
30
20
10
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: P1

Area (MI2) : 0
Downstream : R/p1

Loss Rate: Scs

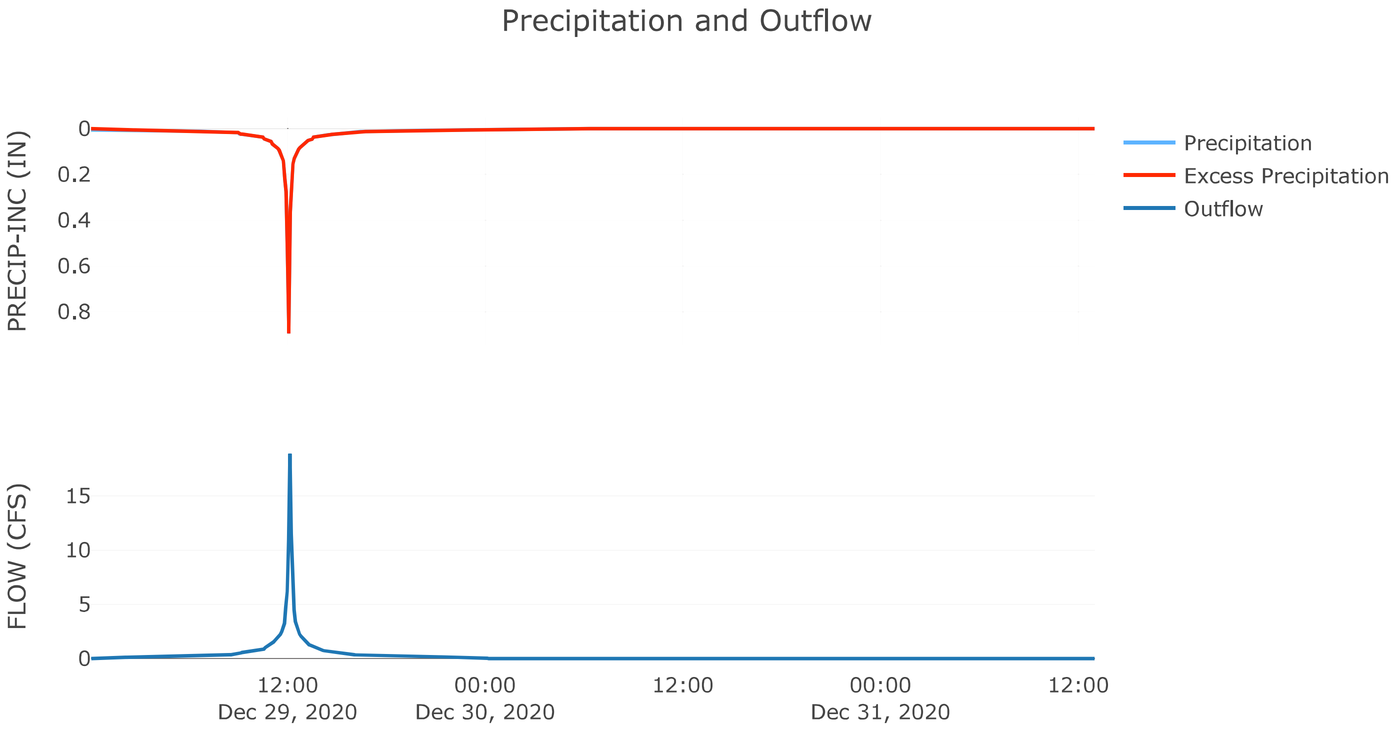
Percent Impervious Area	0
Curve Number	99

Transform: Scs

Lag	0.1
Unitgraph Type	Standard

Results: P1

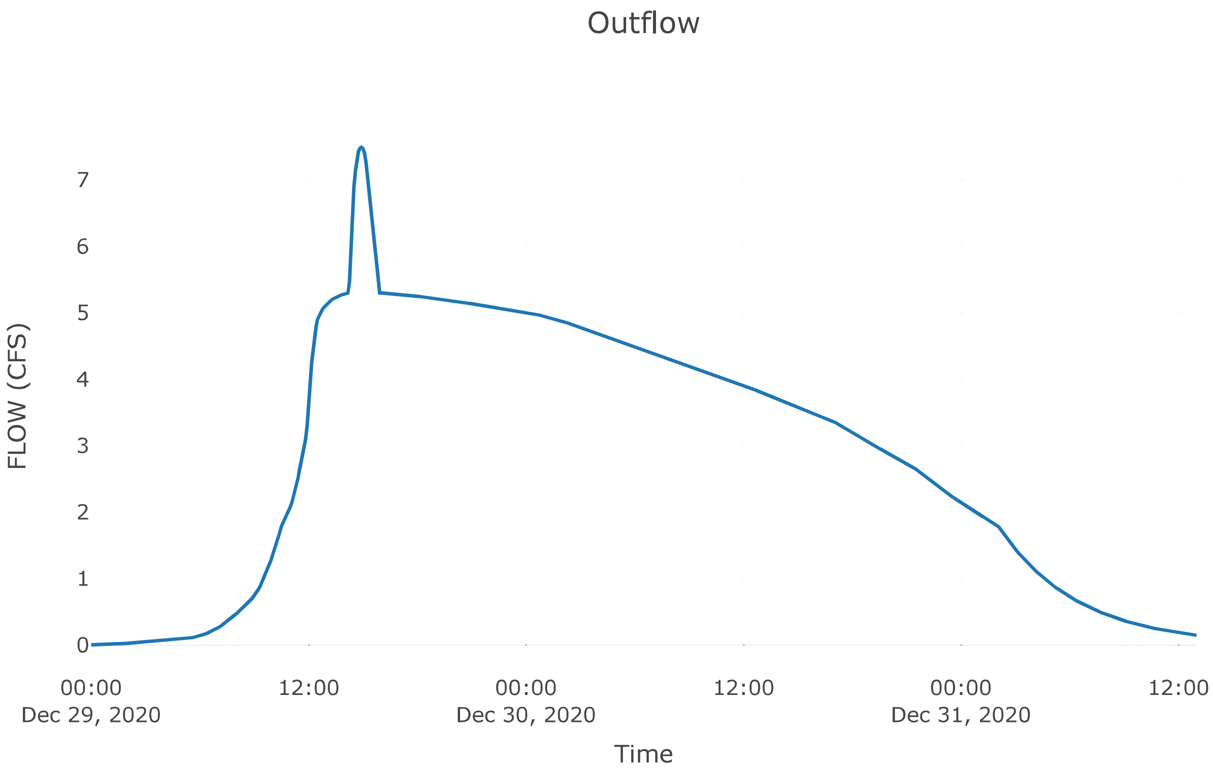
Peak Discharge (CFS)	18.87
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	7.76
Precipitation Volume (AC - FT)	1.3
Loss Volume (AC - FT)	0.02
Excess Volume (AC - FT)	1.28
Direct Runoff Volume (AC - FT)	1.28
Baseflow Volume (AC - FT)	0



Reservoir: R/P1

Downstream : Dp1

Results: R/P1	
Peak Discharge (CFS)	7.49
Time of Peak Discharge	29Dec2020, 14:55
Volume (IN)	5.62
Peak Inflow (CFS)	204.65
Time of Peak Inflow	29Dec2020, 12:05
Inflow Volume (AC - FT)	14.42
Maximum Storage (AC - FT)	10.28
Peak Elevation (FT)	591.93
Discharge Volume (AC - FT)	14.36



Subbasin: S2

Area (MI2) : 0.01
Downstream : Dp1

Loss Rate: Scs

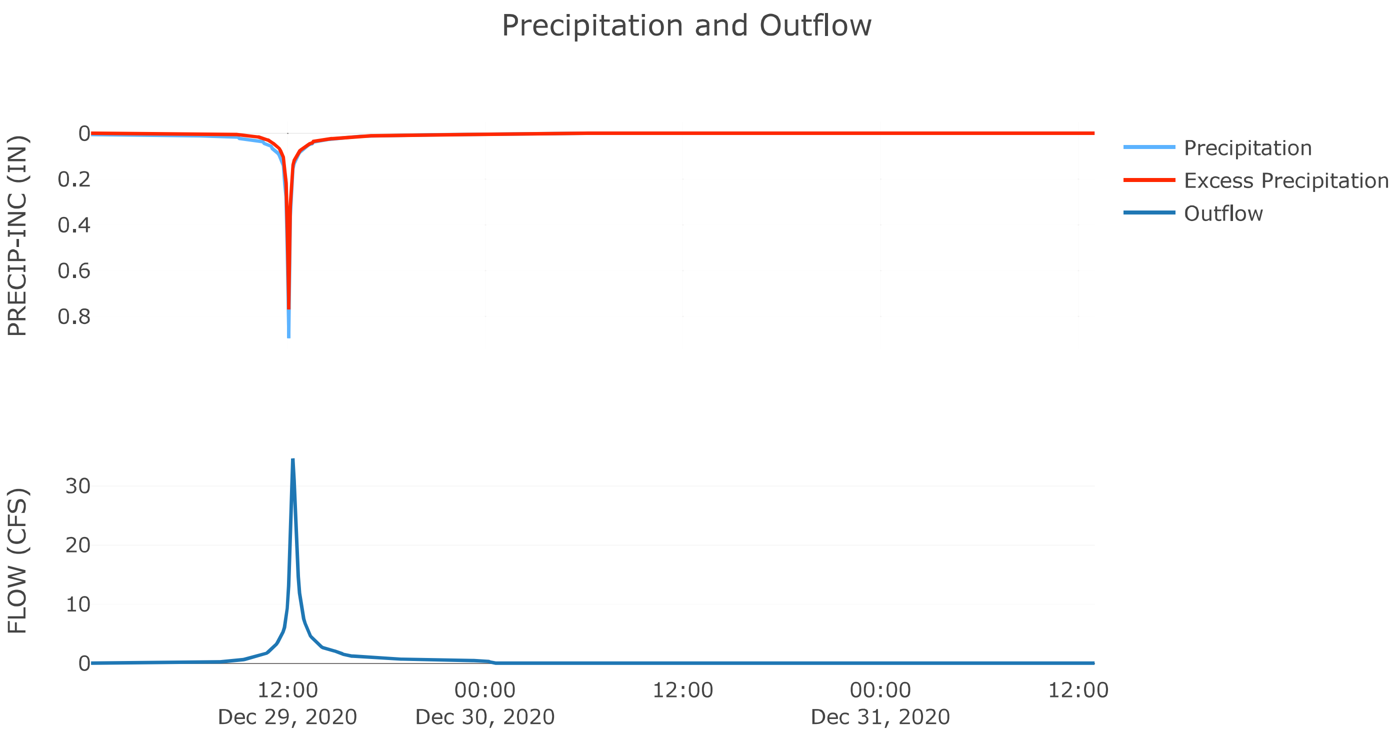
Percent Impervious Area	0
Curve Number	82

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.2
Snyder Cp	0.68

Results: S2

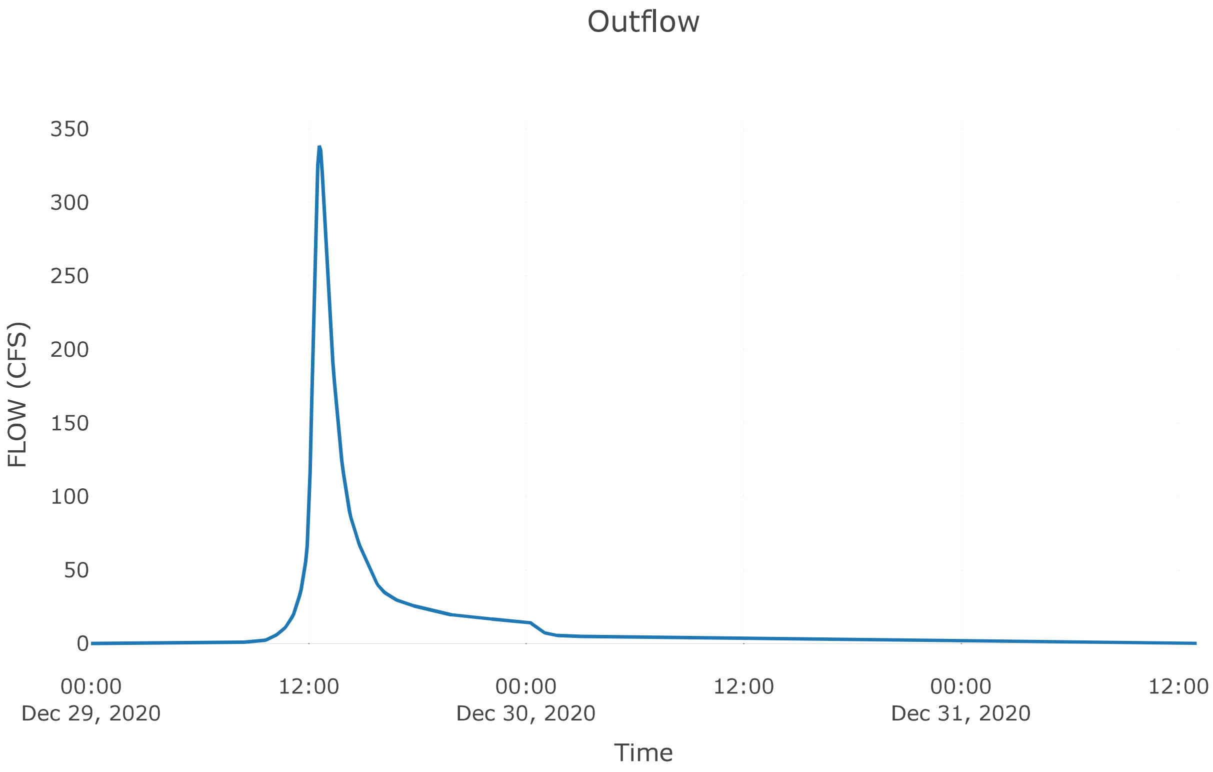
Peak Discharge (CFS)	34.66
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.75
Precipitation Volume (AC - FT)	4.54
Loss Volume (AC - FT)	1.23
Excess Volume (AC - FT)	3.31
Direct Runoff Volume (AC - FT)	3.31
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
30
20
10
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Junction: DP1

Results: DP1

Peak Discharge (CFS)	338.55
Time of Peak Discharge	29Dec2020, 12:35
Volume (IN)	4.32



Subbasin: O6

Area (MI2) : 0.02
Downstream : Dp2

Loss Rate: Scs

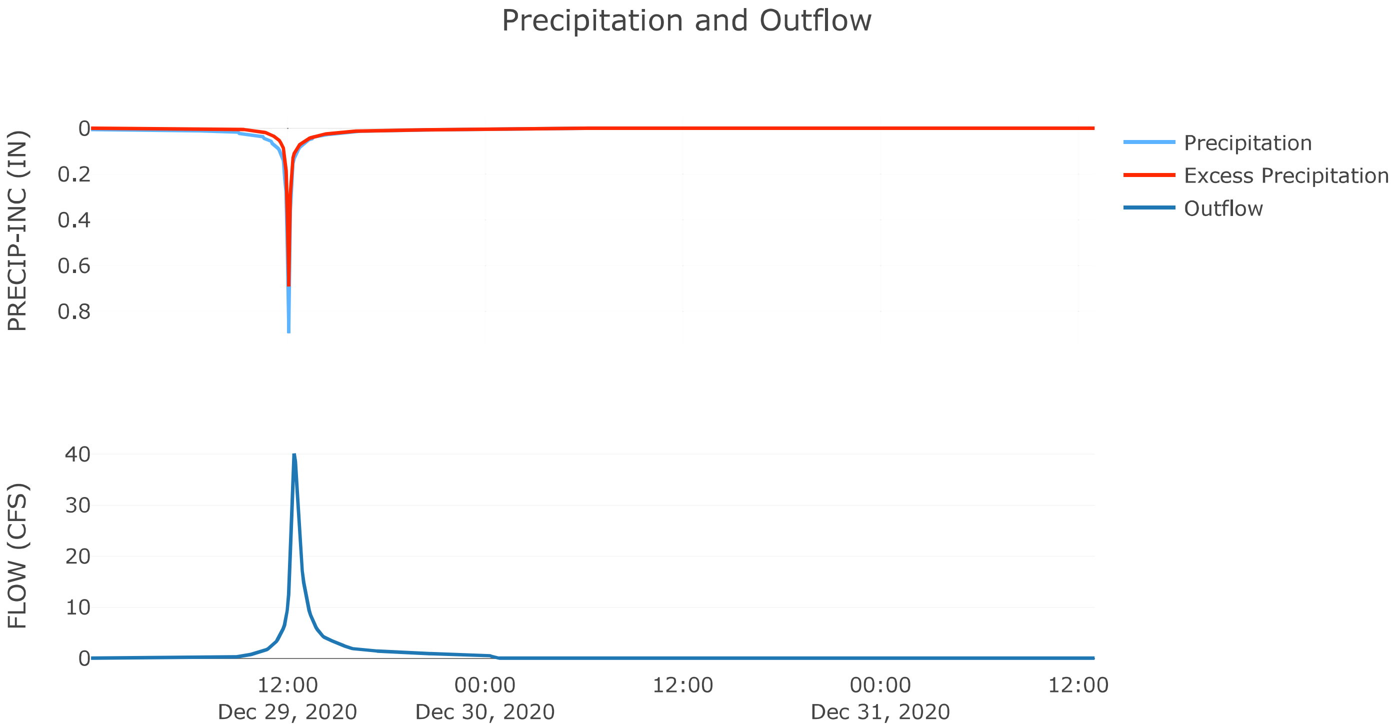
Percent Impervious Area	0
Curve Number	76

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.3
Snyder Cp	0.69

Results: O6

Peak Discharge (CFS)	40.14
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.05
Precipitation Volume (AC - FT)	7.19
Loss Volume (AC - FT)	2.58
Excess Volume (AC - FT)	4.6
Direct Runoff Volume (AC - FT)	4.6
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
40
30
20
10
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: S3

Area (MI2) : 0.01
Downstream : Dp2

Loss Rate: Scs

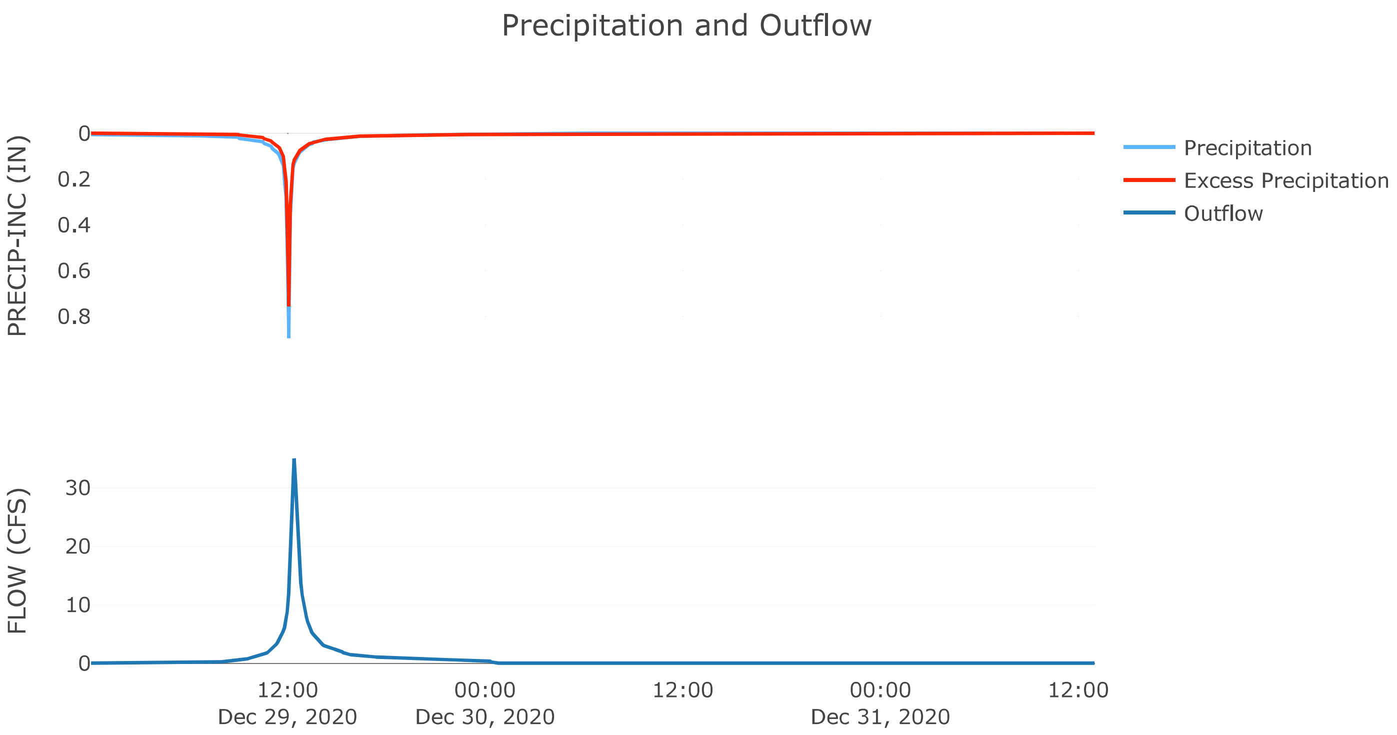
Percent Impervious Area	0
Curve Number	81

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.26
Snyder Cp	0.69

Results: S3

Peak Discharge (CFS)	35.02
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.63
Precipitation Volume (AC - FT)	5.21
Loss Volume (AC - FT)	1.49
Excess Volume (AC - FT)	3.72
Direct Runoff Volume (AC - FT)	3.72
Baseflow Volume (AC - FT)	0

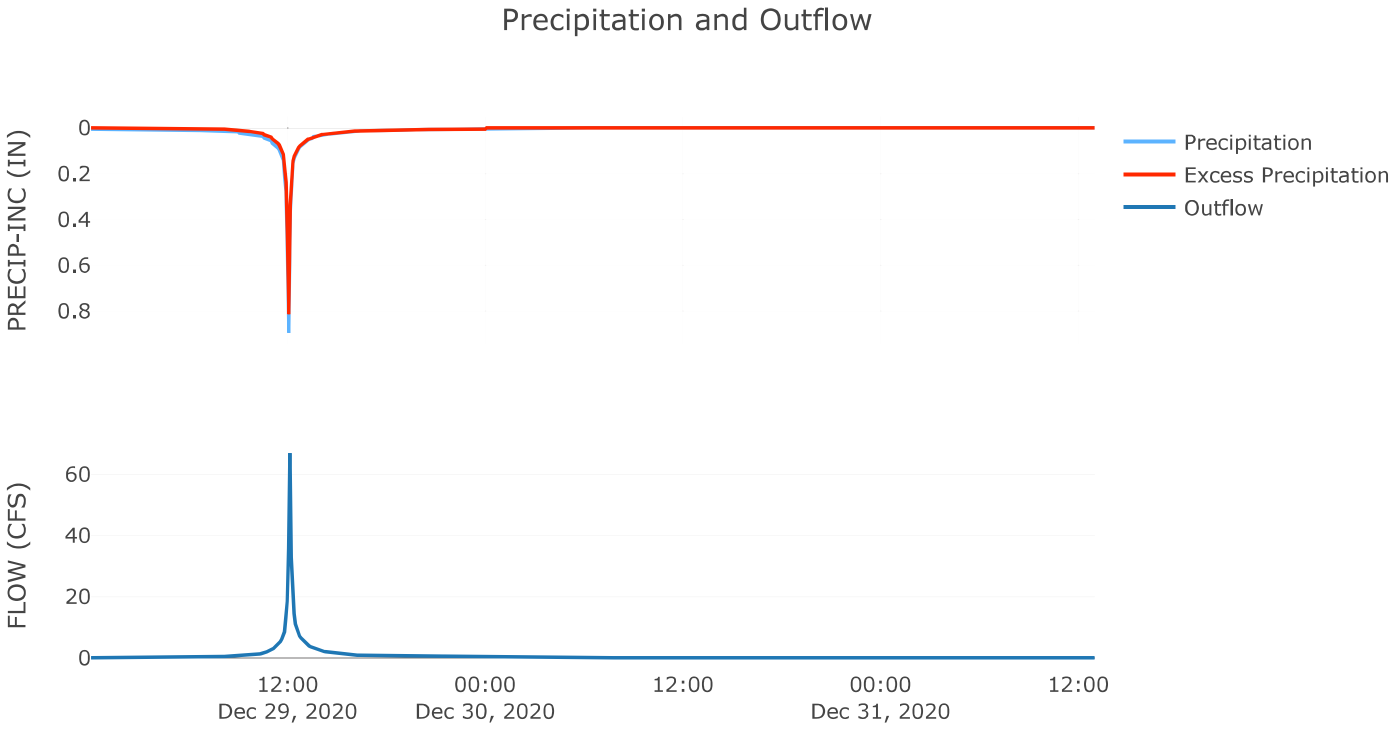

Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
30
20
10
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: DA2

Area (MI2) : 0.01
Downstream : Dp2
Transform : Kinematic Wave

Results: DA2

Peak Discharge (CFS)	66.96
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.78
Precipitation Volume (AC - FT)	4.58
Loss Volume (AC - FT)	0.97
Excess Volume (AC - FT)	3.61
Direct Runoff Volume (AC - FT)	3.36
Baseflow Volume (AC - FT)	0

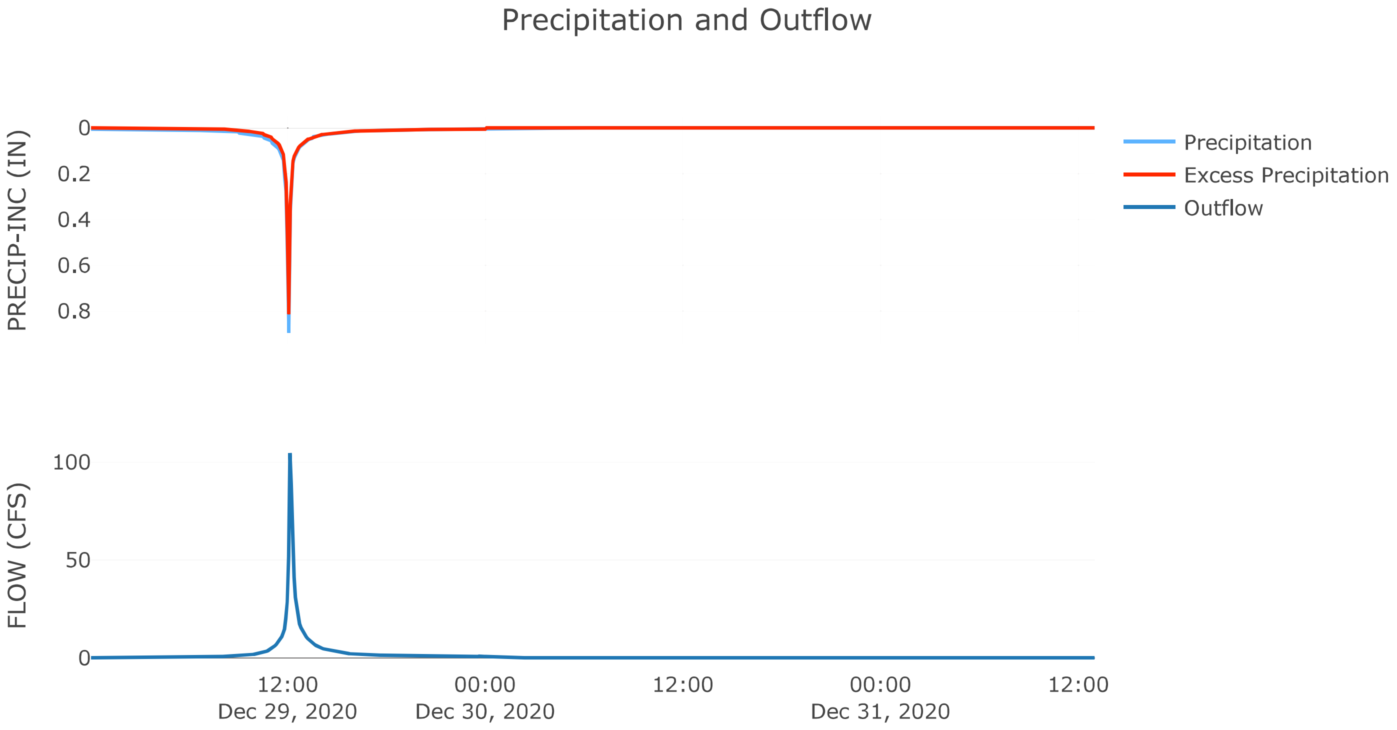


Subbasin: DA3

Area (MI2) : 0.02
Downstream : Ch1
Transform : Kinematic Wave

Results: DA3

Peak Discharge (CFS)	104.63
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.59
Precipitation Volume (AC - FT)	9.41
Loss Volume (AC - FT)	1.99
Excess Volume (AC - FT)	7.42
Direct Runoff Volume (AC - FT)	6.68
Baseflow Volume (AC - FT)	0



Subbasin: O5

Area (MI2) : 0
Downstream : Ch1

Loss Rate: Scs

Percent Impervious Area	0
Curve Number	76

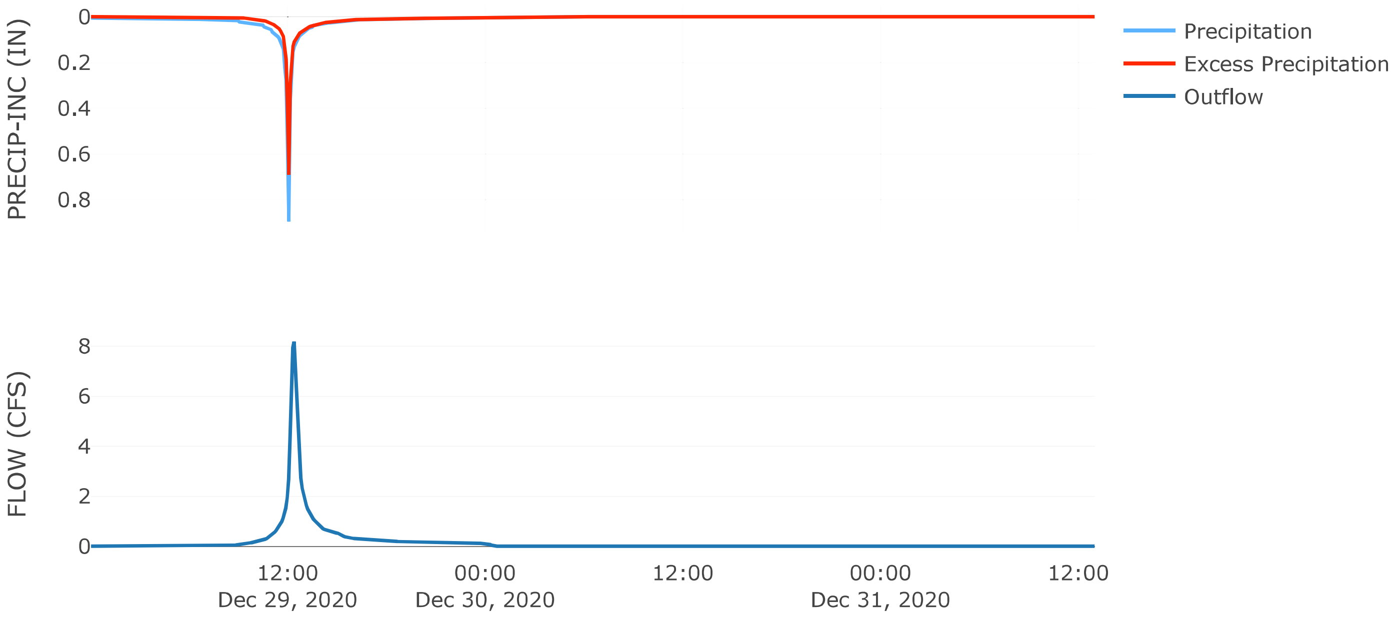
Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.25
Snyder Cp	0.73

Results: O5

Peak Discharge (CFS)	8.18
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.05
Precipitation Volume (AC - FT)	1.26
Loss Volume (AC - FT)	0.45
Excess Volume (AC - FT)	0.81
Direct Runoff Volume (AC - FT)	0.81
Baseflow Volume (AC - FT)	0

Precipitation and Outflow



Subbasin: S4

Area (MI2) : 0
Downstream : Ch1

Loss Rate: Scs

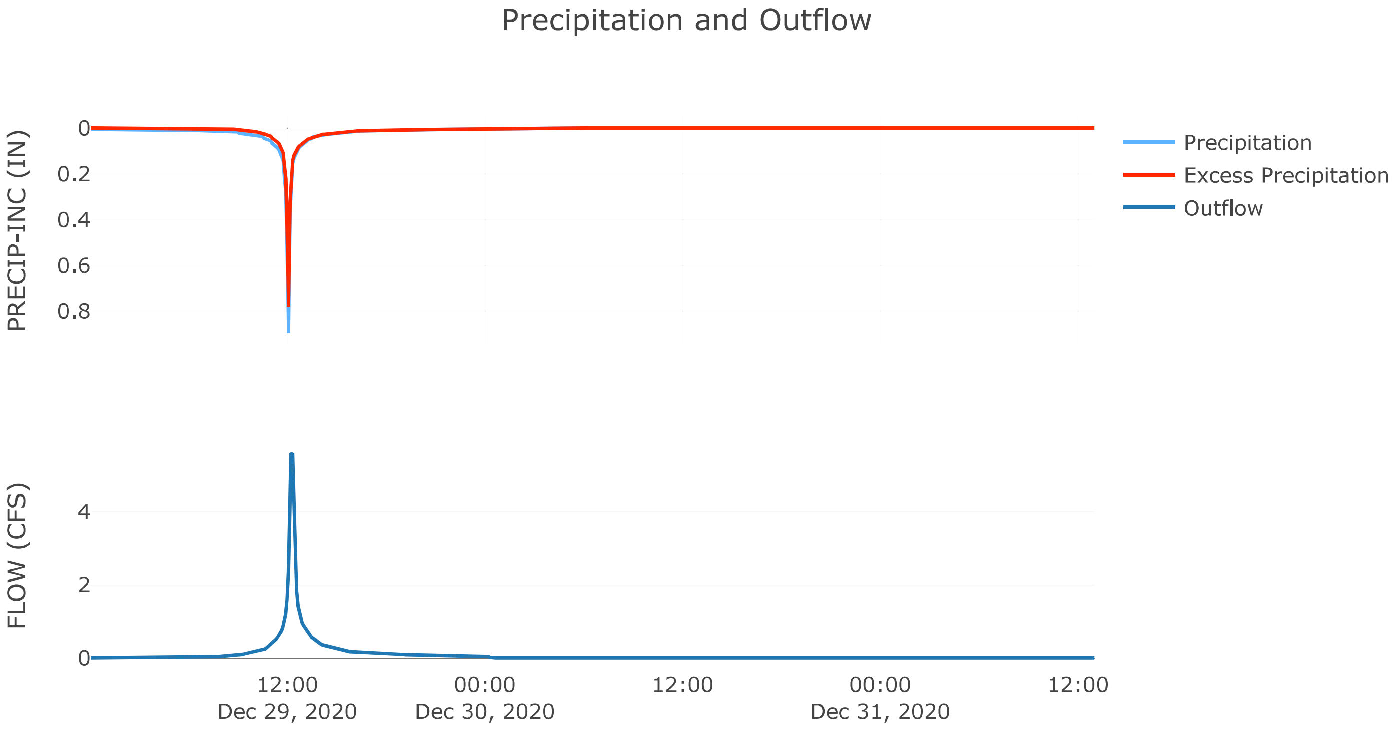
Percent Impervious Area	0
Curve Number	83

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.16
Snyder Cp	0.71

Results: S4

Peak Discharge (CFS)	5.6
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.86
Precipitation Volume (AC - FT)	0.63
Loss Volume (AC - FT)	0.16
Excess Volume (AC - FT)	0.47
Direct Runoff Volume (AC - FT)	0.47
Baseflow Volume (AC - FT)	0

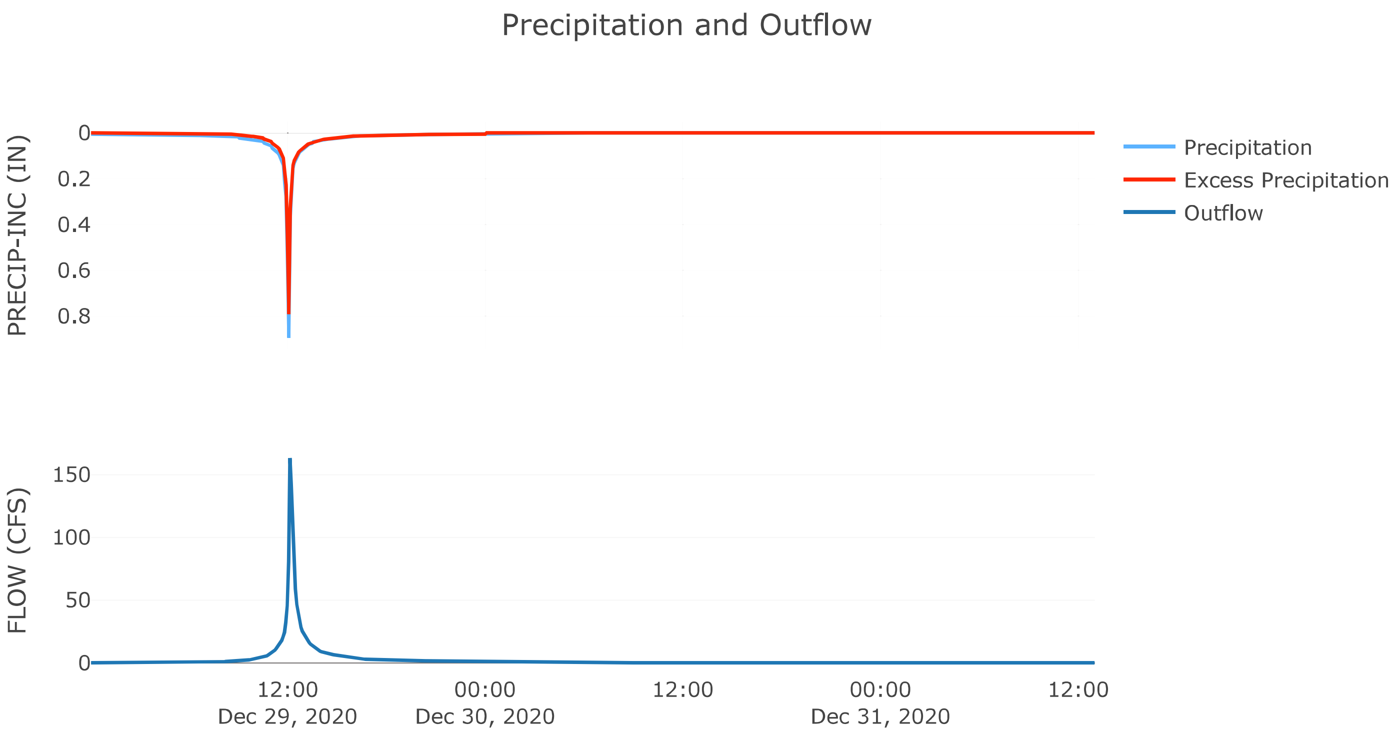

Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
4
2
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: CH1

Area (MI2) : 0.01
Downstream : R/p2
Transform : Kinematic Wave

Results: CH1

Peak Discharge (CFS)	163.16
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.54
Precipitation Volume (AC - FT)	16.26
Loss Volume (AC - FT)	3.92
Excess Volume (AC - FT)	12.34
Direct Runoff Volume (AC - FT)	11.43
Baseflow Volume (AC - FT)	0

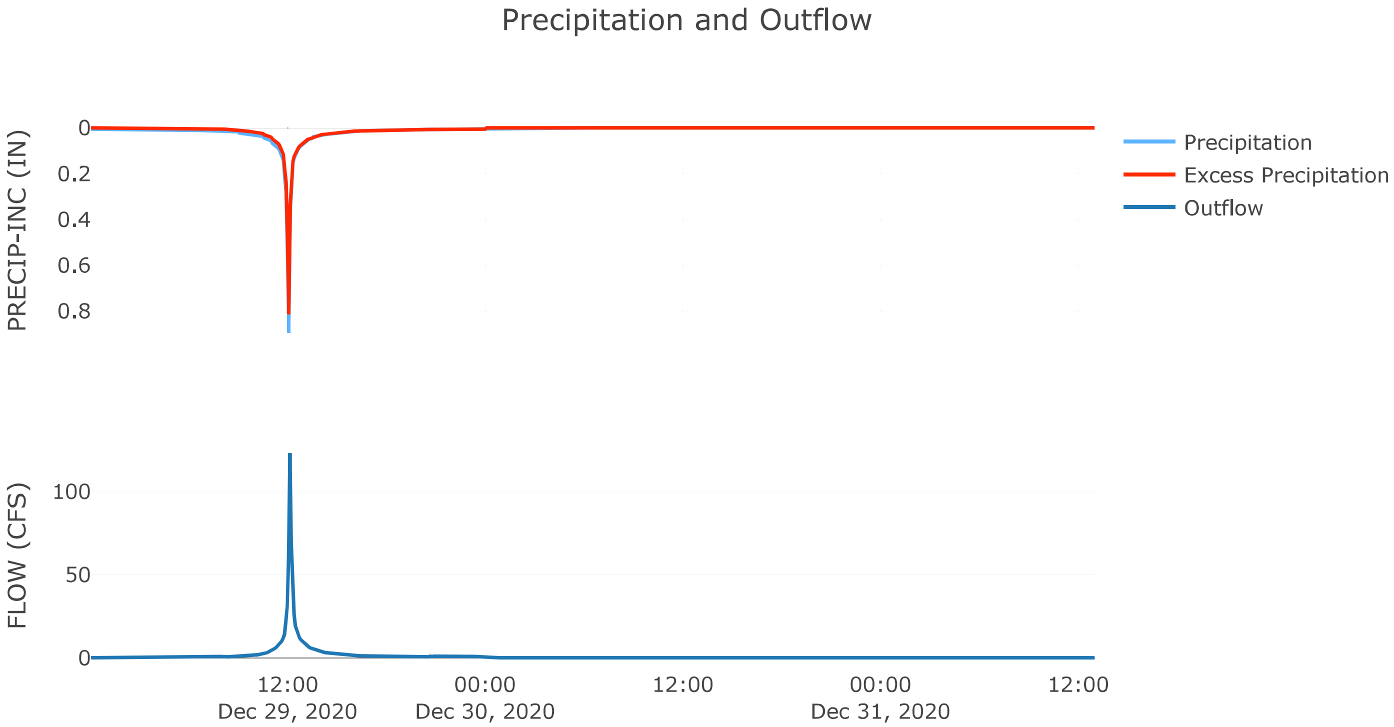


Subbasin: DA4

Area (MI2) : 0.02
Downstream : R/p2
Transform : Kinematic Wave

Results: DA4

Peak Discharge (CFS)	123.17
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	4.88
Precipitation Volume (AC - FT)	9.2
Loss Volume (AC - FT)	1.94
Excess Volume (AC - FT)	7.26
Direct Runoff Volume (AC - FT)	5.71
Baseflow Volume (AC - FT)	0



Subbasin: P2

Area (MI2) : 0.01
Downstream : R/p2

Loss Rate: Scs

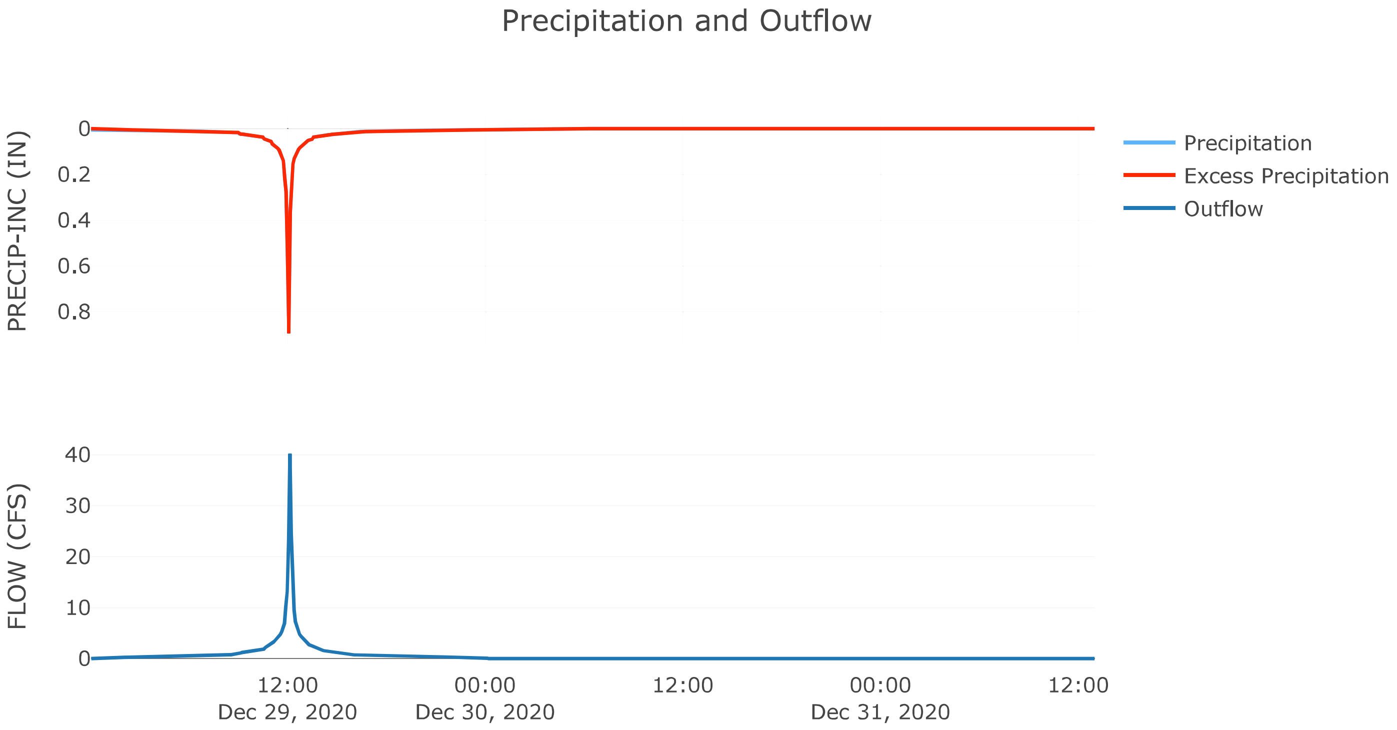
Percent Impervious Area	0
Curve Number	99

Transform: Scs

Lag	0.1
Unitgraph Type	Standard

Results: P2

Peak Discharge (CFS)	40.18
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	7.76
Precipitation Volume (AC - FT)	2.77
Loss Volume (AC - FT)	0.04
Excess Volume (AC - FT)	2.73
Direct Runoff Volume (AC - FT)	2.73
Baseflow Volume (AC - FT)	0

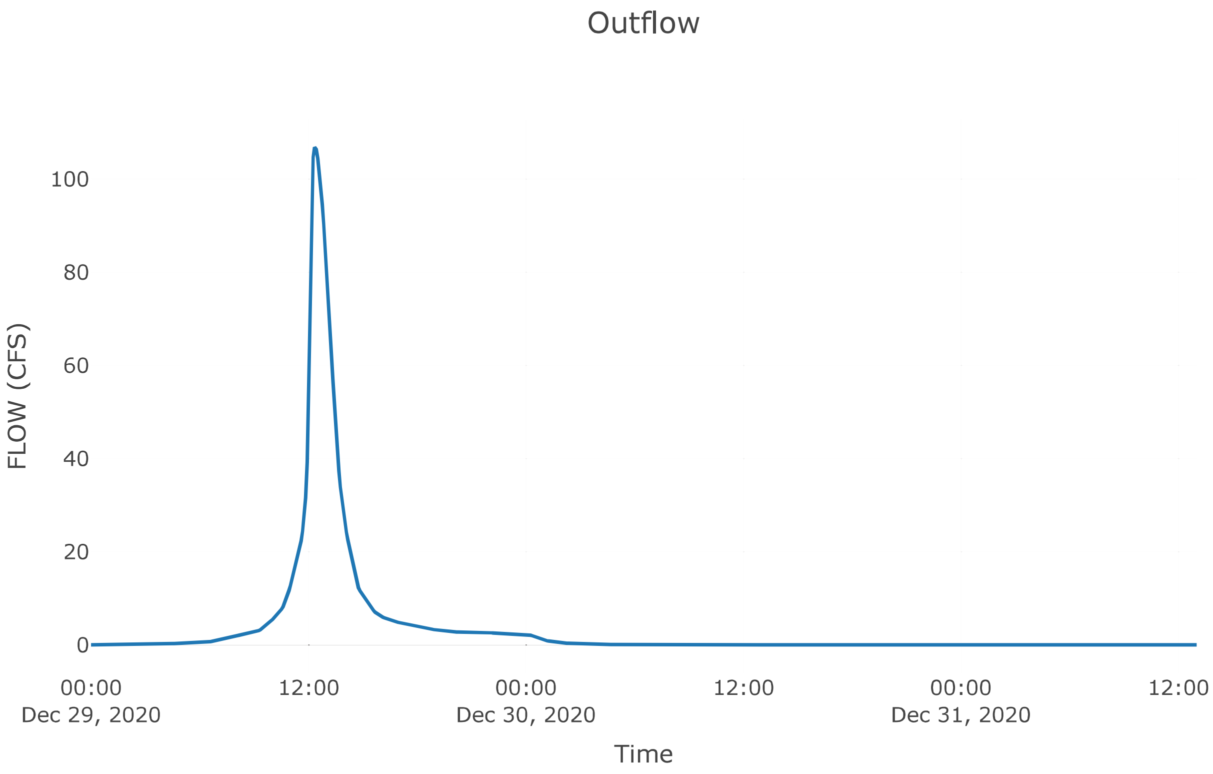


Reservoir: R/P2

Downstream : Dp4

Results: R/P2

Peak Discharge (CFS)	106.86
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.54
Peak Inflow (CFS)	326.51
Time of Peak Inflow	29Dec2020, 12:05
Inflow Volume (AC - FT)	19.87
Maximum Storage (AC - FT)	5.28
Peak Elevation (FT)	547.25
Discharge Volume (AC - FT)	19.84



Subbasin: S5

Area (MI2) : 0.01
Downstream : Dp4

Loss Rate: Scs

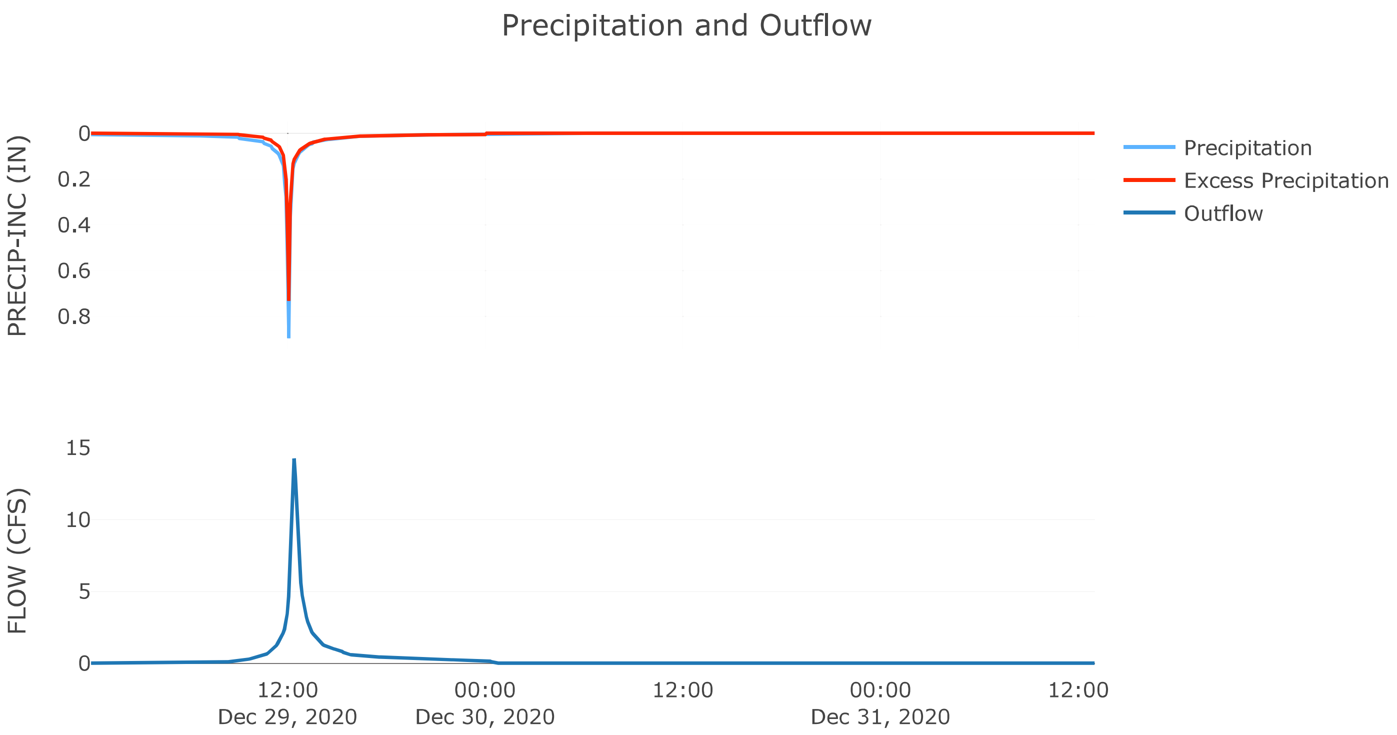
Percent Impervious Area	0
Curve Number	79

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.27
Snyder Cp	0.72

Results: S5

Peak Discharge (CFS)	14.25
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.4
Precipitation Volume (AC - FT)	2.19
Loss Volume (AC - FT)	0.69
Excess Volume (AC - FT)	1.5
Direct Runoff Volume (AC - FT)	1.5
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
15
10
5
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: S8

Area (MI2) : 0.01
Downstream : Ch4

Loss Rate: Scs

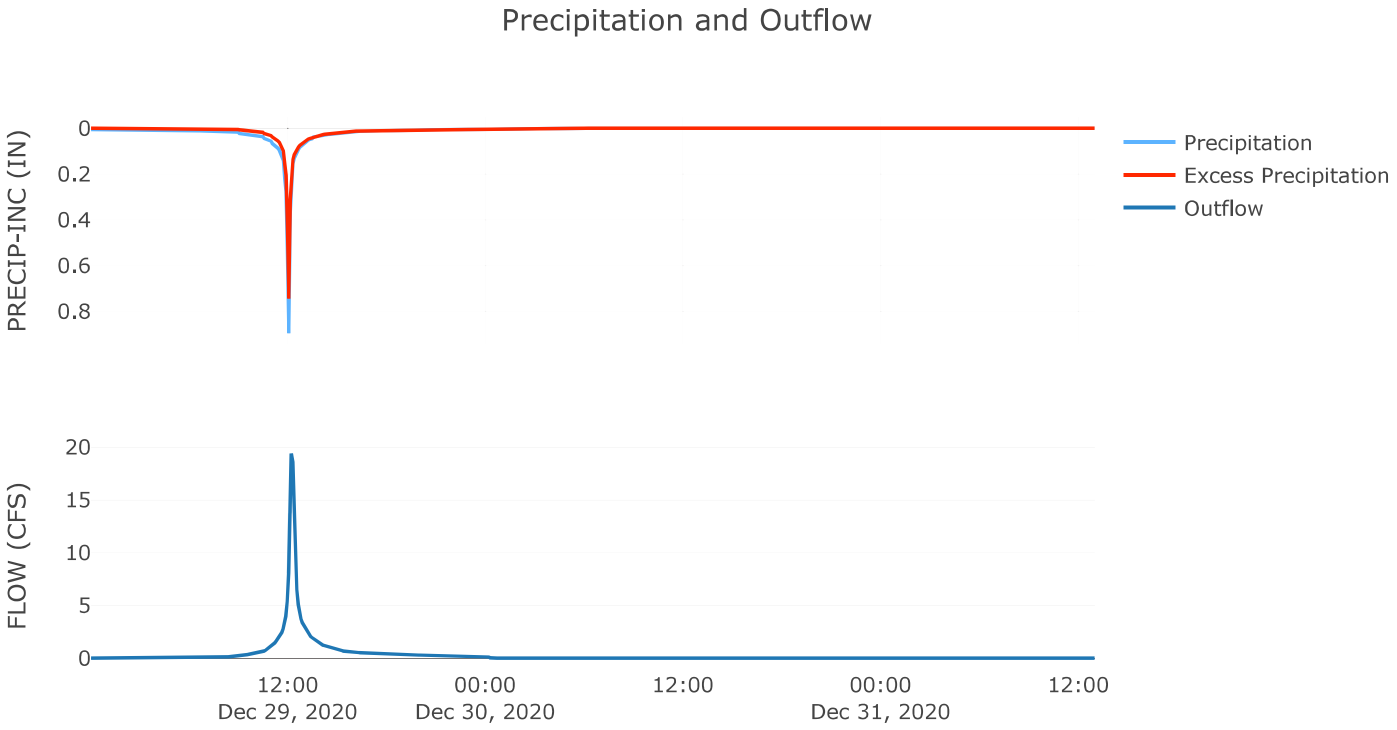
Percent Impervious Area	0
Curve Number	80

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.15
Snyder Cp	0.67

Results: S8

Peak Discharge (CFS)	19.41
Time of Peak Discharge	29Dec2020, 12:10
Volume (IN)	5.51
Precipitation Volume (AC - FT)	2.27
Loss Volume (AC - FT)	0.68
Excess Volume (AC - FT)	1.59
Direct Runoff Volume (AC - FT)	1.59
Baseflow Volume (AC - FT)	0

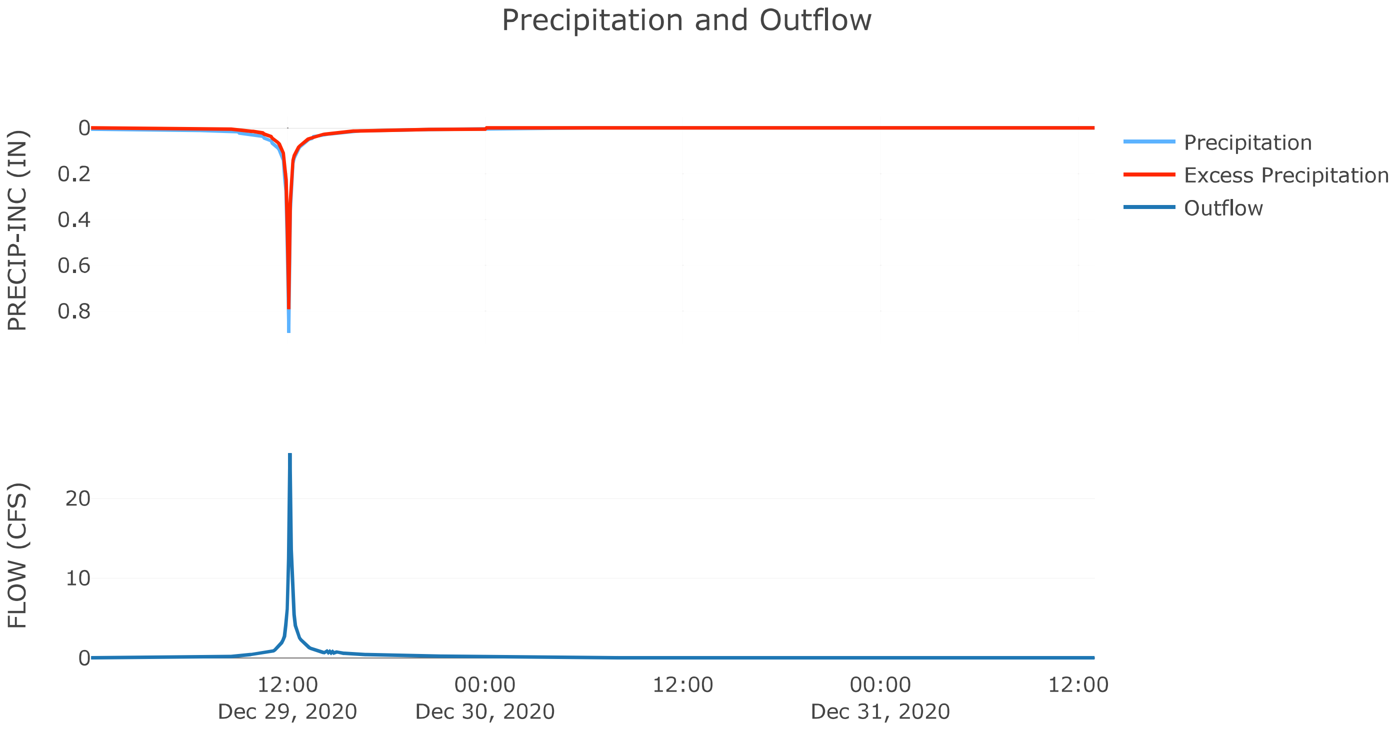

Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
20
15
10
5
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: CH5

Area (MI2) : 0
Downstream : Ch4
Transform : Kinematic Wave

Results: CH5

Peak Discharge (CFS)	25.7
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.36
Precipitation Volume (AC - FT)	1.85
Loss Volume (AC - FT)	0.45
Excess Volume (AC - FT)	1.4
Direct Runoff Volume (AC - FT)	1.26
Baseflow Volume (AC - FT)	0



Subbasin: O2

Area (MI2) : 0.02
Downstream : Ch3

Loss Rate: Scs

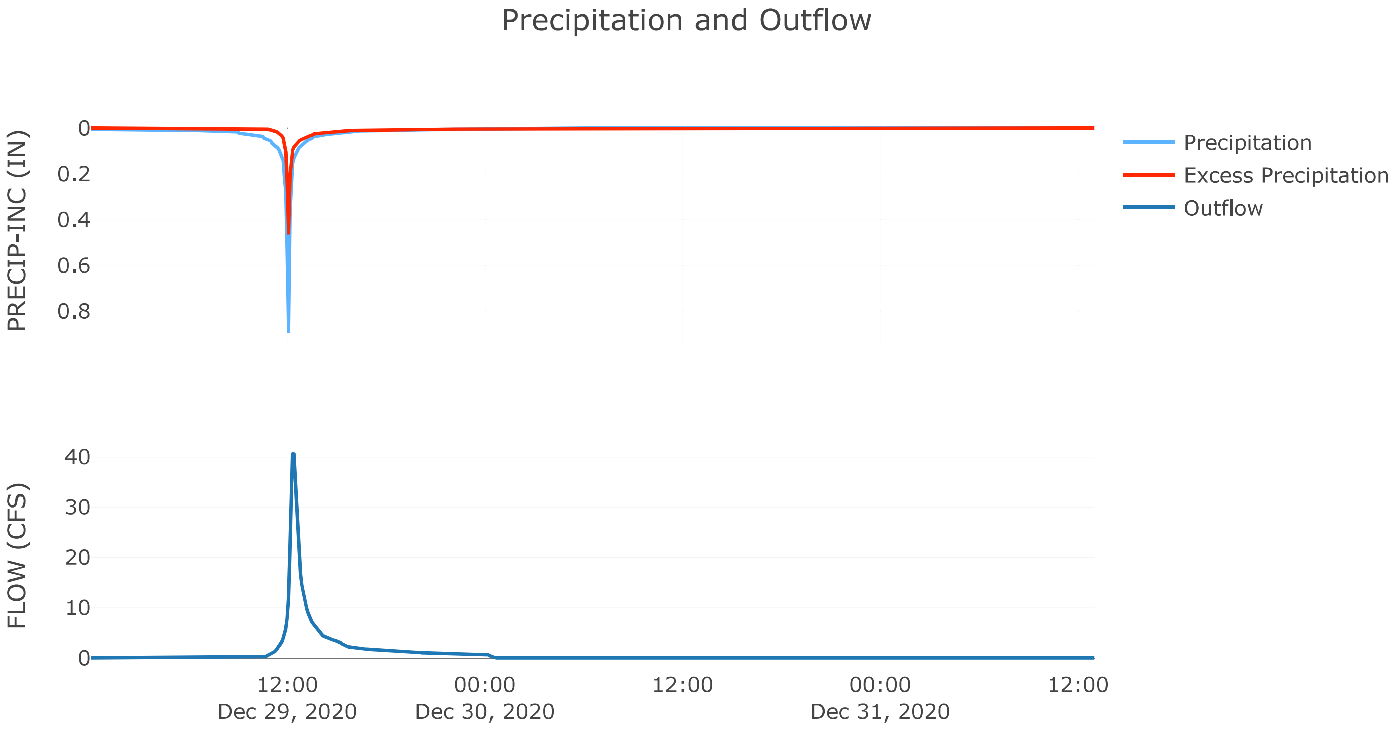
Percent Impervious Area	0
Curve Number	61

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.23
Snyder Cp	0.67

Results: O2

Peak Discharge (CFS)	40.73
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	3.35
Precipitation Volume (AC - FT)	10
Loss Volume (AC - FT)	5.75
Excess Volume (AC - FT)	4.26
Direct Runoff Volume (AC - FT)	4.26
Baseflow Volume (AC - FT)	0

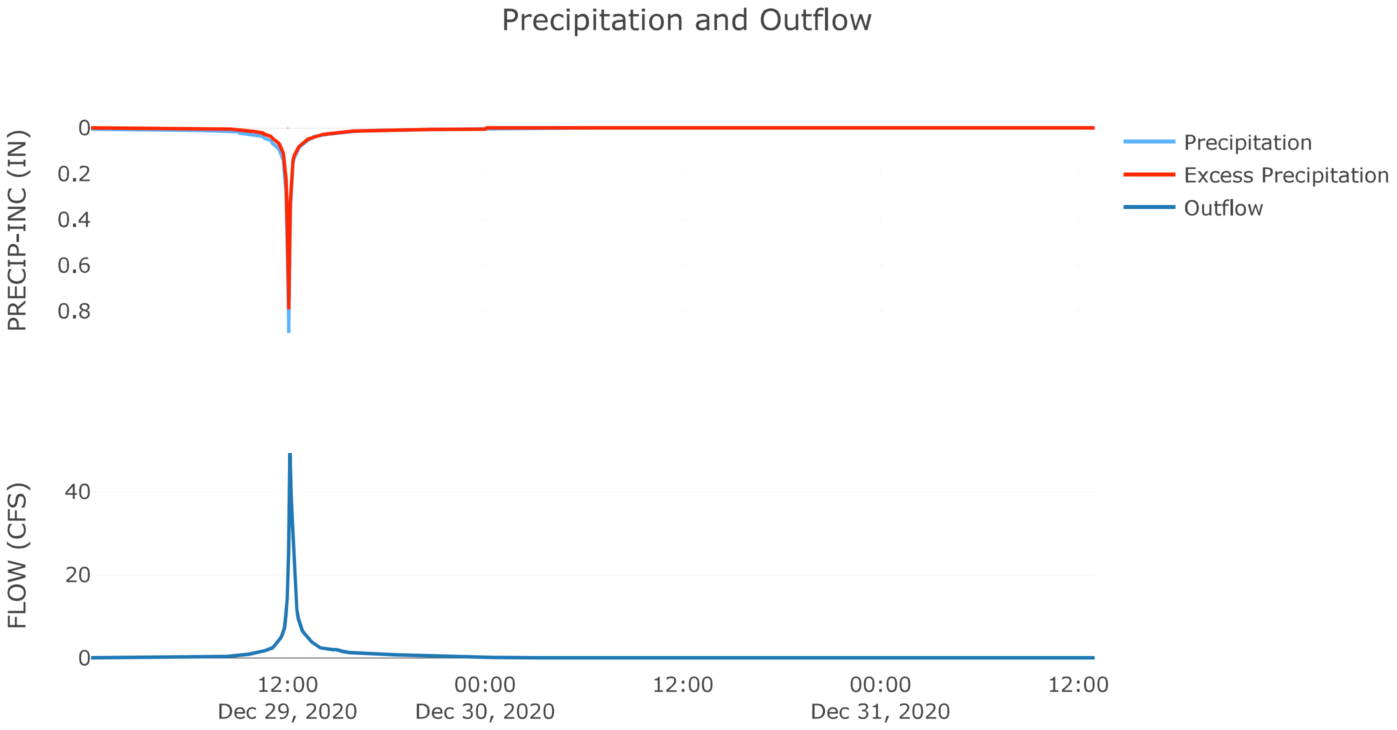

Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
40
30
20
10
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: CH4

Area (MI2) : 0
Downstream : Ch3
Transform : Kinematic Wave

Results: CH4

Peak Discharge (CFS)	49.32
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.48
Precipitation Volume (AC - FT)	4.88
Loss Volume (AC - FT)	1.18
Excess Volume (AC - FT)	3.7
Direct Runoff Volume (AC - FT)	3.39
Baseflow Volume (AC - FT)	0

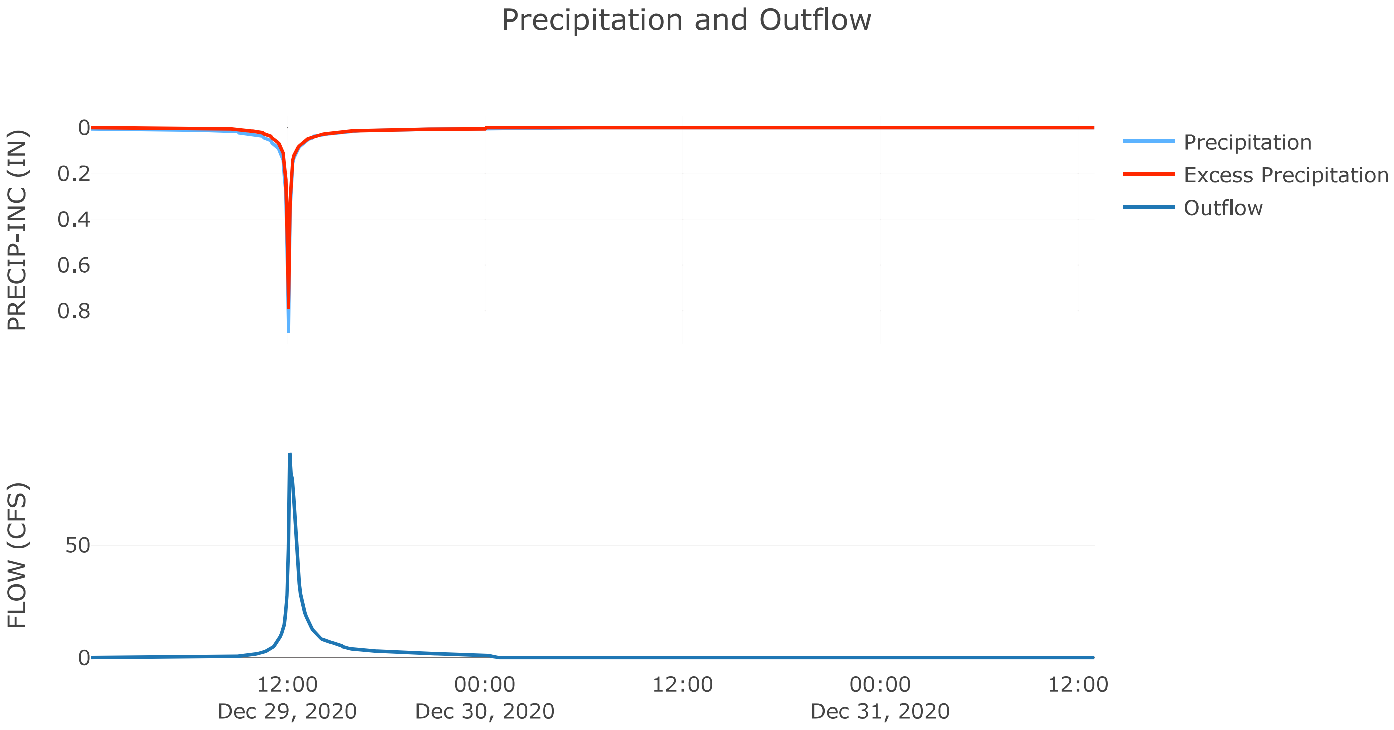


Subbasin: CH3

Area (MI2) : 0
Downstream : Ch2
Transform : Kinematic Wave

Results: CH3

Peak Discharge (CFS)	90.95
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	4.26
Precipitation Volume (AC - FT)	16.85
Loss Volume (AC - FT)	4.06
Excess Volume (AC - FT)	12.79
Direct Runoff Volume (AC - FT)	9.1
Baseflow Volume (AC - FT)	0

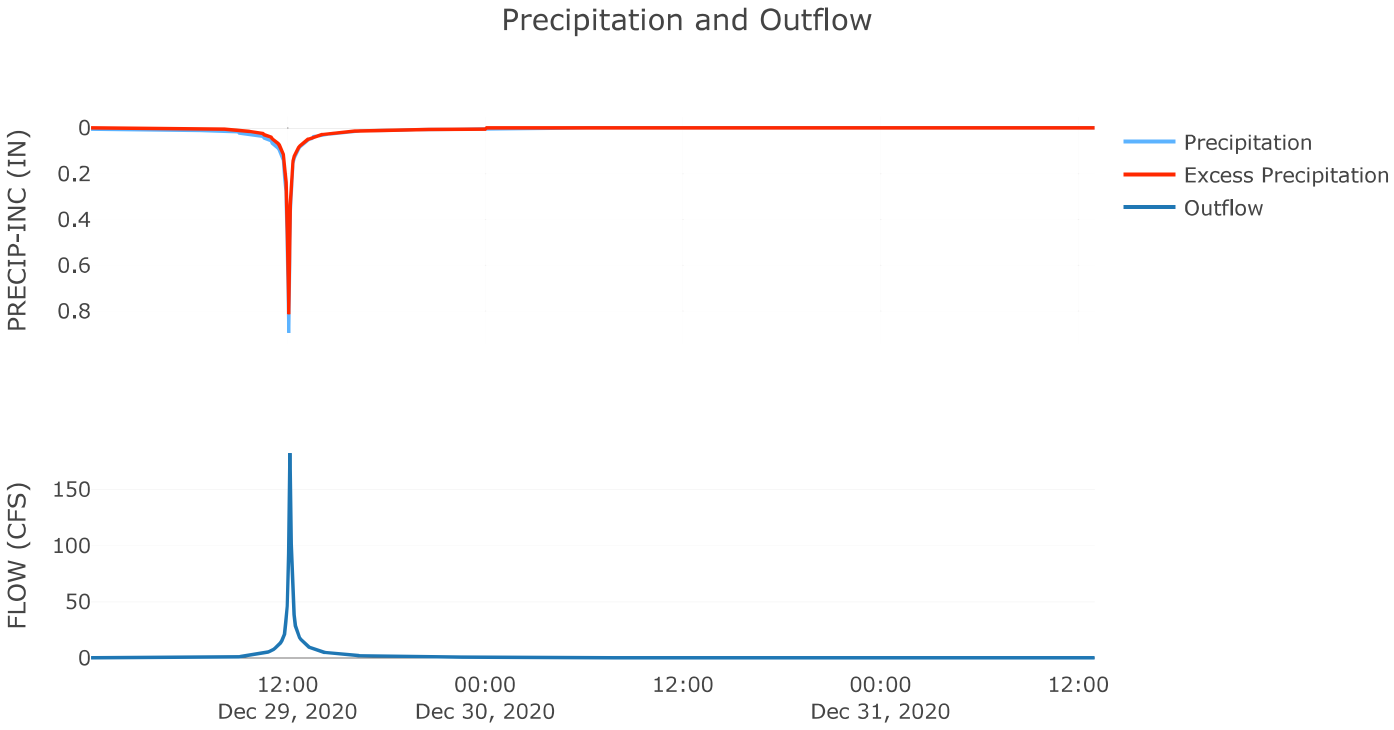


Subbasin: DA5

Area (MI2) : 0.03
Downstream : Ch2
Transform : Kinematic Wave

Results: DA5

Peak Discharge (CFS)	182.49
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	4.98
Precipitation Volume (AC - FT)	13.15
Loss Volume (AC - FT)	2.78
Excess Volume (AC - FT)	10.38
Direct Runoff Volume (AC - FT)	8.31
Baseflow Volume (AC - FT)	0

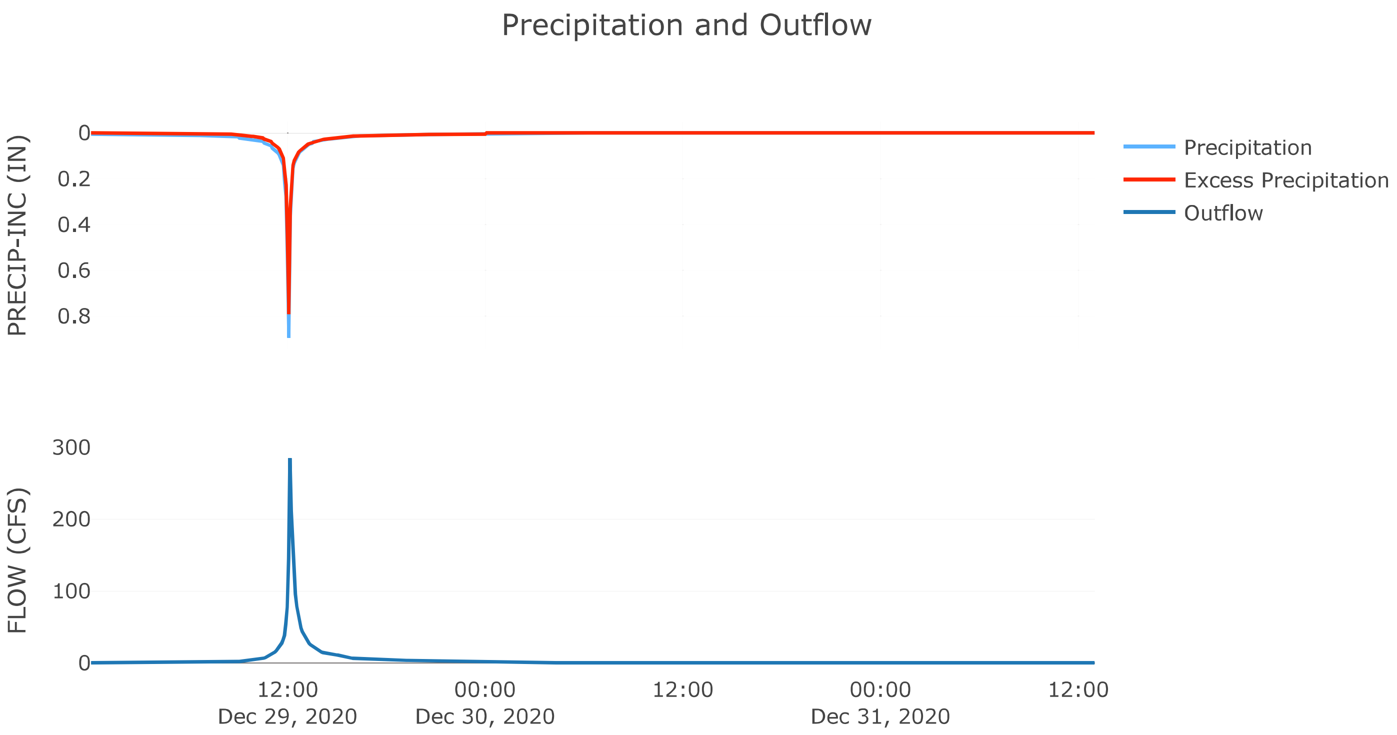


Subbasin: CH2

Area (MI2) : 0
Downstream : R/p3
Transform : Kinematic Wave

Results: CH2

Peak Discharge (CFS)	285.09
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	4.66
Precipitation Volume (AC - FT)	32.02
Loss Volume (AC - FT)	7.72
Excess Volume (AC - FT)	24.3
Direct Runoff Volume (AC - FT)	18.93
Baseflow Volume (AC - FT)	0



Subbasin: P3

Area (MI2) : 0.01
Downstream : R/p3

Loss Rate: Scs

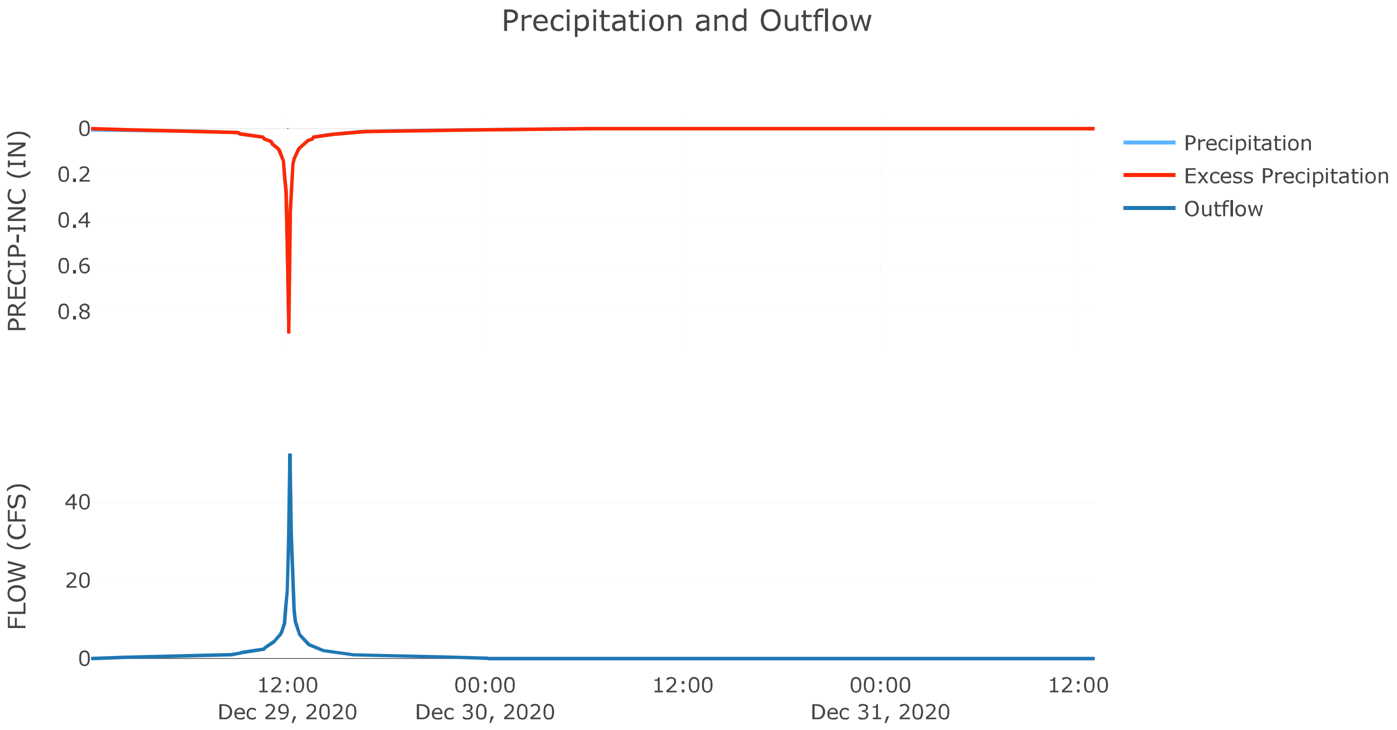
Percent Impervious Area	0
Curve Number	99

Transform: Scs

Lag	0.1
Unitgraph Type	Standard

Results: P3

Peak Discharge (CFS)	52.36
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	7.76
Precipitation Volume (AC - FT)	3.61
Loss Volume (AC - FT)	0.06
Excess Volume (AC - FT)	3.56
Direct Runoff Volume (AC - FT)	3.56
Baseflow Volume (AC - FT)	0



Subbasin: S7

Area (MI2) : 0.01
Downstream : R/p3

Loss Rate: Scs

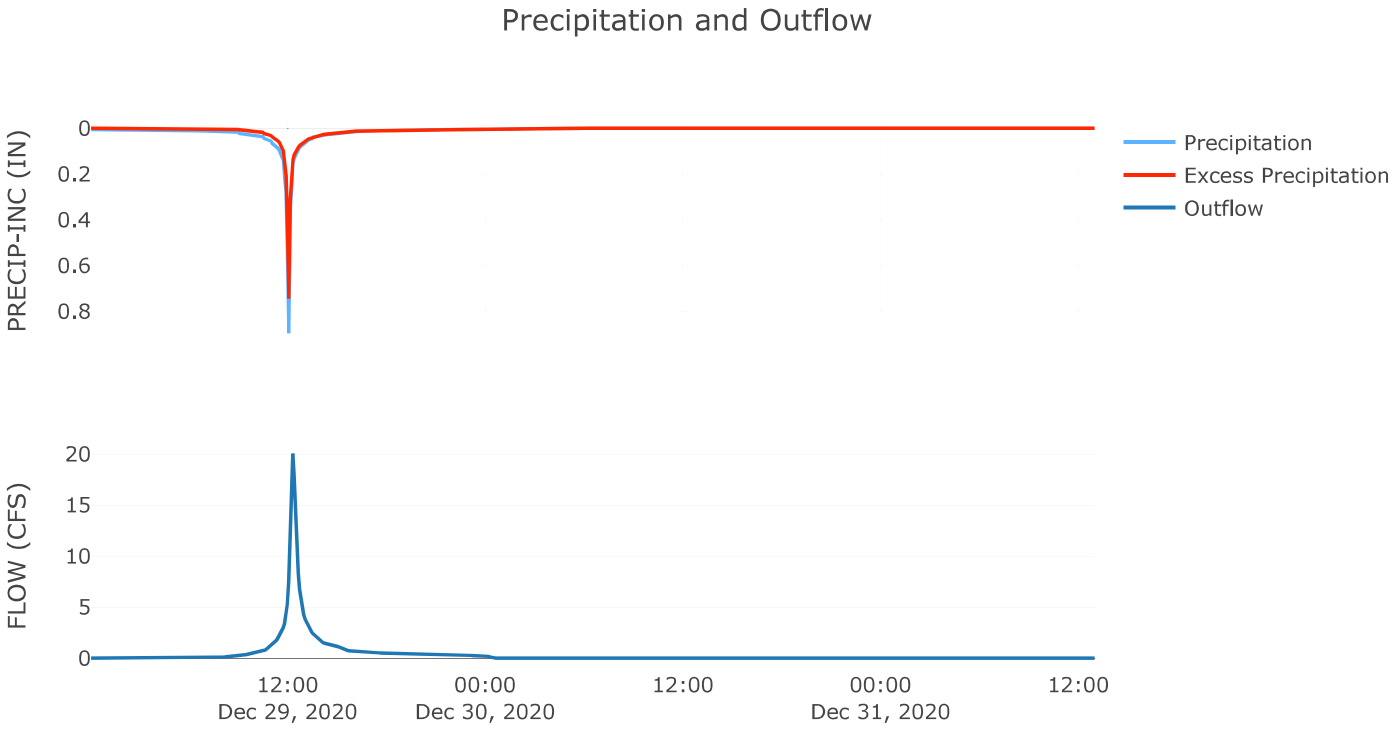
Percent Impervious Area	0
Curve Number	80

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.2
Snyder Cp	0.69

Results: S7

Peak Discharge (CFS)	20.06
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.51
Precipitation Volume (AC - FT)	2.69
Loss Volume (AC - FT)	0.81
Excess Volume (AC - FT)	1.88
Direct Runoff Volume (AC - FT)	1.88
Baseflow Volume (AC - FT)	0



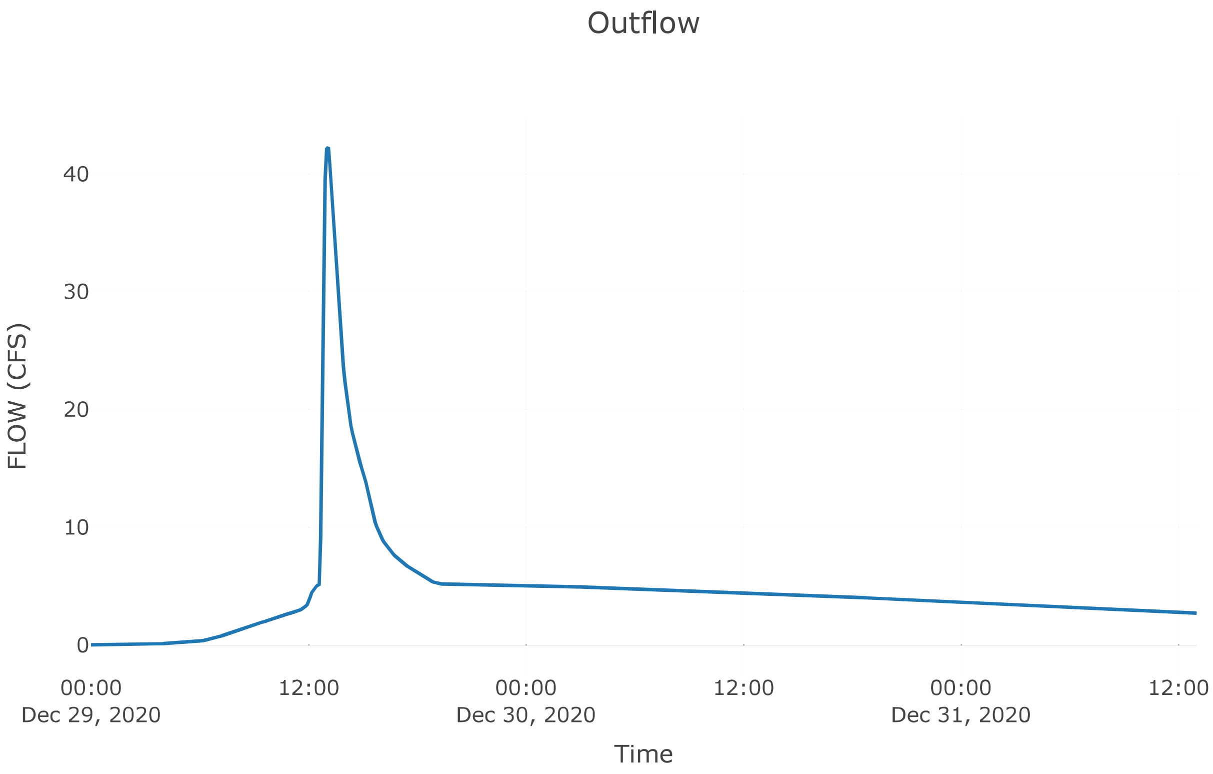
Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
20
15
10
5
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Reservoir: R/P3

Downstream : Dp5

Results: R/P3

Peak Discharge (CFS)	42.27
Time of Peak Discharge	29Dec2020, 13:05
Volume (IN)	4.74
Peak Inflow (CFS)	349.36
Time of Peak Inflow	29Dec2020, 12:05
Inflow Volume (AC - FT)	24.37
Maximum Storage (AC - FT)	14.83
Peak Elevation (FT)	544.5
Discharge Volume (AC - FT)	23.05



Subbasin: O3

Area (MI2) : 0.02
Downstream : Dp5

Loss Rate: Scs

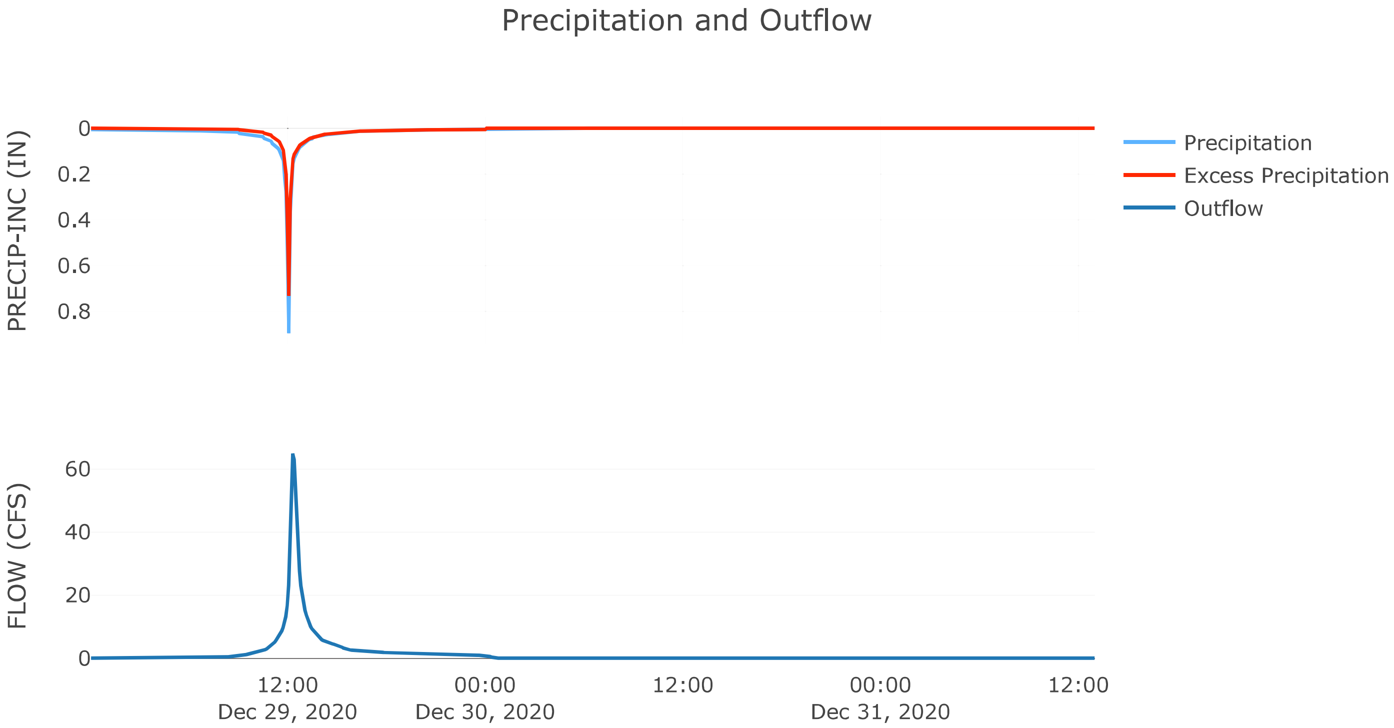
Percent Impervious Area	0
Curve Number	79

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.23
Snyder Cp	0.67

Results: O3

Peak Discharge (CFS)	64.93
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.4
Precipitation Volume (AC - FT)	9.71
Loss Volume (AC - FT)	3.06
Excess Volume (AC - FT)	6.65
Direct Runoff Volume (AC - FT)	6.65
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
60
40
20
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: S6

Area (MI2) : 0
Downstream : Dp5

Loss Rate: Scs

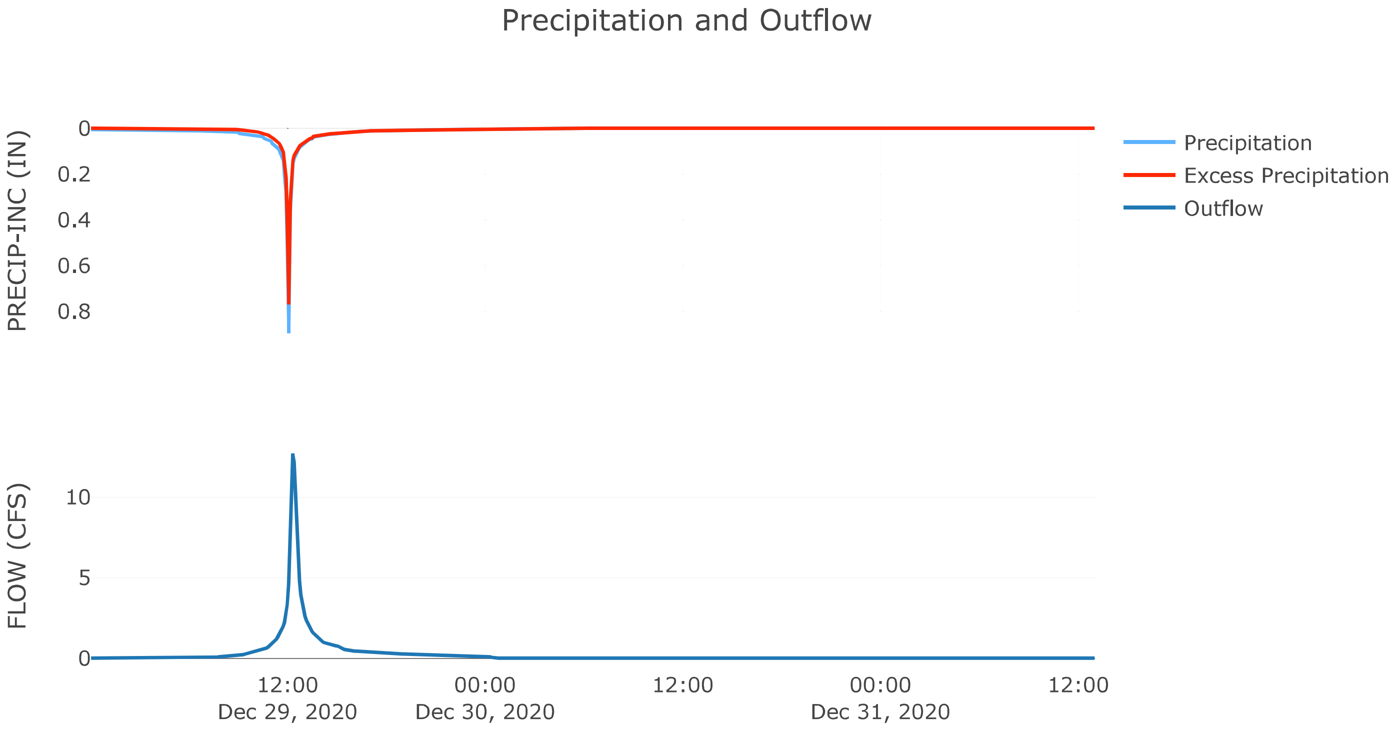
Percent Impervious Area	0
Curve Number	82

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.23
Snyder Cp	0.71

Results: S6

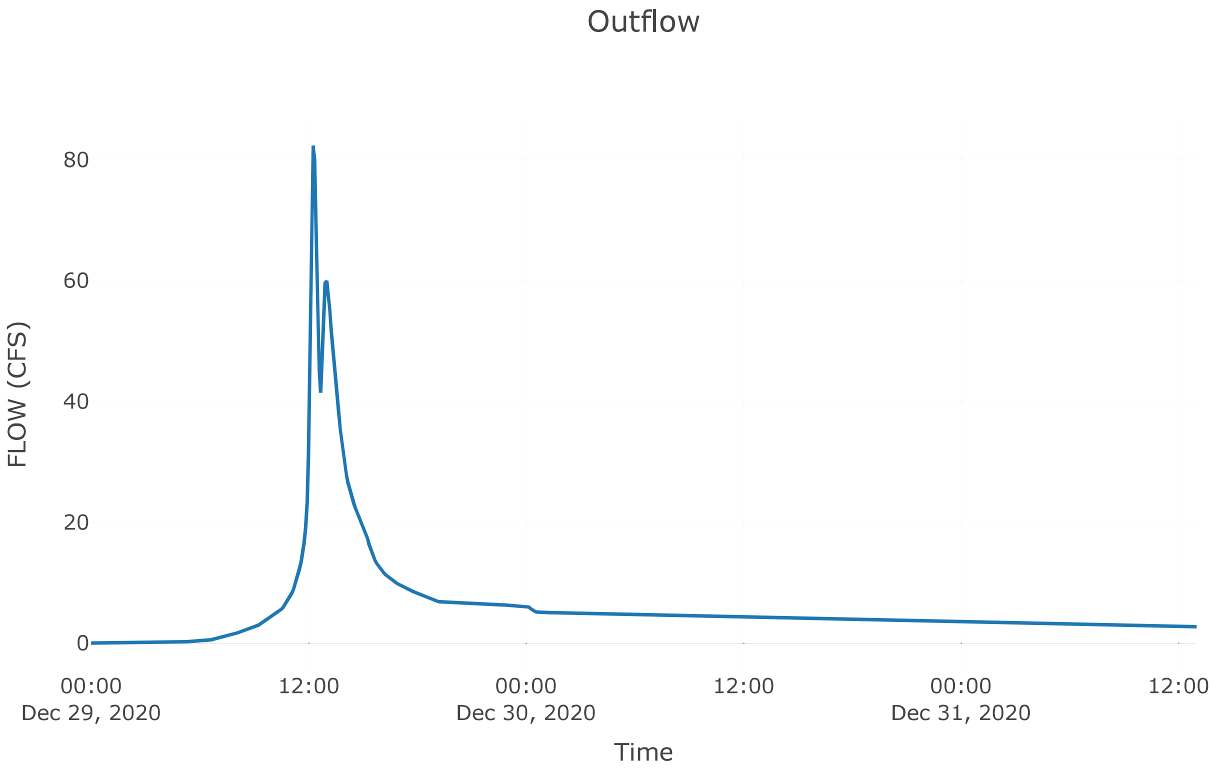
Peak Discharge (CFS)	12.72
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.75
Precipitation Volume (AC - FT)	1.72
Loss Volume (AC - FT)	0.47
Excess Volume (AC - FT)	1.26
Direct Runoff Volume (AC - FT)	1.26
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
10
5
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Junction: DP5

Results: DP5

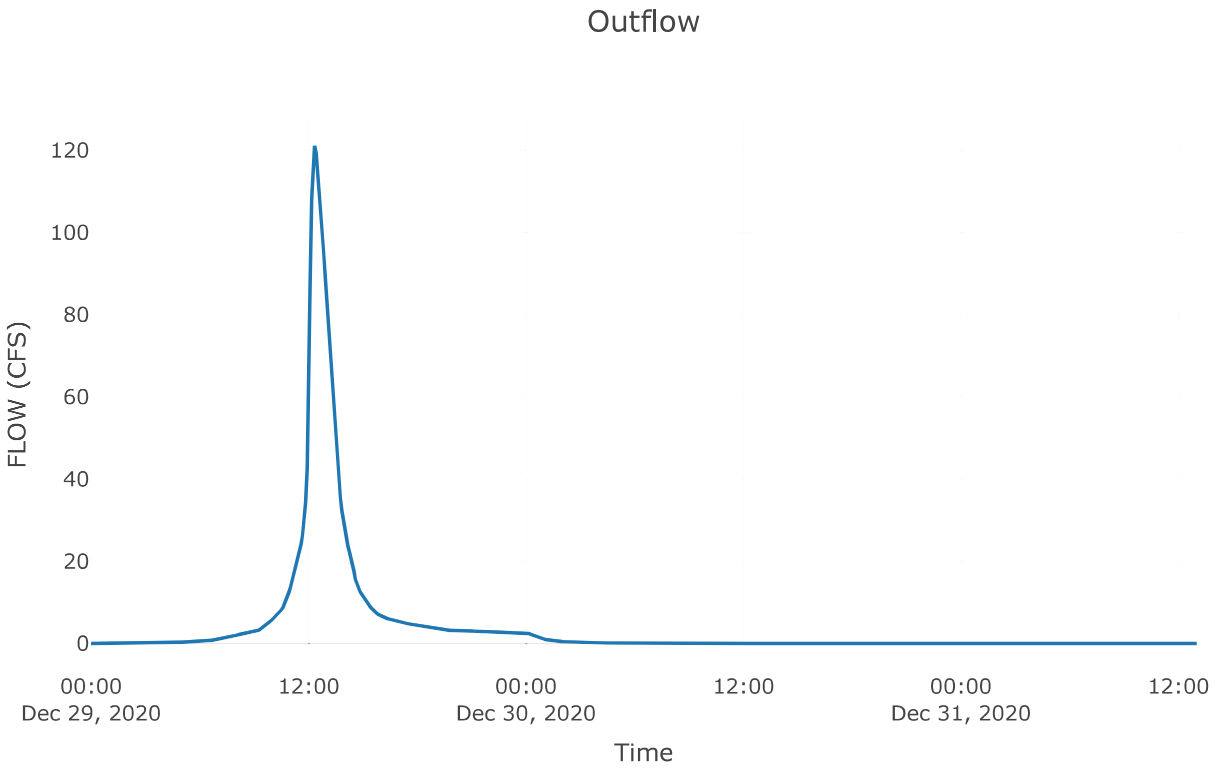
Peak Discharge (CFS)	82.32
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	4.9



Junction: DP4

Results: DP4

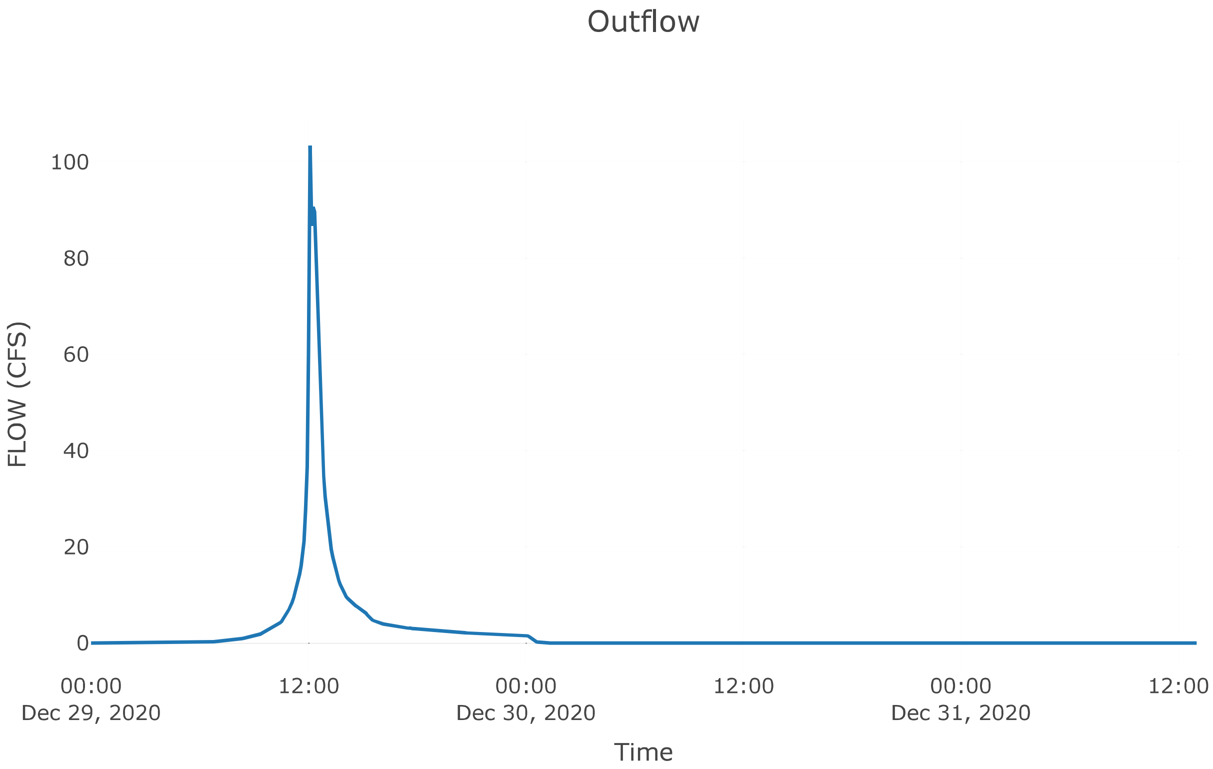
Peak Discharge (CFS)	121.11
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.53



Junction: DP2

Results: DP2

Peak Discharge (CFS)	103.39
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.42



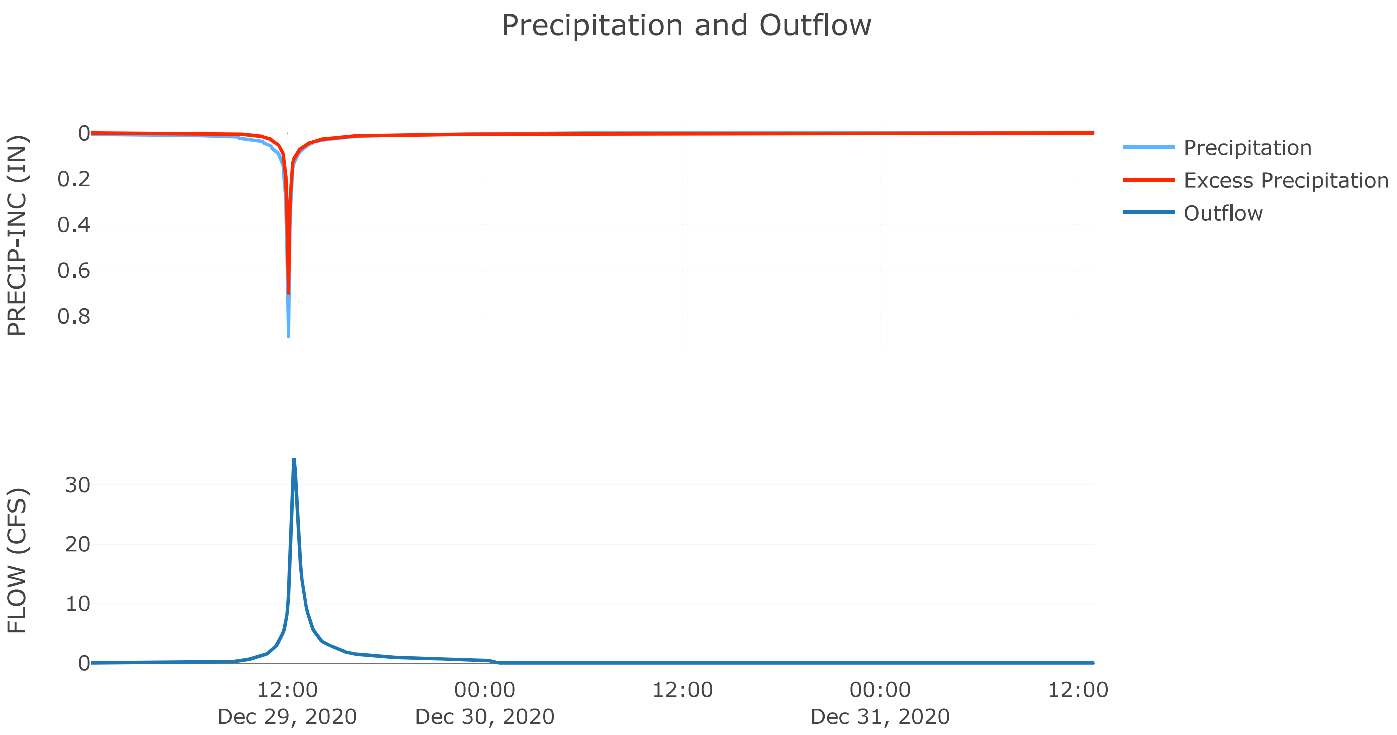
Subbasin: O4

Area (MI2) : 0.01
Downstream : Dp3

Loss Rate: Scs	
Percent Impervious Area	0
Curve Number	77

Transform: Snyder	
Snyder Method	Standard
Snyder Tp	0.29
Snyder Cp	0.69

Results: O4	
Peak Discharge (CFS)	34.48
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.16
Precipitation Volume (AC - FT)	5.93
Loss Volume (AC - FT)	2.04
Excess Volume (AC - FT)	3.88
Direct Runoff Volume (AC - FT)	3.88
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
30
20
10
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Subbasin: S10

Area (MI2) : 0
Downstream : Dp3

Loss Rate: Scs

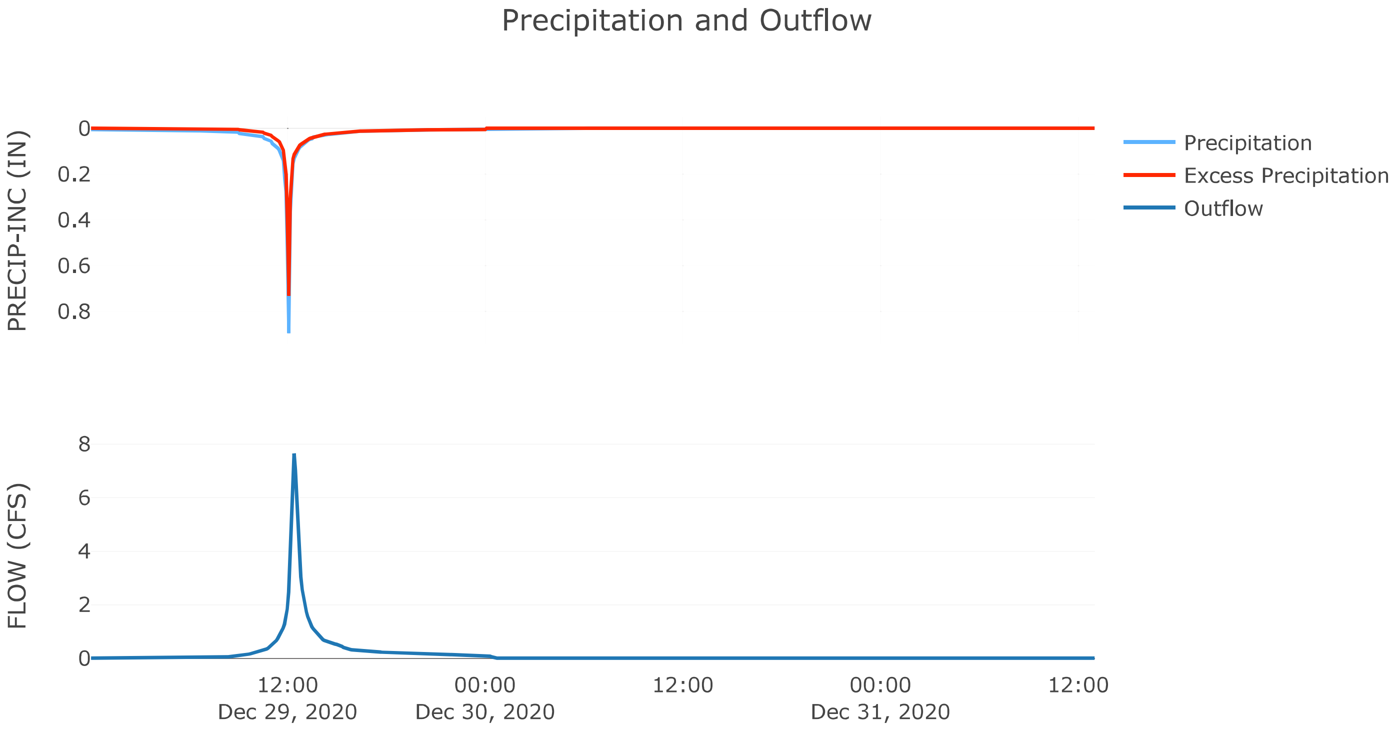
Percent Impervious Area	0
Curve Number	79

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.28
Snyder Cp	0.74

Results: S10

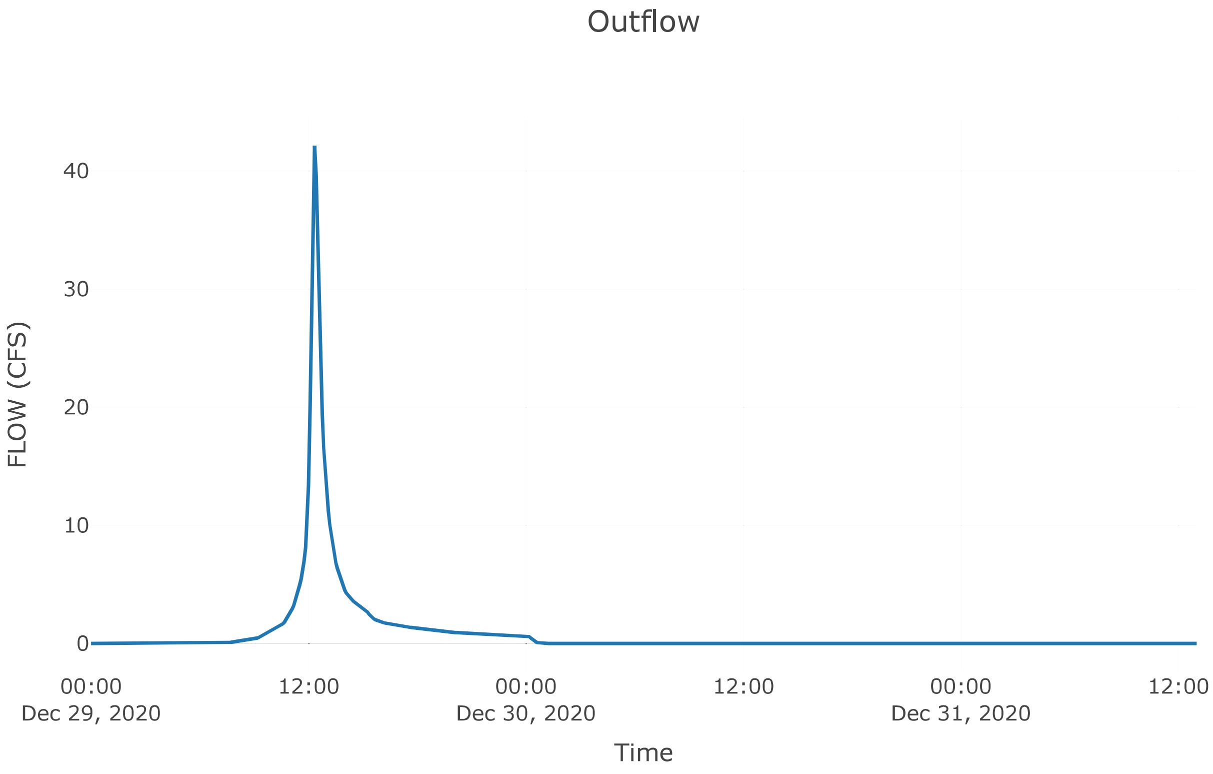
Peak Discharge (CFS)	7.65
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.4
Precipitation Volume (AC - FT)	1.18
Loss Volume (AC - FT)	0.37
Excess Volume (AC - FT)	0.81
Direct Runoff Volume (AC - FT)	0.81
Baseflow Volume (AC - FT)	0


Precipitation and Outflow
PRECIP-INC (IN)
0
0.2
0.4
0.6
0.8
Precipitation
Excess Precipitation
Outflow
FLOW (CFS)
8
6
4
2
0
12:00
Dec 29, 2020
00:00
Dec 30, 2020
12:00
00:00
Dec 31, 2020
12:00

Junction: DP3

Results: DP3

Peak Discharge (CFS)	42.13
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.2



VOLUME CALCULATIONS

EXCESS RAINFALL VOLUME CALCULATION

The volume generated by the site and the surrounding properties is calculated for the 25-year storm event. A summary of the design information that is included in this Appendix and related appendices are listed below.

- Drainage areas used in the volume calculations were taken from the drawing located on page IIIF-A-30.
- 25-year excess rainfall information is included on pages IIIF-A-31 through IIIF-A-91.
- 25-year Post-development condition volume information is summarized on pages IIIF-A-94 through IIIF-A-96.

ROYAL OAKS LANDFILL
0120-076-11-106
25- YEAR EXCESS RAINFALL
VOLUME CALCULATIONS

Required: Determine the volume generated by the site and offsite areas using the excess rainfall calculated in the HEC-HMS analysis of the post-development site conditions.

Method: 1. Use the excessive rainfall data generated by the HEC-HMS analysis (see pages IIIF-A-31 through IIIF-A-91) to determine the volume produced by the site for the post-development conditions.

1. Post-Development Condition

1. Volume Discharging at DP1

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
O1	**0.2607**	**4.02**	**166.84**	**55.89**
S1	**0.0119**	**5.86**	**7.59**	**3.71**
S2	**0.0108**	**5.75**	**6.92**	**3.32**
S9	**0.0019**	**5.98**	**1.19**	**0.59**
DA1	**0.0220**	**6.22**	**14.07**	**7.29**
CH6	**0.0090**	**5.98**	**5.77**	**2.88**
P1	**0.0031**	**7.76**	**2.01**	**1.30**

Total Volume Discharging at DP1= 74.97 ac-ft

2. Volume Discharging at DP2

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
DA2	**0.0109**	**6.22**	**6.99**	**3.62**
O6	**0.0171**	**5.05**	**10.93**	**4.60**
S3	**0.0124**	**5.63**	**7.93**	**3.72**

Total Volume Discharging at DP2= 11.94 ac-ft

ROYAL OAKS LANDFILL
0120-076-11-106
25- YEAR EXCESS RAINFALL
VOLUME CALCULATIONS

3. Volume Discharging at DP3

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
S10	**0.0028**	**5.40**	**1.77**	**0.80**
O4	**0.0141**	**5.16**	**9.00**	**3.87**

Total Volume Discharging at DP3= 4.67 ac-ft

4. Volume Discharging at DP4

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
S4	**0.0015**	**5.86**	**0.94**	**0.46**
S5	**0.0052**	**5.40**	**3.32**	**1.49**
DA3	**0.0224**	**6.22**	**14.33**	**7.43**
DA4	**0.0219**	**6.22**	**13.99**	**7.25**
CH1	**0.0118**	**5.98**	**7.55**	**3.76**
O5	**0.0030**	**5.05**	**1.93**	**0.81**
P2	**0.0066**	**7.76**	**4.23**	**2.74**

Total Volume Discharging at DP4= 23.94 ac-ft

ROYAL OAKS LANDFILL
0120-076-11-106
25- YEAR EXCESS RAINFALL
VOLUME CALCULATIONS

5. Volume Discharging at DP5

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
O2	**0.0238**	**3.35**	**15.24**	**4.25**
O3	**0.0231**	**5.40**	**14.76**	**6.64**
S6	**0.0041**	**5.75**	**2.63**	**1.26**
S7	**0.0064**	**5.51**	**4.07**	**1.87**
S8	**0.0054**	**5.51**	**3.44**	**1.58**
CH2	**0.0048**	**5.98**	**3.09**	**1.54**
CH3	**0.0047**	**5.98**	**2.98**	**1.49**
CH4	**0.0018**	**5.98**	**1.14**	**0.57**
CH5	**0.0044**	**5.98**	**2.79**	**1.39**
DA5	**0.0313**	**6.22**	**20.05**	**10.39**
P3	**0.0086**	**7.76**	**5.52**	**3.57**

Total Volume Discharging at DP5= **34.55** **ac-ft**

Total Volume Discharging At Permit Boundary =	**150.08**	**ac-ft**

VELOCITY CALCULATIONS

ROYAL OAKS LANDFILL
0120-076-11-106
POST-DEVELOPMENT CONDITION VELOCITY CALCULATIONS

Required: Determine the flow velocities entering and exiting the permit boundary using HYDROCALC HYDRAULICS (Version 2.01, 1996-2010) for the flows calculated for the 25-year storm event.

Method:
1. Use the flow data to determine velocity of runoff entering the landfill permit boundary.
2. Use the flow data to determine velocity of runoff exiting the landfill permit boundary.

1. Flow Velocity entering the landfill permit boundary

O1

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 318.9 cfs

Storm Year	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)
25	318.9	0.0316	0.04	5.6	3.3	9.37	2.09	8.16

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O2

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 40.7 cfs

Storm Year	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)
25	40.7	0.0444	0.04	4.1	6.2	51.44	0.25	3.07

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O3

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 64.9 cfs

Storm Year	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)
25	64.9	0.0802	0.04	4.2	5.1	14.06	0.58	6.63

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O4

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 34.5 cfs

Storm Year	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)
25	34.5	0.0871	0.04	1.7	1.9	5.08	0.72	7.54

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O5

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 8.2 cfs

Storm Year	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)
25	8.2	0.0907	0.04	100.0	100.0	100.00	0.05	1.51

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O6

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 40.1 cfs

Storm Year	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)
25	40.1	0.0684	0.04	4.4	5.1	83.69	0.16	2.90

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

2. Flow Velocity exiting the landfill permit boundary

DP 1

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 338.5 cfs

Storm Year	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)
25	338.5	0.0155	0.04	10.6	6.4	130.88	0.70	3.54

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

DP 2

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 103.4 cfs

Storm Year	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)
25	103.4	0.0077	0.04	6.6	10.0	171.77	0.36	1.64

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

developed by Dodson and Associates (Version 2.01, 1996-2010)

DP 3

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 42.1 cfs

Storm Year	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)
25	42.1	0.0736	0.04	4.3	5.1	18.53	0.40	5.16

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

DP 4

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 121.1 cfs

Storm Year	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)
25	121.1	0.0360	0.04	1.6	2.0	3.71	2.03	8.12

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

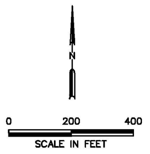
DP 5

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-A for the offsite areas and are summarized below.

Q25 = 82.3 cfs

Storm Year	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)
25	82.3	0.020	0.04	14.4	3.7	27.50	0.68	3.62

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)



LEGEND

— — - — —	PERMIT BOUNDARY
— — — —	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
	DRAINAGE SWALE
	DRAINAGE LETDOWN
	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT-MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.0 FT-MSL.
3. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
4. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

CHARLES R. MARSH
105073

05/20/2024

☐ DRAFT
☒ FOR INFORMATION PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-A-100 VELOCITY CALCS.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT POST-PROJECT VELOCITY CALCULATIONS LOCATIONS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

WWW.WCGRP.COM

DRAWING IIIF-A-100

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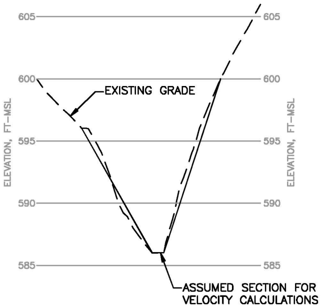
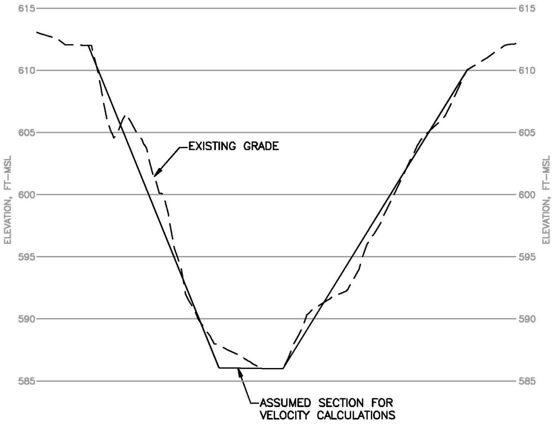


Q25= 318.9 cfs
V25= 8.16 fps

01

01 IIIF-A-100 IIIF-A-101



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V25= 3.07 fps

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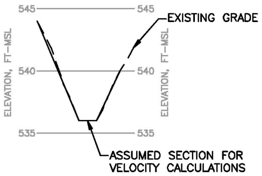
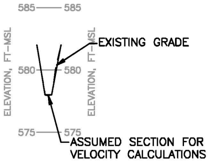
02 IIIF-A-100 IIIF-A-101



Q25= 64.9 cfs
V25= 6.63 fps

03

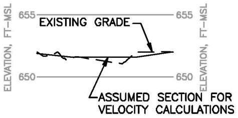
03 IIIF-A-100 IIIF-A-101



Q25= 34.5 cfs
V25= 7.54 fps

04

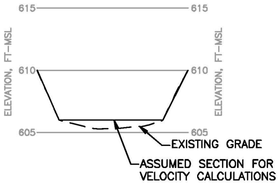
04 IIIF-A-100 IIIF-A-101



Q25= 8.2 cfs
V25= 1.51 fps

05

05 IIIF-A-100 IIIF-A-101



Q25= 40.1 cfs
V25= 2.90 fps

06

06 IIIF-A-100 IIIF-A-101

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105073
05/20/2024

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☐ ISSUED FOR CONSTRUCTION

DATE: 04/2024
FILE: 0120-76-11
CAD: IIIF-A-101 VELOCITY SECTONS.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
POST-PROJECT
VELOCITY SECTIONS
ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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DRAWING IIIF-A-101

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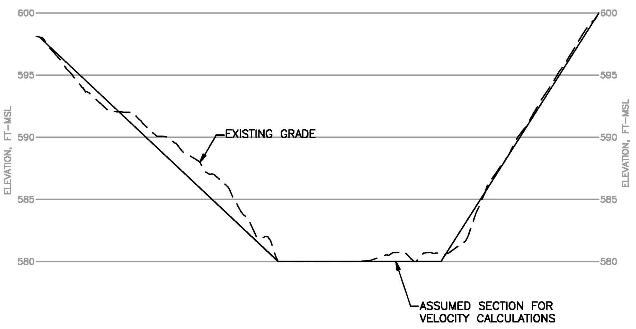
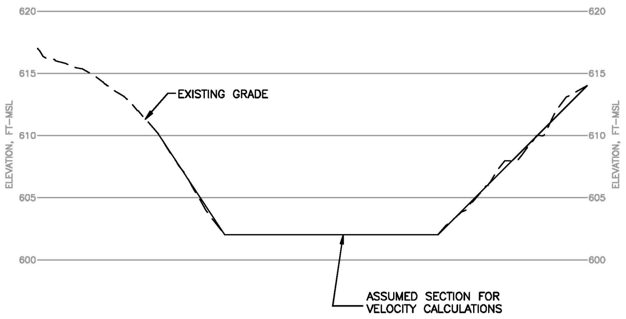


Q25= 338.5 cfs
V25= 3.54 fps

DISCHARGE POINT 1 DP1

IIIF-A-100 IIIF-A-102



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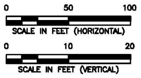
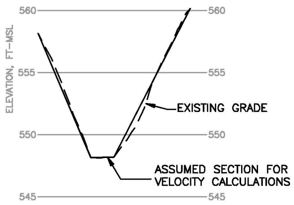
V25= 1.64 fps

DISCHARGE POINT 2 DP2

IIIF-A-100 IIIF-A-102

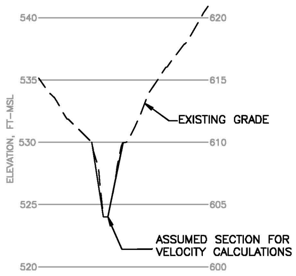




Q25= 42.1 cfs
V25= 5.16 fps

DISCHARGE POINT 3 DP3

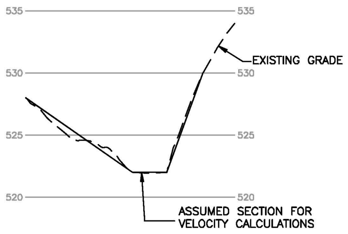
IIIF-A-100 IIIF-A-102



Q25= 121.1 cfs
V25= 8.12 fps

DISCHARGE POINT 4 DP4

IIIF-A-100 IIIF-A-102



Q25= 82.3 cfs
V25= 3.62 fps

DISCHARGE POINT 5 DP5

IIIF-A-100 IIIF-A-102

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105073
05/20/2024

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DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-A-101-102-VELOCITY SECTONS.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
POST-PROJECT
VELOCITY SECTIONS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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DRAWING IIIF-A-102

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APPENDIX IIIF-B

PERIMETER CHANNEL, DETENTION POND, AND CULVERT DESIGN

Includes pages IIIF-B-1 through IIIF-B-18

STATE OF TEXAS
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105073
LICENSED
PROFESSIONAL ENGINEER

05/20/2024

CONTENTS

CHARLES R. MARSH
105073

05/20/2024

PERIMETER CHANNEL DESIGN

Perimeter channels have been designed to contain stormwater runoff from the 25-year frequency storm events. A summary of the design information that is included in this Appendix is listed below.

- Flow rates used for the perimeter channel design were taken from the HEC-HMS analysis included in Appendix IIIF-A.
- Perimeter channel design system information is summarized on Drawing IIIF.4 in Appendix IIIF.
- Channel profiles are presented on Drawings IIIF.5 through IIIF.7 in Appendix IIIF.
- Hydraulic calculations are summarized on pages IIIF-B-2.
- Channel Erosion Control Design information is included on page IIIF-B-5.

Prep By: VG
Date: 5/6/2024

ROYAL OAKS LANDFILL
0120-076-11-106
PERIMETER CHANNEL HYDRAULIC ANALYSIS

Chkd By: BPY / CRM
Date: 5/6/2024

Channel[2]	Station[2]		Flow Rate[3]	Bottom	Bottom	Left Side	Right Side	Manning's	Normal	Flow Vel.	Froude No.	Vel. Head	Energy	Flow Area[1]	Top width of
	From	To	(cfs)	Slope (ft/ft)	Width (ft)	Slope (ft/ft)	Slope (ft/ft)	n-Value	Depth (ft)	(fps)		(ft)	Head (ft)	(sq.ft.)	Flow[1] (ft)
1	0+00.00	2+65.67	163.2	0.0909	10	3	3	0.03	0.99	12.74	2.506	2.52	3.51	12.81	15.93
	2+65.67	5+83.00	163.2	0.0547	10	3	3	0.03	1.14	10.70	1.980	1.78	2.92	15.26	16.83
	5+83.00	15+15.10	163.2	0.0690	10	3	3	0.03	1.07	11.58	2.203	2.08	3.15	14.09	16.40
2	0+00.00	4+05.25	285.1	0.0845	10	3	3	0.03	1.37	14.74	2.522	3.38	4.75	19.34	18.22
	4+05.25	8+07.66	285.1	0.0651	10	3	3	0.03	1.47	13.45	2.234	2.81	4.28	21.20	18.83
3	0+00.00	3+36.93	90.9	0.0178	10	3	3	0.03	1.12	6.06	1.128	0.57	1.69	15.01	6.06
	3+36.93	6+22.03	90.9	0.0140	30	3	3	0.03	0.66	4.28	0.953	0.28	0.95	21.26	4.28
4	0+00.00	2+88.98	49.3	0.1283	10	3	3	0.03	0.45	9.63	2.674	1.44	1.89	5.12	9.63
5	0+00.00	6+11.66	25.7	0.0326	6	3	3	0.03	0.60	5.48	1.381	0.47	1.07	4.69	5.48
6	0+00.00	4+09.85	33.5	0.0536	6	3	3	0.03	0.61	7.06	1.773	0.77	1.38	4.75	9.64
	4+09.85	9+40.72	33.5	0.0867	10	3	3	0.03	0.40	7.41	2.164	0.85	1.26	4.52	12.42
	9+40.72	16+11.36	33.5	0.0238	10	3.5	3.5	0.03	0.58	4.77	1.192	0.35	0.94	7.02	4.77

Note:

1) Calculations were performed using the HYDROCALC HYDRAULIC FOR WINDOWS Computer Program developed by Dodson and Associates (Version 2.0.1, 1996-2010).
2) Refer to Drawing IIIF.4 for channel locations.
3) Flow rates shown are the peak flow rates obtained from the HEC-HMS model. See HEC-HMS Output-Post Project Conditions in Appendix IIIF-A.

Example Calculation: Calculate the normal depth for Channel 1 between stations 0+00.00 and 2+65.67

List of Symbols

Q_d = peak flow rate for channel, cfs - obtained from HEC-HMS Analysis (Appendix IIIF-A)
R = hydraulic radius, ft
n = Manning's roughness coefficient
S = channel slope, ft/ft
b = bottom width of channel, ft
z = z-ratio (ratio of run to rise for channel sideslope)
A_f = flow area, sf
g = gravitational acceleration = 32.2 ft/s^2
T = top width of flow, ft
d = normal depth of channel, ft

The program uses an iterative process to calculate the normal depth of the channel to satisfy Manning's Equation

$$Q = \frac{1.486}{n} A R^{0.67} S^{0.5}$$

Design Inputs:

Q_d = 163.2 cfs
S = 0.0909 ft/ft
b = 10 ft
z = 3 (H) : 1 (V)
n = 0.03

Step 1 - Based on the geometry of the channel cross-section, solve for R and A_f

$$R = \frac{bd + zd^2}{b + 2d(z^2 + 1)^{0.5}}$$

$$A_f = bd + zd^2$$

assume: d = 0.99 ft

R = 0.790 ft

A_f = 12.81 sf

solve for Q: Q = 163.20

if Q is not equal to Q_d, select a new d and repeat calculations

Step 2 - solve for velocity, T, Froude number, velocity head, and energy head

Q = VA => V = Q/A

V = 12.74 ft/s

T = b + 2(z x d)

T = 15.93 ft

$$F_r = \frac{V}{(gA/T)^{0.5}}$$

$F_r =$ 2.506

$$\text{Velocity Head} = \frac{V^2}{2g}$$

Velocity Head = 2.52 ft

Energy Head = water elevation + velocity head

Energy Head = 3.51 ft

CHANNEL EROSION CONTROL DESIGN

Channel erosion controls have been designed for flow velocities resulted from the 25-year frequency flow rates. As shown on pages IIIF-B-2, 25-year velocities in the perimeter channels range from 4.28 ft/s to 14.74 ft/s. The channel lining needed to protect against erosive velocities is shown on Drawings IIIF.4 through IIIF.7 in Appendix IIIF. All channels and drainage features will be inspected and maintained in accordance with the Site Operating Plan.

The following was used to select the type of channel lining material.

- Vegetation – used in all areas where velocities are less than 5 ft/s for channels.
- Turf reinforcement matting – used in channels for velocities between 5 ft/s and 13 ft/s. Please refer to page IIIF-B-6 for more information.
- 2-foot-thick Gabions, Flexamat, or FML – used at chute discharges in channels, areas in channels where flow velocities exceed 13 ft/s, and detention ponds (see Appendix IIIF-C – Final Cover Erosion Control Structure Design). Please refer to pages IIIF-B-7 and IIIF-B-8 for more information.

Channel lining details are presented on Drawing IIIF.8 in Appendix IIIF.

TECHNICAL DATA SHEET

MACMAT®NC10

Composite Turf Reinforcement Mat

MacMat® NCi O provides immediate erosion protection to prevent soil loss and creates the optimum micro-environment to enhance seed germination and plant emergence. The Inclusion of the specially formulated MacMat® component$_{\text{1}}$ with Its 95% open structure$_{\text{1}}$ adds the best permanent protection avaHab[e. The biodegradab[e component of MacMat® NCiO ls designed to create the right environment to enhance seed germination by Insulating the seed bed, while absorbing and retaining optimal moisture.

Technlcal Data				
Physical Properties	**Property**	**Ron Value (MD)**		**Test Method**
	Tensile Strength	**150 lbs/ft (2189 NJm2)**		ASTM D 5035 (modified)
	Thickness	0.4 In (1O mm)		**ASTM D5199**
	Mass Unit/Area	15.0 oz/yd^2(.508 kg/m^2)		ASTM D5261
	UV Stability	80% {strength retained)		ASTM D 053/04355 ASATM D 5035 (modlfled)
	Resmency	80% (thickness retained)		**ASTMD6524**
	Sediment Trapping Capacity	376 In^3/ydit(7367 cm /rn')		Calculated
Performance Properties	**Property**	**Roll Value**		**Test Method**
		Unvegetated	Vegetateci"	
	Permissible Veloclty so min	13.0 fVs (3.96 mis)	**19.0 ft/s (5,79 mis)**	Large Scale Flume Test[1]
	Permissible Velocity"50 hr	7.0 ft/s (2.13 mis}	14.0 ft/s (4.26 mis}	Large Scale Flume Test[1]
	Permissible Shear 30 min	3.1 lbs/ft^2 (.148 kN/m^2)	10.0 lbs/ff(.478 kN/m^2)	Large Scale Flume Test'
	Permlssible Shear-SO hr	**2.2 lbs/ft^2(,1O5 kN/m2)**	a.O lbs/fr(.383 kN/m^2)	Large Scale Flume Test[1]
	,.V getated data extrapolated from actual test data with historically predictable results. [1]Flume test performed at Independent laboratorv-data and dtJfails avallable UPOn reauesl			
Index Properties	**Property**	**Ron Value {MD)**		**Test Method**
	"Benchscale" Shear (unveaetated)	>5 lbs/fr (.239 kN/m^2)		**ECTCTM#S**
	Water Absorption	**400%**		ECTO Modified

Seller makes no warranty, express or implied, concerning the product furnished hereunder other than at the time of delivery it shall be of the quality and spectt!callons stated herein. *ANY IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE* IS *EXPRESSLY B<CWDED AND, TO THE EXTENr THAT IT JS CONTRARY TO TH£ FOREGOING SENTENCE, ANY IMPLIED WARRANTY OF MERCHANTABILJTY IS EXPRESSLY EXCLUDED.* Any recommendations made by lhe Sel[er concerning uses or applications of said product are believed relfable, and Seller make$ no warranty of results to be obtained. The technical information supplied for this product type is subject to change at any time without notice.

This Data Sheet supersedes al! previous Data Sheets for this style and is subject to change without notice. .

MMAT NCiO 8/2006

Table 3 - Indicative thicknesses of Reno mattress and gabion revetments [11].

Type	Thickness m (ft.)	Rock Fill		Critical velocity m/s (ft/sec)	Limit velocity m/s (ft/sec)
		Size mm	d_{50} m (ft.)		
Reno mattress	0.15 - 0.17	70 - 100	0.085	3.5	4.2
		70 - 150	0.110	4.2	4.5
	0.23 - 0.25	70 - 100	0.085	3.6	5.5
		70 - 150	0.120	4.5	6.1
	0.30	70 - 120	0.100	4.2	5.5
		100 - 150	0.125	5.0	6.4
Gabions	0.50 (1.64)	100 - 200	0.150 (0.49)	5.8 (19)	7.6 (25)
		120 - 250	0.190 (0.62)	6.4 (21)	8.0 (26)

Where the revetment has to be placed under water the thickness of the Reno mattress remains the same since it can be launched from a pontoon whereas rip rap has to be increased by 50% [12, 13, 49, 50, 51].

The big reduction in the revetment thickness, which is achieved using Reno mattress instead of rip rap, is of economic significance in protection projects in large rivers, given the same area of work, and, therefore, the quantity of material used.

2.2 Semi permeable and impermeable linings with sand asphalt mastic.

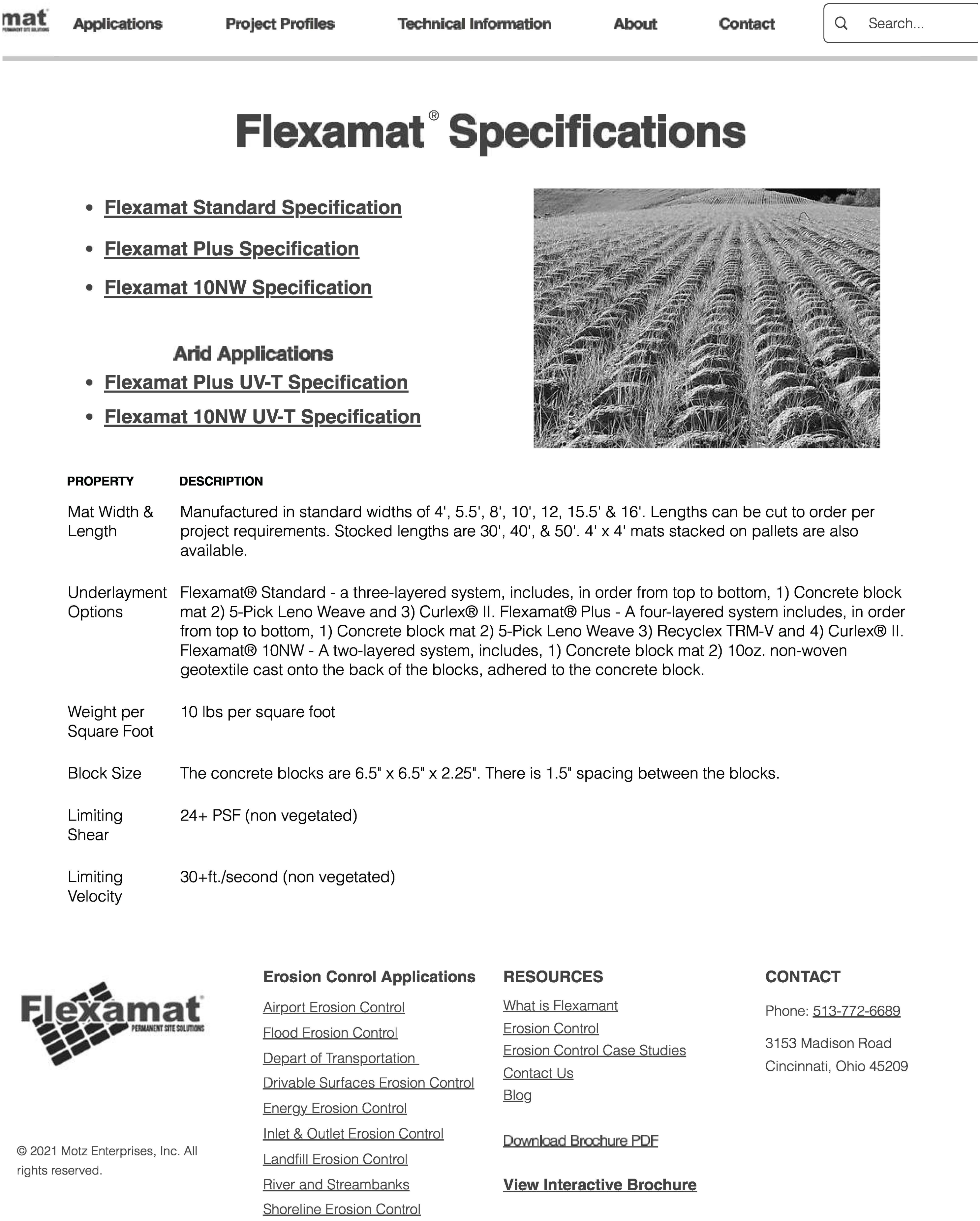
a) General characteristics of sand asphalt mastic grouted Reno mattress.

The combination of the stone filled Reno mattress and sand asphalt mastic has the characteristics of both gabion work and asphalt concrete. The addition of bituminous mastic to the Reno mattress produces a structure which combines the properties and performance of both materials. The mattress retains its flexibility, while the density of the filling is increased and therefore the efficiency of the protection. If all the voids between the stones in the layer are filled and the surface of the mattress covered, the lining will be completely impervious. The mastic also protects the wire mesh against corrosion and from abrasion by transported material.

The wire mesh reinforces the grouted stone layer and gives it strength in tension. Hence, the thickness of the combined structure can be considerably less than that of ordinary mastic grouted stone to withstand the same stresses. The resulting saving in bitumen and aggregate, and the increased flexibility due to the reduced thickness, have given rise to extensive use of this type of lining for protection in a variety of waterways.

b) Mix design of sand asphalt mastic.

To avoid excessive detail, only the fundamental data on mix design is given here. For fuller information, reference should be made to the specific publications listed in the bibliography [5, 6].



Flexamat® Specifications

- **Flexamat Standard Specification**
- **Flexamat Plus Specification**
- **Flexamat 10NW Specification**

Arid Applications

- **Flexamat Plus UV-T Specification**
- **Flexamat 10NW UV-T Specification**

PROPERTY	DESCRIPTION
Mat Width & Length	Manufactured in standard widths of 4', 5.5', 8', 10', 12, 15.5' & 16'. Lengths can be cut to order per project requirements. Stocked lengths are 30', 40', & 50'. 4' x 4' mats stacked on pallets are also available.
Underlayment Options	Flexamat® Standard - a three-layered system, includes, in order from top to bottom, 1) Concrete block mat 2) 5-Pick Leno Weave and 3) Curlex® II. Flexamat® Plus - A four-layered system includes, in order from top to bottom, 1) Concrete block mat 2) 5-Pick Leno Weave 3) Recyclex TRM-V and 4) Curlex® II. Flexamat® 10NW - A two-layered system, includes, 1) Concrete block mat 2) 10oz. non-woven geotextile cast onto the back of the blocks, adhered to the concrete block.
Weight per Square Foot	10 lbs per square foot
Block Size	The concrete blocks are 6.5" x 6.5" x 2.25". There is 1.5" spacing between the blocks.
Limiting Shear	24+ PSF (non vegetated)
Limiting Velocity	30+ft./second (non vegetated)

Erosion Conrol Applications

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CONTACT

Phone: 513-772-6689

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DETENTION POND DESIGN

Detention ponds have been analyzed by using HEC-HMS, storage routing method. The input parameters for the model are presented in Appendix IIIF-A. A summary of HEC-HMS results are presented on page IIIF-B-10.

Downstream sides of the low-water outlets for each pond will be designed with either rock riprap or gabions as shown on pages IIIF-B-11 and IIIF-B-12.

DETENTION POND DESIGN

Purpose: Demonstrate that the detention pond outlet structure designs are adequate to convey runoff from the various subbasins to their discharge points.

Method:

1. Use the 25-year, 24-hour flow rates and water surface elevations for the drainage areas that will discharge to each detention pond from the HEC-HMS analysis (see Appendix IIIF-A).
2. Use the Weir Equation to calculate the flow rate over the spillways as appropriate.

Solution:

	P1 [1,2]	P2	P3
Bottom ELEV, ft[1]	576.0	540.0	526.0
Spillway ELEV, ft	596.0	548.0	544.0
Spillway Length, ft	20	262	40
Top of Road/Berm, ft	600.0	550.0	550.0
Discharge Pipe Downstream Invert ELEV, ft	578.0	539.71	531.97
Peak Inflow Q_{25}, cfs	204.6	326.5	349.4
Peak Outflow Q_{25}, cfs	7.5	106.9	42.3
Peak Stage in Pond Q_{25}, ft	591.9	547.2	544.5
Est. Flow (Q_{25}) over Spillway, cfs	--	--	37.3

[1] Pond P1 information was reproduced from attachment 6 Ground Water and Surface Water Protection Plan prepared by HMA Environmental Services, INC. (Refer to Appendix IIIF-E, pages IIIF-E-123 through IIIF-E-125)

[2] The outlet control structure in pond 1 includes an 8-in low-flow outlet pipe, a vertical 48-inch overflow weir, and a 20-foot emergency spillway.

Note:
1) Details of the pond outlet structures are presented on Drawings IIIF.13 through IIIF.15.
2) The flow over the spillway is estimated using the formula $Q = CLH^{3/2}$ where C = 2.64, L is the length of the spillway in feet, and H is the head on the spillway in feet. The flow over the spillway conservatively assumes no flow through the low water outlet.

ROYAL OAKS LANDFILL
0120-076-11-106
DETENTION POND OUTLET STRUCTURE AND CULVERT EROSION PROTECTION CALCULATIONS

Required: Determine the minimum length and median diameter of riprap required at the detention pond outlet structures and creek culverts to control erosion in the detention pond outlet channels.

Reference:

1. Haan, Barfield, and Hayes, *Design Hydrology and Sedimentology for Small Catchments* , 1994.
2. Dodson's and Associates, Inc., *ProHec-1 Plus Program Documentation,* 1995.
3. Freeman, Gary E., J. Craig Fischenich, Gabion for Streambank Erosion Control, 2000. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-22), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Solution: The riprap will be designed for the 25-year flow rates at the detention pond outlet structures and culverts. The flow at the outlet structures and culverts can be divided into two categories:

1. Flow over the Spillway/Road

Erosion protection calculations for the drainage structures will be based on flow through low water outlets/culverts only.

Flow Structure Spillway Topslope	25-Year Flow Rate (cfs)	25-Year Velocity (ft/s)	25-Year Flow Depth (ft)	25-Year Foude Number	25-Year Velocity Head (ft)	25-Year Energy Head (ft)	25-Year Flow Area (sq. ft.)	25-Year Top Width (ft)
P1	--	--	--	--	--	--	--	--
P2	--	--	--	--	--	--	--	--
P3	37.3	1.58	0.52	0.408	0.04	0.56	23.55	50.42

Flow Structure Spillway Sideslope	25-Year Flow Rate (cfs)	25-Year Velocity (ft/s)	25-Year Flow Depth (ft)	25-Year Foude Number	25-Year Velocity Head (ft)	25-Year Energy Head (ft)	25-Year Flow Area (sq. ft.)	25-Year Top Width (ft)
P1	--	--	--	--	--	--	--	--
P2	--	--	--	--	--	--	--	--
P3	37.3	4.93	0.14	2.606	0.38	0.52	7.57	68.02

2. Flow through the Low Water Outlet

The flow rate through the low water outlet (LWO) is summarized below.

Flow Structure	Pond Bottom Elev (ft-msl)	LWO Invert Elev.		LWO Diameter (in)	25-Year Flow Rate[2] (cfs)	25-Year Outlet Velocity[1] (ft/s)
		Upstream (ft-msl)	Downstream (ft-msl)			
P1	576.00	580.00	578.00	1 x 48"	7.5	0.58
P2	540.00	540.00	539.71	1 x 42"	106.9	11.11
P3	526.00	526.00	531.97	1 x 10"	5.0	9.27

[1] Velocities through the low water outlets were calculated using the HYDROCALC HYDRAULICS FOR WINDOWS program developed by Dodson and Associates (Version 1.2a, 1996).

[2] The flowrates for all low water outlets are the peak discharges for the respective areas as calculated by HEC-HMS since the spillway crest is not overtopped in the 25-year event.

Erosion protection is already provided for the existing for pond P1; therefore, no additioned erosion protection is required.

The flowrate through the low water outlet is used to design the riprap apron.
The nomograph used for design of the length of the riprap and the median diameter are shown on page IIIF-B-13 (Figure 5.25).

DETENTION POND OUTLET STRUCTURE AND CULVERT EROSION PROTECTION CALCULATIONS

The minimum riprap length and diameter for each outlet is summarized below.
The length of the riprap is increased by 20 percent to provide for a conservative design.

Pond	Riprap Design Flowrate (cfs)	Pipe Diameter (in)	Riprap Length (ft)	Adjusted Length L x 1.2 (ft)	Median Rock Diameter (ft)
P1	7.5	48	12	14	0.25
P2	106.9	42	30	36	0.80
P3	5	10	12	14	0.25

Apron width required for the ponds (e.g., width of erosion protection in outlet channel) are:
W_{req}=LWO diameter + 0.4*(RipRap Length)

Pond	W_{req} (ft)	$W_{provided}$ (ft)
P1	8.8	18.8
P2	15.5	25.5
P3	5.6	15.6

The median diameter of riprap is intended to determine the minimum diameter of the riprap that will be used. As an alternative, 2-foot thick gabions with a d_{50} of 6-inches can be used.

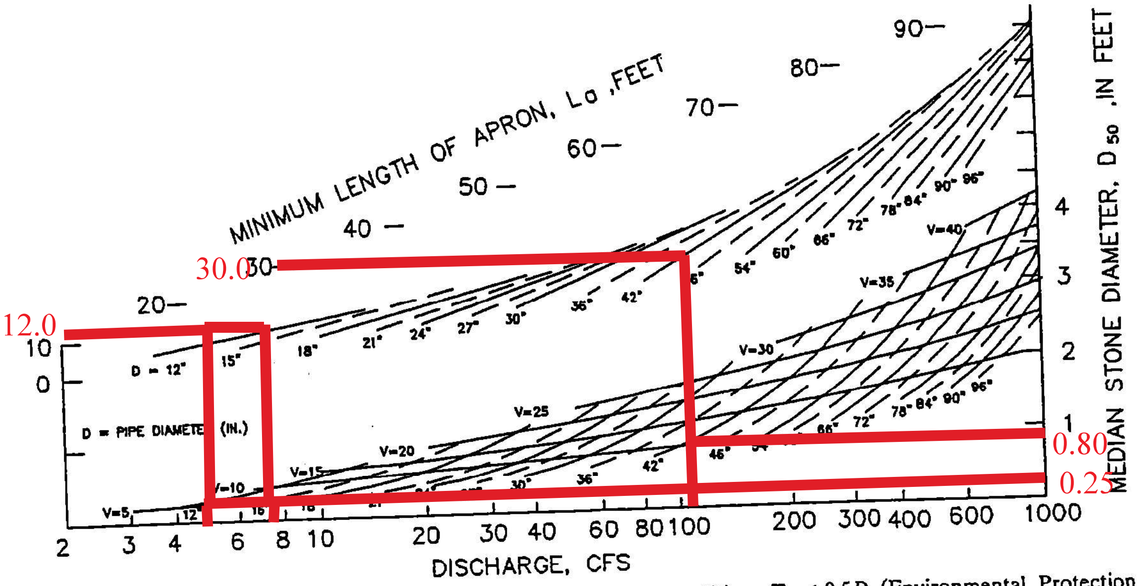


Figure 5.24 Design of outlet protection—minimum tailwater condition, $T_w < 0.5D$ (Environmental Protection Agency, 1976).

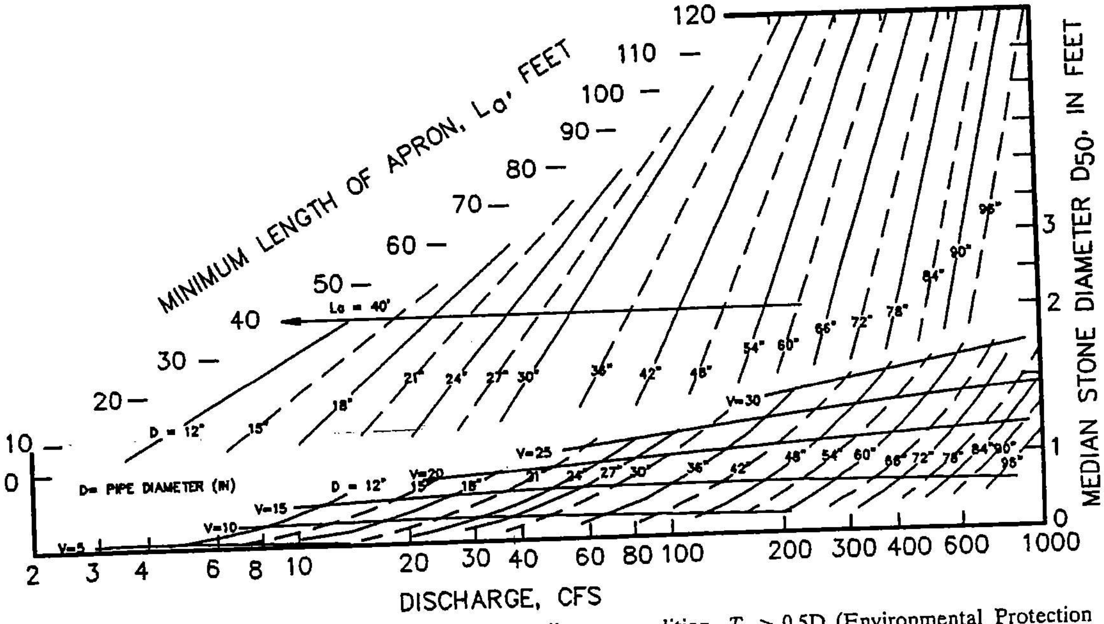
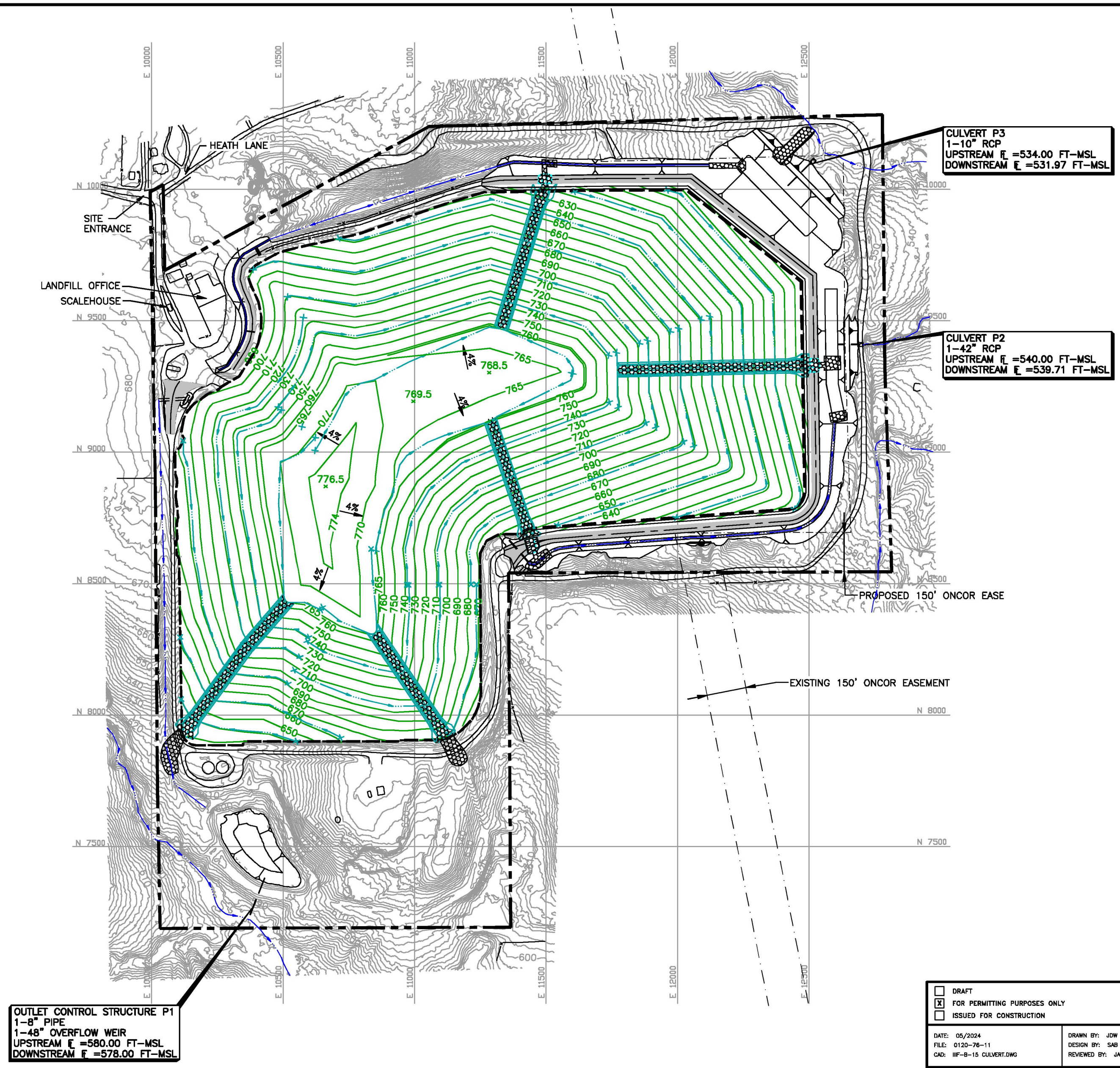


Figure 5.25 Design of outlet protection—maximum tailwater condition, $T_w \geq 0.5D$ (Environmental Protection Agency, 1976).

into the riser 3 ft below its top, what discharge will pass through the four holes with the water level at 1, 2, 4, and 8 ft above the riser? (c) What is the total discharge through the pipe? (d) How might the orifices be sized to provide better stormwater control? (e) Explain whether you would expect two rows (each consisting of four holes) of 8-in.-diameter holes to provide better results? Assume that one row is 2 ft below the riser invert and the other row is 4 ft below the riser invert.

(5.6) A gravel roadway is constructed in a low-lying area such that the roadway is frequently overtopped as a result of severe storms. The roadway is 40 ft wide, and its elevation is 36 ft. (a) If the water level upstream of the roadway is 2 ft above the crest of the roadway, what is the discharge across the roadway? (b) If the roadway is paved, what upstream depth would be required to carry the same flow? (c) Would paving reduce flooding problems?

CULVERT DESIGN



CULVERT P3
1–10" RCP
UPSTREAM ℄ =534.00 FT–MSL
DOWNSTREAM ℄ =531.97 FT–MSL

CULVERT P2
1–42" RCP
UPSTREAM ℄ =540.00 FT–MSL
DOWNSTREAM ℄ =539.71 FT–MSL

OUTLET CONTROL STRUCTURE P1
1–8" PIPE
1–48" OVERFLOW WEIR
UPSTREAM ℄ =580.00 FT–MSL
DOWNSTREAM ℄ =578.00 FT–MSL

N

0 200 400
SCALE IN FEET

LEGEND

▬ ▪ ▬	PERMIT BOUNDARY
▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. MAXIMUM FINAL COVER ELEVATION IS 776.5 FT–MSL. MAXIMUM TOP OF WASTE ELEVATION IS 773.5 FT–MSL.
3. TYPICAL SIDESLOPES ARE 4H:1V. TYPICAL TOPSLOPE IS 4%.
4. PERMIT BOUNDARY WAS REPRODUCED FROM LEGAL DESCRIPTION PROVIDED BY STANGER SURVEYING COMPANY, DATED APRIL 1995.

CHARLES R. MARSH
105073

05/20/2024

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DATE: 05/2024
FILE: 0120–76–11
CAD: IIIF–B–15 CULVERT.DWG

DRAWN BY: JDW
DESIGN BY: SAB
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
CULVERT LOCATIONS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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DRAWING IIIF–B–15

ROYAL OAKS LANDFILL
0120-076-11-106
CULVERT DESIGN

Required: Design culverts to convey the flow.

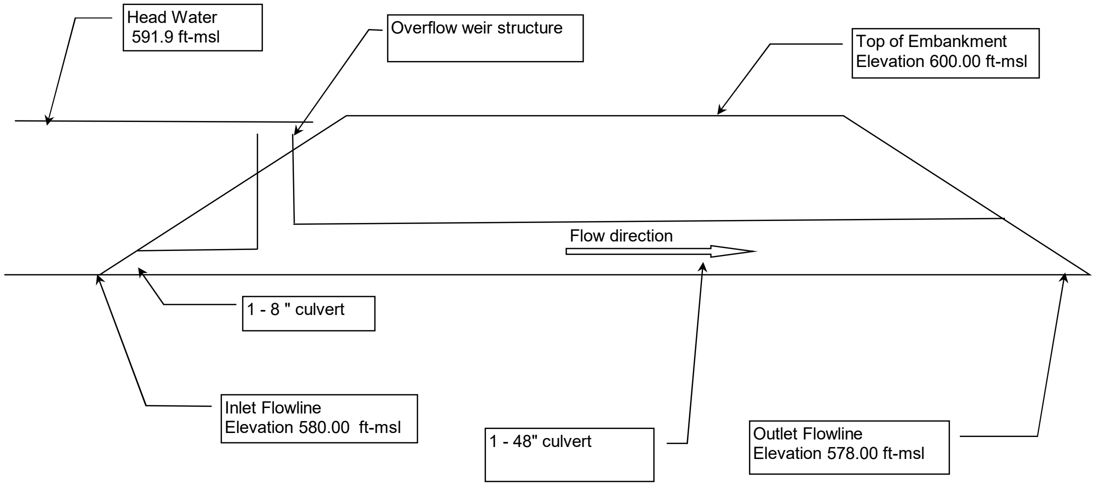
Method: Use HYDROCALC Hydraulics for Windows computer program to determine number and size of the culverts.
Use total 25-year frequency storm event flow estimated by HEC-HMS included in Appendix IIIF-A.

Existing overflow control structure pipe outlet.

Total Flow= 7.5 cfs
No. of Culverts= 1
Culvert Span= -- inches
Culvert Rise= -- inches
Culvert Diameter= 48 inches

Culvert ID	Culvert Span (ft)	Culvert Span (ft)	FHWA Chart Number	FHWA Scale Number	Culvert Diameter ^{3} (ft)	Manning's Coefficient	Entrance Loss Coefficient	Culvert Length (ft)	Downstream Invert Elevation (ft msl)	Upstream Invert Elevation (ft msl)	Flow Rate (cfs)	Tailwater Depth^2 (ft)	Headwater Inlet Control (ft)	Headwater Outlet Control (ft)	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
P1	--	--	1	1	4	0.016	0.8	150.00	578.00	580.00	7.50	0.93	1.05	0.00	0.64	0..8	0.64	0.58

1. Calculations were performed using the HYDROCALC Hydraulics for Windows program developed by Dodson and Associates (Version 2.0, 1996-2010).
2. Tailwater depth is assumed to be the 25-year, 24-hour storm normal depth in the channel downstream of the culvert.
3. The overflow control structure pipe outlet was modeled as a 48-inch culvert for calculation purposes.



Prep by: VG
Date: 5/6/2024

Chkd By: BPY/CRM
Date: 5/6/2024

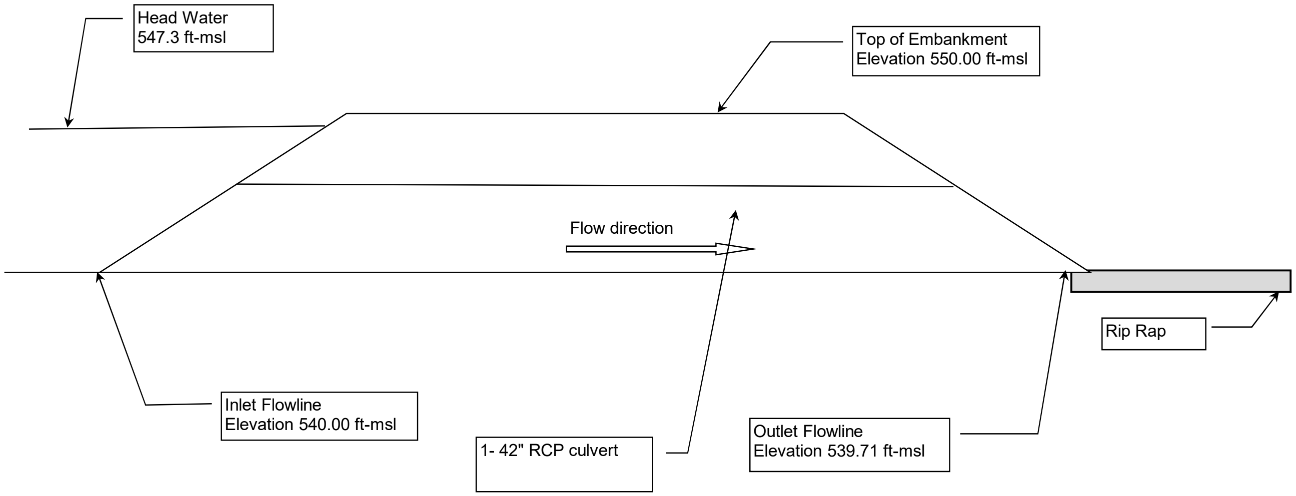
ROYAL OAKS LANDFILL
0120-076-11-106
CULVERT DESIGN

For proposed 42" RCP culvert at downstream end of P2

Total Flow=	106.9	cfs
No. of Culverts=	1	
Culvert Span=	--	inches
Culvert Rise=	--	inches
Culvert Diameter=	42	inches

Culvert ID	Culvert Span	Culvert Span (ft)	FHWA Chart Number	FHWA Scale Number	Culvert Diameter (ft)	Manning's Coefficient	Entrance Loss Coefficient	Culvert Length (ft)	Downstream Invert Elevation (ft msl)	Upstream Invert Elevation (ft msl)	Flow Rate (cfs)	Tailwater Depth[2] (ft)	Headwater Inlet Control (ft)	Headwater Outlet Control (ft)	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
P2	--	--	1	1	3.5	0.016	0.8	77.00	539.71	540.00	106.9	1.30	7.25	5.92	3.50	3.14	3.50	11.11

1. Calculations were performed using the HYDROCALC Hydraulics for Windows program developed by Dodson and Associates (Version 2.0, 1996-2010).
2. Tailwater depth is assumed to be the 25-year, 24-hour normal depth in the channel downstream of the culvert.



Prep by: VG
Date: 5/6/2024

Chkd By: BPY/CRM
Date: 5/6/2024

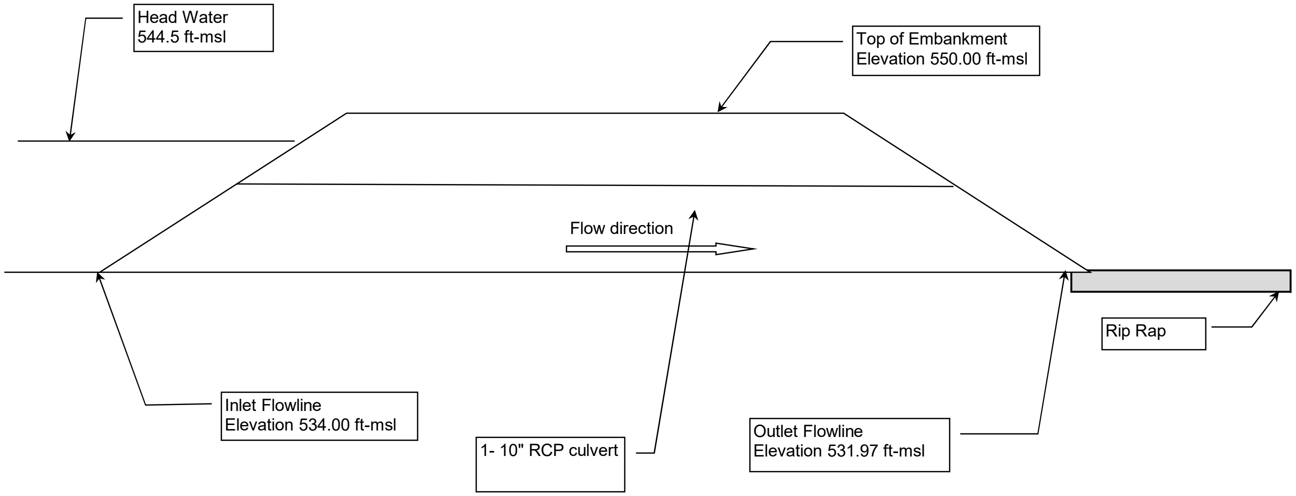
ROYAL OAKS LANDFILL
0120-076-11-106
CULVERT DESIGN

For proposed 10" RCP Culvert at downstream end of pond P3

Total Flow= 5.0 cfs
No. of Culverts= 1
Culvert Span= -- inches
Culvert Rise= -- inches
Culvert Diameter= 10 inches

Culvert ID	Culvert Span (ft)	Culvert Span (ft)	FHWA Chart Number	FHWA Scale Number	Culvert Diameter (ft)	Manning's Coefficient	Entrance Loss Coefficient	Culvert Length (ft)	Downstream Invert Elevation (ft msl)	Upstream Invert Elevation (ft msl)	Flow Rate (cfs)	Tailwater Depth[2] (ft)	Headwater Inlet Control (ft)	Headwater Outlet Control (ft)	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
P3	--	--	1	1	0.83	0.016	0.8	122.00	531.97	534.00	5.0	0.14	3.95	9.69	0.83	0.82	0.82	9.27

1. Calculations were performed using the HYDROCALC Hydraulics for Windows program developed by Dodson and Associates (Version 2.0, 1996-2010).
2. Tailwater depth is assumed to be the 25-year, 24-hour normal depth in the channel downstream of the culvert.



APPENDIX IIIF-C

FINAL COVER EROSION CONTROL STRUCTURE DESIGN

Includes pages IIIF-C-1 through IIIF-C-23

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

05/20/2024

CONTENTS

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED PROFESSIONAL ENGINEER
05/20/2024

DRAINAGE SWALE DESIGN

- The drainage swale layout is shown on Drawing IIIF.1 – Drainage Structure Plan. A swale detail is provided on Drawing IIIF.8 – Drainage Details.
- Typical Swale Design Summary:
  - Typical swale drainage areas analyzed are shown on sheet IIIF-C-3.
  - Hydraulic calculations are summarized on page IIIF-C-4.
  - Maximum normal depth is 1.45 feet (Drainage Area SW3).
  - Maximum flow velocity is 2.68 fps (Drainage Area SW3 and SW4).
  - Vegetation will be established on the swales to protect against erosion.
  - Typical swale drainage areas were selected such that all slope conditions (4% and 25%) are included in this analysis. Additionally, swales with large individual drainage areas and short and long swale lengths are included in this analysis.

ROYAL OAKS LANDFILL
0120-076-11-106
SWALE ANALYSIS

Required: Analyze swales to determine the adequacy of the swale design.

Method:

1. Determine the 25-year, 24-hour flow rates for the swale drainage areas by the Rational Method.

Reference:

1. State of Texas, Department of Transportation, Bridge Division, Hydraulic Manual, September 2019.
2. NOAA Atlas 14 - Precipitation-Frequency Atlas of the United States, Volume 11, Version 2.0: Texas (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Weather Service, 2018)

Solution:

1. Determine the 25-year intensity flow rates.

$$Q = CIA$$

Where:
C= 0.7 (runoff coefficient, Ref 1.)
I = intensity in/hr
A= drainage area, ac

From Ref. 2, for
25-year storm event

t_c is assumed to be 10 min.

I = 8.59 in/hr

Swale	Area[1] (ac)	Flow Rate (cfs)
S1	2.45	14.7
S2	1.21	7.3
S3	2.84	17.1
S4	2.70	16.2
S5	3.81	22.9
S6	2.43	14.6

[1] Swale drainage areas are shown on Sheet IIIF-C-3.

N

0 200 400
SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LIMIT OF WASTE
- E 10500 SITE GRID
- 610 EXISTING CONTOUR (SEE NOTE 1)
- 624 PROPOSED FINAL COVER CONTOUR
- DRAINAGE SWALE
- DRAINAGE LETDOWN
- CHANNEL CENTERLINE
- DRAINAGE AREA BOUNDARY
- S4 SWALE DRAINAGE AREA DESIGNATION

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.

TYPICAL SWALE DRAINAGE AREA DESIGNATION	AREA (ACRES)
S1	2.45
S2	1.21
S3	2.84
S4	2.70
S5	3.81
S6	2.43

CHARLES R. MARSH
105073
05/20/2024

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF-C\IIIF-C-3 SWALE DRNG AREAS.dwg, byoung, 1:2

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DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-C-3-SWALE DRNG AREAS.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
TYPICAL SWALE DRAINAGE AREAS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

WWW.WCGRP.COM

DRAWING IIIF-C-3

Prep By: VG
Date: 5/6/2024

ROYAL OAKS LANDFILL
0120-076-11-106
SWALE ANALYSIS

Chkd By: BPY/CRM
Date: 5/6/2024

Swale	Flow Rate (cfs)	Bottom Slope (ft/ft)	n-value	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude No.	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq. ft.)	Top Width of Flow (ft)
S1	14.7	0.005	0.03	2.0	4	0	1.37	2.61	0.557	0.11	1.48	5.63	8.22
S2	7.3	0.005	0.03	2.0	4	0	1.05	2.19	0.532	0.07	1.13	3.33	6.32
S3	17.1	0.005	0.03	2.0	4	0	1.45	2.71	0.562	0.11	1.56	6.30	8.70
S4	16.2	0.005	0.03	2.0	4	0	1.42	2.68	0.560	0.11	1.53	6.05	8.52
S5	22.9	0.005	0.03	2.0	25	0	0.91	2.05	0.537	0.07	0.97	11.15	24.54
S6	14.6	0.005	0.03	2.0	25	0	0.77	1.84	0.524	0.05	0.82	7.94	20.70

Note: Calculations were performed using the HYDROCALC HYDRAULICS program developed by Dodson and Associates (Version 2.01, 1996-2010).
Maximum flow depth is 1.45 ft < 2.0 ft (swale height).

Design is okay.

Example Calculation: Calculate the normal depth for the swale for drainage area S1 (See IIIF-C-4)

List of Symbols

Q_d = design flow rate for channel, cfs
R = hydraulic radius, ft
n = Manning's roughness coefficient
S = channel slope, ft/ft
b = bottom width of channel, ft
z_r = z-ratio (ratio of run to rise for channel sideslope) for right side slope of swale
z_l = z-ratio (ratio of run to rise for channel sideslope) for left side slope of swale
A_f = flow area, sf
g = gravitational acceleration = 32.2 ft/s^2
T = top width of flow, ft
d = normal depth of swale, ft

The program uses an iterative process to calculate the normal depth of the swale to satisfy Manning's Equation

$$Q = \frac{1.486}{n} A\, R^{0.67} S^{0.5}$$

Design Inputs:

Q_d = 14.7 cfs
S = 0.005 ft/ft
b = 0 ft
z_r = 2 (H) : 1 (V)
z_l = 4 (H) : 1 (V)
n = 0.03

Step 1 - Based on the geometry of the swale cross-section, solve for R and A_f

$$R = \frac{bd + 1/2d^2(z_r + z_l)}{b + d((z_l^2 + 1)^{0.5} + (z_r^2 + 1)^{0.5})}$$

$$A_f = bd + 1/2d^2(z_r + z_l)$$

assume: d = 1.37 ft

R = 0.65 ft

A_f = 5.63 sf

solve for Q: $Q =$ 14.7

if Q is not equal to Q_d, select a new d and repeat calculations

Step 2 - solve for velocity, T, Froude number, velocity head, and energy head

$Q = VA \Rightarrow \quad V = Q/A$

$V =$ 2.61 ft/s

$T = b + d(z_l + z_r)$

$T =$ 8.22 ft

$$F_r = \frac{V}{(gA/T)^{0.5}}$$

$F_r =$ 0.557

$$\text{Velocity Head} = \frac{V^2}{2g}$$

Velocity Head = 0.11 ft

Energy Head = water elevation + velocity head

Energy Head = 1.48 ft

DRAINAGE LETDOWN (OR CHUTE) DESIGN

Chute Design

The letdown structures are designed using gabions, FML, or Flexamat as a liner. Bedding for the gabions will be prepared subgrade soil overlain by 8 oz/sy geotextile (refer to Drawing IIIF.10). The liner materials are placed along the entire chute to protect the chute bottom and the final cover from erosion due to potential erosive velocities. Tumbling flow energy dissipators will be placed at the bottom end of the letdown structure to dissipate excess energy present in the water as it travels down the 2 and 25 percent slopes in the low-water crossings over the perimeter road.

The following design information is included in this Appendix:

- 25-year flow rates used in the chutes are presented in the HEC-HMS computer program output file, pages IIIF-A-30 to IIIF-A-90.
- Hydraulic calculations are summarized on pages IIIF-C-10 and IIIF-C-11, and the calculation procedure is provided on pages IIIF-C-12 and IIIF-C-13.
- Chute layouts and drainage areas are shown on Sheet IIIF-C-9.
- The chute energy dissipator sizing calculation procedure is provided on pages IIIF-C-14 through IIIF-C-18.
- Additional stormwater details are included on Drawings IIIF.7 through IIIF.12.

Flowrate Data

Flowrate data are the result of hydrological modeling of the drainage areas by HEC-HMS software.

Reference:

1. State of Texas, Department of Transportation, Bridge Division, Hydraulic Manual, September 2019.
2. U.S. Army Corps of Engineers, Hydrologic Engineering Center. 2021. HEC-HMS Hydrologic Modeling System, User's Manual, Version 4.10, CPD-74A. Hydrologic Engineering Center, Davis, CA.

Swale	Area[1] (ac)	Flow Rate[2] (cfs)
LD1	14.07	135.7
LD2	6.99	67.0
LD3	14.33	104.6
LD4	13.99	123.2
LD5	20.05	182.5

[1] The letdown drainage areas are shown on Drawing IIIF-C-9.

[2] Flow rates are calculated with HEC-HMS.

N

0 200 400
SCALE IN FEET

LEGEND

- ▬ · ▬ PERMIT BOUNDARY
- ▬ ▬ ▬ LIMIT OF WASTE
- E 10500 SITE GRID
- 610 EXISTING CONTOUR (SEE NOTE 1)
- 624 PROPOSED FINAL COVER CONTOUR
- DRAINAGE SWALE
- DRAINAGE LETDOWN
- CHANNEL CENTERLINE
- DRAINAGE AREA BOUNDARY
- DA4 DRAINAGE AREA DESIGNATION

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.

DRAINAGE LETDOWN DRAINAGE AREA DESIGNATION	AREA (ACRES)
DA1	14.07
DA2	6.99
DA3	14.33
DA4	13.99
DA5	20.05

CHARLES R. MARSH
105073
05/20/2024

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-C-9-LETDOWN DRNG.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
LETDOWN DRAINAGE AREAS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

WWW.WCGRP.COM

DRAWING IIIF-C-9

Prep By: VG
Date: 5/6/2024

Chkd By: BPY/CRM
Date: 5/6/2024

ROYAL OAKS LANDFILL
0120-076-11-106
CHUTE ANALYSIS
NORMAL DEPTH CALCULATIONS FOR
GABION AND FLEXAMAT-LINED CHUTES

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
SIDESLOPE (25%) AREAS													
LD1	135.7	0.25	0.04	3.0	3.0	8.0	0.88	14.52	3.050	3.28	4.15	9.35	13.27
LD2	67.0	0.25	0.04	3.0	3.0	8.0	0.59	11.59	2.889	2.09	2.68	5.78	11.55
LD3	104.6	0.25	0.04	3.0	3.0	8.0	0.76	13.37	2.988	2.78	3.54	7.82	12.36
LD4	123.2	0.25	0.04	3.0	3.0	8.0	0.83	14.08	3.024	3.08	3.91	8.75	13.00
LD5	182.5	0.25	0.04	3.0	3.0	8.0	1.04	15.87	3.111	3.91	4.95	11.50	14.21

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
LOW WATER CROSSING (2%) AREAS													
LD1	135.7	0.02	0.04	8.0	8.0	16.0	1.15	4.67	0.897	0.34	1.49	29.03	34.42
LD2	67.0	0.02	0.04	8.0	8.0	8.0	1.02	4.05	0.867	0.25	1.28	16.54	24.36
LD3	104.6	0.02	0.04	8.0	8.0	12.0	1.12	4.46	0.887	0.31	1.43	23.48	29.92
LD4	123.2	0.02	0.04	8.0	8.0	14.0	1.15	4.61	0.894	0.33	1.48	26.75	32.43
LD5	182.5	0.02	0.04	8.0	8.0	20.0	1.23	4.97	0.911	0.38	1.61	36.73	39.69

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010).

Prep By: VG
Date: 5/6/2024

Chkd By: BPY/CRM
Date: 5/6/2024

ROYAL OAKS LANDFILL
0120-076-11-106
CHUTE ANALYSIS
NORMAL DEPTH CALCULATIONS FOR
FML-LINED CHUTES

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
SIDESLOPE (25%) AREAS													
LD1	135.7	0.25	0.01	2.0	2.0	8.0	0.41	38.00	10.996	22.44	22.84	3.57	9.62
LD2	67.0	0.25	0.01	2.0	2.0	8.0	0.27	29.36	10.320	13.40	13.67	2.28	9.07
LD3	104.6	0.25	0.01	2.0	2.0	8.0	0.35	34.55	10.728	18.55	18.90	3.03	9.39
LD4	123.2	0.25	0.01	2.0	2.0	8.0	0.38	36.72	10.909	20.95	21.33	3.36	9.53
LD5	182.5	0.25	0.01	2.0	2.0	8.0	0.48	42.17	11.262	27.64	28.12	4.33	9.93

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
LOW WATER CROSSING (2%) AREAS													
LD1	135.7	0.02	0.04	8.0	8.0	16.0	1.15	4.67	0.897	0.34	1.49	29.03	34.42
LD2	67.0	0.02	0.04	8.0	8.0	8.0	1.02	4.05	0.867	0.25	1.28	16.54	24.36
LD3	104.6	0.02	0.04	8.0	8.0	12.0	1.12	4.46	0.887	0.31	1.43	23.48	29.92
LD4	123.2	0.02	0.04	8.0	8.0	14.0	1.15	4.61	0.894	0.33	1.48	26.75	32.43
LD5	182.5	0.02	0.04	8.0	8.0	20.0	1.23	4.97	0.911	0.38	1.61	36.73	39.69

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010).

ROYAL OAKS LANDFILL
0120-076-11-106
CHUTE ANALYSIS
EXAMPLE CALCULATION FOR
GABION-LINED CHUTES

Example Calculation: Calculate the normal depth for the chute for the 25% slope portion of drainage area LD1.

List of Symbols

Q_d = design flow rate for channel, cfs
R = hydraulic radius, ft
n = Manning's roughness coefficient
S = channel slope, ft/ft
b = bottom width of channel, ft
z = z-ratio (ratio of run to rise for channel sideslope)
A_f = flow area, sf
g = gravitational acceleration = 32.2 ft/s^2
T = top width of flow, ft
d = normal depth of chute, ft

The program uses an iterative process to calculate the normal depth of the chute to satisfy Manning's Equation

$$Q = \frac{1.486}{n} A\ R^{0.67}\ S^{0.5}$$

Design Inputs:

Q_d = 135.7 cfs
S = 0.25 ft/ft
b = 8 ft
z = 3 (H) : 1 (V)
n = 0.04

Step 1 - Based on the geometry of the chute cross-section, solve for R and A_f

$$R = \frac{bd + zd^2}{b + 2d(z^2 + 1)^{0.5}}$$

$$A_f = bd + zd^2$$

assume: d = 0.88 ft

R = 0.690 ft

A_f = 9.35 sf

solve for Q: Q = 135.7 cfs

if Q is not equal to Q_d, select a new d and repeat calculations

ROYAL OAKS LANDFILL
0120-076-11-106
CHUTE ANALYSIS
EXAMPLE CALCULATION FOR
GABION-LINED CHUTES

Step 2 - solve for velocity, T, Froude number, velocity head, and energy head

$Q = VA \Rightarrow \quad V = Q/A$

$V = 14.52$ ft/s

$T = b + 2(z \times d)$

$T = 13.27$ ft

$$F_r = \frac{V}{(gA/T)^{0.5}}$$

$F_r = 3.050$

$$\text{Velocity Head} = \frac{V^2}{2g}$$

Velocity Head = 3.28 ft

Energy Head = water elevation + velocity head

Energy Head = 3.28 ft

Required: Determine the hydraulic properties for the grouted ripraps as energy letdown structures (chutes).

Method:

1. Calculate the design flow rate of the chute section.
2. Estimate the normal and flow velocity from Hydrocalc using calculated design flow rate.
3. Calculate the critical depth and critical flow velocity.
4. Calculate the height of the roughness element and spacing between the rows of the roughness elements.
5. Calculate the total length of roughness elements.

References:

1. Henry M. Morris, *Hydraulic Dissipation in Steep, Rough Channels* , Bulletin19, Research Division, Virginia Polytechnic Institute, 1968.
2. "Open Channel Hydraulics" by V.T. Chow.
3. "Hydraulic Design of Energy Dissipators for Culverts and Channels", FHWA Hydraulics Engineering Circular Number 14, Third Edition.
4. "Hydraulic Considerations for Corrugated Plastic Pipes" Plastic Pipe Institute.
5. "Reclamation Managing Water in the West" Erosion and Sedimentation Manual. US Department of the Interior Bureau of Reclamation, November 2006.
6. Fort Bend County, Texas, Drainage District "Drainage Criteria Manual", 2nd Revision, February, 2011. Interim Atlas 14 Drainage Criteria Manual and Minimum Slab Elevation Criteria December, 2019.

Solution:

The design of energy dissipators for the 25 percent sideslope is based on tumbling flow in the chute. Tumbling flow consists of a series of hydraulic jumps on overfalls that maintain the critical velocity in the chute.

1. For Chute LD1 (For the Upper Portion of a FML Chute):

1.A Design flow rates for energy dissipation.

According to the definition of the unit flow rate,

q = Q/b

Where:
Q = Design flow rate for channel, cfs
b = Bottom width of chute, ft
q = Unit flowrate, cfs/ft of chute width

Q =	135.7	cfs
b =	8	ft
q =	16.47	cfs/ft

1.B. Estimate the normal depth and flow velocity from Hydrocalc using the design flow rate and appropriate Manning's coefficient.

Where:
n = Manning's roughness coefficient
S = channel slope, ft/ft
b = Width of the channel, ft
z = z-ratio (ratio of run to rise for channel sideslope) for side slope
d = Normal Depth of the channel
v = Flow Velocity in the channel

Q =	135.7	cfs
n =	0.01	
S =	0.25	ft/ft
z =	2	ft/ft
b =	8	ft

From Hydrocalc

d =	0.41	ft
v =	38.00	ft/sec

1.C For Chute LD1 (For the Lower Portion of the Chute):

Design flow rates for energy dissipation.

According to the definition of the unit flow rate,

q = Q/b

Where:
Q = Design flow rate for channel, cfs
b = Bottom width of chute, ft
q = Unit flowrate, cfs/ft of chute width

Q = 135.7 cfs
b = 16 ft

q = 8.48 cfs/ft

2. Estimate the normal and flow velocity due to the roughness elements from Hydrocalc using flow rate and appropriately adjusted Manning's coefficient.

The roughness coefficient can be calculated from Equation 5-12 from Reference 2

n= $(n_0+n_1+n_2+n_3+n_4)\ m_5$ (Equation 5-12, Reference 2)

Where:
n_0 basic n value for straight, uniform, smooth channel based on material = 0.025 (Reference 2, Page 111, Table 5-6)
n_1 value added for surface irregularities = 0.01 (Reference 2, Page 109, Table 5-5)
n_2 value added for variation in channel cross section= 0.0 (Reference 2, Page 109, Table 5-5)
n_3 value added for obstructions = 0.015 (Reference 2, Page 109, Table 5-5)
n_4 value added for vegetation and flow conditions = 0.001 (Reference 2, Page 109, Table 5-5)
m_5 correction factor for meandering of channel =1.0 (Reference 2, Page 109, Table 5-5)

n = (0.025+0.01+0.0+0.015+0.001)*1.0
n = 0.055

Therefore:
Q = 135.7 cfs
n = 0.055
S = 0.25 ft/ft
z = 3 ft/ft
b = 16 ft

From Hydrocalc

d = 0.74 ft
v = 10.13 ft/sec

3. Calculate the critical depth and critical flow velocity.

Y_c $= (q2/g)^{1/3}$ (Reference 3, Equation 7.1)
V_c $= (gq)^{1/3}$ (Reference 3)

Where:
Y_c = Critical depth, ft
q = Unit flowrate, cfs/ft of channel width
g = Acceleration due to gravity = 32.2 ft/s^2
V_c = Critical velocity, ft/s

q = 8.48 cfs

Y_c = 1.31 ft
V_c = 6.49 ft/s

4. Calculate the height of the roughness element and spacing between the rows of the roughness elements.

h = Y_c/((3-3.7S)^(2/3)) (Reference 3, Equation 7.2)

Where: Y_c = Critical depth, ft
S = Channel slope, ft/ft
h = Element height, ft

S = 0.25 ft/ft

h = 0.80 ft
h = 9.6 in

$h_{provided}$ = 12.0 in

$h_{provided}$ > h, so the design is adequate.

5. Calculate the total length of roughness elements.

L = 9.25*h (Reference 3)

Where: L = Spacing between the roughness elements, ft
h = Element height, ft
L_{Total} = Total length of roughened section, ft

L = 7.43 ft

The spacing and height of the roughness elements are designed based on 5 rows of roughness elements. (Reference 3)

$L_{total\ (recommended)}$ = L5

$L_{total\ (recommended)}$ = 37.1

$L_{total(provided)}$ = 40.00 ft

$L_{total(provided)} \geq L_{total\ (recommended)}$, so the design is adequate.

The following table summarizes the calculations for gabion and flexmat chutes.

Upper Portion of Chutes

Chute	[1]Q	W_{Design}	q	n-value	Bottom Slope	Side Slope	Normal Depth	Flow Velocity
	(cfs)	(ft)	(cfs/ft)		(ft/ft)	(ft/ft)	(ft)	(ft/sec)
LD1	135.7	8	16.96	0.04	0.25	4	0.85	13.92
LD2	67.0	8	8.38	0.04	0.25	4	0.58	11.20
LD3	104.6	8	13.08	0.04	0.25	4	0.74	12.86
LD4	123.2	8	15.40	0.04	0.25	4	0.81	13.53
LD5	182.5	8	22.81	0.04	0.25	4	1.04	15.87

Lower Portion of Chutes

Chute	[1]Q	W_{Design}	q	n-value	Bottom Slope	Side Slope	Normal Depth	Flow Velocity	Y_c	V_c	h	L (=9.25h)	h_{Design}	[2]L_{Total} (Recommended)	$W_{Provided}$	$h_{Provided}$	L_{Total} (Provided)
	(cfs)	(ft)	(cfs/ft)		(ft/ft)	(ft/ft)	(ft)	(ft/sec)	(ft)	(fps)	(ft)	(ft)	(in)	(ft)	(ft)	(in)	(ft)
LD1	135.7	16	8.48	0.055	0.25	3	0.74	10.13	1.30	6.49	0.80	7.4	9.6	37.1	16	12.0	40.0
LD2	67.0	8	8.38	0.055	0.25	3	0.70	9.29	1.29	6.46	0.79	7.4	9.5	36.8	8	12.0	40.0
LD3	104.6	12	8.72	0.055	0.25	3	0.75	10.03	1.33	6.55	0.82	7.5	9.8	37.7	12	12.0	40.0
LD4	123.2	14	8.80	0.055	0.25	3	0.76	10.20	1.34	6.57	0.82	7.6	9.9	38.0	14	12.0	40.0
LD5	182.5	20	9.13	0.055	0.25	3	0.77	10.59	1.37	6.65	0.84	7.8	10.1	38.9	20	12.0	40.0

1. The flowrates were reproduced from Appendix IIIF-A.
2. Total length of the roughened section was calculated based on FHWA recommendation of 5 rows of roughened elements.

The following table summarizes the calculations for FML chutes.

Upper Portion of Chutes

Chute	[1]Q	W_{Design}	q	n-value	Bottom Slope	Side Slope	Normal Depth	Flow Velocity
	(cfs)	(ft)	(cfs/ft)		(ft/ft)	(ft/ft)	(ft)	(ft/sec)
LD1	135.7	8	16.96	0.01	0.25	2	0.41	38.00
LD2	67.0	8	8.38	0.01	0.25	2	0.27	29.36
LD3	104.6	8	13.08	0.01	0.25	2	0.35	34.55
LD4	123.2	8	15.40	0.01	0.25	2	0.38	36.72
LD5	182.5	8	22.81	0.01	0.25	2	0.48	42.17

Lower Portion of Chutes

Chute	[1]Q	W_{Design}	q	n-value	Bottom Slope	Side Slope	Normal Depth	Flow Velocity	Y_c	V_c	h	L (=9.25h)	h_{Design}	[2]L_{Total} (Recommended)	$W_{Provided}$	$h_{Provided}$	L_{Total} (Provided)
	(cfs)	(ft)	(cfs/ft)		(ft/ft)	(ft/ft)	(ft)	(ft/sec)	(ft)	(fps)	(ft)	(ft)	(in)	(ft)	(ft)	(in)	(ft)
LD1	135.7	16	8.48	0.055	0.25	3	0.74	10.13	1.30	6.49	0.80	7.4	9.6	37.1	16	12.0	40.0
LD2	67.0	8	8.38	0.055	0.25	3	0.7	9.29	1.29	6.46	0.79	7.4	9.5	36.8	8	12.0	40.0
LD3	104.6	12	8.72	0.055	0.25	3	0.75	10.03	1.33	6.55	0.82	7.5	9.8	37.7	12	12.0	40.0
LD4	123.2	14	8.80	0.055	0.25	3	0.76	10.2	1.34	6.57	0.82	7.6	9.9	38.0	14	12.0	40.0
LD5	182.5	20	9.13	0.055	0.25	3	0.77	10.59	1.37	6.65	0.84	7.8	10.1	38.9	20	12.0	40.0

1. The flowrates were reproduced from Appendix IIIF-A.
2. Total length of the roughened section was calculated based on FHWA recommendation of 5 rows of roughened elements.

ROYAL OAKS LANDFILL
0120-076-11-106
FML-LINED CHUTE ANCHOR TRENCH DESIGN
25-YEAR, 24 HOUR STORM

Required: Provide topslope and sideslope anchor trench design for a geomembrane-lined letdown structure (or chute).

Method:

1. Design anchor trench spacing and depths.
2. Design upstream end anchor trench.

Assumptions:

1. The geomembrane-lined chute will transition to its maximum width for the energy dissipater design where maximum total flow for chute is expected to occur.
2. Proposed chutes will convey runoff from the following chute drainage area:

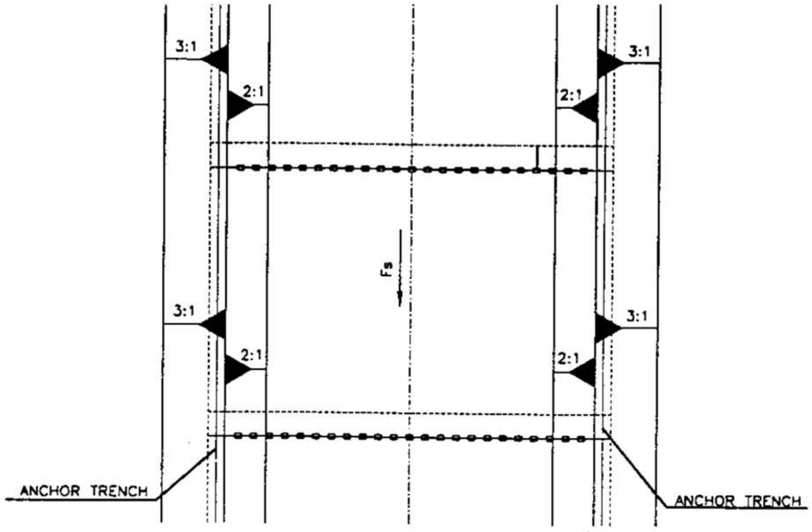
Proposed Chute	Chute Drainage Areas	25-year Total Flow (cfs)[1]
1	LD1	135.7
2	LD2	67.0
3	LD3	104.6
4	LD4	123.2
5	LD5	182.5

[1] From HEC-HMS Analysis, Appendix IIIF-A

References:

1. Gamelsky, S.G., *Innovations in Stormwater Management for Landfill Closure* Technical Paper
2. Koerner, R.M., *Designing with Geosynthetics* , 5th Edition, Prentice-Hall, Inc, 2005.
3. Morris, H.M., *Hydraulics of Energy Dissipators in Steep Rough Channels* , Bulletin 19, Research Division, Virginia Polytechnic Institute, Blacksburg, Virginia.

Design anchor trench spacing and depths.



Shear force pulling on geomembrane due to water:

The shear force acting on the geomembrane per square foot of water in the chute:

$T = \gamma_w \times D \times S$ where:

γ_w = unit weight of water (lb/cf)
D = maximum water depth (ft)
S = hydraulic gradient (ft/ft)

Shear force acting on the geomembrane per foot of anchor trench:

$F_{s1} = T \times P$

where:

P = wetted perimeter of the chute = $(W + 2 \times (a^2+D^2)^{1/2})$
a = h x D = horizontal distance from bottom of chute to the depth submerged on the sideslopes
h = Slope of sidewalls = 2 (H) : 1 (V)
W = Minimum bottom width of flow = 8 ft

Conservatively, the maximum calculated water depth in the chutes will be used to verify the design. Thus, the water depth in the narrowest part of the chute with the highest depth will be used.

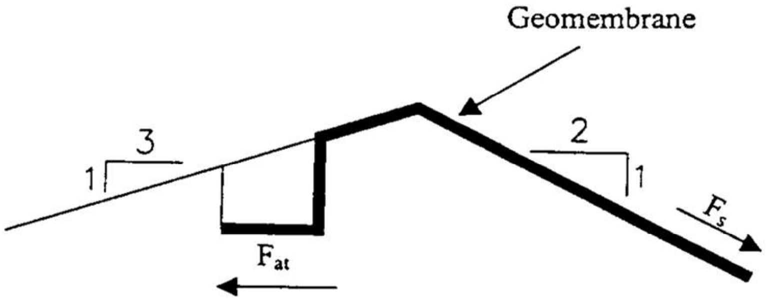
ROYAL OAKS LANDFILL
0120-076-11-106
FML-LINED CHUTE ANCHOR TRENCH DESIGN
25-YEAR, 24 HOUR STORM

Letdown	Maximum Water Depth (ft)[1]	Hydraulic Gradient (ft/ft)	T (lb/sf)	a (ft)	F_{s1} (lb/ft)
LD1	0.41	0.25	6.40	0.82	63
LD2	0.27	0.25	4.21	0.54	39
LD3	0.35	0.25	5.46	0.7	52
LD4	0.39	0.25	6.08	0.78	59
LD5	0.48	0.25	7.49	0.96	76

1 See design depths on page IIIF-C-11.

Pullout Resistance from Edges, F_{at1} [2]

Assuming pullout only opposed by trench (conservative assumption)



$$F_{at} = 2[\{K_o\gamma(D/2)\}\{\tan\zeta\}\{D\} + \{\gamma D\}\{\tan\zeta\}\{w\}] \quad \text{(Ref 3)}$$

where:
ζ = interface friction angle
K_o = 1 - sin ζ
γ = unit weight of soil (lb/cf)
D = depth of anchor trench (ft)
w = bottom width of anchor trench (ft)

soil friction angle =	16	degrees
soil/geomembrane friction angle =	18.2	degrees
unit weight =	112	lb/ft^3
depth of anchor trench =	1	ft
bottom width of anchor trench =	1	ft

[2] See detail D22 - Anchor Trench Type 2 on Drawing IIIF-8 for dimensions.

$K_o =$ 0.72

$F_{at1} =$ 87 lb/ft width on one side

Factor of Safety = $2F_{at1}/F_{s1} = \frac{175}{76}$ FS = 2.3

3. Upstream End Anchor Trench Design

Shear force pulling on geomembrane due to water:

$F_{s2} = T \times A$

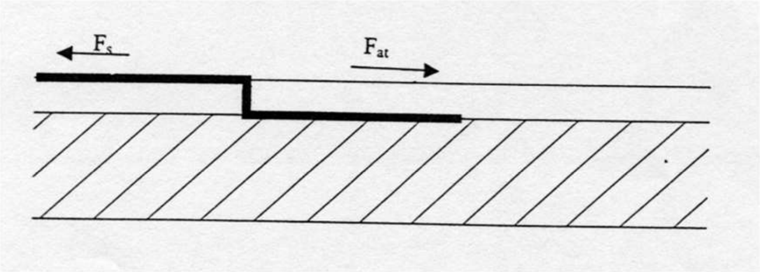
where:
T = Maximum shear force acting on the geomembrane per square foot of water in the chute (lb/sf)
A = area of geomembrane at the top of the chute (ft^2)

Area of geomembrane at top of chute = 116 ft x 17 ft = 1,972 sf

Conservatively, use the maximum shear force per square foot calculated in Part 2

$F_{s2} =$ 14,766 lbs

Pullout resistance of upstream end, F_{at2} [3]



$F_{at} = 2[\{K_o\gamma(D/2)\}\{\tan\zeta\}\{D\} + \{\gamma D\}\{\tan\zeta\}\{w\}]$ (Ref 3)

where:
ζ = interface friction angle
K_o = 1 - sin ζ
γ = unit weight of soil (lb/cf)
D = depth of anchor trench (ft)
w = bottom width of anchor trench (ft)

FML-LINED CHUTE ANCHOR TRENCH DESIGN
25-YEAR, 24 HOUR STORM

friction angle = 18.2 degrees
anchor trench soil unit weight = 112 lb/ft^3
depth of anchor trench = 0.5 ft
bottom width of anchor trench = 3 ft

K_o = 0.69

F_{at2}= 117 lb/ft width

Total End Anchor Length (L_T) ^{4} = 150 ft

F_{pr} = Pullout Resistance (End) = F_{at2} x L_T = 17,520 lbs

Factor of Safety = F_{pr}/F_{s2} = $\frac{17,520}{14,766}$ FS = 1.2

Summary of Results

Side Anchor Trench Pullout resistance:

FS = $\frac{2F_{AT2}}{F_{S1}}$ ==> FS = 2.3

Upstream End Anchor Trench Pullout resistance:

FS = $\frac{F_{pr}}{F_{s2}}$ ==> FS = 1.2

As it is stated on page 557 of Reference 4, the typical factors of safety for the proposed anchor trenches are between 0.7 to 5.0. Therefore, the design is acceptable.

APPENDIX IIIF-D

EROSION LAYER EVALUATION

Includes pages IIIF-D-1 through IIIF-D-33

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED PROFESSIONAL ENGINEER

05/20/2024

EROSION LAYER EVALUATION

This appendix presents the supporting documentation for evaluation of the thickness of the erosion layer for the final cover system at the Royal Oaks Landfill. The evaluation is based on the premise of adding excess soil to increase the time required before maintenance is needed as recommended in the EPA Solid Waste Disposal Facility Criteria Technical Manual (EPA 530-R-93-017, November 1993).

The design procedure is as follows:

1. Minimum thickness of the erosion layer at the end of the 30-year postclosure period is evaluated based on the depth of frost penetration or 6 inches, whichever is greater. For Cherokee County, the approximate depth of frost penetration is approximately 6 inches (see IIIF-D-18). Therefore, the minimum erosion layer thickness is 6 inches.

2. Soil loss is calculated using the Universal Soil Loss Equation (USLE) by following SCS procedures. The soil loss is adjusted by a safety factor of 2 and is then converted to a thickness. The thickness of the soil loss over a 30-year postclosure period is added to the minimum thickness of the erosion layer (from Step 1) to yield an initial thickness to be placed at closure of the site. According to the USLE, the typical 4 percent topslope and 25 percent side slope require a minimum of 6.033 inches and 6.500 inches, respectively, for the erosion layer. These USLE requirements include the 6-inch minimum required by regulations. Conservatively, a 12-inch erosion layer is proposed over final cover. These calculations begin on page IIIF-D-3.

3. Stormwater flows over the final cover system by (1) sheet flow over the topslope and sideslopes and (2) channelized flow in the drainage berms (or swales). As discussed in Section 2.2 and Appendix IIIF-C, flow also occurs in the letdown structures. The letdown structures are lined to prevent erosion given that the velocities in the letdowns are over 5 ft/sec.

   Sheet flow velocities for the topslope and sideslope cases for a 25-year storm event are calculated to be less than permissible nonerosive velocities. A permissible nonerosive velocity is defined as 5.0 ft/sec or less. Calculated sheet flow velocities range from 0.84 to 1.50 ft/sec for topslope and sideslope cases. The supporting calculations are presented on pages IIIF-D-22 through IIIF-D-24.

Channelized flow for drainage swales is also calculated to be less than permissible nonerosive velocities. The maximum calculated channelized flow velocity is 2.68 ft/sec for the drainage swales. The supporting calculations are presented on pages IIIF-C-2 through IIIF-C-6.

4. Vegetation for the site will be native and introduced grasses with root depths of 6 inches to 8 inches. The erosion layer shall also include a mixture of Bermuda, vetch, rye, wheat grass, wild flowers, and flowering plants. The seeding is specified on the attached pages IIIF-D-27 through IIIF-D-33. The seeding is specified by TxDOT for temporary and permanent erosion control for Cherokee County, Texas (Tyler).

5. Native and introduced grasses will be hydroseeded with fertilizer on the disked (parallel to contours) erosion layer upon final grading. Temporary cold weather vegetation will be established if needed. Irrigation will be employed for 6 to 8 weeks or until vegetation is well established. Erosion control measures such as silt fences and straw bales will be used to minimize erosion until the vegetation is established. Areas that experience erosion or do not readily vegetate after hydroseeding will be reseeded until vegetation is established or the soil will be replaced with soil that will support the grasses.

6. Slope stability information is included in Appendix IIIJ.

ROYAL OAKS LANDFILL
0120-076-11-106
EROSION LAYER EVALUATION

Required: Determine expected soil loss and minimum thickness for the erosion layer.

Method: Expected soil loss is calculated using the Universal Soil Loss Equation. Minimum erosion layer thickness is determined by adding the minimum thickness allowed by TCEQ to the expected soil loss.

References:

1. SCS National Engineering Handbook, Chapter 3 - Erosion.
2. TNRCC, *Use of the USLE in Final Cover/Configuration Design* , 1993.
3. United States Department of Agriculture, National Resource Conservation Service, Web Soil Survey for Cherokee County, Texas (http://websoilsurvey.nrcs.usda.gov).
4. United States Environmental Protection Agency, *Solid Waste Disposal Facility Criteria Technical Manual* , 1993.

Solution: 1. Soil Loss Equation: $A=RKL_SCP$

Where:

A= Soil loss (tons/ac/yr)
R= Rainfall factor
K= Soil erodibility factor
L_S= Slope length/slope gradient factor
C= Plant cover or cropping management factor
P= Erosion practice factor

The rainfall factor, R, represents the average intensity for the maximum intensity, 30 minute storms over a 22 year period of record compiled by the SCS. Using Figure 1 (Ref 1), Average Annual Values of the R Factor, the R factor for Cherokee County is:

R = 370

K based on values from TNRCC Use of Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural handbook, 1993, for combination sandy clay, silty clay loam with 2 percent organic matter (from Ref 2, p.10)

K = 0.2

The slope length/slope gradient factor, L_s, represents the erosion of the soil due to both slope length and degree of slope. The slopes of interest are the typical side slope and top slope conditions.
See sheet IIIF-D-7 for the locations of the slopes analyzed.

Case 1.	Typical Top Slope			Case 2.	Longest Top Slope		
	slope =	4	%		slope =	4	%
	length =	150	ft		length =	180	ft
Case 3.	Typical Side Slope			Case 4.	Longest Side Slope		
	slope =	25	%		slope =	25	%
	length =	120	ft		length =	160	ft

Case	Slope		
	Slope	Length	L_s
	(%)	(ft)	
1. Typical Top Slope	4	150	0.47
2. Longest Top Slope	4	180	0.50
3. Typical Side Slope	25	120	6.50
4. Longest Side Slope	25	160	7.50

The plant cover or 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. C Factor for Permanent Pasture, Range, and Idle Land with No Appreciable Canopy has the following relation with percent ground cover (GC) (from Ref 3, p.11) .

% GC	C Factor
0	0.45
20	0.2
40	0.1
60	0.042
80	0.013
95	0.0030

[1] Linear Interpolation was utlized for % GC between reported values.

C Factor = 0.0030 (For 95% Ground Cover)

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. Contouring for this site will be done only to establish vegetation.

P = 1.00

2 Slope Condition Soil loss calculations

	R	K	L_s	C	P	A (tons/ac/yr)
1. Typical Top Slope 4% slope 150 ft length	370	0.2	0.47	0.0030	1.00	0.10
2. Longest Top Slope 4% slope 180 ft length	370	0.2	0.50	0.0030	1.00	0.11
3. Typical Side Slope 25% slope 120 ft length	370	0.2	6.50	0.0030	1.00	1.44
4. Longest Side Slope 25% slope 160 ft length	370	0.2	7.50	0.0030	1.00	1.67

3. Note: Erosion layer will be maintained to provide 95% ground cover.

Erosion layer thickness calculations:

$$T_{el} = 6in + \frac{AYF(2000lb/ton)(12in/ft)}{w(43{,}560sf/ac)}$$

Where:
T_{el} = Erosion layer thickness
A = Soil loss (ton/ac/yr)
Y = Postclosure period (yr)
F = Factor of Safety
w = Specific weight of soil (pcf)

Y = 30 yr
F = 2
w = 110 pcf

1. Typical 4% Top Slope Thickness:		
T_{el}, Required thickness[1] =	6.031	in
Total estimated soil loss =	0.031	in
Specified thickness =	12.000	in
2. Longest 4% Top Slope Thickness:		
T_{el}, Required thickness[1] =	6.033	in
Total estimated soil loss =	0.033	in
Specified thickness =	12.000	in
3. Typical 25% Side Slope Thickness:		
T_{el}, Required thickness[1] =	6.434	in
Total estimated soil loss =	0.434	in
Specified thickness =	12.000	in
4. Longest 25% Side Slope Thickness:		
T_{el}, Required thickness[1] =	6.500	in
Total estimated soil loss =	0.500	in
Specified thickness =	12.000	in

4. Note: [1]Required thicknesses include 6 inch minimum required and estimated soil loss.

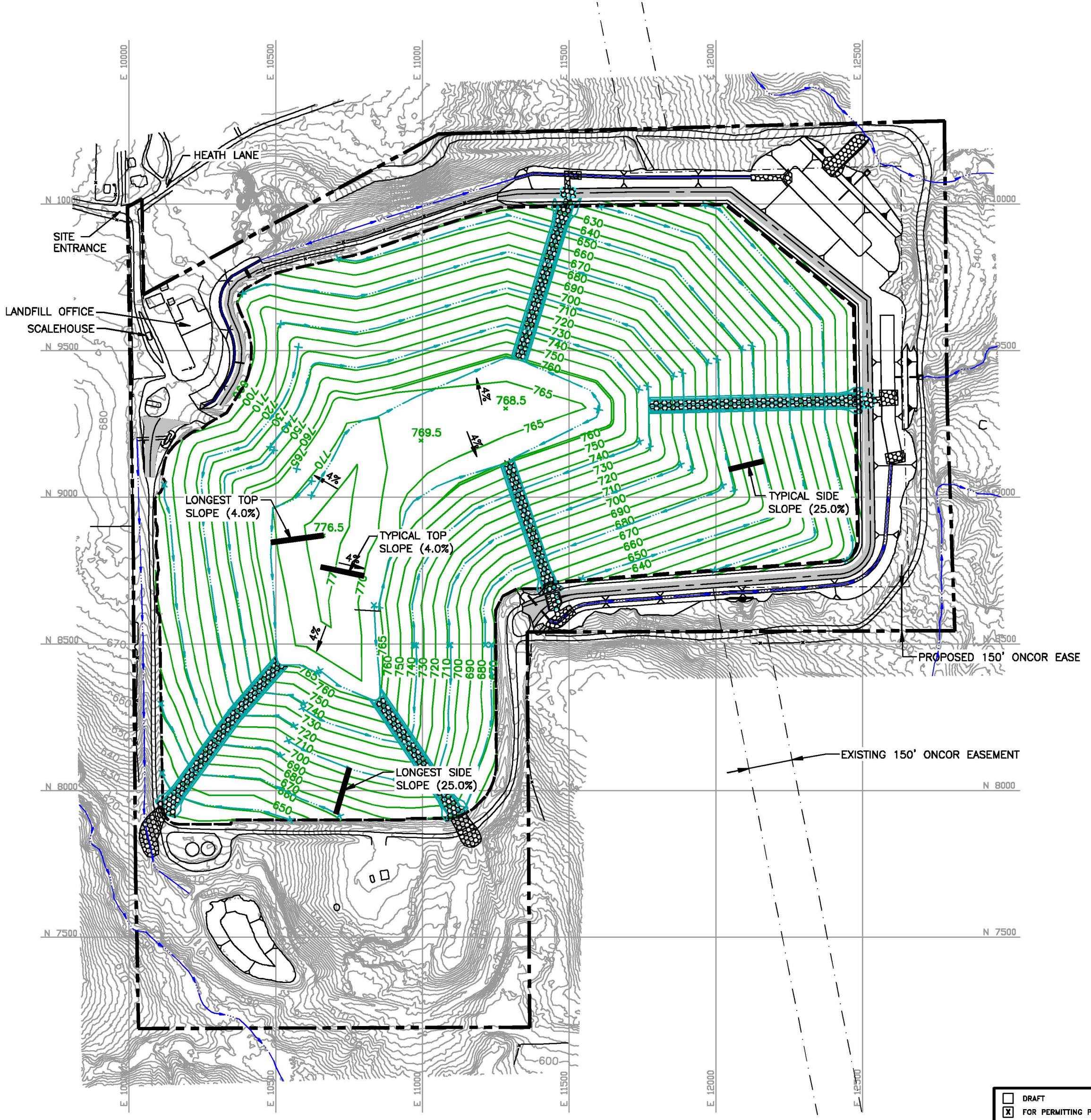
Summary:

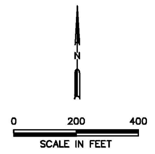
Calculated erosion losses are shown in Step 2 above.
The erosion layer will be a minimum of 12 inches thick.
As shown above, this is a conservative design considering
the maximum expected soil loss for a 30 year period is 0.500 inches.

ROYAL OAKS LANDFILL
0120-076-11-106
EROSION LAYER EVALUATION

SOIL LOSS ESTIMATE SUMMARY TABLE

Case	Slope (%)	Length (ft)	L_s	Percent Ground Cover	C Factor	A (tons/ac/yr)
Typical Top Slope	4	150	0.47	60	0.042	1.5
Typical Top Slope	4	150	0.47	70	0.028	1.0
Typical Top Slope	4	150	0.47	80	0.013	0.5
Typical Top Slope	4	150	0.47	95	0.0030	0.1
Longest Top Slope	4	180	0.50	60	0.042	1.6
Longest Top Slope	4	180	0.50	70	0.028	1.0
Longest Top Slope	4	180	0.50	80	0.013	0.5
Longest Top Slope	4	180	0.50	95	0.0030	0.1
Typical Side Slope	25	120	6.50	60	0.042	20.2
Typical Side Slope	25	120	6.50	70	0.028	13.2
Typical Side Slope	25	120	6.50	80	0.013	6.3
Typical Side Slope	25	120	6.50	95	0.0030	1.4
Longest Side Slope	25	160	7.50	60	0.042	23.3
Longest Side Slope	25	160	7.50	70	0.028	15.3
Longest Side Slope	25	160	7.50	80	0.013	7.2
Longest Side Slope	25	160	7.50	95	0.0030	1.7





LEGEND

▬ · ▬	PERMIT BOUNDARY
▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PROPOSED FINAL COVER CONTOUR
→	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
→	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.
2. TYPICAL SIDESLOPES ARE (25%). TYPICAL TOPSLOPE IS 4:1 (4%).

CHARLES R. MARSH
105073
05/20/2024

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-D-7-SLOPE LENGTH.DWG

DRAWN BY: JDW
DESIGN BY: SAB
REVIEWED BY: KDG

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT EROSION LAYER EVALUATION TYPICAL SLOPE LENGTHS

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

WWW.WCGRP.COM

DRAWING IIIF-D-7

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF-D\IIIF-D-7 SLOPE LENGTHS.dwg, byoung, 1:2

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

USE OF THE UNIVERSAL SOIL LOSS EQUATION IN FINAL COVER/CONFIGURATION DESIGN

PROCEDURAL HANDBOOK

PERMITS SECTION
MUNICIPAL SOLID WASTE DIVISION

OCTOBER 1993

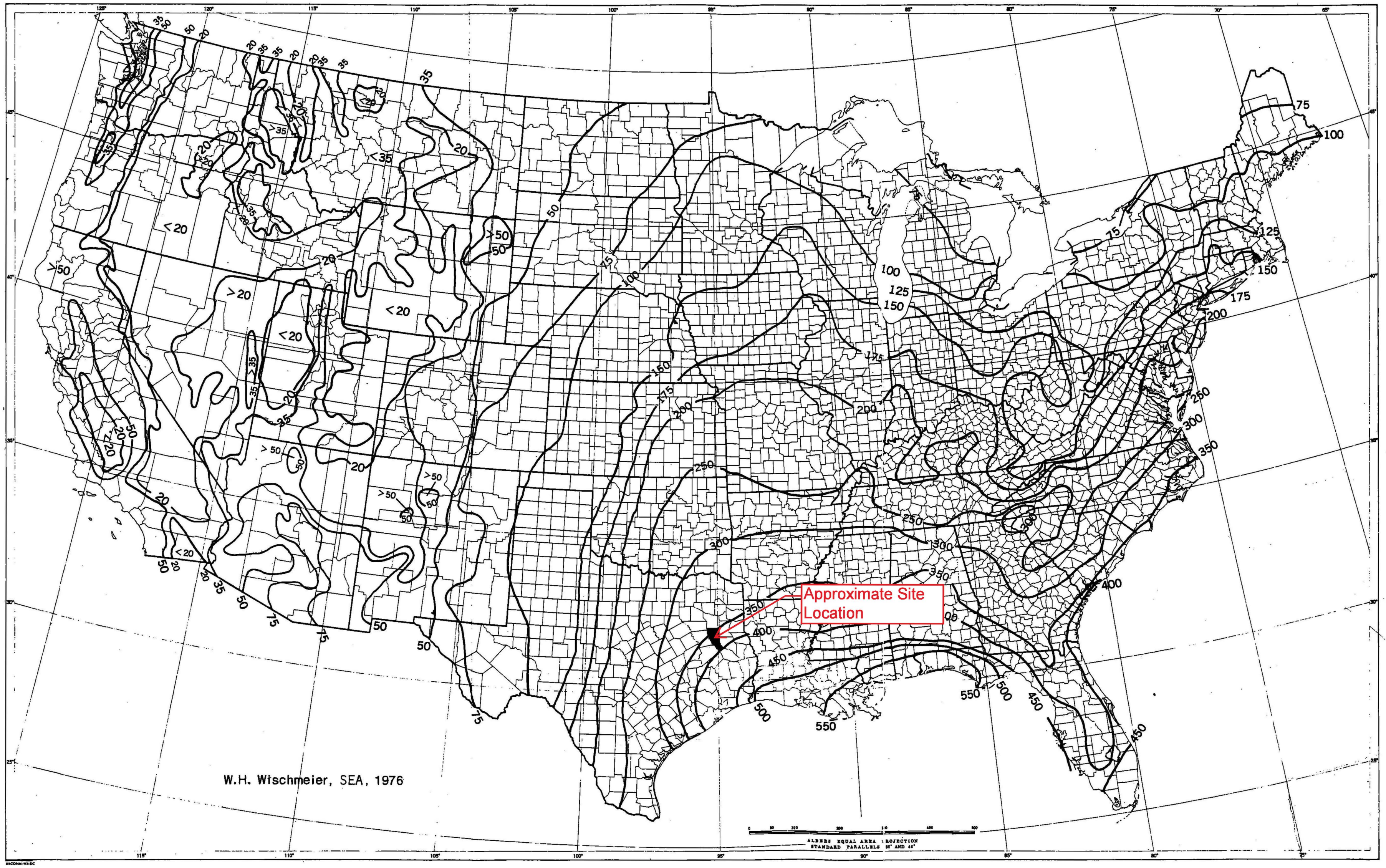


FIGURE 1.—Average annual values of the rainfall erosion index.

Table 1 Approximate Values of Factor K for USDA Textural Classes

Texture Class	Organic Matter Content		
	<0.5%	2%	4%
	K	K	K
Sand	0.05	0.03	0.02
Fine Sand	0.16	0.14	0.10
Very Fine Sand	0.42	0.36	0.28
Loamy Sand	0.12	0.10	0.08
Loamy Fine Sand	0.24	0.20	0.16
Loamy Very Fine Sand	0.44	0.38	0.30
Sandy Loam	0.27	0.24	0.19
Fine Sandy Loam	0.35	0.30	0.24
Very Fine Sandy Loam	0.47	0.41	0.33
Loam	0.38	0.32	0.29
Silt Loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy Clay Loam	0.27	0.25	0.21
Clay Loam	0.28	0.25	0.21
Silty Clay Loam	0.37	0.32	0.26
Sandy Clay	0.14	0.13	0.12
Silty Clay	0.25	0.23	0.19
Clay		0.13 - 0.29	K = 0.25

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

tion and developmental areas can be obtained from table 5 if good judgment is exercised in comparing the surface conditions with those of agricultural conditions specified in lines of the table. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions. The procedure is then similar to that described for cropland.

Establishing vegetation on the denuded areas as quickly as possible is highly important. A good sod has a C value of 0.01 or less (table 5-B), but such a low C value can be obtained quickly only by laying sod on the area, at a substantial cost. When grass or small grain is started from seed, the probable soil loss for the period while cover is developing can be computed by the procedure outlined for estimating cropstage-period soil losses. If the seeding is on topsoil, without a mulch, the soil loss ratios given in line 141 of table 5 are appropriate for cropstage C values. If the seeding is on a desurfaced area, where residual effects of prior vegetation are no longer significant, the ratios for periods SB, 1 and 2 are 1.0, 0.75 and 0.50, respectively, and line 141 applies for cropstage 3. When the seedbed is protected by a mulch, the pertinent mulch factor from the upper curve of figure 6 or table 9 is applicable until good canopy cover is attained. The combined effects of vegetative mulch and low-growing canopy are given in figure 7. When grass is established in small grain, it can usually be evaluated as established meadow about 2 mo after the grain is cut.

C Values for Pasture, Range, and Idle Land

Factor C for a specific combination of cover conditions on these types of land may be obtained from table 10 (57). The cover characteristics that must be appraised before consulting this table are defined in the table and its footnotes. Cropstage periods and EI monthly distribution data are generally not necessary where perennial vegetation has become established and there is no mechanical disturbance of the soil.

Available soil loss data from undisturbed land were not sufficient to derive table 10 by direct comparison of measured soil loss rates, as was done for development of table 5. However, analyses of the assembled erosion data showed that the research information on values of C can be extended to completely different situations by combining subfactors that evaluate three separate and distinct, but interrelated, zones of influence: (a) vegetative cover in direct contact with the soil surface, (b) canopy cover, and (c) residual and tillage effects.

Subfactors for various percentages of surface cover by mulch are given by the upper curve of

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

[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.

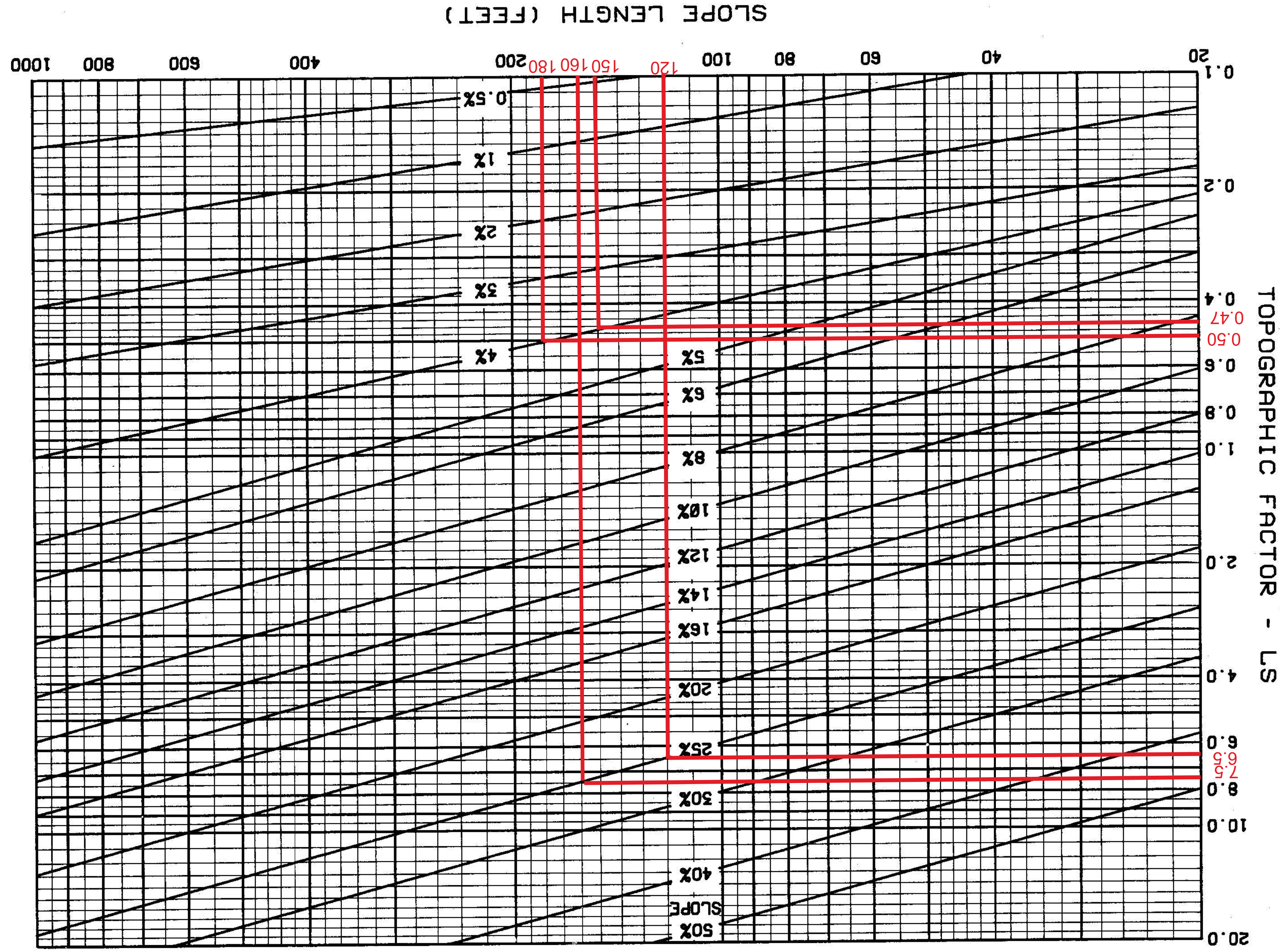


FIGURE 4.—Slope-effect chart (topographic factor, LS). LS = $(\lambda/72.6)^m$ (65.41 $\sin^2\theta$ + 4.56 $\sin\theta$ + 0.065) where λ = slope length in feet; θ = angle of slope; and m = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, and 0.5 for slopes of 5 percent or steeper.

Soil Map - Cherokee County, Texas

Map Scale: 1:10,900 if printed on A landscape (11" x 8.5") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cherokee County, Texas
Survey Area Data: Version 21, Aug 24, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Dec 18, 2019—Feb 1, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Bf	Sacul fine sandy loam, 8 to 15 percent slopes	10.6	2.0%
Bg	Sacul fine sandy loam, strongly sloping, eroded	47.5	9.0%
Bm	Bowie fine sandy loam, 1 to 3 percent slopes	1.3	0.2%
Bn	Bowie fine sandy loam, 3 to 8 percent slopes	5.8	1.1%
Bp	Lilbert loamy fine sand, 1 to 3 percent slopes	13.5	2.6%
Br	Lilbert loamy fine sand, 3 to 8 percent slopes	48.3	9.1%
Bt	Trawick-Bub complex, 8 to 40 percent slopes	176.7	33.3%
Ca	Alazan very fine sandy loam, 0 to 1 percent slopes	5.3	1.0%
Eb	Betis loamy fine sand, 3 to 8 percent slopes	27.9	5.3%
Ia	Bienville loamy fine sand, 1 to 3 percent slopes	1.6	0.3%
Ie	Iulus fine sandy loam, 0 to 1 percent slopes, frequently flooded	7.1	1.3%
La	Darco loamy fine sand, 1 to 3 percent slopes	14.8	2.8%
Ma	Elrose fine sandy loam, 1 to 3 percent slopes	3.8	0.7%
Mb	Elrose fine sandy loam, 3 to 8 percent slopes	10.8	2.0%
Md	Angelina	91.8	17.3%
Nf	Nacogdoches fine sandy loam, sloping	7.0	1.3%
Ng	Nacogdoches fine sandy loam, sloping, eroded	18.8	3.5%
Nh	Trawick fine sandy loam, 8 to 20 percent slopes	11.8	2.2%
Nk	Trawick fine sandy loam, strongly sloping, eroded	18.1	3.4%
Ra	Ruston fine sandy loam, 1 to 3 percent slopes	1.1	0.2%
Rb	Ruston fine sandy loam, 3 to 8 percent slopes	6.4	1.2%
Totals for Area of Interest		**530.1**	**100.0%**

United States
Environmental Protection
Agency

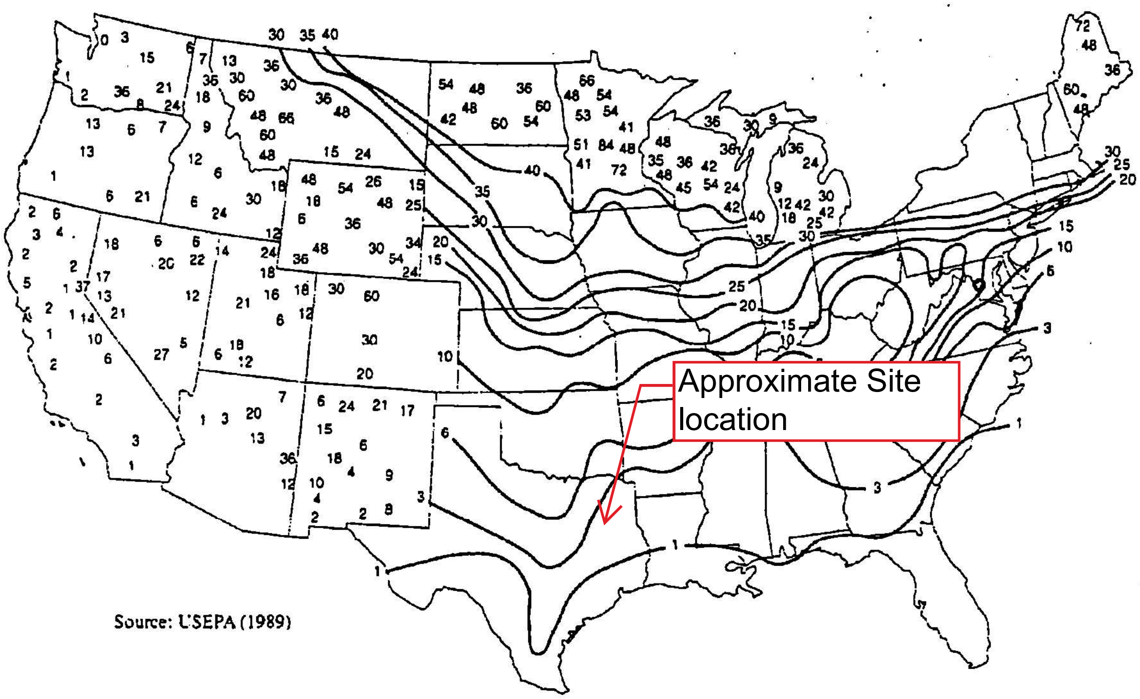
Solid Waste and
Emergency Response
(5305)

EPA530-R-93-017
November 1993
www.epa.gov/osw

EPA

Solid Waste Disposal Facility Criteria

Technical Manual



Approximate Site location

Source: USEPA (1989)

Figure 6-4
Regional Depth of Frost Penetration in Inches

Required:

Determine the sheet flow velocity for the final cover system design and compare to the permissible non-erodible flow velocity.

Method:

1. Determine the flow using the Rational Method.
2. Calculate flow depth using Kinematic Wave procedures.
3. Compute flow velocity and compare to permissible non-erodibility velocity.

References:

1. *NOAA Atlas 14 for 2 years interval with a duration of 24 hours*
2. United States Soil Conservation Service, *TR-55 Hydrology for Small Watersheds*, June 1986.

Solution:

Use the typical case scenarios from the USLE calculation to determine the expected sheet flow velocity.

Case 1. Typical top slope
slope = 0.04 ft/ft
length = 150 ft

Case 2. Longest top slope
slope = 0.04 ft/ft
length = 180 ft

Case 3. Typical side slope
slope = 0.25 ft/ft
length = 120 ft

Case 4. Longest side slope
slope = 0.25 ft/ft
length = 160 ft

Time of Concentration:

$$t_c = \frac{0.007(nL)^{0.8}}{(P_{2,24})^{0.5} S^{0.4}}$$

Where:
t_c = time of concentration (hr)
n = Manning's roughness coefficient
L = slope length
$P_{2,24}$ = 2-year, 24-hour rainfall depth (in)
S = slope (ft/ft)

United States
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**Natural
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Urban Hydrology for Small Watersheds

TR-55

Chapter 3

Time of Concentration and Travel Time

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

T_c influences the shape and peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Factors affecting time of concentration and travel time

Surface roughness

One of the most significant effects of urban development on flow velocity is less retardance to flow. That is, undeveloped areas with very slow and shallow overland flow through vegetation become modified by urban development: the flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Channel shape and flow patterns

In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope

Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when channels are straightened and decrease when overland flow is directed through storm sewers, street gutters, and diversions.

Computation of travel time and time of concentration

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

$$T_t = \frac{L}{3600V} \qquad \text{[eq. 3-1]}$$

where:

T_t = travel time (hr)
L = flow length (ft)
V = average velocity (ft/s)
3600 = conversion factor from seconds to hours.

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments:

$$T_c = T_{t_1} + T_{t_2} + \ldots T_{t_m} \qquad \text{[eq. 3-2]}$$

where:

T_c = time of concentration (hr)
m = number of flow segments

Determine $P_{2,24}$:

$P_{2,24}$ = 4.17 in (Ref 1.)

Reference: NOAA Atlas 14 for 2 years interval with a duration of 24 hours

Calculate t_c:

Case 1:

n = 0.24
L = 150
$P_{2,24}$ = 4.17
S = 0.04

t_c = 0.22 hr
13.10 min

Case 2:

n = 0.24
L = 180
$P_{2,24}$ = 4.17
S = 0.04

t_c = 0.25 hr
15.16 min

Case 3:

n = 0.24
L = 120
$P_{2,24}$ = 4.17
S = 0.25

t_c = 0.09 hr
5.27 min

Case 4:

n = 0.24
L = 160
$P_{2,24}$ = 4.17
S = 0.25

t_c = 0.11 hr
6.63 min

ROYAL OAKS LANDFILL
0120-076-11-106
EROSION LAYER EVALUATION

Calculate the design 25-year frequency for each condition:

Q = CiA

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

Where: i = rainfall intensity (in/hr) = 8.59

Reference: NOAA Atlas 14 for 25 - years interval with a duration of 10 minutes

For a unit width of final cover, the flow lengths shown on sheet IIIF-D-7 for each case is used.

A=[Length (ft) x Width (ft)] / 43560 sq. ft/acre = A in acres

Case 1:

C =	0.7	
i =	8.59	in/hr
Length:	150	ft
A	0.0034	ac
Q =	0.021	cfs

Case 2:

C =	0.7	
i =	8.59	in/hr
Length:	180	ft
A	0.0041	ac
Q =	0.025	cfs

Case 3:

C =	0.7	
i =	8.59	in/hr
Length:	120	ft
A	0.0028	ac
Q =	0.017	cfs

Case 4:

C =	0.7	
i =	8.59	in/hr
Length:	160	ft
A	0.0037	ac
Q =	0.022	cfs

Prep By: VG
Date: 5/9/2024

Chkd By: BPY/CRM
Date: 5/9/2024

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EROSION LAYER EVALUATION

Approximate depth of flow:

Using Manning's Equation

$$V = (1.49/n)\ y^{0.67}\ S^{0.5}$$

$Q = VA$ => $V = Q/A$

$A = y \times 1$ (assuming unit width of flow)

substituting for V

$$Q/y = (1.49/n)\ y^{0.67}\ S^{0.5}$$

$$Q = (1.49/n)\ y^{1.67}\ S^{0.5}$$

solve for y

$$y = (Qn/1.49\ S^{0.5})^{1/1.67}$$

$$y = (Qn/1.49S^{0.5})^{0.6}$$

Case 1:
Q = 0.021 cfs
n = 0.03
S = 0.04 ft/ft
y = 0.025 ft

Case 2:
Q = 0.025 cfs
n = 0.03
S = 0.04 ft/ft
y = 0.027 ft

Case 3:
Q = 0.017 cfs
n = 0.03
S = 0.25 ft/ft
y = 0.012 ft

Case 4:
Q = 0.022 cfs
n = 0.03
S = 0.25 ft/ft
y = 0.015 ft

Determine sheet flow velocity:

V = Q/A (assume unit flow width for the flow area, A)

Case 1:

Q = 0.021 cfs

A = 0.025 sf

V = 0.84 ft/s

Case 2:

Q = 0.025 cfs

A = 0.027 sf

V = 0.90 ft/s

Case 3:

Q = 0.017 cfs

A = 0.012 sf

V = 1.33 ft/s

Case 4:

Q = 0.022 cfs

A = 0.015 sf

V = 1.50 ft/s

Permissible non-erodible velocity is 5.0 ft/s. Therefore, expected sheet flow velocity is acceptable on the final cover system top and side slopes.

NOAA Atlas 14, Volume 11, Version 2
Location name: Jacksonville, Texas, USA*
Latitude: 32.0035°, Longitude: -95.2748°
Elevation: 701 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

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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	**0.432** (0.327-0.571)	**0.511** (0.388-0.665)	**0.636** (0.483-0.834)	**0.743** (0.557-0.988)	**0.895** (0.651-1.22)	**1.02** (0.720-1.41)	**1.14** (0.789-1.62)	**1.28** (0.861-1.86)	**1.47** (0.956-2.19)	**1.62** (1.03-2.47)
10-min	**0.689** (0.522-0.910)	**0.816** (0.619-1.06)	**1.02** (0.772-1.33)	**1.19** (0.891-1.58)	**1.43** (1.04-1.95)	**1.63** (1.16-2.27)	**1.83** (1.26-2.60)	**2.04** (1.37-2.96)	**2.33** (1.52-3.48)	**2.56** (1.62-3.89)
15-min	**0.867** (0.657-1.14)	**1.02** (0.777-1.33)	**1.27** (0.966-1.67)	**1.48** (1.11-1.97)	**1.78** (1.30-2.43)	**2.02** (1.43-2.82)	**2.27** (1.57-3.23)	**2.54** (1.71-3.69)	**2.92** (1.89-4.35)	**3.21** (2.03-4.89)
30-min	**1.22** (0.925-1.61)	**1.44** (1.09-1.87)	**1.78** (1.35-2.34)	**2.07** (1.56-2.76)	**2.49** (1.81-3.38)	**2.81** (1.99-3.91)	**3.16** (2.18-4.49)	**3.54** (2.38-5.13)	**4.08** (2.65-6.08)	**4.51** (2.86-6.86)
60-min	**1.59** (1.20-2.10)	**1.88** (1.43-2.45)	**2.34** (1.78-3.07)	**2.73** (2.05-3.64)	**3.29** (2.39-4.48)	**3.74** (2.64-5.19)	**4.21** (2.90-5.98)	**4.74** (3.19-6.88)	**5.51** (3.58-8.22)	**6.14** (3.88-9.33)
2-hr	**1.92** (1.47-2.51)	**2.32** (1.77-2.97)	**2.93** (2.24-3.80)	**3.47** (2.63-4.56)	**4.26** (3.12-5.73)	**4.90** (3.49-6.73)	**5.60** (3.88-7.85)	**6.39** (4.32-9.14)	**7.54** (4.92-11.1)	**8.50** (5.40-12.7)
3-hr	**2.11** (1.62-2.74)	**2.58** (1.97-3.26)	**3.29** (2.53-4.24)	**3.93** (2.99-5.14)	**4.87** (3.59-6.52)	**5.66** (4.05-7.73)	**6.52** (4.54-9.08)	**7.51** (5.08-10.7)	**8.94** (5.84-13.1)	**10.1** (6.46-15.1)
6-hr	**2.47** (1.92-3.18)	**3.06** (2.35-3.81)	**3.93** (3.05-5.00)	**4.73** (3.63-6.11)	**5.92** (4.40-7.84)	**6.92** (5.00-9.35)	**8.04** (5.63-11.1)	**9.31** (6.34-13.0)	**11.2** (7.34-16.1)	**12.7** (8.14-18.7)
12-hr	**2.91** (2.28-3.69)	**3.58** (2.78-4.42)	**4.59** (3.60-5.77)	**5.51** (4.27-7.04)	**6.87** (5.15-8.98)	**8.01** (5.82-10.7)	**9.30** (6.56-12.6)	**10.8** (7.37-14.9)	**13.0** (8.55-18.4)	**14.8** (9.51-21.4)
24-hr	**3.41** (2.69-4.28)	**4.17** (3.27-5.10)	**5.31** (4.21-6.61)	**6.35** (4.96-8.02)	**7.88** (5.95-10.2)	**9.15** (6.70-12.0)	**10.6** (7.50-14.2)	**12.2** (8.41-16.7)	**14.7** (9.71-20.5)	**16.7** (10.8-23.8)
2-day	**3.99** (3.18-4.96)	**4.86** (3.86-5.89)	**6.18** (4.95-7.61)	**7.37** (5.82-9.20)	**9.11** (6.94-11.6)	**10.6** (7.79-13.7)	**12.2** (8.68-16.1)	**13.9** (9.63-18.7)	**16.5** (10.9-22.7)	**18.6** (12.0-26.0)
3-day	**4.40** (3.53-5.43)	**5.34** (4.27-6.44)	**6.76** (5.44-8.28)	**8.03** (6.37-9.96)	**9.89** (7.57-12.5)	**11.4** (8.46-14.7)	**13.1** (9.37-17.1)	**14.9** (10.3-19.8)	**17.4** (11.6-23.8)	**19.5** (12.6-27.1)
4-day	**4.72** (3.80-5.79)	**5.69** (4.58-6.85)	**7.18** (5.81-8.76)	**8.50** (6.77-10.5)	**10.4** (7.99-13.1)	**12.0** (8.89-15.4)	**13.6** (9.79-17.8)	**15.4** (10.7-20.5)	**17.9** (12.0-24.4)	**20.0** (12.9-27.6)
7-day	**5.45** (4.42-6.62)	**6.47** (5.28-7.76)	**8.08** (6.60-9.77)	**9.46** (7.60-11.6)	**11.4** (8.82-14.2)	**13.0** (9.70-16.5)	**14.6** (10.6-18.9)	**16.4** (11.5-21.5)	**18.8** (12.6-25.3)	**20.8** (13.5-28.4)
10-day	**6.06** (4.95-7.33)	**7.12** (5.86-8.53)	**8.82** (7.25-10.6)	**10.3** (8.28-12.5)	**12.3** (9.50-15.2)	**13.8** (10.4-17.4)	**15.4** (11.2-19.8)	**17.2** (12.1-22.4)	**19.6** (13.2-26.1)	**21.5** (14.0-29.0)
20-day	**8.03** (6.62-9.60)	**9.19** (7.69-11.0)	**11.1** (9.27-13.3)	**12.7** (10.4-15.3)	**14.8** (11.5-18.1)	**16.3** (12.3-20.3)	**17.9** (13.0-22.6)	**19.5** (13.8-25.0)	**21.7** (14.7-28.5)	**23.4** (15.3-31.2)
30-day	**9.68** (8.03-11.5)	**10.9** (9.22-13.0)	**13.1** (11.0-15.5)	**14.7** (12.1-17.6)	**16.9** (13.2-20.5)	**18.5** (14.0-22.7)	**20.0** (14.6-25.0)	**21.5** (15.2-27.4)	**23.5** (16.0-30.6)	**25.1** (16.4-33.1)
45-day	**12.0** (10.0-14.1)	**13.4** (11.4-15.8)	**15.8** (13.3-18.6)	**17.7** (14.6-20.9)	**20.0** (15.8-24.1)	**21.7** (16.5-26.5)	**23.2** (17.1-28.9)	**24.7** (17.6-31.2)	**26.7** (18.1-34.4)	**28.0** (18.4-36.7)
60-day	**14.1** (11.8-16.5)	**15.6** (13.3-18.4)	**18.3** (15.5-21.4)	**20.3** (16.8-23.9)	**22.9** (18.1-27.4)	**24.7** (18.8-30.0)	**26.3** (19.4-32.4)	**27.8** (19.8-34.9)	**29.6** (20.2-37.9)	**30.9** (20.3-40.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical

NOAA Atlas 14, Volume 11, Version 2
Location name: Jacksonville, Texas, USA*
Latitude: 32.0035°, Longitude: -95.2746°
Elevation: 699 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/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**5.18** (3.92-6.85)	**6.13** (4.66-7.98)	**7.63** (5.80-10.0)	**8.92** (6.68-11.9)	**10.7** (7.81-14.6)	**12.2** (8.64-17.0)	**13.7** (9.47-19.5)	**15.4** (10.3-22.3)	**17.7** (11.5-26.3)	**19.5** (12.3-29.6)
10-min	**4.13** (3.13-5.46)	**4.90** (3.71-6.37)	**6.09** (4.63-7.99)	**7.12** (5.35-9.47)	**8.59** (6.26-11.7)	**9.77** (6.93-13.6)	**11.0** (7.58-15.6)	**12.3** (8.24-17.8)	**14.0** (9.09-20.9)	**15.3** (9.71-23.3)
15-min	**3.47** (2.63-4.58)	**4.10** (3.11-5.33)	**5.08** (3.86-6.67)	**5.93** (4.45-7.88)	**7.13** (5.19-9.71)	**8.09** (5.73-11.3)	**9.10** (6.28-12.9)	**10.2** (6.84-14.7)	**11.7** (7.58-17.4)	**12.9** (8.14-19.5)
30-min	**2.44** (1.85-3.23)	**2.88** (2.19-3.75)	**3.56** (2.71-4.67)	**4.15** (3.11-5.51)	**4.98** (3.62-6.77)	**5.63** (3.98-7.82)	**6.32** (4.36-8.98)	**7.08** (4.76-10.3)	**8.15** (5.29-12.2)	**9.02** (5.71-13.7)
60-min	**1.59** (1.20-2.10)	**1.88** (1.43-2.45)	**2.34** (1.78-3.07)	**2.73** (2.05-3.64)	**3.29** (2.39-4.48)	**3.74** (2.64-5.19)	**4.21** (2.90-5.98)	**4.74** (3.19-6.88)	**5.51** (3.58-8.22)	**6.14** (3.88-9.33)
2-hr	**0.962** (0.735-1.26)	**1.16** (0.884-1.48)	**1.46** (1.12-1.90)	**1.73** (1.31-2.28)	**2.13** (1.56-2.86)	**2.45** (1.74-3.37)	**2.80** (1.94-3.92)	**3.19** (2.16-4.57)	**3.77** (2.46-5.55)	**4.25** (2.70-6.37)
3-hr	**0.703** (0.540-0.913)	**0.860** (0.656-1.09)	**1.10** (0.843-1.41)	**1.31** (0.996-1.71)	**1.62** (1.20-2.17)	**1.88** (1.35-2.57)	**2.17** (1.51-3.02)	**2.50** (1.69-3.55)	**2.98** (1.95-4.35)	**3.38** (2.15-5.02)
6-hr	**0.412** (0.320-0.530)	**0.511** (0.392-0.636)	**0.656** (0.509-0.835)	**0.789** (0.606-1.02)	**0.988** (0.735-1.31)	**1.16** (0.834-1.56)	**1.34** (0.940-1.84)	**1.55** (1.06-2.18)	**1.87** (1.22-2.69)	**2.13** (1.36-3.12)
12-hr	**0.241** (0.188-0.306)	**0.297** (0.230-0.366)	**0.380** (0.298-0.479)	**0.456** (0.354-0.583)	**0.570** (0.427-0.745)	**0.664** (0.483-0.886)	**0.771** (0.544-1.05)	**0.894** (0.612-1.24)	**1.08** (0.709-1.53)	**1.23** (0.789-1.78)
24-hr	**0.141** (0.112-0.178)	**0.173** (0.136-0.212)	**0.221** (0.175-0.275)	**0.264** (0.206-0.334)	**0.328** (0.247-0.423)	**0.381** (0.279-0.502)	**0.440** (0.312-0.590)	**0.509** (0.350-0.694)	**0.611** (0.404-0.855)	**0.697** (0.448-0.992)
2-day	**0.083** (0.066-0.103)	**0.101** (0.080-0.122)	**0.128** (0.103-0.158)	**0.153** (0.121-0.191)	**0.189** (0.144-0.242)	**0.220** (0.162-0.286)	**0.253** (0.180-0.334)	**0.289** (0.200-0.389)	**0.342** (0.228-0.472)	**0.386** (0.249-0.542)
3-day	**0.061** (0.049-0.075)	**0.074** (0.059-0.089)	**0.093** (0.075-0.114)	**0.111** (0.088-0.138)	**0.137** (0.105-0.174)	**0.158** (0.117-0.204)	**0.181** (0.130-0.238)	**0.206** (0.143-0.275)	**0.241** (0.161-0.330)	**0.270** (0.174-0.375)
4-day	**0.049** (0.039-0.060)	**0.059** (0.047-0.071)	**0.074** (0.060-0.091)	**0.088** (0.070-0.109)	**0.108** (0.083-0.136)	**0.124** (0.092-0.159)	**0.141** (0.102-0.185)	**0.160** (0.111-0.213)	**0.186** (0.124-0.253)	**0.207** (0.134-0.287)
7-day	**0.032** (0.026-0.039)	**0.038** (0.031-0.046)	**0.048** (0.039-0.058)	**0.056** (0.045-0.068)	**0.067** (0.052-0.084)	**0.077** (0.057-0.098)	**0.087** (0.062-0.112)	**0.097** (0.068-0.127)	**0.112** (0.075-0.150)	**0.123** (0.080-0.168)
10-day	**0.025** (0.020-0.030)	**0.029** (0.024-0.035)	**0.036** (0.030-0.044)	**0.042** (0.034-0.051)	**0.051** (0.039-0.063)	**0.057** (0.043-0.072)	**0.064** (0.046-0.082)	**0.071** (0.050-0.093)	**0.081** (0.054-0.108)	**0.089** (0.058-0.121)
20-day	**0.016** (0.013-0.019)	**0.019** (0.016-0.022)	**0.023** (0.019-0.027)	**0.026** (0.021-0.031)	**0.030** (0.024-0.037)	**0.034** (0.025-0.042)	**0.037** (0.027-0.047)	**0.040** (0.028-0.052)	**0.045** (0.030-0.059)	**0.048** (0.031-0.064)
30-day	**0.013** (0.011-0.015)	**0.015** (0.012-0.018)	**0.018** (0.015-0.021)	**0.020** (0.016-0.024)	**0.023** (0.018-0.028)	**0.025** (0.019-0.031)	**0.027** (0.020-0.034)	**0.029** (0.021-0.038)	**0.032** (0.022-0.042)	**0.034** (0.022-0.045)
45-day	**0.011** (0.009-0.013)	**0.012** (0.010-0.014)	**0.014** (0.012-0.017)	**0.016** (0.013-0.019)	**0.018** (0.014-0.022)	**0.020** (0.015-0.024)	**0.021** (0.015-0.026)	**0.022** (0.016-0.028)	**0.024** (0.016-0.031)	**0.025** (0.017-0.033)
60-day	**0.009** (0.008-0.011)	**0.010** (0.009-0.012)	**0.012** (0.010-0.014)	**0.014** (0.011-0.016)	**0.015** (0.012-0.018)	**0.017** (0.013-0.020)	**0.018** (0.013-0.022)	**0.019** (0.013-0.024)	**0.020** (0.014-0.026)	**0.021** (0.014-0.027)

[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

Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges

Adopted by the
Texas Department of Transportation

November 1, 2014

Item 164
Seeding for Erosion Control

Texas Department of Transportation

1. DESCRIPTION

Provide and install temporary or permanent seeding for erosion control as shown on the plans or as directed.

2. MATERIALS

2.1. **Seed**. Provide seed from the previous season's crop meeting the requirements of the Texas Seed Law, including the testing and labeling for pure live seed (PLS = Purity × Germination). Furnish seed of the designated species, in labeled unopened bags or containers to the Engineer before planting. Use within 12 mo. from the date of the analysis. When Buffalograss is specified, use seed that is treated with KNO_3 (potassium nitrate) to overcome dormancy.

Use Tables 1–4 to determine the appropriate seed mix and rates as specified on the plans. If a plant species is not available by the producers, the other plant species in the recommended seed mixture will be increased proportionally by the PLS/acre of the missing plant species.

Table 1
Permanent Rural Seed Mix

District and Planting Dates	Clay Soils Species and Rates (lb. PLS/acre)		Sandy Soils Species and Rates (lb. PLS/acre)	
1 (Paris) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (Haskell)	3.2	Bermudagrass	1.5
	Bermudagrass	1.8	Bahiagrass (Pensacola)	6.0
	Little Bluestem (Native)	1.7	Sand Lovegrass	0.6
	Illinois Bundleflower	1.0	Weeping Lovegrass (Ermelo)	0.8
			Partridge Pea	1.0
2 (Ft. Worth) Feb. 1–May 15	Green Sprangletop (Van Horn)	1.0	Green Sprangletop (Van Horn)	1.0
	Sideoats Grama (Haskell)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Texas Grama (Atascosa)	1.0	Shortspike Windmillgrass (Welder)	0.2
	Hairy Grama (Chaparral)	0.4	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Slender Grama (Dilley)	1.0
	Little Bluestem (OK Select)	0.8	Sand Lovegrass (Mason)	0.2
	Purple Prairie Clover (Cuero)	0.6	Sand Dropseed (Borden County)	0.2
	Engelmann Daisy (Eldorado)	0.75	Partridge Pea (Comanche)	0.6
	Illinois Bundleflower	1.3	Little Bluestem (OK Select)	0.8
	Awnless Bushsunflower (Plateau)	0.2	Englemann Daisy (Eldorado)	0.75
			Purple Prairie Clover	0.3
3 (Wichita Falls) Feb. 1–May 15	Green Sprangletop (Van Horn)	0.6	Green Sprangletop (Van Horn)	1.0
	Sideoats Grama (Haskell)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Texas Grama (Atascosa)	1.0	Shortspike Windmillgrass (Welder)	0.2
	Hairy Grama (Chaparral)	0.4	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Sand Lovegrass (Mason)	0.2
	Little Bluestem (OK Select)	0.8	Sand Dropseed (Borden County)	0.2
	Blue Grama (Hachita)	0.4	Partridge Pea (Comanche)	0.6
	Western Wheatgrass (Barton)	1.2	Little Bluestem (OK Select)	0.8
	Galleta Grass (Viva)	0.6	Englemann Daisy (Eldorado)	0.75
	Engelmann Daisy (Eldorado)	0.75	Purple Prairie Clover (Cuero)	0.3
	Awnless Bushsunflower (Plateau)	0.2		
4 (Amarillo) Feb. 15–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (Haskell)	3.6	Weeping Lovegrass (Ermelo)	0.8
	Blue Grama (Hachita)	1.2	Blue Grama (Hachita)	1.0
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.3
	Illinois Bundleflower	1.0	Sand Bluestem	1.8
			Purple Prairie Clover	0.5

Table 1 (continued)
Permanent Rural Seed Mix

District and Planting Dates	Clay Soils Species and Rates (lb. PLS/acre)		Sandy Soils Species and Rates (lb. PLS/acre)	
5 (Lubbock)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 15–May 15	Sideoats Grama (El Reno)	3.6	Weeping Lovegrass (Ermelo)	0.8
	Blue Grama (Hachita)	1.2	Blue Grama (Hachita)	1.0
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.3
	Illinois Bundleflower	1.0	Sand Bluestem	1.8
			Purple Prairie Clover	0.5
6 (Odessa)	Green Sprangletop (Van Horn)	1.0	Green Sprangletop (Van Horn)	1.0
Feb. 1–May 15	Sideoats Grama (South Texas)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Blue Grama (Hachita)	0.4	Blue Grama (Hachita)	0.4
	Galleta Grass (Viva)	0.6	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Sand Lovegrass (Mason)	0.2
	Pink Pappusgrass (Maverick)	0.6	Sand Dropseed (Borden County)	0.2
	Alkali Sacaton (Saltalk)	0.2	Indian Ricegrass (Rim Rock)	1.6
	Plains Bristlegrass (Catarina Blend)	0.2	Sand Bluestem (Cottle County)	1.2
	False Rhodes Grass (Kinney)	0.1	Little Bluestem (Pastura)	0.8
	Whiplash Pappusgrass (Webb)	0.6	Purple Prairie Clover (Cuero)	0.3
	Arizona Cottontop (La Salle)	0.2		
7 (San Angelo)	Green Sprangletop (Van Horn)	1.0	Green Sprangletop (Van Horn)	1.0
Feb. 1–May 1	Sideoats Grama (Haskell)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Texas Grama (Atascosa)	1.0	Shortspike Windmillgrass (Welder)	0.2
	Hairy Grama (Chaparral)	0.4	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Sand Lovegrass (Mason)	0.2
	Little Bluestem (OK Select)	0.4	Sand Dropseed (Borden County)	0.2
	Blue Grama (Hachita)	0.4	Sand Bluestem (Cottle County)	1.2
	Western Wheatgrass (Barton)	1.2	Partridge Pea (Comanche)	0.6
	Galleta Grass (Viva)	0.6	Little Bluestem (OK Select)	0.8
	Engelmann Daisy (Eldorado)	0.75	Englemann Daisy (Eldorado)	0.75
	Illinois Bundleflower (Sabine)	1.0	Purple Prairie Clover (Cuero)	0.3
8 (Abilene)	Green Sprangletop (Van Horn)	1.0	Green Sprangletop (Van Horn)	1.0
Feb. 1–May 15	Sideoats Grama (Haskell)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Texas Grama (Atascosa)	1.0	Shortspike Windmillgrass (Welder)	0.2
	Hairy Grama (Chaparral)	0.4	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Sand Lovegrass (Mason)	0.2
	Little Bluestem (OK Select)	0.4	Sand Dropseed (Borden County)	0.2
	Blue Grama (Hachita)	0.4	Sand Bluestem (Cottle County)	1.2
	Western Wheatgrass (Barton)	1.2	Partridge Pea (Comanche)	0.6
	Galleta Grass (Viva)	0.6	Little Bluestem (OK Select)	0.8
	Engelmann Daisy (Eldorado)	0.75	Englemann Daisy (Eldorado)	0.75
	Illinois Bundleflower (Sabine)	1.0	Purple Prairie Clover (Cuero)	0.3
9 (Waco)	Green Sprangletop (Van Horn)	1.0	Green Sprangletop (Van Horn)	1.0
Feb. 1–May 15	Sideoats Grama (Haskell)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Texas Grama (Atascosa)	1.0	Shortspike Windmillgrass (Welder)	0.2
	Hairy Grama (Chaparral)	0.4	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Slender Grama (Dilley)	1.0
	Little Bluestem (OK Select)	0.8	Sand Lovegrass (Mason)	0.2
	Purple Prairie Clover (Cuero)	0.6	Sand Dropseed (Borden County)	0.2
	Engelmann Daisy (Eldorado)	0.75	Partridge Pea (Comanche)	0.6
	Illinois Bundleflower	1.3	Little Bluestem (OK Select)	0.8
	Awnless Bushsunflower (Plateau)	0.2	Englemann Daisy (Eldorado)	0.75
			Purple Prairie Clover	0.3
10 (Tyler)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Bermudagrass	1.8	Bermudagrass	1.8
	Bahiagrass (Pensacola)	9.0	Bahiagrass (Pensacola)	9.0
	Sideoats Grama (Haskell)	2.7	Weeping Lovegrass (Ermelo)	0.5
	Illinois Bundleflower	1.0	Sand Lovegrass	0.5
			Lance-Leaf Coreopsis	1.0
11 (Lufkin)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Bermudagrass	1.8	Bermudagrass	2.1
	Bahiagrass (Pensacola)	9.0	Bahiagrass (Pensacola)	9.0
	Sideoats Grama (Haskell)	2.7	Sand Lovegrass	0.5
	Illinois Bundleflower	1.0	Lance-Leaf Coreopsis	1.0

Table 1 (continued)
Permanent Rural Seed Mix

District and Planting Dates	Clay Soils Species and Rates (lb. PLS/acre)		Sandy Soils Species and Rates (lb. PLS/acre)	
24 (El Paso)	Green Sprangletop (Van Horn)	1.0	Green Sprangletop (Van Horn)	1.0
Feb. 1–May 15	Sideoats Grama (South Texas)	1.0	Hooded Windmillgrass (Mariah)	0.2
	Blue Grama (Hachita)	0.4	Blue Grama (Hachita)	0.4
	Galleta Grass (Viva)	0.6	Hairy Grama (Chaparral)	0.4
	Shortspike Windmillgrass (Welder)	0.2	Sand Lovegrass (Mason)	0.2
	Pink Pappusgrass (Maverick)	0.6	Sand Dropseed (Borden County)	0.2
	Alkali Sacaton (Saltalk)	0.2	Indian Ricegrass (Rim Rock)	1.6
	Plains Bristlegrass (Catarina Blend)	0.2	Sand Bluestem (Cottle County)	1.2
	False Rhodes Grass (Kinney)	0.1	Little Bluestem (Pastura)	0.8
	Whiplash Pappusgrass (Webb)	0.6	Purple Prairie Clover (Cuero)	0.3
	Arizona Cottontop (La Salle)	0.2		
25 (Childress)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Sideoats Grama (El Reno)	2.7	Weeping Lovegrass (Ermelo)	1.2
	Blue Grama (Hachita)	0.9	Sand Dropseed (Borden Co.)	0.5
	Western Wheatgrass	2.1	Sand Lovegrass	0.8
	Galleta	1.6	Purple Prairie Clover	0.5
	Illinois Bundleflower	1.0		

Table 2
Permanent Urban Seed Mix

District and Planting Dates	Clay Soils Species and Rates (lb. PLS/acre)		Sandy Soils Species and Rates (lb. PLS/acre)	
1 (Paris)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Bermudagrass	2.4	Bermudagrass	5.4
	Sideoats Grama (Haskell)	4.5		
2 (Ft. Worth)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Sideoats Grama (El Reno)	3.6	Sideoats Grama (El Reno)	3.6
	Bermudagrass	2.4	Bermudagrass	2.1
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.3
3 (Wichita Falls)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Sideoats Grama (El Reno)	4.5	Sideoats Grama (El Reno)	3.6
	Bermudagrass	1.8	Bermudagrass	1.8
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.4
4 (Amarillo)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 15–May 15	Sideoats Grama (El Reno)	3.6	Sideoats Grama (El Reno)	2.7
	Blue Grama (Hachita)	1.2	Blue Grama (Hachita)	0.9
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.4
			Buffalograss (Texoka)	1.6
5 (Lubbock)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 15–May 15	Sideoats Grama (El Reno)	3.6	Sideoats Grama (El Reno)	2.7
	Blue Grama (Hachita)	1.2	Blue Grama (Hachita)	0.9
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.4
			Buffalograss (Texoka)	1.6
6 (Odessa)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Sideoats Grama (Haskell)	3.6	Sideoats Grama (Haskell)	2.7
	Blue Grama (Hachita)	1.2	Sand Dropseed (Borden Co.)	0.4
	Buffalograss (Texoka)	1.6	Blue Grama (Hachita)	0.9
			Buffalograss (Texoka)	1.6
7 (San Angelo)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 1	Sideoats Grama (Haskell)	7.2	Sideoats Grama (Haskell)	3.2
	Buffalograss (Texoka)	1.6	Sand Dropseed (Borden Co.)	0.3
			Blue Grama (Hachita)	0.9
			Buffalograss (Texoka)	1.6
8 (Abilene)	Green Sprangletop	0.3	Green Sprangletop	0.3
Feb. 1–May 15	Sideoats Grama (Haskell)	3.6	Sand Dropseed (Borden Co.)	0.3
	Blue Grama (Hachita)	1.2	Sideoats Grama (Haskell)	3.6
	Buffalograss (Texoka)	1.6	Blue Grama (Hachita)	0.8
			Buffalograss (Texoka)	1.6

Table 2 (continued)
Permanent Urban Seed Mix

District and Planting Dates	Clay Soils Species and Rates (lb. PLS/acre)		Sandy Soils Species and Rates (lb. PLS/acre)	
9 (Waco) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	1.8	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6	Bermudagrass	3.6
	Sideoats Grama (Haskell)	4.5	Sand Dropseed (Borden Co.)	0.4
10 (Tyler) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	2.4	Bermudagrass	5.4
	Sideoats Grama (Haskell)	4.5		
11 (Lufkin) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	2.4	Bermudagrass	5.4
	Sideoats Grama (Haskell)	4.5		
12 (Houston) Jan. 15–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (Haskell)	4.5	Bermudagrass	5.4
	Bermudagrass	2.4		
13 (Yoakum) Jan. 15–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (South Texas)	4.5	Bermudagrass	5.4
	Bermudagrass	2.4		
14 (Austin) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	2.4	Bermudagrass	4.8
	Sideoats Grama (South Texas)	3.6	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6		
15 (San Antonio) Feb. 1–May 1	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (South Texas)	3.6	Bermudagrass	4.8
	Bermudagrass	2.4	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6		
16 (Corpus Christi) Jan. 1–May 1	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (South Texas)	3.6	Bermudagrass	4.8
	Bermudagrass	2.4	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6		
17 (Bryan) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	2.4	Bermudagrass	5.4
	Sideoats Grama (Haskell)	4.5		
18 (Dallas) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (El Reno)	3.6	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6	Bermudagrass	3.6
	Bermudagrass	2.4	Sand Dropseed (Borden Co.)	0.4
19 (Atlanta) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	2.4	Bermudagrass	5.4
	Sideoats Grama (Haskell)	4.5		
20 (Beaumont) Jan. 15–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Bermudagrass	2.4	Bermudagrass	5.4
	Sideoats Grama (Haskell)	4.5		
21 (Pharr) Jan. 15–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (South Texas)	3.6	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6	Bermudagrass	3.6
	Bermudagrass	2.4	Sand Dropseed (Borden Co.)	0.4
22 (Laredo) Jan. 15–May 1	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (South Texas)	4.5	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6	Bermudagrass	3.6
	Bermudagrass	1.8	Sand Dropseed	0.4
23 (Brownwood) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (Haskell)	3.6	Buffalograss (Texoka)	1.6
	Bermudagrass	1.2	Bermudagrass	3.6
	Blue Grama (Hachita)	0.9	Sand Dropseed (Borden Co.)	0.4
24 (El Paso) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (South Texas)	3.6	Buffalograss (Texoka)	1.6
	Blue Grama (Hachita)	1.2	Sand Dropseed (Borden Co.)	0.4
	Buffalograss (Texoka)	1.6	Blue Grama (Hachita)	1.8
25 (Childress) Feb. 1–May 15	Green Sprangletop	0.3	Green Sprangletop	0.3
	Sideoats Grama (El Reno)	3.6	Sand Dropseed (Borden Co.)	0.4
	Blue Grama (Hachita)	1.2	Buffalograss (Texoka)	1.6
	Buffalograss (Texoka)	1.6	Bermudagrass	1.8

Table 3
Temporary Cool Season Seeding

Districts	Dates	Seed Mix and Rates (lb. PLS/acre)	
Paris (1), Amarillo (4), Lubbock (5), Dallas (18)	September 1–November 30	Tall Fescue Western Wheatgrass Wheat (Red, Winter)	4.5 5.6 34
Odessa (6), San Angelo (7), El Paso (24)	September 1–November 30	Western Wheatgrass Wheat (Red, Winter)	8.4 50
Waco (9), Tyler (10), Lufkin (11), Austin (14), San Antonio (15), Bryan (17), Atlanta (19)	September 1–November 30	Tall Fescue Oats Wheat	4.5 24 34
Houston (12), Yoakum (13), Corpus Christi (16), Beaumont (20), Pharr (21), Laredo (22)	September 1–November 30	Oats	72
Ft. Worth (2), Wichita Falls (3), Abilene (8), Brownwood (23), Childress (25)	September 1–November 30	Tall Fescue Western Wheatgrass Cereal Rye	4.5 5.6 34

Table 4
Temporary Warm Season Seeding

Districts	Dates	Seed Mix and Rates (lb. PLS/acre)	
All	May 1–August 31	Foxtail Millet	34

2.2. **Fertilizer**. Use fertilizer in conformance with Article 166.2., “Materials.”

2.3. **Vegetative Watering**. Use water that is clean and free of industrial wastes and other substances harmful to the growth of vegetation.

2.4. **Mulch**.

2.4.1. **Straw or Hay Mulch**. Use straw or hay mulch in conformance with Section 162.2.5., “Mulch.”

2.4.2. **Cellulose Fiber Mulch**. Use only cellulose fiber mulches that are on the Approved Products List, *Erosion Control Approved Products*. (http://www.txdot.gov/business/resources/erosion-control.html) Submit one full set of manufacturer’s literature for the selected material. Keep mulch dry until applied. Do not use molded or rotted material.

2.5. **Tacking Methods**. Use a tacking agent applied in accordance with the manufacturer’s recommendations or a crimping method on all straw or hay mulch operations. Use tacking agents as approved or as specified on the plans.

3. CONSTRUCTION

Cultivate the area to a depth of 4 in. before placing the seed unless otherwise directed. Use approved equipment to vertically track the seedbed as shown on the plans or as directed. Cultivate the seedbed to a depth of 4 in. or mow the area before placement of the permanent seed when performing permanent seeding after an established temporary seeding. Plant the seed specified and mulch, if required, after the area has been completed to lines and grades as shown on the plans.

3.1. **Broadcast Seeding**. Distribute the seed or seed mixture uniformly over the areas shown on the plans using hand or mechanical distribution or hydro-seeding on top of the soil unless otherwise directed. Apply the mixture to the area to be seeded within 30 min. of placement of components in the equipment when seed and water are to be distributed as a slurry during hydro-seeding. Roll the planted area with a light roller or other suitable equipment. Roll sloped areas along the contour of the slopes.

3.2. **Straw or Hay Mulch Seeding**. Plant seed according to Section 164.3.1., "Broadcast Seeding." Apply straw or hay mulch uniformly over the seeded area immediately after planting the seed or seed mixture. Apply straw mulch at 2 to 2.5 tons per acre. Apply hay mulch at 1.5 to 2 tons per acre. Use a tacking method over the mulched area.

3.3. **Cellulose Fiber Mulch Seeding**. Plant seed in accordance with Section 164.3.1., "Broadcast Seeding." Apply cellulose fiber mulch uniformly over the seeded area immediately after planting the seed or seed mixture at the following rates.

- Sandy soils with slopes of 3:1 or less—2,500 lb. per acre.
- Sandy soils with slopes greater than 3:1—3,000 lb. per acre.
- Clay soils with slopes of 3:1 or less—2,000 lb. per acre.
- Clay soils with slopes greater than 3:1—2,300 lb. per acre.

Cellulose fiber mulch rates are based on dry weight of mulch per acre. Mix cellulose fiber mulch and water to make a slurry and apply uniformly over the seeded area using suitable equipment.

3.4. **Drill Seeding**. Plant seed or seed mixture uniformly over the area shown on the plans at a depth of 1/4 to 1/3 in. using a pasture or rangeland type drill unless otherwise directed. Plant seed along the contour of the slopes.

3.5. **Straw or Hay Mulching**. Apply straw or hay mulch uniformly over the area as shown on the plans. Apply straw mulch at 2 to 2.5 tons per acre. Apply hay mulch at 1.5 to 2 tons per acre. Use a tacking method over the mulched area.

Apply fertilizer in conformance with Article 166.3., "Construction." Seed and fertilizer may be distributed simultaneously during "Broadcast Seeding" operations, provided each component is applied at the specified rate. Apply half of the required fertilizer during the temporary seeding operation and the other half during the permanent seeding operation when temporary and permanent seeding are both specified for the same area.

Water the seeded areas at the rates and frequencies as shown on the plans or as directed.

4. MEASUREMENT

This Item will be measured by the square yard or by the acre.

5. PAYMENT

The work performed and the materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Broadcast Seeding (Perm)" of the rural or urban seed mixture and sandy or clay soil specified, "Broadcast Seeding (Temp)" of warm or cool season specified, "Straw or Hay Mulch Seeding (Perm)" of the rural or urban seed mixture and sandy or clay soil specified, "Straw or Hay Mulch Seeding (Temp)" of warm or cool season specified, "Cellulose Fiber Mulch Seeding (Perm)" of the rural or urban seed mixture and sandy or clay soil specified, "Cellulose Fiber Mulch Seeding (Temp)" of warm or cool season specified, "Drill Seeding (Perm)" of the rural or urban seed mixture and sandy or clay soil specified, "Drill Seeding (Temp)" of warm or cool season specified, and "Straw or Hay Mulching." This price is full compensation for furnishing materials, including water for hydro-seeding and hydro-mulching operations, mowing, labor, equipment, tools, supplies, and incidentals. Fertilizer will not be paid for directly but will be subsidiary to this Item. Water for irrigating the seeded area, when specified, will be paid for under Item 168, "Vegetative Watering."

APPENDIX IIIF-E

PERMITTED LANDFILL CONDITION HYDROLOGIC CALCULATIONS

Includes pages IIIF-E-1 through IIIF-E-126

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

05/20/2024

CONTENTS

CHARLES R. MARSH
105073

05/20/2024

UPDATED PERMITTED CONDITION HYDROLOGIC CALCULATIONS

Appendix IIIF-E presents the hydrologic calculations for the updated permitted conditions summarized on Drawings IIIF-E-16 and IIF-E-17. The following summarizes the content of this appendix:

- Hypothetical Storm data are provided on page IIIF-E-3.
- Precipitation loss information is included on pages IIIF-E-5 and IIIF-E-6.
- Hydrograph development information is presented on IIIF-E-7 through IIIF-E-12.
- A comparison between the existing permitted, updated permitted, and proposed drainage conditions is presented in Section 4 of Appendix IIIF – Drainage Design Report.
- The HEC-HMS output for the 25-year storm event for the updated permitted conditions is presented on IIIF-E-18 through IIIF-E-68.
- Volume and Velocity Calculations are presented on Pages IIIF-E-69 through IIIF-E-73 and IIIF-E-74 through IIIF-E-76, respectively.
- Excerpts from the currently permitted drainage analysis are included on Pages IIIF-E-80 to IIIF-E-126.

HYPOTHETICAL STORM DATA

Hypothetical Storm Data

Precipitation data taken from NOAA Atlas 14 rainfall data.

Time	5 min	15 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr
25-Year Event	0.895	1.78	3.29	4.26	4.87	5.92	6.87	7.88

NOAA Atlas 14 - Precipitation-Frequency Atlas of the United States, Volume 11, Version 2.0: Texas (*U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Weather Service, 2018*) was used to identify precipitation values for storm durations ranging from 5 minutes to 24 hours.

PRECIPITATION LOSS DATA

Prep By: VG
Date: 5/9/2024

Chkd By: BPY/CRM
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
PRECIPITATION LOSS DATA

Required: Determine the SCS curve numbers for both on-site and off-site drainage areas for use in the HEC-HMS analysis.

References:

1. U.S. Army Corps of Engineers, Hydrologic Engineering Center, *HEC-HMS Hydrologic Modeling System 4.9,* January 2022.
2. United States Department of Agriculture, National Resource Conservation Service, Web Soil Survey for Johnson County, Texas (http://websoilsurvey.nrcs.usda.gov).
3. The Hydrologic Evaluation of Landfill Performance (HELP) Model - Engineering Documentation for version 3. EPA/600/R-94/168b, September 1994.

Note: Approximate non landfill areas within the permit boundary on SCS map (page IIIF-A-6).

Solution: Based on the soil survey information found in Ref. 2, hydrologic groups A, B, C, and D soils are found within the permit boundary. (See pages IIIF-A-6 trough IIIF-A-9)

All non-landfill on-site and offsite drainage areas and drainage channels were considered pasture land in fair condition. A curve number was selected using the table on page IIIF-A-12.

Hydrologic Group	A	B	C	D
CN	49	69	79	84

Composite calculations for offsite and non-landfill drainage areas are shown on page IIIF-E-6.

The final cover system was assumed to be in place and the erosion layer will control precipitation loss. A curve number that is corrected for the surface slope of the erosion layer may be computed first using the chart on page IIIF-A-12 to select an un-adjusted curve number. Calculate the adjusted curve number using equation 34 from Ref. 3 (see page IIIF-A-11).

$$CN_{II} = 100 - (100 - CN_{II\,o}) * (L^{*\,2} / S^{*}) \wedge (CN_{II\,o}^{-0.81})$$

Use: $CN_{II\,o} = 85$, $L^{*} = (500/500)$, $S^{*} = (.04/.04)$ for top dome surfaces
Use: $CN_{II\,o} = 85$, $L^{*} = (120/500)$, $S^{*} = (.25/.04)$ for side slopes

Calculate: CN = 85 for top dome surfaces
Calculate: CN = 86 for side slopes

- Use curve number calculated for side slopes for the entire final cover area, inculding top dome areas, conservatively.

The pond areas are assumed to collect all precipitation for their areas:

Use: CN = 99

The initial abstraction is:

Use: I = 0.0"

- All drainage areas were modeled to assume no inital abstractions.

Prep By: VG
Date: 5/9/2024

Chkd By:BPY/CRM
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
COMPOSITE CURVE NUMBER SUMMARY

Drainage Area	Hydraulic Soil Group Area (ac)				Total Area (ac)	Composite CN
	A	B	C	D		
	CN = 49	CN = 69	CN = 79	CN = 84		
S1	0.00	0.00	2.12	6.12	8.24	83
S2	0.00	0.00	3.36	3.56	6.92	82
S3	0.00	0.30	4.33	3.83	8.46	81
S4	0.00	0.00	1.14	1.20	2.34	82
S5	0.00	0.00	19.41	7.30	26.71	80
S6	0.00	0.00	0.00	5.75	5.75	84
S7	0.00	1.03	0.00	1.08	2.11	77
S8	0.04	0.00	2.66	1.16	3.86	80
S9	0.49	0.30	0.64	2.34	3.77	77
S10	0.00	0.00	0.00	1.54	1.54	84
S11	0.00	0.00	1.77	0.00	1.77	79
O1	43.62	67.68	48.23	7.31	166.84	67
O2	7.03	5.64	2.57	0.00	15.24	61
O3	0.00	0.00	14.70	0.06	14.76	79
O4	0.00	1.79	7.21	0.00	9.00	77
O5	0.00	0.67	1.26	0.00	1.93	76
O6	0.00	3.37	7.56	0.00	10.93	76

HYDROGRAPH DEVELOPMENT INFORMATION

HYDROGRAPH DEVELOPMENT INFORMATION

Landfill Areas

Direct runoff methods (i.e., kinematic wave) have been used for the landfill final cover areas. The kinematic wave method has been used to model the four percent slope top dome areas before flow is intercepted by top dome swales. The kinematic wave method is a physically based method using slope, surface roughness, catchment lengths and areas. This method does not consider attenuation for flood wave; as a consequence, this method provides for a conservative analysis. The following typical parameters for the direct runoff method have been developed for the landfill areas consistent with the parameters used in the currently approved hydrologic analysis (HEC-HMS output file included in pages IIIF-E-18 through IIIF-E-68.

Kinematic wave parameters for overland flow:

Slope:	Varies from 0.04 to 0.25 ft/ft landfill slopes
N:	0.30 Manning's friction coefficient for sheet flow
L:	Represents a typical distance between swales for overland flow.

Percentage of drainage area represented by this element is 100 percent.

Muskingum-Cunge routing is used along with the kinematic wave method to estimate hydrographs at the outfall of each separate drainage area analyzed using the direct runoff method.

Muskingum-Cunge routing data for swale:

- Swale length (ft): Typical swale lengths for each drainage area were used.
- Swale bottom slope (ft/ft): 0.005 ft/ft
- Swale roughness coefficient: 0.03
- Swale type: A trapezoidal channel was used with no bottom width to simulate a triangular channel.

Muskingum-Cunge routing data for channels:

- Channel length (ft): The length of the channel section.
- Channel slope (ft/ft): Varies from 0.005 to 0.1075.
- Channel roughness coefficient: 0.03 for grass lined.
- Channel type: A trapezoidal channel was used with varying bottom width and 3:1 side slopes.

Non-Landfill Final Cover Areas

Hydrographs for a portion of the non-landfill final cover areas within the permit boundary (e.g., pond areas) and all off-site areas were developed using the Snyder unit hydrograph method. Espey “10-Minute” method has been used to estimate Snyder parameters. Snyder parameter estimations are provided on the pages IIIF-E-11 and IIIF-E-12.

As discussed in Section 2 of Appendix IIIF, hydrographs for the areas outside of the permit boundary (O1, O2, O3, O4, O5, and O6), and larger areas inside the permit boundary (S1 through S11) were developed using the Snyder unit hydrograph method. The percent imperviousness ranges from 2 percent to 25 percent for the non-landfill on-site and off-site areas. Pond areas are assumed to be 99 percent impervious, and areas with significant channel surface or paved surfaces were assigned higher percentages of impervious area, as shown on IIIF-E-11.

Drainage Areas

The drainage areas used for this analysis are shown on Sheet IIIF-E-16 and Sheet IIIF-E-17. The routing scheme for the updated permitted condition is shown in the HEC-HMS output file presented on pages IIIF-E-18 through IIIF-E-68.

ESPEY 10-MINUTE METHOD PARAMETERS

Prep By: VG
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
ESPEY 10 MINUTE CALCULATION
UPDATED PERMITTED CONDITION

Chkd By: BPY/CRM
Date: 5/9/2024

Snyder's Hydrograph Coefficients (Espey's 10 Minute Method)

Updated Permitted Expansion Conditions

Area No.	Area (acres)	Max. Flow Length (L) (ft)	S (ft/ft)	I (%)	Manning "n"	Φ[1]	T_r[2] (min)	T_{lag}[3] (min)	T_{lag} (hr)	Area[4] (sq mi)	q_p[5] (cfs/sq mi)	C_p[6]
O1	166.84	4,242	0.0316	2	0.04	0.87	35.6	33.1	0.55	0.2607	729.1	0.63
O2	15.24	990	0.0444	10	0.04	0.84	16.6	14.1	0.23	0.0238	1818.1	0.67
O3	14.76	1,771	0.0802	10	0.04	0.84	16.4	13.9	0.23	0.0231	1848.0	0.67
O4	9.00	987	0.0871	2	0.04	0.87	19.8	17.3	0.29	0.0141	1538.7	0.69
O5	1.93	670	0.0970	2	0.04	0.87	17.6	15.1	0.25	0.0030	1852.7	0.73
O6	10.93	935	0.0684	2	0.04	0.87	20.7	18.2	0.30	0.0171	1450.4	0.69
S1	8.24	1,052	0.0570	10	0.04	0.84	15.8	13.3	0.22	0.0129	1962.6	0.68
S2	6.92	1,041	0.0768	10	0.04	0.84	14.6	12.1	0.20	0.0108	2145.9	0.68
S3	8.46	1,061	0.0650	5	0.04	0.86	18.0	15.5	0.26	0.0132	1704.4	0.69
S4	2.34	373	0.0724	5	0.04	0.86	13.8	11.3	0.19	0.0037	2388.6	0.70
S5	26.71	1,442	0.0804	5	0.04	0.86	18.3	15.8	0.26	0.0417	1597.7	0.66
S6	5.75	972	0.0494	5	0.04	0.86	18.9	16.4	0.27	0.0090	1643.4	0.70
S7	2.11	486	0.0494	5	0.04	0.86	16.1	13.6	0.23	0.0033	2028.9	0.72
S8	3.86	1,191	0.0998	10	0.04	0.84	14.1	11.6	0.19	0.0060	2279.3	0.69
S9	3.77	1,120	0.0661	25	0.03	0.75	11.0	8.5	0.14	0.0059	2993.9	0.66
S10	1.32	283	0.0671	15	0.04	0.82	10.0	7.5	0.13	0.0021	3431.0	0.67
S11	1.77	675	0.0711	2	0.04	0.87	19.1	16.6	0.28	0.0028	1707.7	0.74

[1] Conveyance efficiency coefficient from Dodson & Associates Inc., *ProHec-1 Program Documentation* , 1995, pages 6-19 and 6-20.

[2] $T_r = 3.1(L^{0.23})(S^{-0.25})(I^{-0.18})(\Phi^{1.57})$

[3] $T_{lag} = T_r - \Delta t/2$

[4] From area summary sheet

[5] $q_p = 31600(A^{-0.04})(T_r^{-1.07})$

[6] $C_p = 49.375(A^{-0.04})(T_r^{-1.07})(T_{lag})$

T_r = surface runoff to unit hydrograph peak (min)
L = distance along main channel from study point to watershed boundary (ft)
S = main channel slope (ft/ft)
I = impervious cover within the watershed (%)
T_{lag} = watershed lag time (min)
Δt= computation interval (minutes)
q_p = unit hydrograph peak discharge (cfs/sq mi)
C_p = Snyder's peaking coefficient

ROYAL OAKS LANDFILL
0120-076-11-106
ESPEY 10 MINUTE SAMPLE CALCULATION

Snyder Unit Hydrograph uses lag time (T_{lag}) and peaking coefficient accounting for flood wave and watershed storage conditions.

Drainage area "S10" in the post-project condition is used in this example.

Estimated Watershed specific parameters

A =	1.32	acres	watershed area
L =	283	feet	maximun flow length with this watershed
S =	0.0671	feet/feet	watershed slope
I =	15	percent (%)	watershed imperviousness
n =	0.04		Manning's coefficient

Calculate Tr: time beginning of surface runoff to the unit hydrograph peak in minutes

$T_r = 3.1(L^{0.23})(S^{-0.25})(I^{-0.18})(\Phi^{1.57})$

Estimate : conveyance efficiency coefficient

Φ = for 2 percent impervious cover and n = 0.06

$\Phi = 0.82$

$T_r = 3.1(283^{0.23})(0.0671^{-0.25})(15^{-0.18})(0.82^{.57})$

$T_r = 10.0$ min

Calculate T_{lag}: watershed lag time

$T_{lag} = Tr - (\Delta t/2)$ Δt is calculation interval, and 5 minutes is used in the HEC - HMS modeling in this project

$T_{lag} = 7.5$ minutes

$T_{lag} = 0.13$ hours

$A = A/640$

$A = 0.0021$ square miles

Calculate q_p: peak discharge of unit hydrograph per unit area (cfs/sq. mi).

$q_p = 31600(A^{-0.04})(T_r^{-1.07})$

$q_p = 31600(0.0021^{-0.04})(10^{-1.07})$

$q_p = 3431.0$ cfs/sq. mi

Calculate Peaking coefficient C_p:

$C_p = 49.375(A^{-0.04})(T_r^{-1.07})(T_{lag})$

$C_p = 49.375(0.0021^{-0.04})(10^{-1.07})(0.13)$

$C_p = 0.67$

POND ROUTING INFORMATION

Pond Routing Information

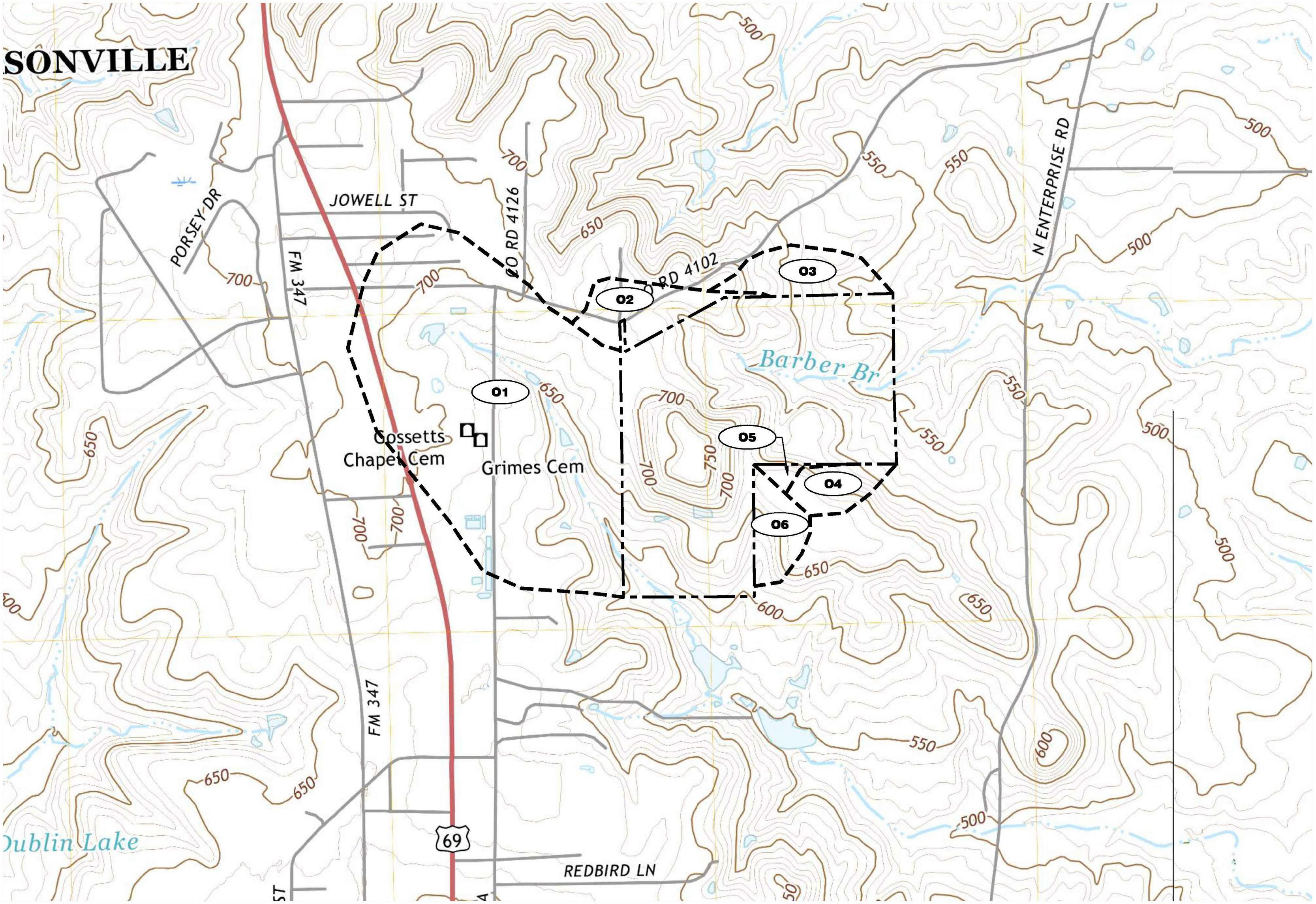
The following information was used to develop the existing condition.

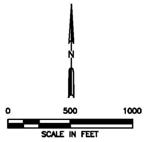
The elevation/storage/discharge functions which are used to determine the volume of the detention ponds is summarized below.

Pond P1[1]			Pond P2[1]			Pond P3[1]		
Elevation (ft-msl)	Storage (ac-ft)	Discharge (cfs)	Elevation (ft-msl)	Storage (ac-ft)	Discharge (cfs)	Elevation (ft-msl)	Storage (ac-ft)	Discharge (cfs)
580.00	0.00	0.0	610.00	0.00	0.0	530.00	0.00	0.0
582.00	0.65	1.8	612.00	0.85	2.7	532.00	1.16	3.8
584.00	1.52	2.7	614.00	1.91	4.2	534.00	2.57	5.9
586.00	2.65	3.4	616.00	3.21	5.2	536.00	4.28	7.5
588.00	4.05	3.9	618.00	4.78	6.1	538.00	6.29	8.7
590.00	5.77	4.4	619.00	5.71	6.5	540.00	8.64	9.9
592.00	7.81	4.9	620.00	6.63	42.9	542.00	11.36	10.9
594.00	10.20	5.3	621.00	7.72	109.0	544.00	14.47	11.8
595.00	11.59	41.4	~	~	~	545.00	16.25	48.2
596.00	12.97	107.4	~	~	~	546.00	18.02	114.4

[1] Elevation/storage/discharge information was reproduced from Attachment 6 (pages IIIF-E-123 through IIIF-E-125), Ground water and Surface Water Protection Plan prepared by HMA Environmental Services Inc. dated May 10, 1996.

UPATED PERMITTED HEC-HMS ANALYSIS
DRAINAGE AREAS





LEGEND

LANDFILL PROPERTY

DRAINAGE AREA BOUNDARY

O1 DRAINAGE AREA DESIGNATION

DRAINAGE AREA NO.	AREA (ACRES)
O1	166.84
O2	15.24
O3	14.76
O4	9.00
O5	1.93
O6	10.93

CHARLES R. MARSH
105073
05/20/2024

JACKSONVILLE WEST, TX
2022

JACKSONVILLE EAST, TX
2022

MOUNT SELMAN, TX
2022

TECULA, TX
2022

NOTES:

1. REPRODUCED FROM 7.5 MINUTE, JACKSONVILLE WEST, JACKSONVILLE EAST, MOUNT SELMAN, AND TECULA TEXAS QUADRANGLE USGS MAP DATED 2022.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-E-16 OFFSITE DRAINAGE.DWG

DRAWN BY: JDW
DESIGN BY: VG
REVIEWED BY: JAE

REVISIONS

NO.	DATE	DESCRIPTION

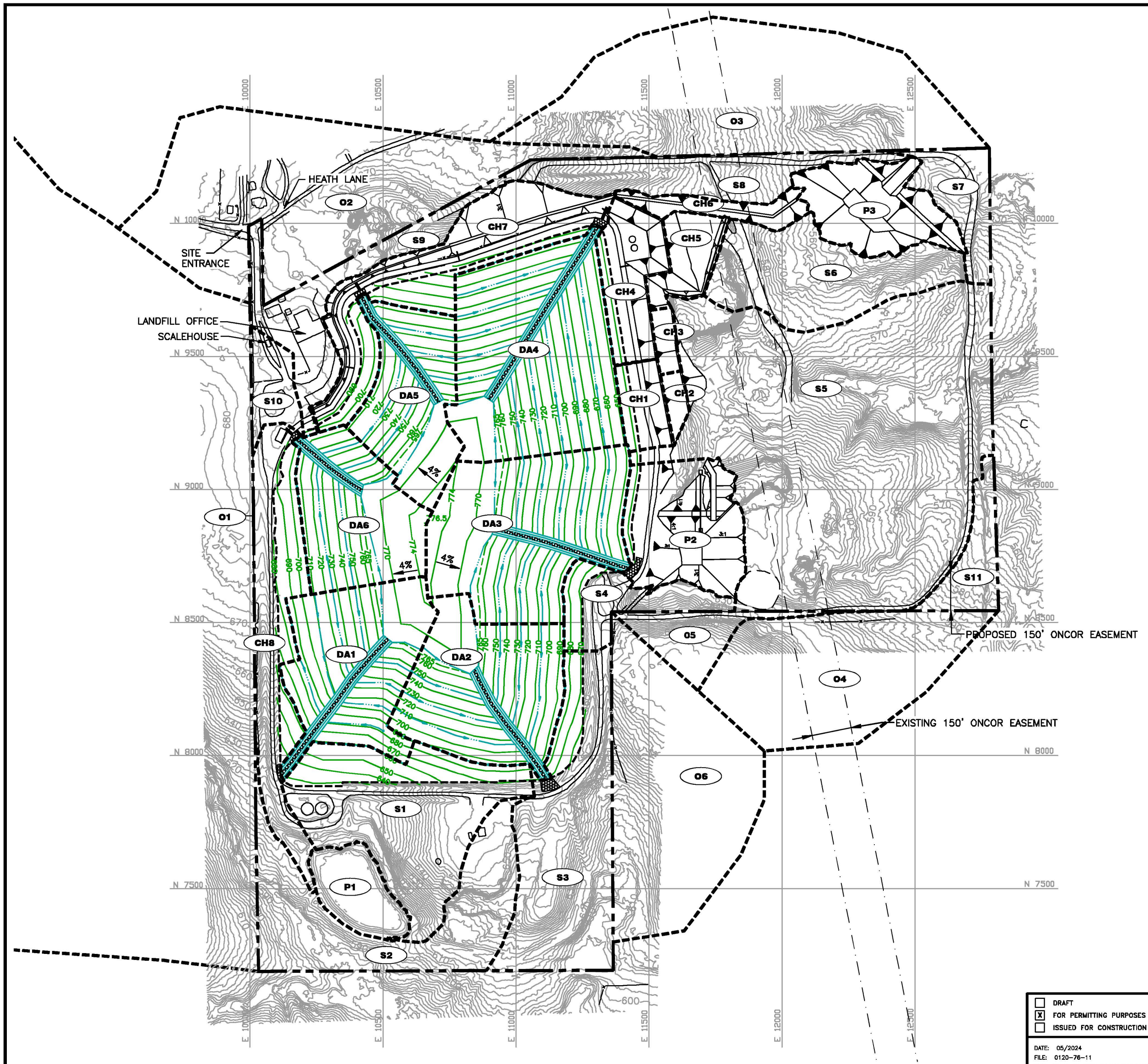
Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT OFFSITE DRAINAGE AREA MAP

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

WWW.WCGRP.COM

DRAWING IIIF-E-16



N

0 200 400
SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LIMIT OF WASTE
- E 10500 SITE GRID
- 610 EXISTING CONTOUR (SEE NOTE 1)
- 624 PROPOSED FINAL COVER CONTOUR
- DRAINAGE SWALE
- DRAINAGE LETDOWN
- CHANNEL CENTERLINE
- DRAINAGE AREA BOUNDARY
- DA3 DRAINAGE AREA DESIGNATION

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED PROFESSIONAL ENGINEER

05/20/2024

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.

DRAINAGE AREA NO.	AREA (ACRES)	DRAINAGE AREA NO.	AREA (ACRES)
DA1	6.50	CH1	1.28
DA2	7.03	CH2	0.40
DA3	9.01	CH3	0.46
DA4	10.35	CH4	2.67
DA5	5.02	CH5	1.58
DA6	5.28	CH6	1.23
S1	8.24	CH7	6.45
S2	6.92	CH8	5.53
S3	8.46	P1	2.01
S4	2.34	P2	4.64
S5	26.71	P3	3.64
S6	5.75	01	166.84
S7	2.11	02	15.24
S8	3.86	03	14.76
S9	3.77	04	9.00
S10	1.32	05	1.93
S11	1.77	06	10.93

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-E-17 PERM COMPLETION PLAN.DWG

DRAWN BY: JDW
DESIGN BY: BPY
REVIEWED BY: JAE

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT UPDATED PERMITTED PROJECT DRAINAGE AREAS

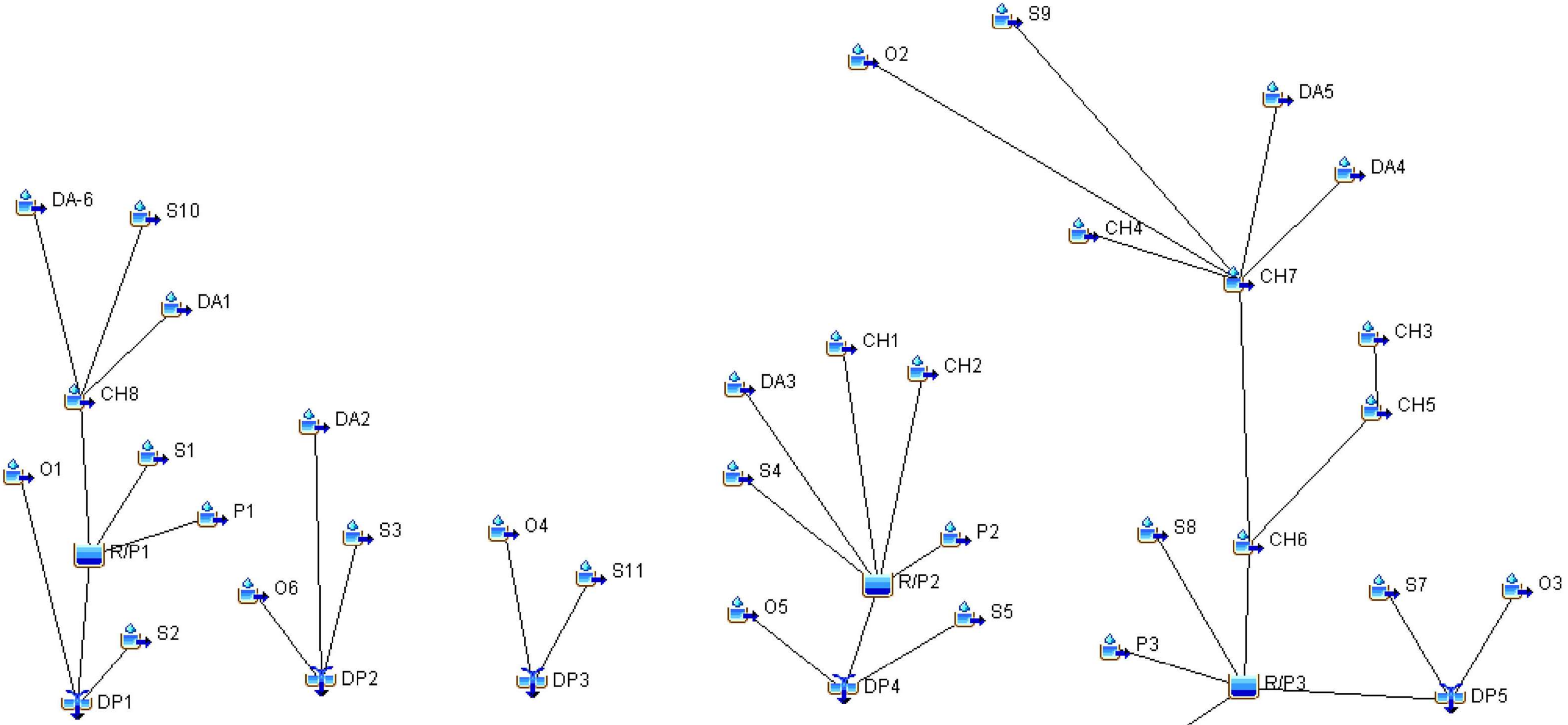
ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

WWW.WCGRP.COM

DRAWING IIIF-E-17

O:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF-E\IIIF-E-17 -PERMITTED DRAINAGE.dwg, byoung, 1:2

HEC-HMS OUTPUT – UPDATED PERMITTED 25-YEAR, 24-HOUR STORM EVENT


DA-6
S10
DA1
CH8
O1
S1
P1
R/P1
S2
DP1
DA2
S3
O6
DP2
O4
S11
DP3
DA3
CH1
CH2
S4
P2
R/P2
O5
S5
DP4
S9
O2
DA5
DA4
CH4
CH7
CH3
CH5
S8
CH6
S7
O3
P3
R/P3
DP5
S6

Project: Royal_Oaks_Permitted
Simulation Run: 25-Year Run
Simulation Start: 28 December 2020, 24:00
Simulation End: 31 December 2020, 13:00

HMS Version: 4.10
Executed: 27 December 2023, 18:49

Global Parameter Summary - Subbasin

Area (MI2)

Element Name	Area (MI2)
Da6	0.01
S10	0
Ch8	0.01
S1	0.01
O1	0.26
Da1	0.01
P1	0
S2	0.01
O6	0.02
S3	0.01
Da2	0.01
Da3	0.01
P2	0.01
Ch1	0
S4	0
Ch2	0
S5	0.04
O2	0.02
Da5	0.01
S9	0.01
Ch7	0.01
Da4	0.02
Ch4	0
Ch3	0
Ch5	0
Ch6	0
S6	0.01

S8	0.01
P3	0.01
O3	0.02
S7	0
O5	0
O4	0.01
S11	0

Downstream

Element Name	Downstream
Da6	Ch8
S10	Ch8
Ch8	R/p1
S1	R/p1
O1	Dp1
Da1	R/p1
P1	R/p1
S2	Dp1
O6	Dp2
S3	Dp2
Da2	Dp2
Da3	R/p2
P2	R/p2
Ch1	R/p2
S4	R/p2
Ch2	R/p2
S5	Dp4
O2	Ch7
Da5	Ch7
S9	Ch7
Ch7	R/ch6
Da4	R/ch6
Ch4	R/ch6
Ch3	Ch5
Ch5	R/ch6
Ch6	R/p3
S6	R/p3
S8	R/p3
P3	R/p3
O3	Dp5
S7	Dp5
O5	Dp4
O4	Dp3
S11	Dp3

LossRate 1

Element Name	Percent Impervious Area	Curve Number
Da6	0	86
Ch8	0	84
Da1	0	86
Da2	0	86
Da3	0	86
Ch1	0	84
Ch2	0	84
Da5	0	86
Ch7	0	84
Da4	0	86
Ch4	0	84
Ch3	0	84
Ch5	0	84
Ch6	0	84

Transform: Kinematic Wave

Element Name	Transform
Da6	Kinematic Wave
Ch8	Kinematic Wave
Da1	Kinematic Wave
Da2	Kinematic Wave
Da3	Kinematic Wave
Ch1	Kinematic Wave
Ch2	Kinematic Wave
Da5	Kinematic Wave
Ch7	Kinematic Wave
Da4	Kinematic Wave
Ch4	Kinematic Wave
Ch3	Kinematic Wave
Ch5	Kinematic Wave
Ch6	Kinematic Wave

Transform: Snyder

Element Name	Snyder Method	Snyder Tp	Snyder Cp
S10	Standard	0.13	0.67
S1	Standard	0.22	0.68
O1	Standard	0.55	0.63
S2	Standard	0.2	0.68
O6	Standard	0.3	0.69
S3	Standard	0.26	0.69
S4	Standard	0.19	0.7
S5	Standard	0.26	0.66
O2	Standard	0.23	0.67
S9	Standard	0.14	0.66
S6	Standard	0.27	0.7
S8	Standard	0.19	0.69
O3	Standard	0.23	0.67
S7	Standard	0.23	0.72
O5	Standard	0.25	0.73
O4	Standard	0.29	0.69
S11	Standard	0.28	0.74

Transform: Scs

Element Name	Lag	Unitgraph Type
P1	0.1	Standard
P2	0.1	Standard
P3	0.1	Standard

Global Results Summary

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Da6	0.01	51.56	29Dec2020, 12:05	5.83
S10	0	8.46	29Dec2020, 12:10	5.98
Ch8	0.02	79.76	29Dec2020, 12:05	5.48
S1	0.01	40.16	29Dec2020, 12:15	5.86
O1	0.26	318.89	29Dec2020, 12:35	4.02
Da1	0.01	61.91	29Dec2020, 12:05	5.65
P1	0	18.87	29Dec2020, 12:05	7.76
R/p1	0.05	5.26	29Dec2020, 15:20	5.77
S2	0.01	34.66	29Dec2020, 12:15	5.75
Dp1	0.32	338.5	29Dec2020, 12:35	4.33
O6	0.02	40.14	29Dec2020, 12:20	5.05
S3	0.01	37.28	29Dec2020, 12:20	5.63
Da2	0.01	66	29Dec2020, 12:05	5.31

Da3	0.01	86.65	29Dec2020, 12:05	5.68
P2	0.01	44.44	29Dec2020, 12:05	7.76
Ch1	0	11.22	29Dec2020, 12:05	5.63
S4	0	12.45	29Dec2020, 12:15	5.75
Ch2	0	3.6	29Dec2020, 12:05	5.97
S5	0.04	112.45	29Dec2020, 12:20	5.51
R/p2	0.03	6.74	29Dec2020, 13:50	6.24
O2	0.02	40.73	29Dec2020, 12:20	3.35
Da5	0.01	46.25	29Dec2020, 12:05	6.24
S9	0.01	20.16	29Dec2020, 12:10	5.16
Ch7	0.05	127.57	29Dec2020, 12:05	4.45
Da4	0.02	92.43	29Dec2020, 12:05	6.24
Ch4	0	24.85	29Dec2020, 12:05	5.74
Ch3	0	4.16	29Dec2020, 12:05	5.91
Ch5	0	17.64	29Dec2020, 12:05	5.99
R/ch6	0.07	262.5	29Dec2020, 12:05	5
Ch6	0.07	265.06	29Dec2020, 12:05	5.03
S6	0.01	26.34	29Dec2020, 12:20	5.98
S8	0.01	19.33	29Dec2020, 12:15	5.51
P3	0.01	34.7	29Dec2020, 12:05	7.76
R/p3	0.09	36.18	29Dec2020, 13:20	5.32
O3	0.02	64.93	29Dec2020, 12:15	5.4
S7	0	9.4	29Dec2020, 12:15	5.16
Dp5	0.12	84.78	29Dec2020, 12:15	5.33
O5	0	8.18	29Dec2020, 12:20	5.05
Dp4	0.07	126.65	29Dec2020, 12:20	5.77
Dp2	0.04	103.58	29Dec2020, 12:05	5.3
O4	0.01	34.48	29Dec2020, 12:20	5.16
S11	0	7.65	29Dec2020, 12:20	5.4
Dp3	0.02	42.13	29Dec2020, 12:20	5.2

Subbasin: DA6

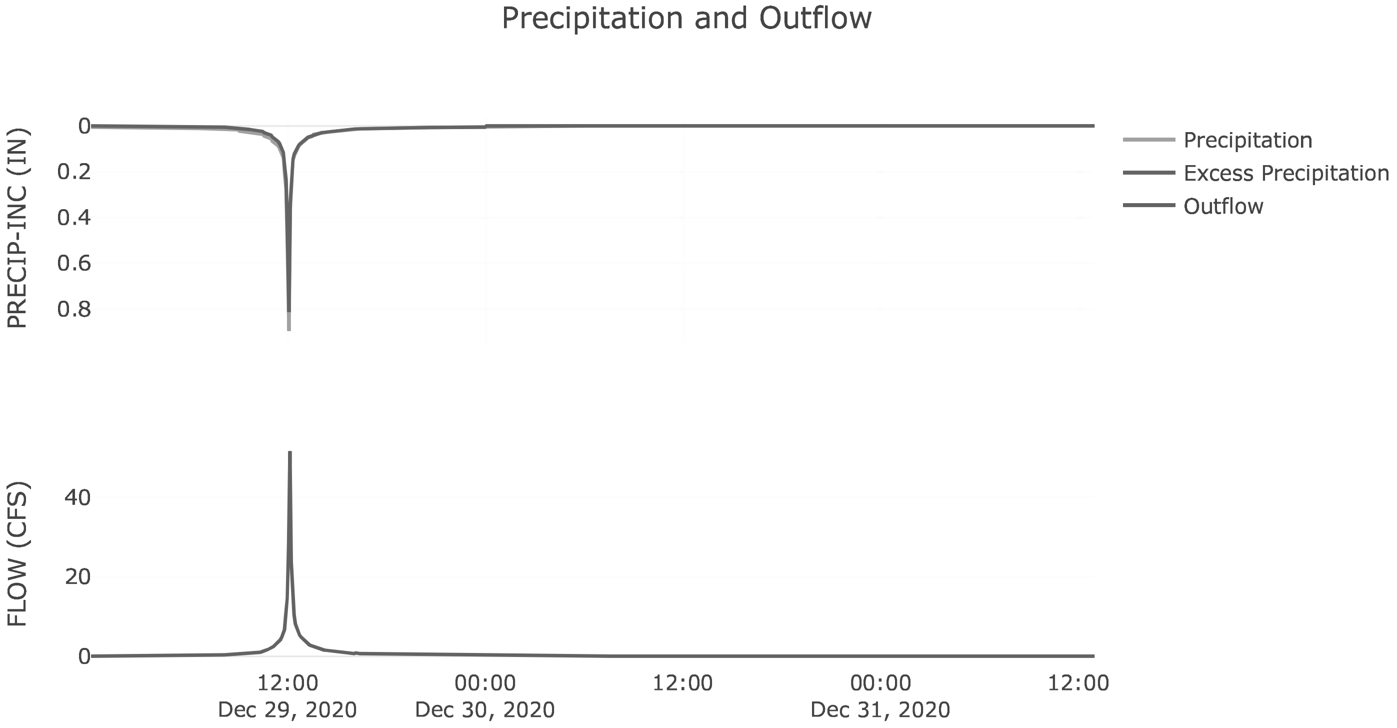
Area (MI2) : 0.01
Downstream : Ch8
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	86

Results: DA6

Peak Discharge (CFS)	51.56
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.83
Precipitation Volume (AC - FT)	3.49
Loss Volume (AC - FT)	0.74
Excess Volume (AC - FT)	2.75
Direct Runoff Volume (AC - FT)	2.58
Baseflow Volume (AC - FT)	0



Subbasin: S10

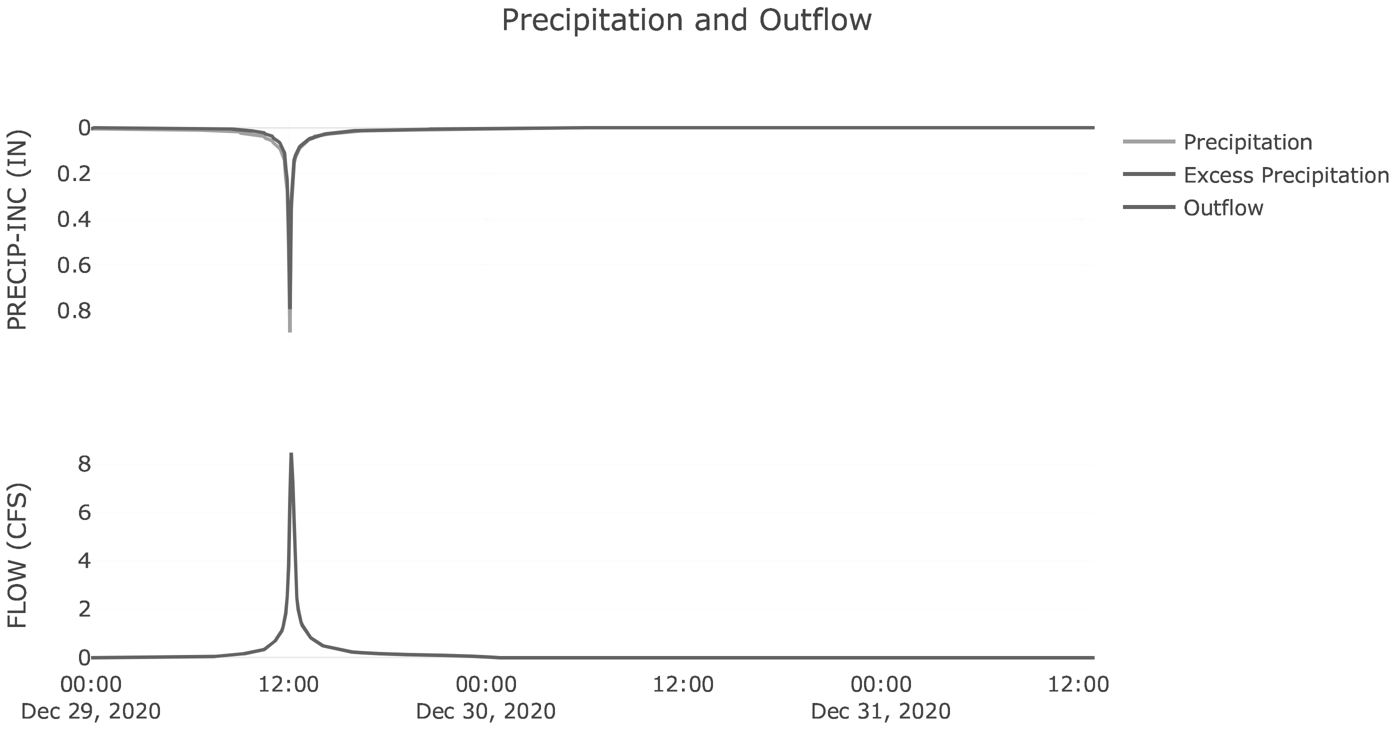
Area (MI2) : 0
Downstream : Ch8

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.13
Snyder Cp	0.67

Results: S10

Peak Discharge (CFS)	8.46
Time of Peak Discharge	29Dec2020, 12:10
Volume (IN)	5.98
Precipitation Volume (AC - FT)	0.88
Loss Volume (AC - FT)	0.21
Excess Volume (AC - FT)	0.67
Direct Runoff Volume (AC - FT)	0.67
Baseflow Volume (AC - FT)	0



Subbasin: CH8

Area (MI2) : 0.01
Downstream : R/p1
Transform : Kinematic Wave

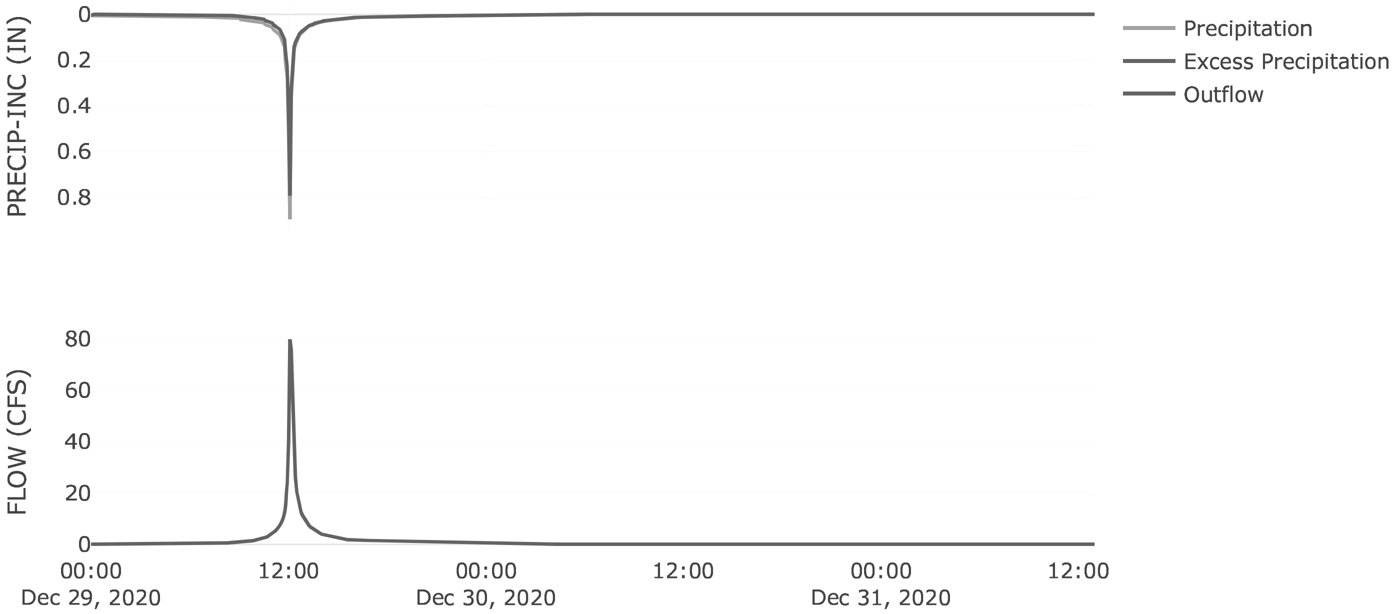
LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH8

Peak Discharge (CFS)	79.76
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.48
Precipitation Volume (AC - FT)	7.99
Loss Volume (AC - FT)	1.93
Excess Volume (AC - FT)	6.06
Direct Runoff Volume (AC - FT)	5.56
Baseflow Volume (AC - FT)	0

Precipitation and Outflow



Subbasin: S1

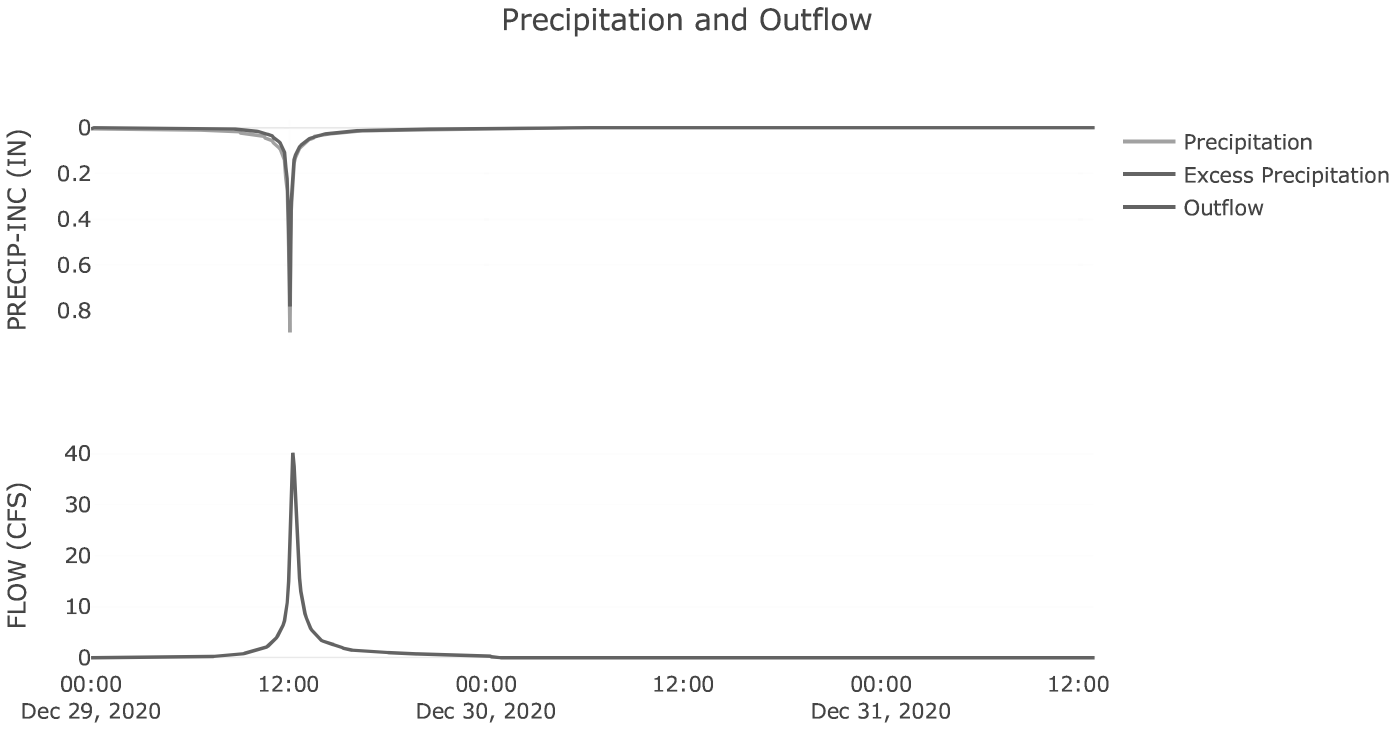
Area (MI2) : 0.01
Downstream : R/p1

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.22
Snyder Cp	0.68

Results: S1

Peak Discharge (CFS)	40.16
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.86
Precipitation Volume (AC - FT)	5.42
Loss Volume (AC - FT)	1.39
Excess Volume (AC - FT)	4.03
Direct Runoff Volume (AC - FT)	4.03
Baseflow Volume (AC - FT)	0



Subbasin: O1

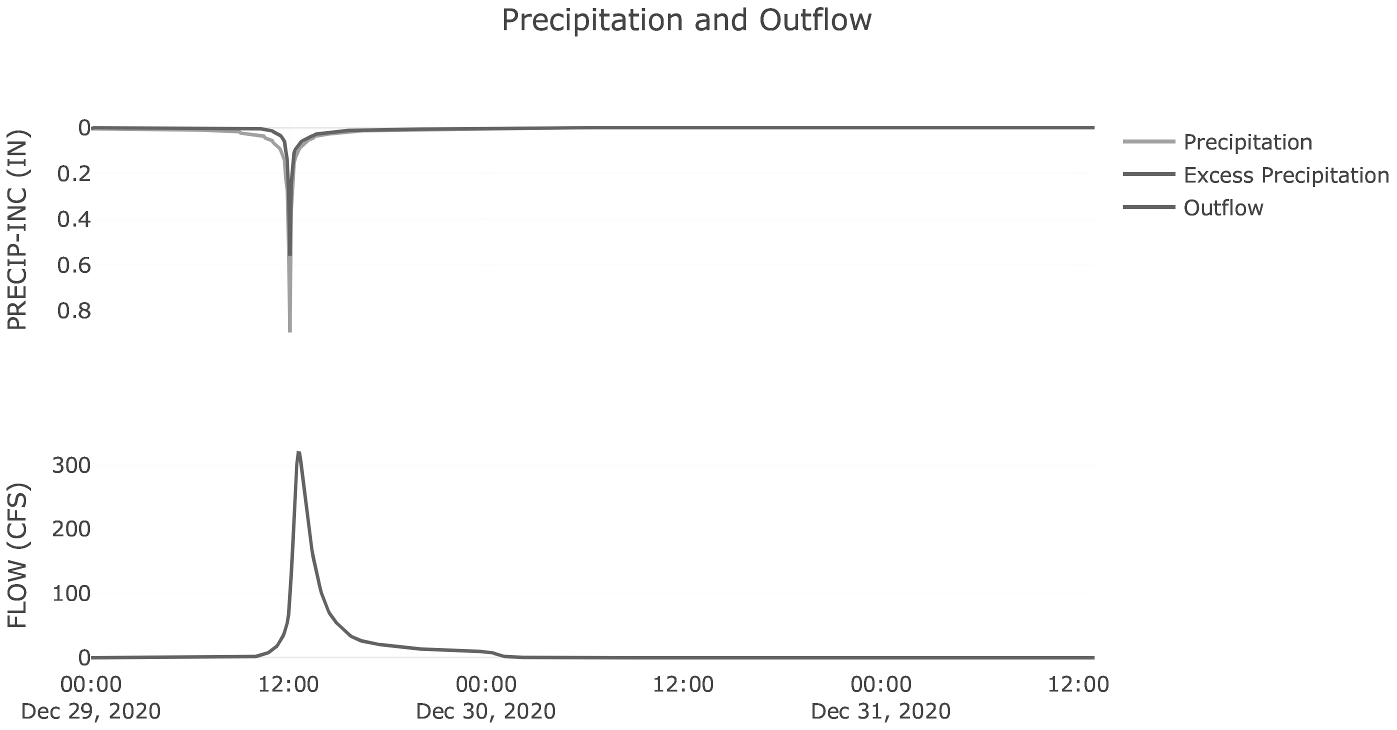
Area (MI2) : 0.26
Downstream : Dp1

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.55
Snyder Cp	0.63

Results: O1

Peak Discharge (CFS)	318.89
Time of Peak Discharge	29Dec2020, 12:35
Volume (IN)	4.02
Precipitation Volume (AC - FT)	109.56
Loss Volume (AC - FT)	53.64
Excess Volume (AC - FT)	55.92
Direct Runoff Volume (AC - FT)	55.92
Baseflow Volume (AC - FT)	0



Subbasin: DA1

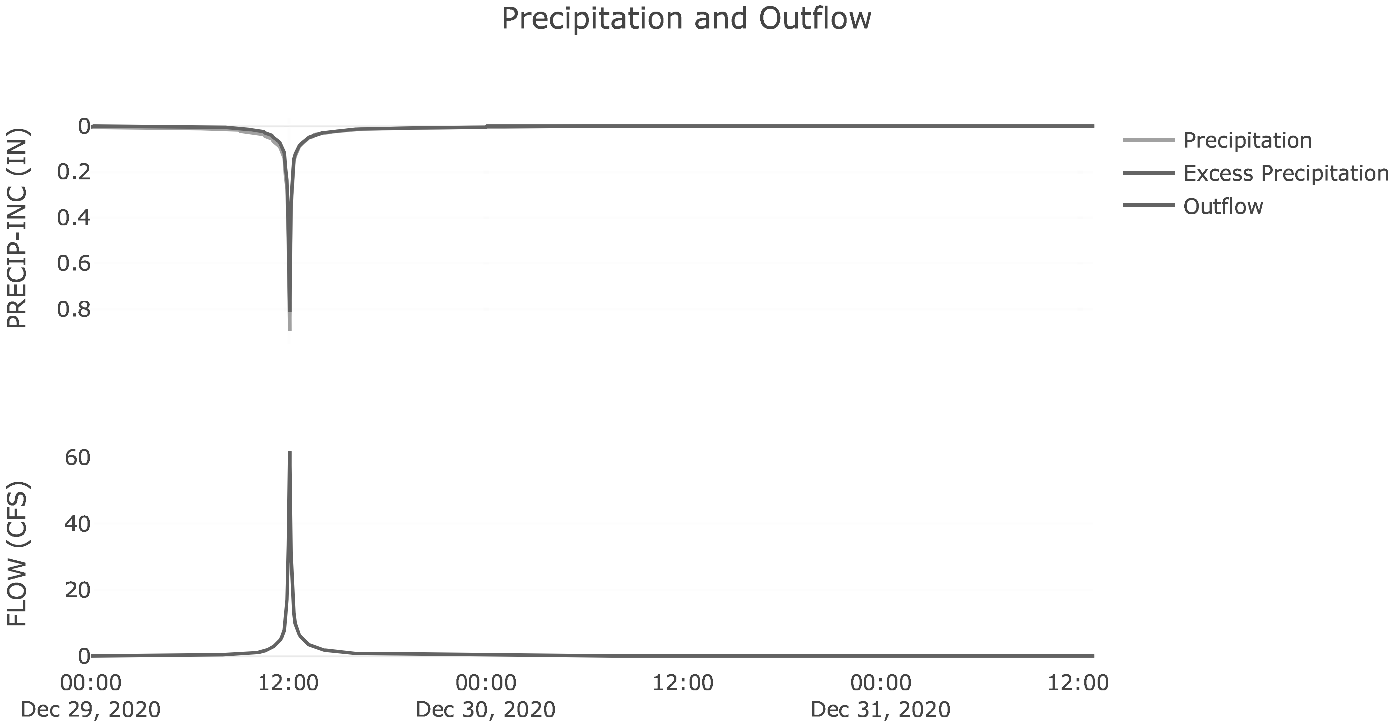
Area (MI2) : 0.01
Downstream : R/p1
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	86

Results: DA1

Peak Discharge (CFS)	61.91
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.65
Precipitation Volume (AC - FT)	4.29
Loss Volume (AC - FT)	0.91
Excess Volume (AC - FT)	3.38
Direct Runoff Volume (AC - FT)	3.07
Baseflow Volume (AC - FT)	0



Subbasin: P1

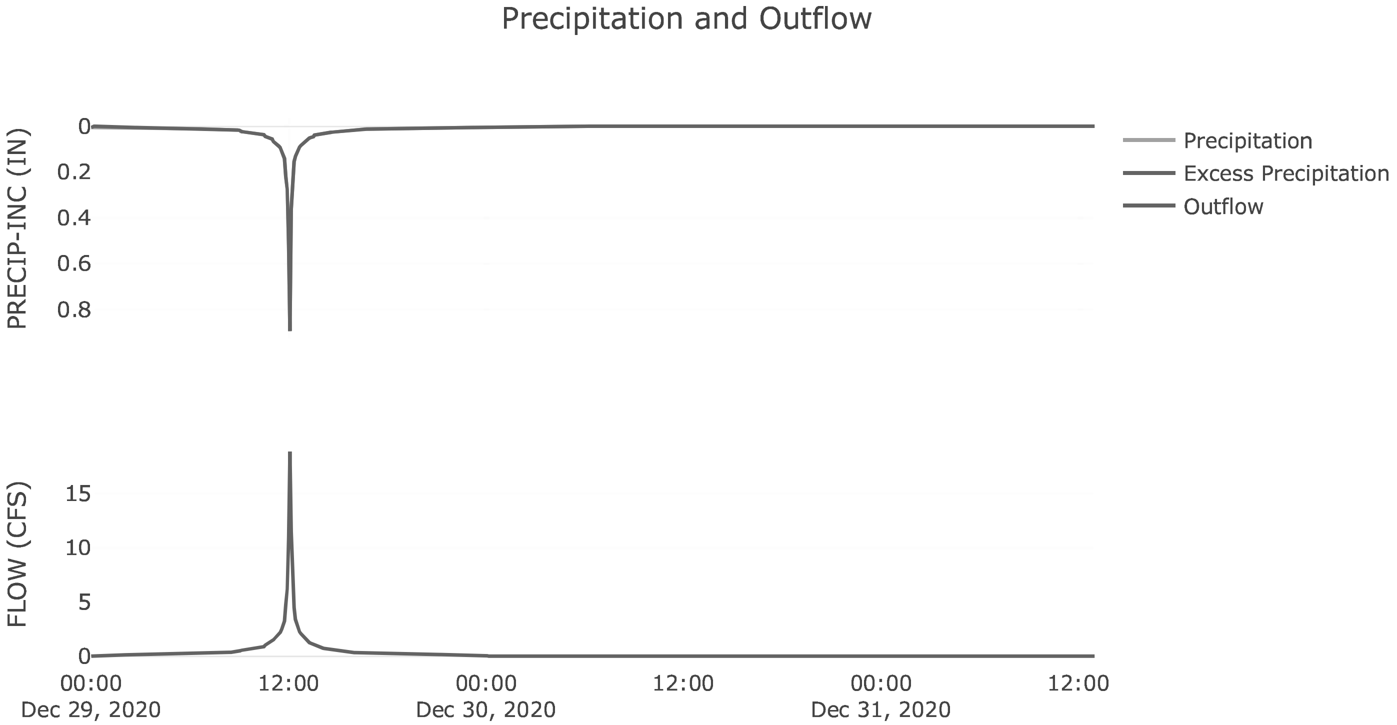
Area (MI2) : 0
Downstream : R/p1

Transform: Scs

Lag	0.1
Unitgraph Type	Standard

Results: P1

Peak Discharge (CFS)	18.87
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	7.76
Precipitation Volume (AC - FT)	1.3
Loss Volume (AC - FT)	0.02
Excess Volume (AC - FT)	1.28
Direct Runoff Volume (AC - FT)	1.28
Baseflow Volume (AC - FT)	0

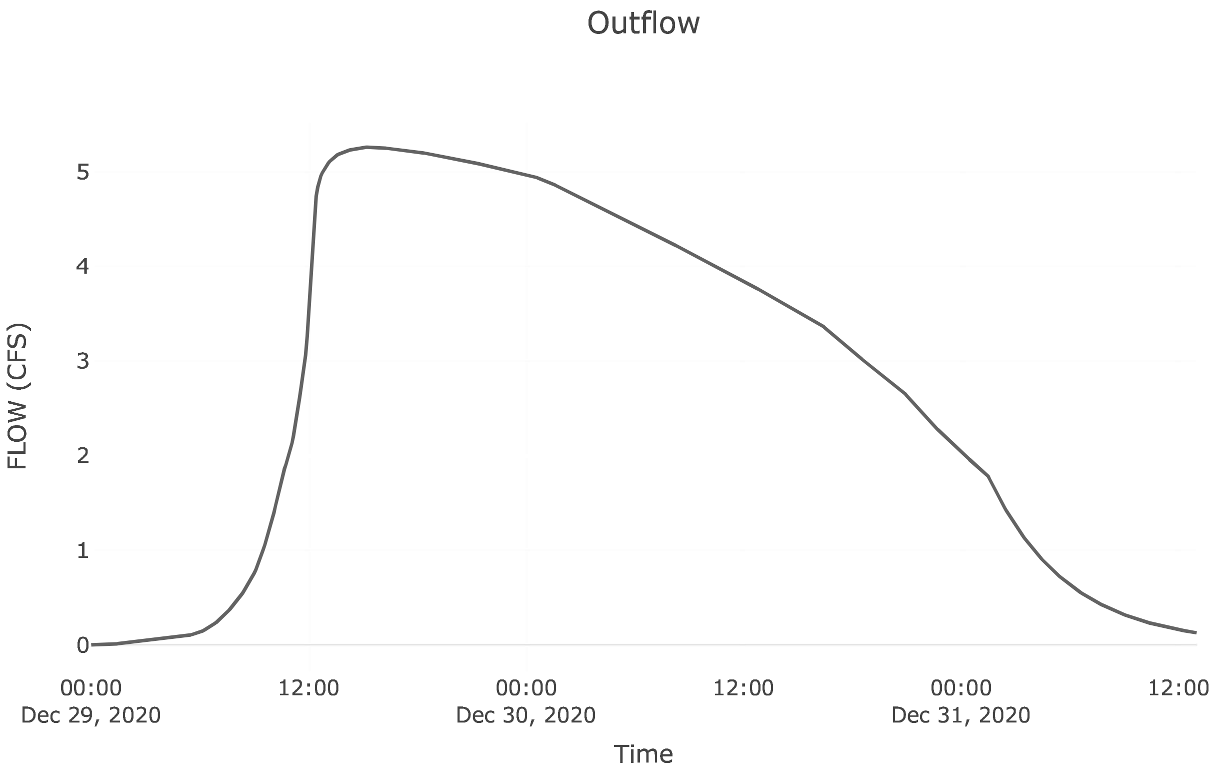


Reservoir: R/P1

Downstream : Dp1

Results: R/P1

Peak Discharge (CFS)	5.26
Time of Peak Discharge	29Dec2020, 15:20
Volume (IN)	5.77
Peak Inflow (CFS)	183.8
Time of Peak Inflow	29Dec2020, 12:05
Inflow Volume (AC - FT)	13.94
Maximum Storage (AC - FT)	9.96
Peak Elevation (FT)	593.8
Discharge Volume (AC - FT)	13.9



Subbasin: S2

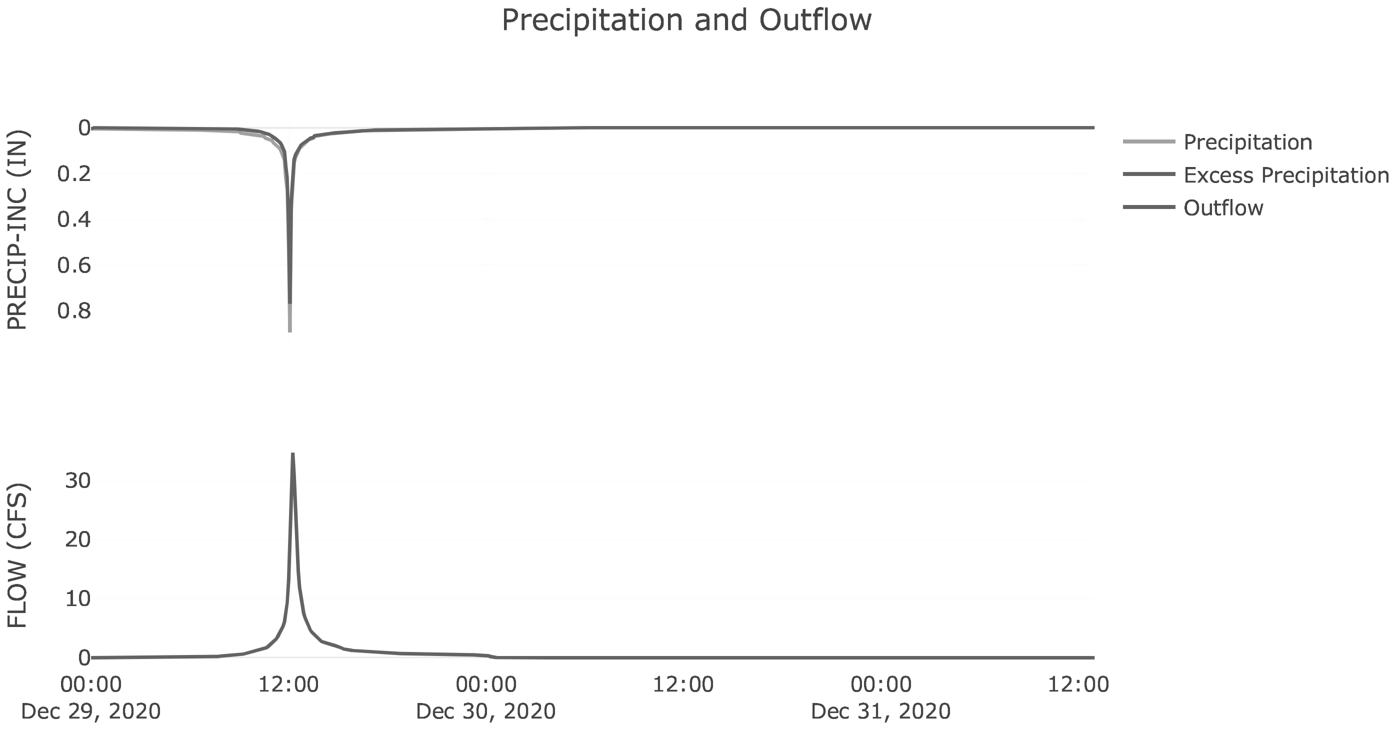
Area (MI2) : 0.01
Downstream : Dp1

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.2
Snyder Cp	0.68

Results: S2

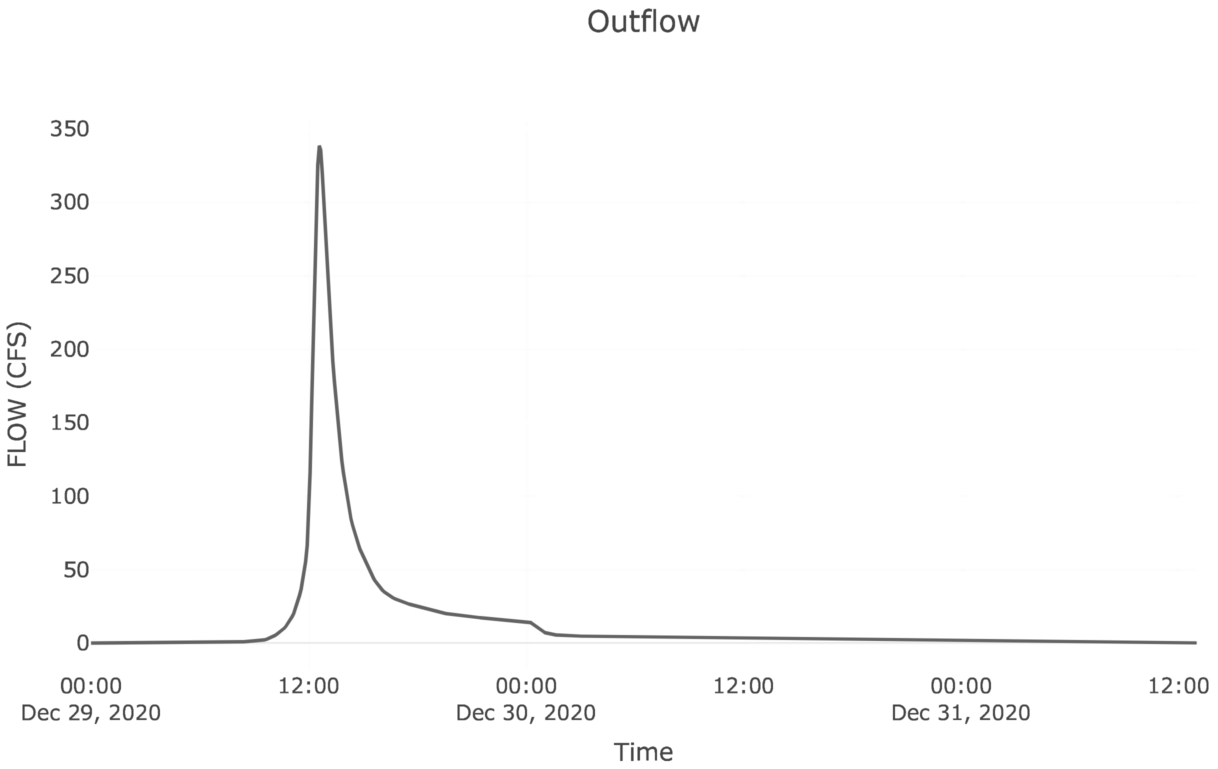
Peak Discharge (CFS)	34.66
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.75
Precipitation Volume (AC - FT)	4.54
Loss Volume (AC - FT)	1.23
Excess Volume (AC - FT)	3.31
Direct Runoff Volume (AC - FT)	3.31
Baseflow Volume (AC - FT)	0



Junction: DP1

Results: DP1

Peak Discharge (CFS)	338.5
Time of Peak Discharge	29Dec2020, 12:35
Volume (IN)	4.33



Subbasin: O6

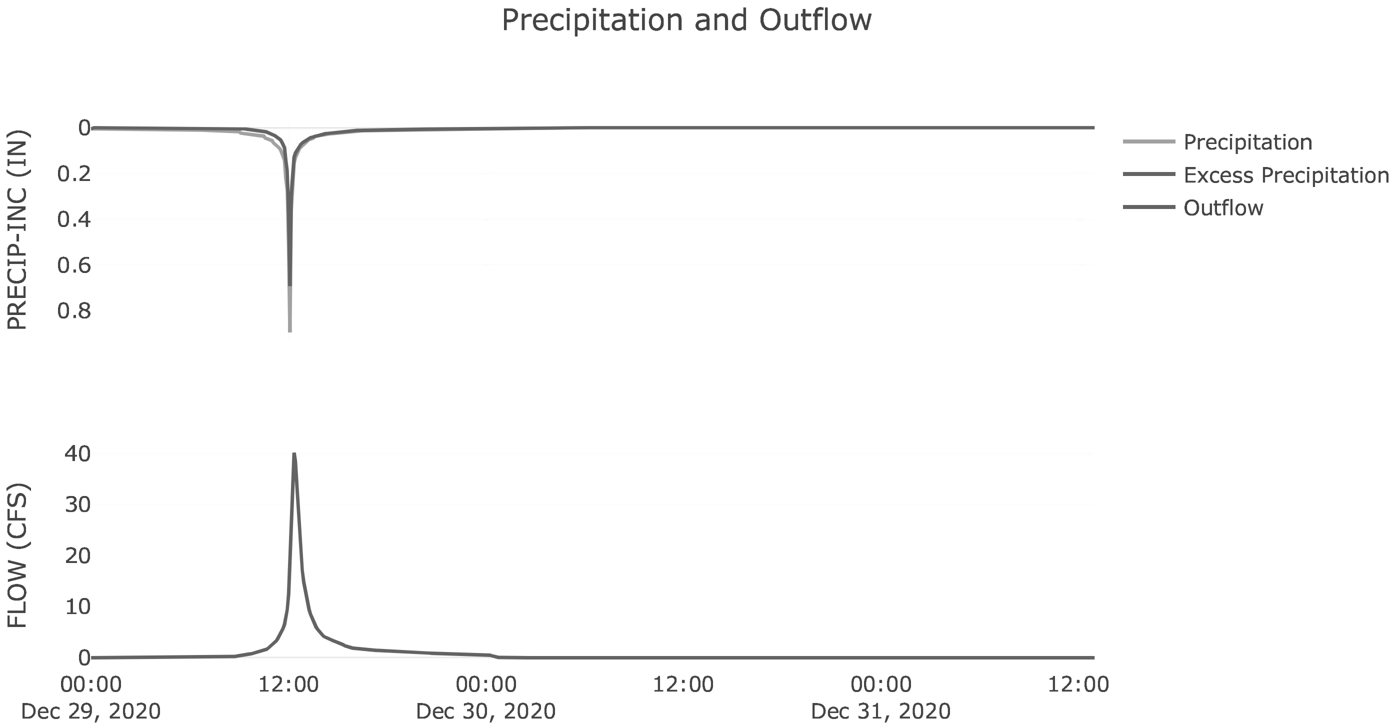
Area (MI2) : 0.02
Downstream : Dp2

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.3
Snyder Cp	0.69

Results: O6

Peak Discharge (CFS)	40.14
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.05
Precipitation Volume (AC - FT)	7.19
Loss Volume (AC - FT)	2.58
Excess Volume (AC - FT)	4.6
Direct Runoff Volume (AC - FT)	4.6
Baseflow Volume (AC - FT)	0


Precipitation and Outflow

Subbasin: S3

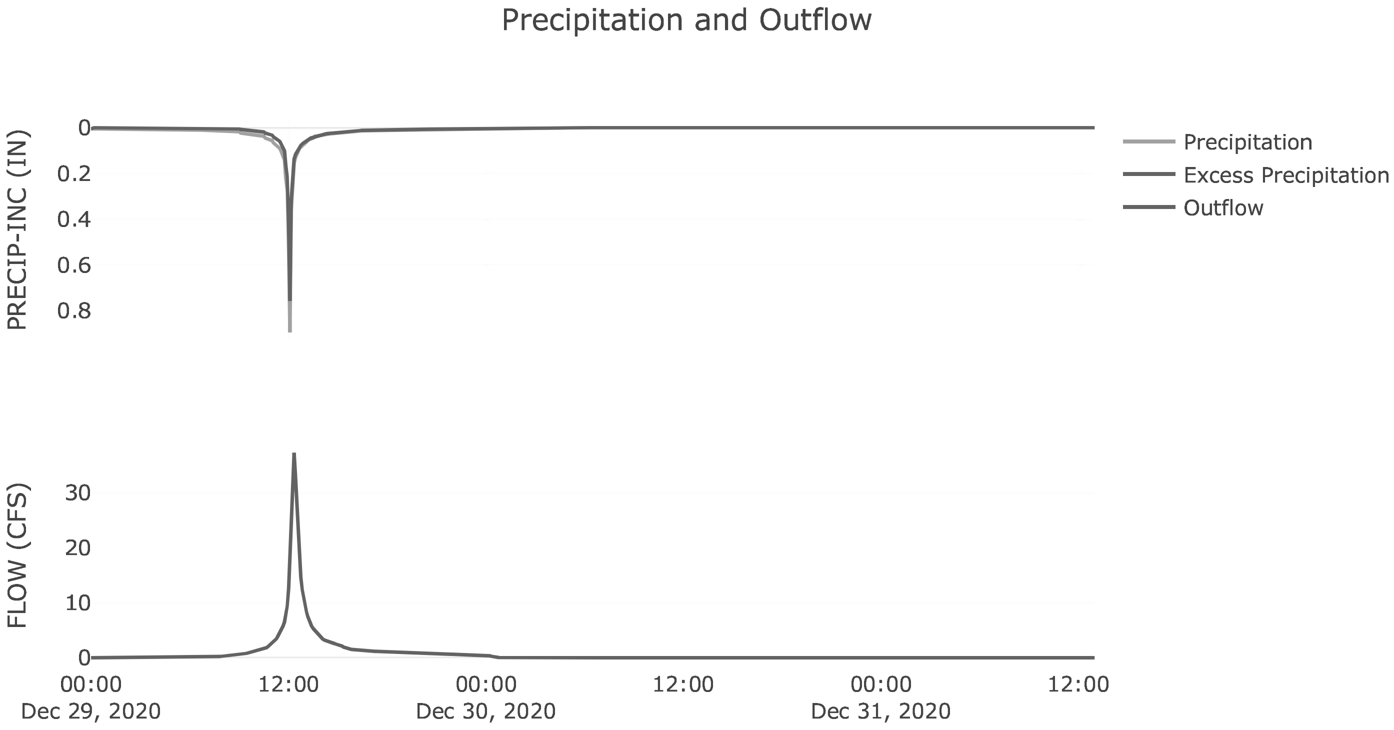
Area (MI2) : 0.01
Downstream : Dp2

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.26
Snyder Cp	0.69

Results: S3

Peak Discharge (CFS)	37.28
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.63
Precipitation Volume (AC - FT)	5.55
Loss Volume (AC - FT)	1.58
Excess Volume (AC - FT)	3.96
Direct Runoff Volume (AC - FT)	3.96
Baseflow Volume (AC - FT)	0



Subbasin: DA2

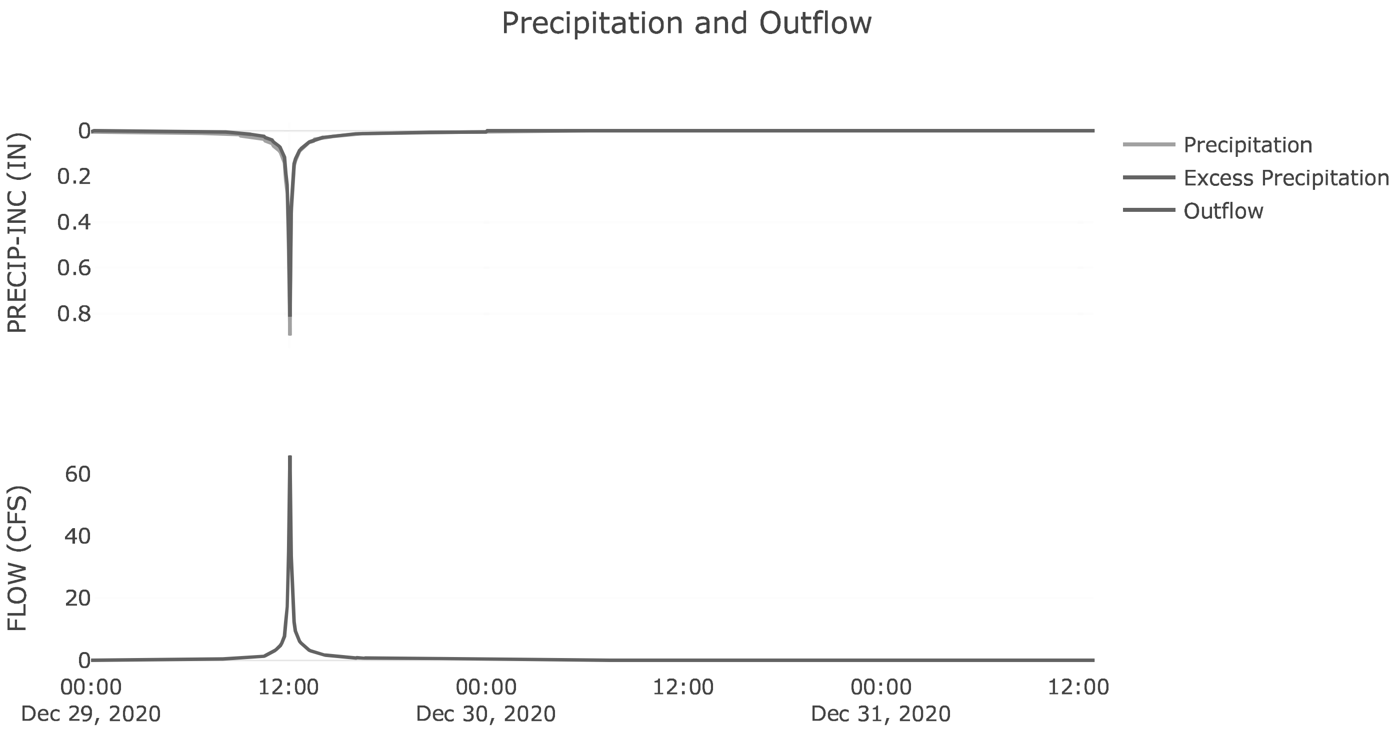
Area (MI2) : 0.01
Downstream : Dp2
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	86

Results: DA2

Peak Discharge (CFS)	66
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.31
Precipitation Volume (AC - FT)	4.62
Loss Volume (AC - FT)	0.98
Excess Volume (AC - FT)	3.65
Direct Runoff Volume (AC - FT)	3.11
Baseflow Volume (AC - FT)	0



Subbasin: DA3

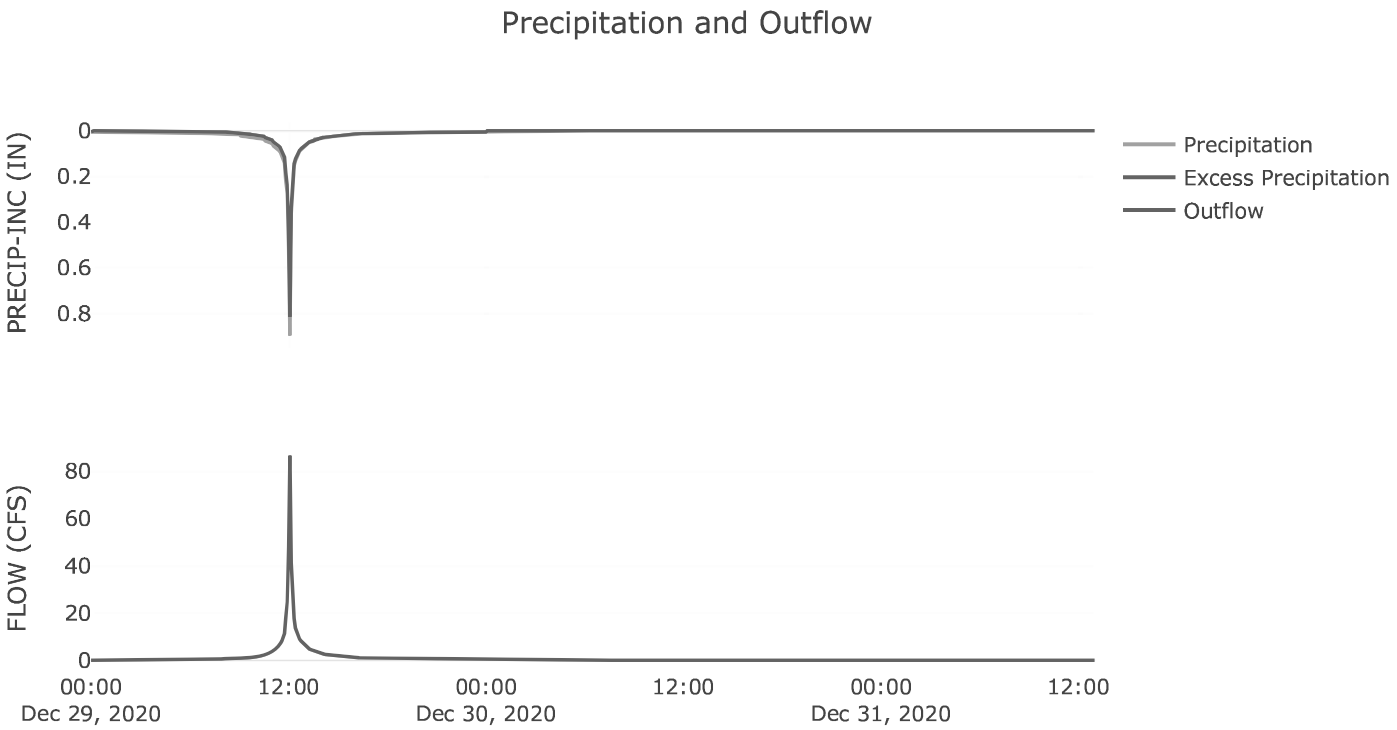
Area (MI2) : 0.01
Downstream : R/p2
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	86

Results: DA3

Peak Discharge (CFS)	86.65
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.68
Precipitation Volume (AC - FT)	5.93
Loss Volume (AC - FT)	1.25
Excess Volume (AC - FT)	4.67
Direct Runoff Volume (AC - FT)	4.27
Baseflow Volume (AC - FT)	0



Subbasin: P2

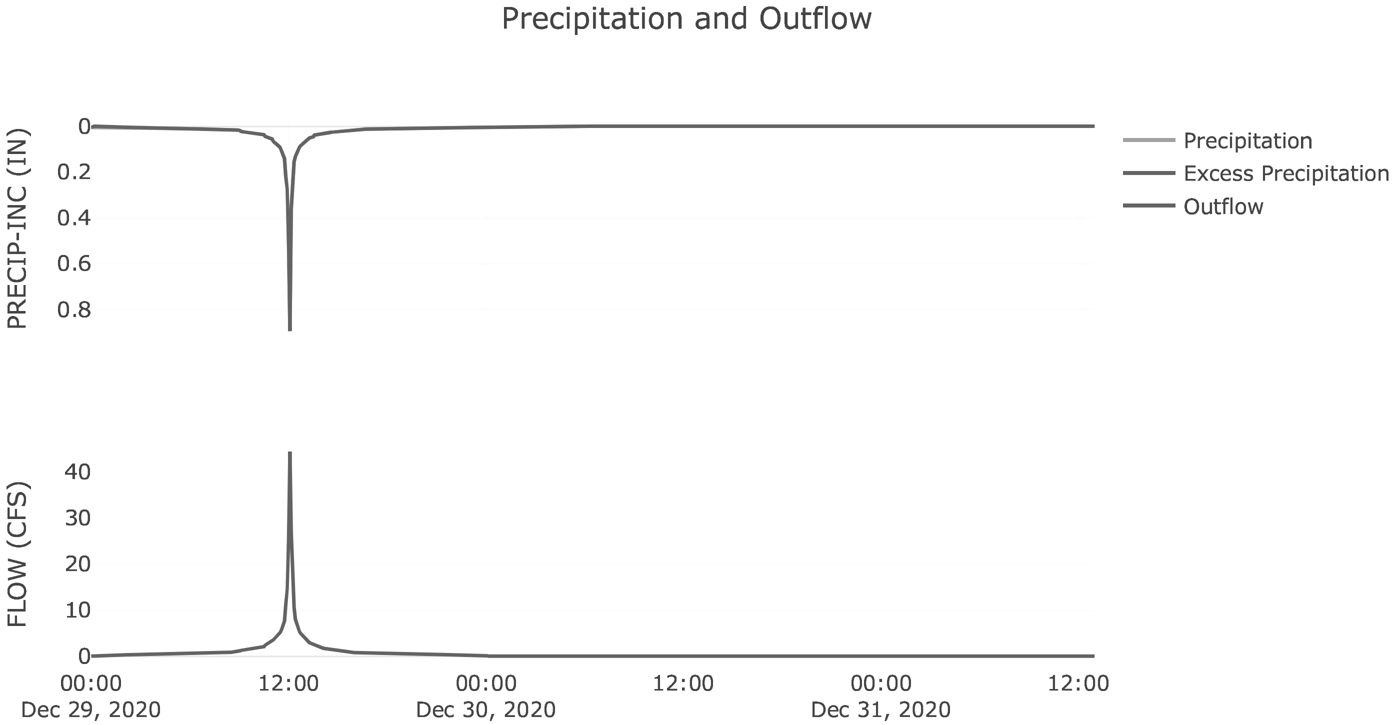
Area (MI2) : 0.01
Downstream : R/p2

Transform: Scs

Lag	0.1
Unitgraph Type	Standard

Results: P2

Peak Discharge (CFS)	44.44
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	7.76
Precipitation Volume (AC - FT)	3.07
Loss Volume (AC - FT)	0.05
Excess Volume (AC - FT)	3.02
Direct Runoff Volume (AC - FT)	3.02
Baseflow Volume (AC - FT)	0



Subbasin: CH1

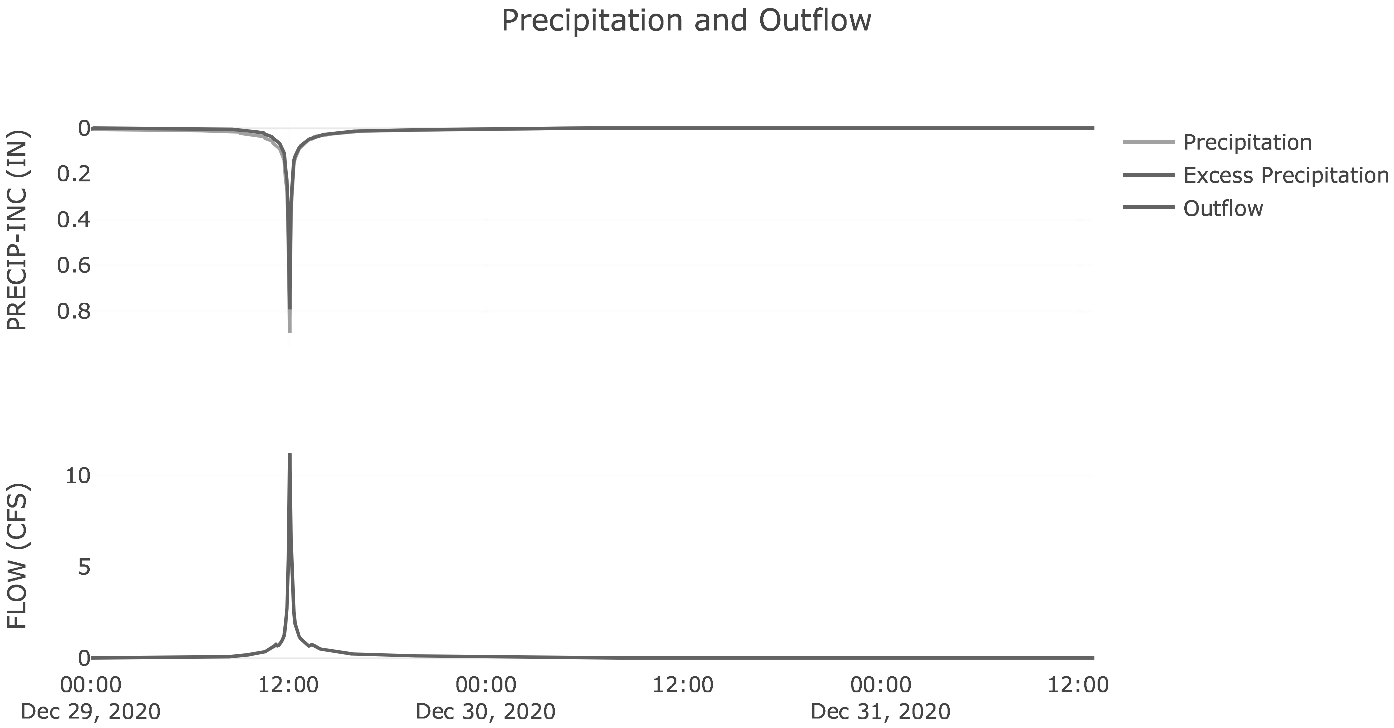
Area (MI2) : 0
Downstream : R/p2
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH1

Peak Discharge (CFS)	11.22
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.63
Precipitation Volume (AC - FT)	0.84
Loss Volume (AC - FT)	0.2
Excess Volume (AC - FT)	0.64
Direct Runoff Volume (AC - FT)	0.6
Baseflow Volume (AC - FT)	0



Subbasin: S4

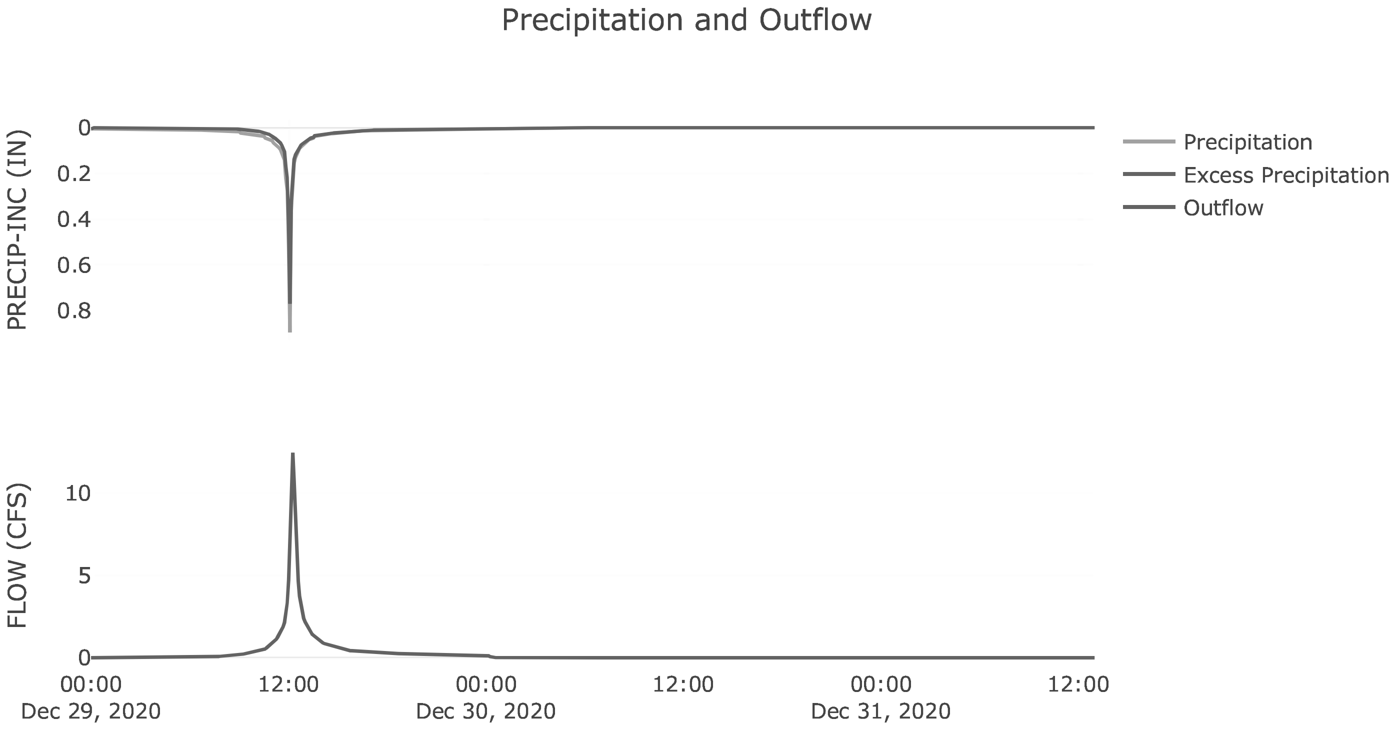
Area (MI2) : 0
Downstream : R/p2

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.19
Snyder Cp	0.7

Results: S4

Peak Discharge (CFS)	12.45
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.75
Precipitation Volume (AC - FT)	1.55
Loss Volume (AC - FT)	0.42
Excess Volume (AC - FT)	1.13
Direct Runoff Volume (AC - FT)	1.13
Baseflow Volume (AC - FT)	0



Subbasin: CH2

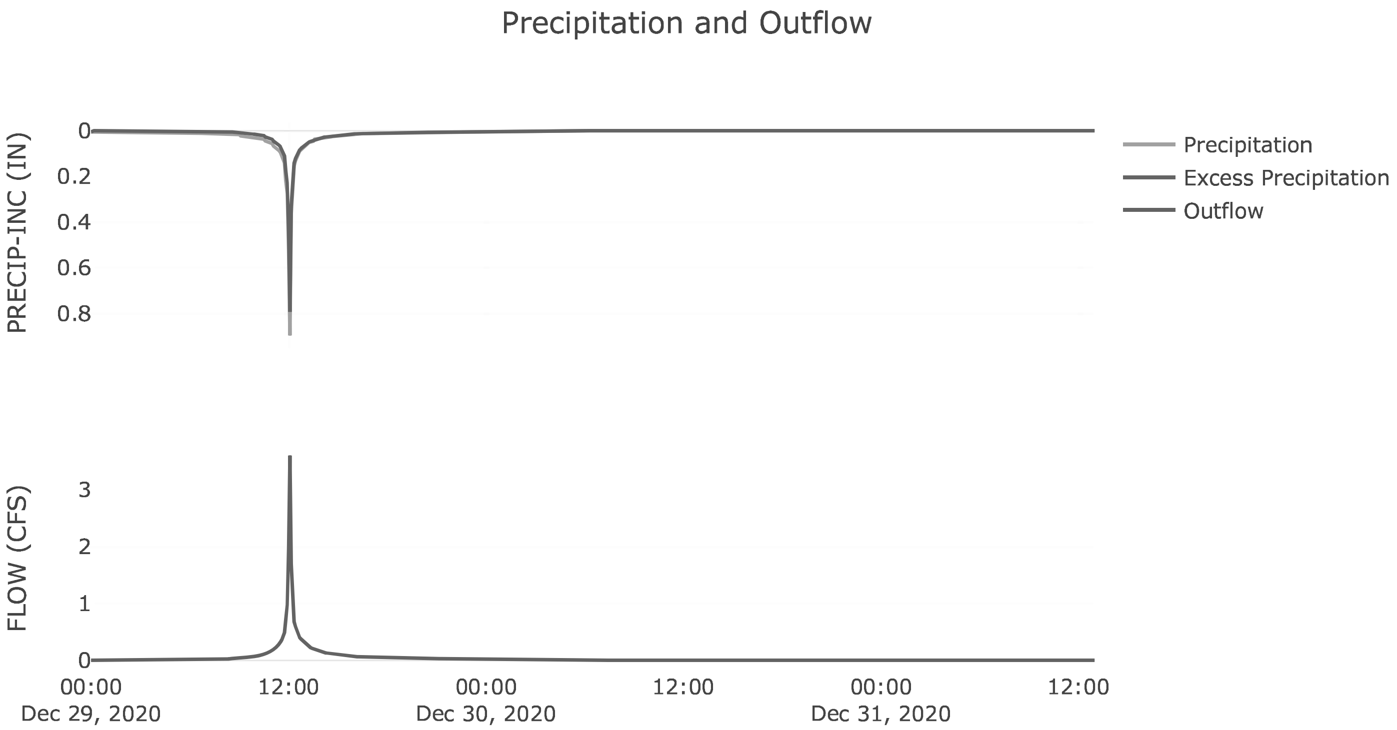
Area (MI2) : 0
Downstream : R/p2
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH2

Peak Discharge (CFS)	3.6
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.97
Precipitation Volume (AC - FT)	0.25
Loss Volume (AC - FT)	0.06
Excess Volume (AC - FT)	0.19
Direct Runoff Volume (AC - FT)	0.19
Baseflow Volume (AC - FT)	0



Subbasin: S5

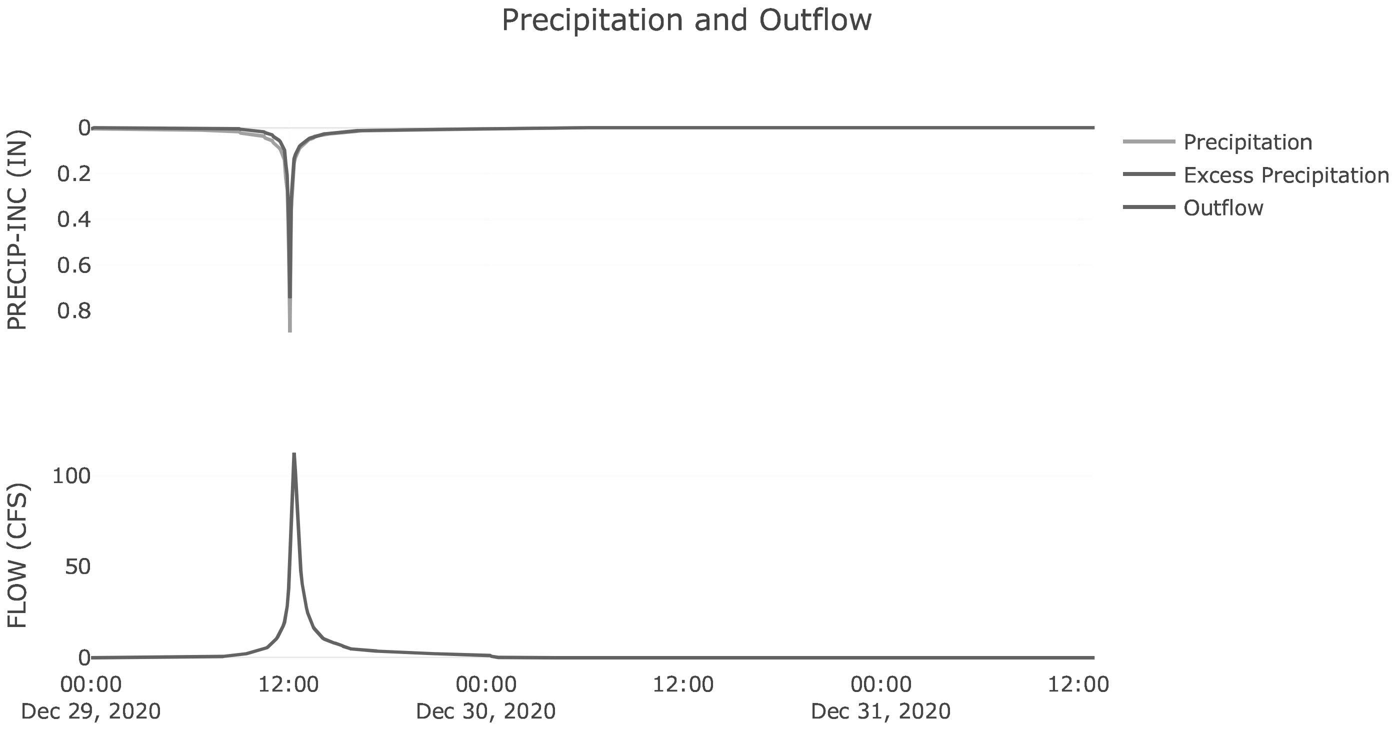
Area (MI2) : 0.04
Downstream : Dp4

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.26
Snyder Cp	0.66

Results: S5

Peak Discharge (CFS)	112.45
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.51
Precipitation Volume (AC - FT)	17.53
Loss Volume (AC - FT)	5.27
Excess Volume (AC - FT)	12.26
Direct Runoff Volume (AC - FT)	12.26
Baseflow Volume (AC - FT)	0

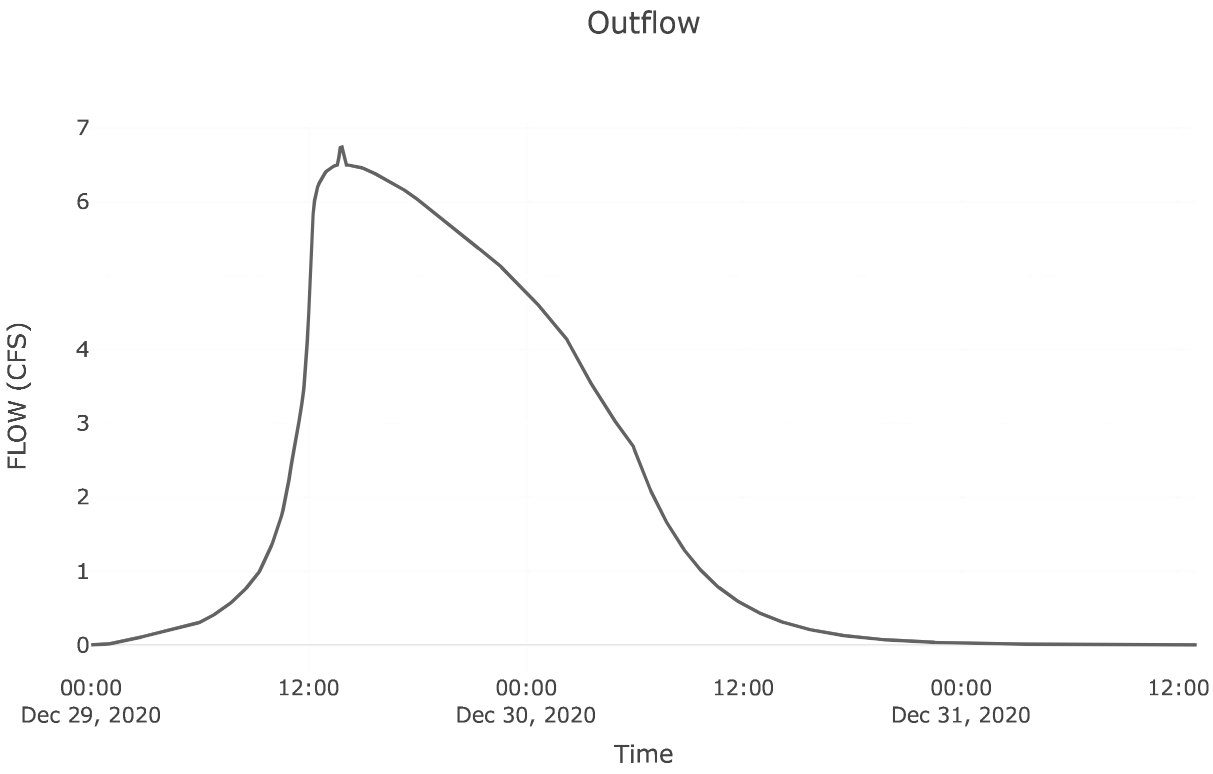


Reservoir: R/P2

Downstream : Dp4

Results: R/P2

Peak Discharge (CFS)	6.74
Time of Peak Discharge	29Dec2020, 13:50
Volume (IN)	6.24
Peak Inflow (CFS)	153.51
Time of Peak Inflow	29Dec2020, 12:05
Inflow Volume (AC - FT)	9.22
Maximum Storage (AC - FT)	5.72
Peak Elevation (FT)	619.01
Discharge Volume (AC - FT)	9.22



Subbasin: O2

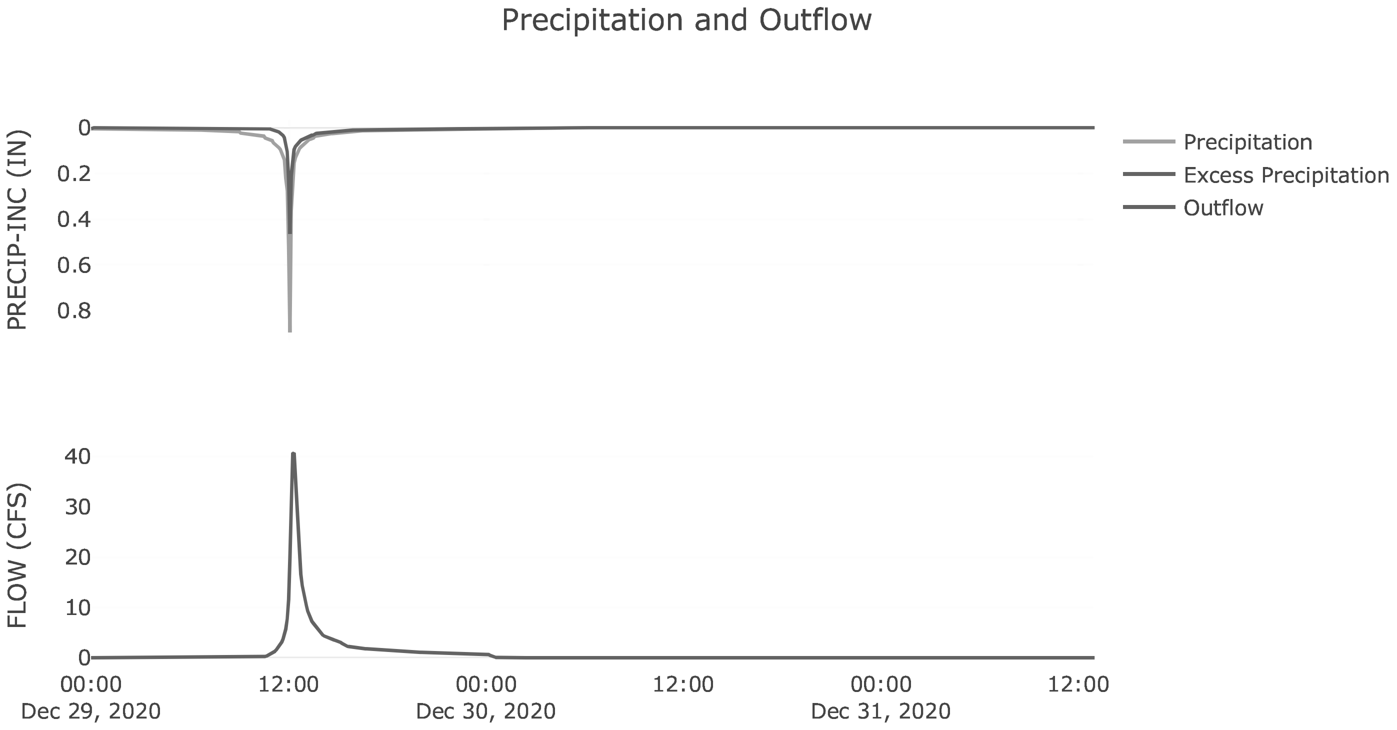
Area (MI2) : 0.02
Downstream : Ch7

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.23
Snyder Cp	0.67

Results: O2

Peak Discharge (CFS)	40.73
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	3.35
Precipitation Volume (AC - FT)	10
Loss Volume (AC - FT)	5.75
Excess Volume (AC - FT)	4.26
Direct Runoff Volume (AC - FT)	4.26
Baseflow Volume (AC - FT)	0



Subbasin: DA5

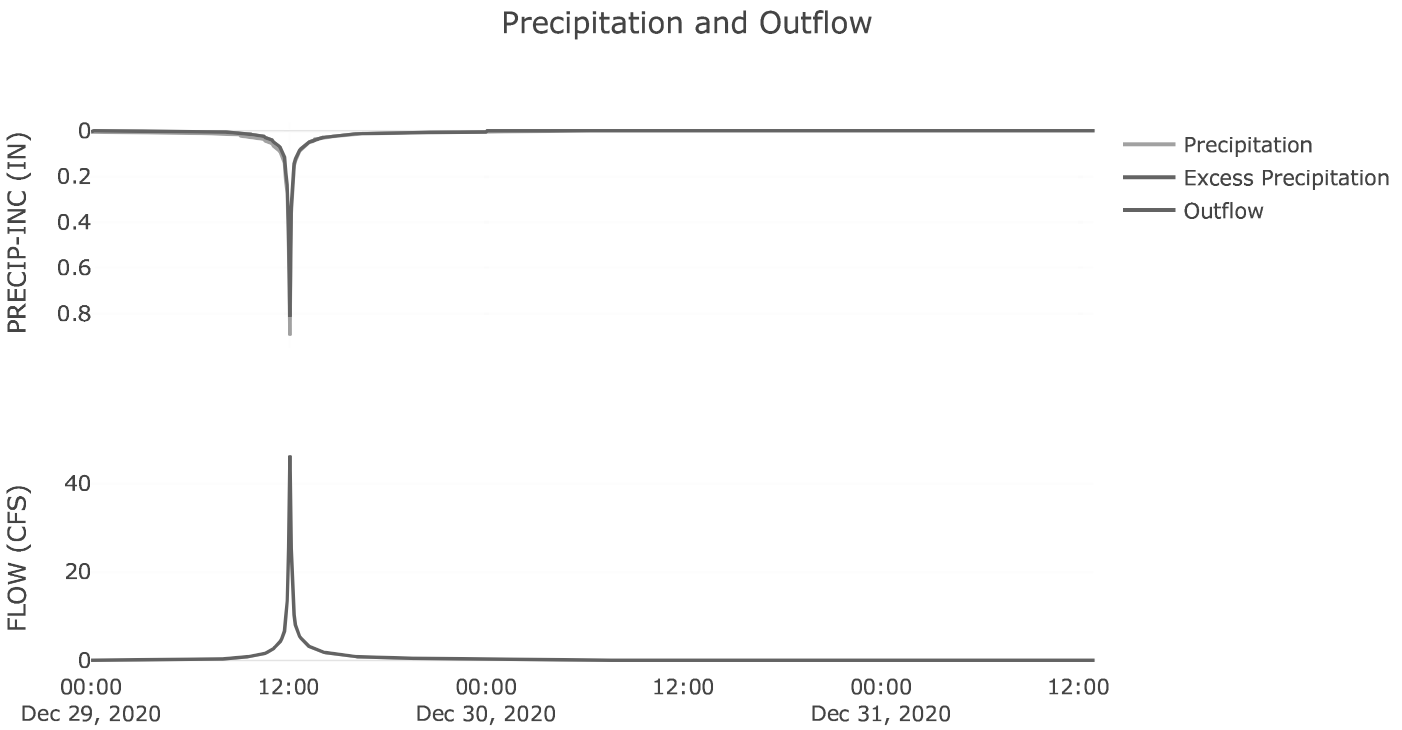
Area (MI2) : 0.01
Downstream : Ch7
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	86

Results: DA5

Peak Discharge (CFS)	46.25
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	6.24
Precipitation Volume (AC - FT)	3.28
Loss Volume (AC - FT)	0.69
Excess Volume (AC - FT)	2.59
Direct Runoff Volume (AC - FT)	2.6
Baseflow Volume (AC - FT)	0



Subbasin: S9

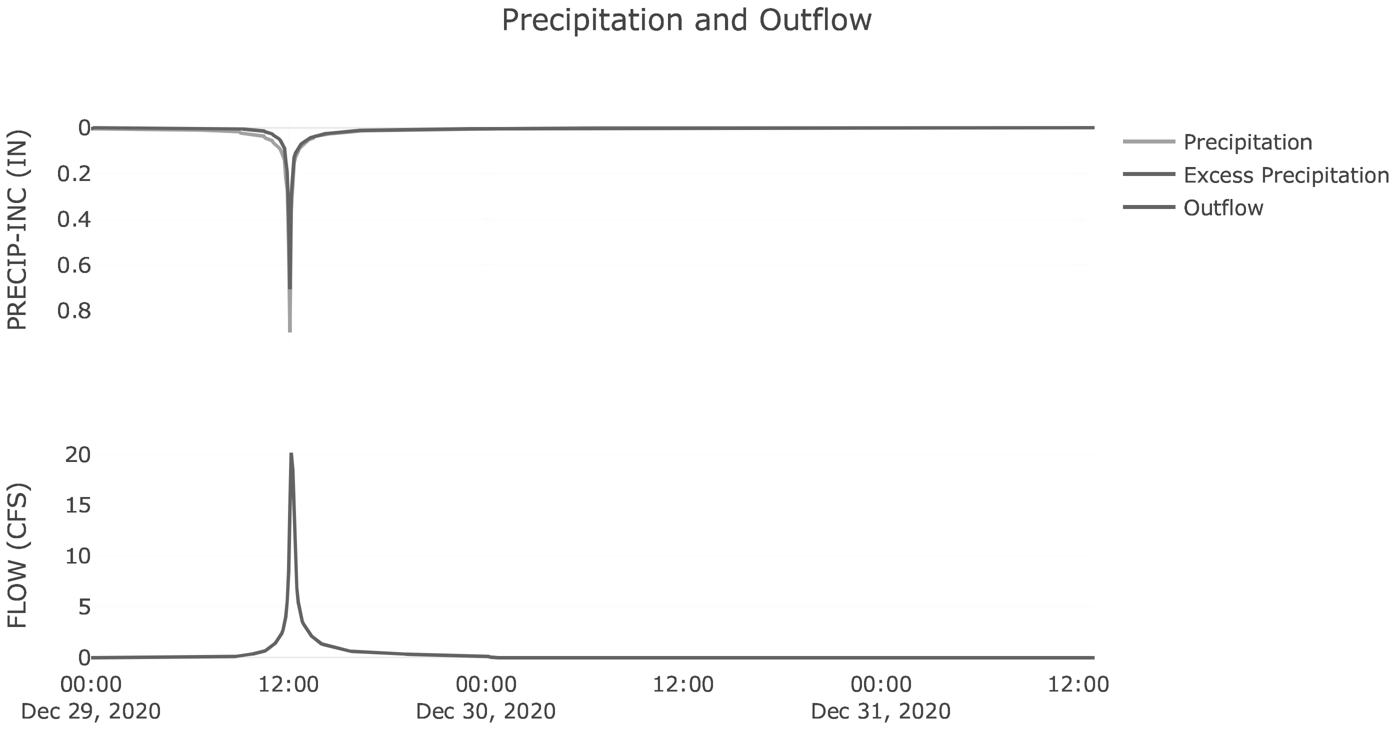
Area (MI2) : 0.01
Downstream : Ch7

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.14
Snyder Cp	0.66

Results: S9

Peak Discharge (CFS)	20.16
Time of Peak Discharge	29Dec2020, 12:10
Volume (IN)	5.16
Precipitation Volume (AC - FT)	2.48
Loss Volume (AC - FT)	0.85
Excess Volume (AC - FT)	1.63
Direct Runoff Volume (AC - FT)	1.63
Baseflow Volume (AC - FT)	0



Subbasin: CH7

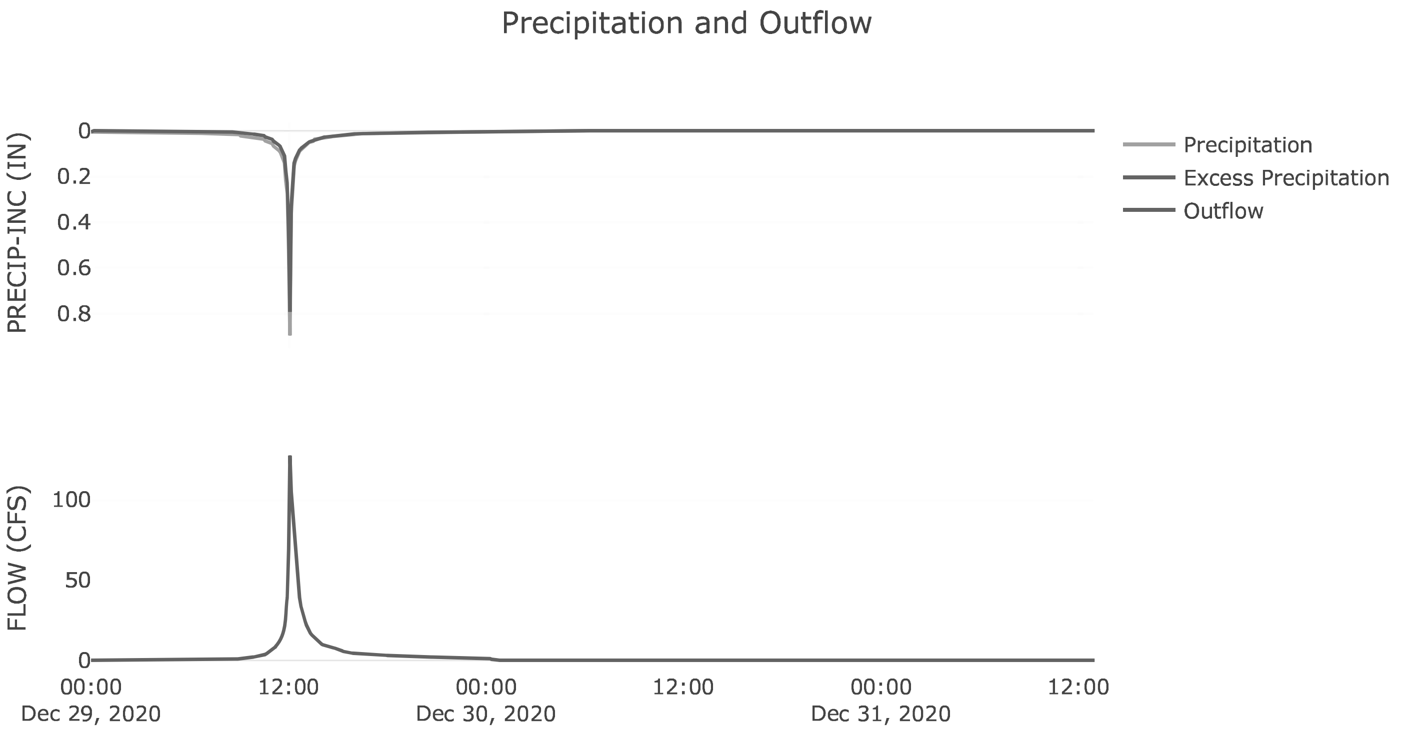
Area (MI2) : 0.01
Downstream : R/ch6
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH7

Peak Discharge (CFS)	127.57
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	4.45
Precipitation Volume (AC - FT)	20
Loss Volume (AC - FT)	4.82
Excess Volume (AC - FT)	15.18
Direct Runoff Volume (AC - FT)	11.3
Baseflow Volume (AC - FT)	0



Subbasin: DA4

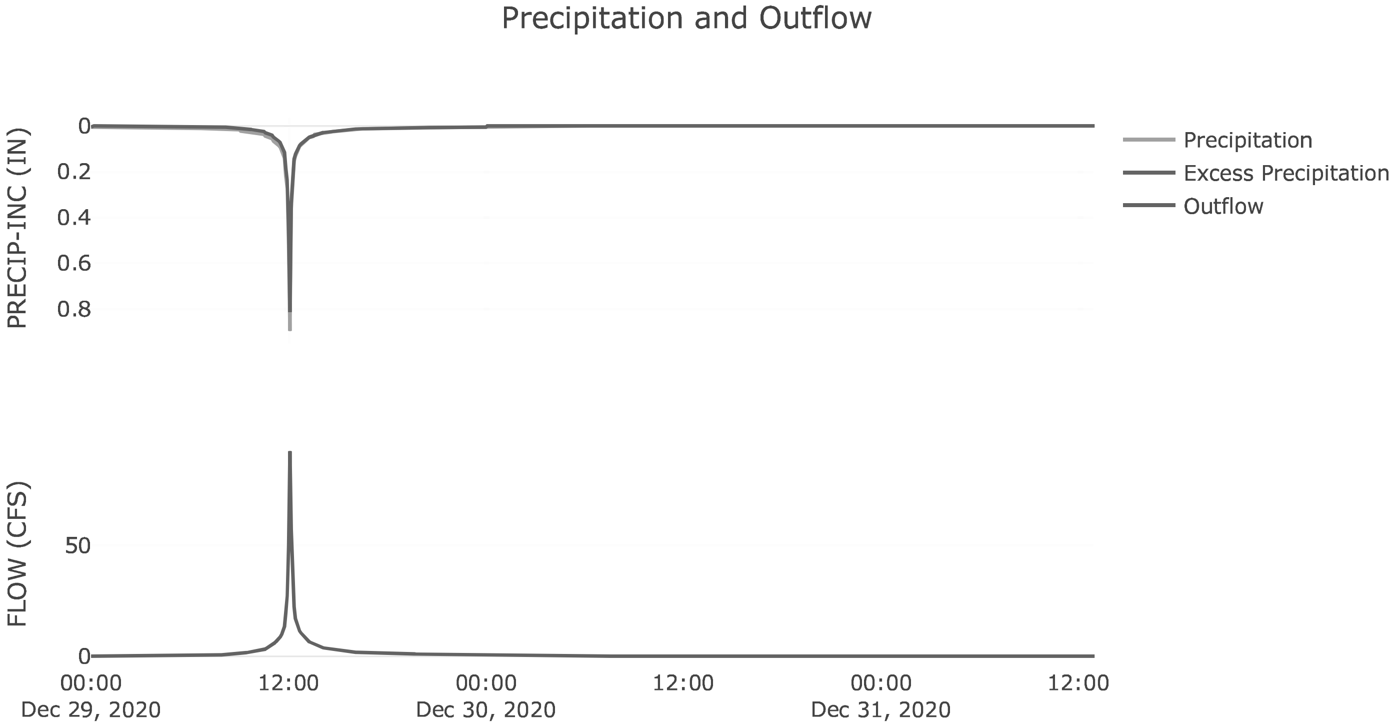
Area (MI2) : 0.02
Downstream : R/ch6
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	86

Results: DA4

Peak Discharge (CFS)	92.43
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	6.24
Precipitation Volume (AC - FT)	6.81
Loss Volume (AC - FT)	1.44
Excess Volume (AC - FT)	5.37
Direct Runoff Volume (AC - FT)	5.39
Baseflow Volume (AC - FT)	0

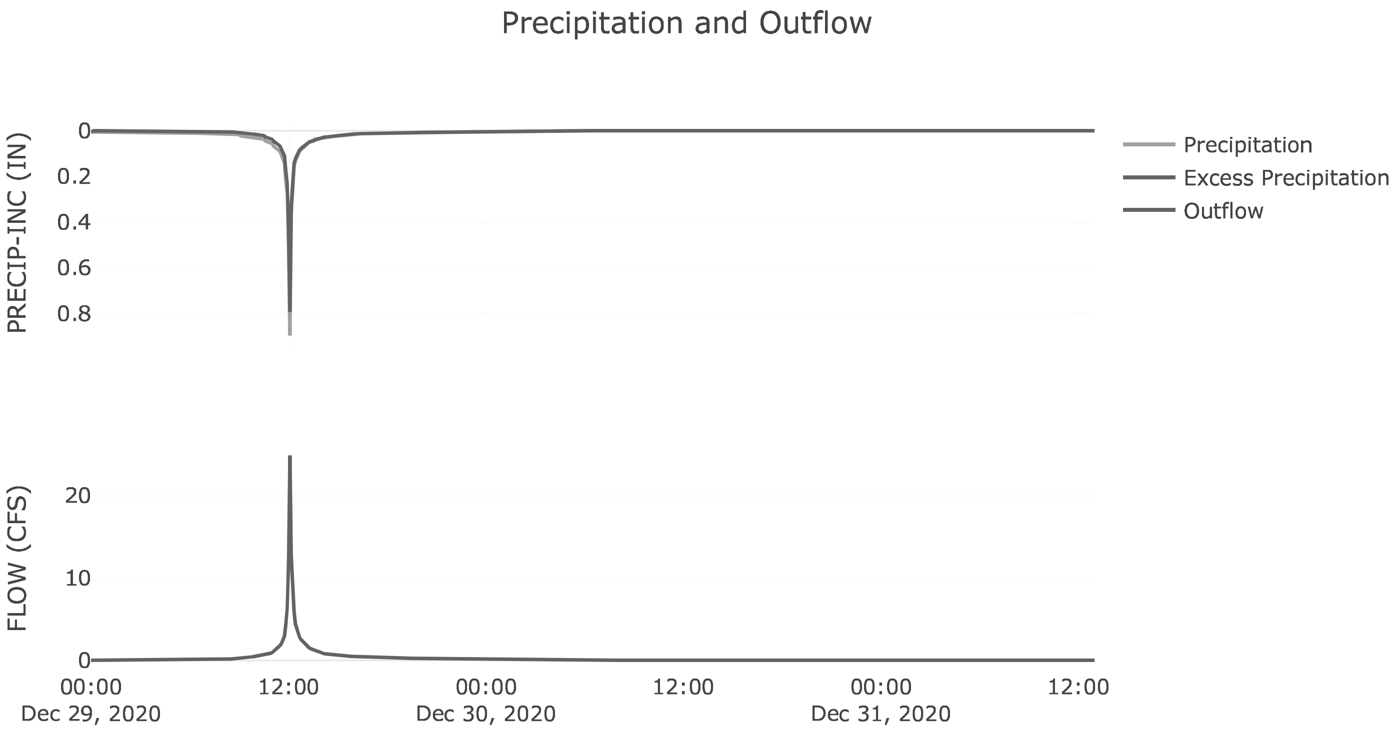


Subbasin: CH4

Area (MI2) : 0
Downstream : R/ch6
Transform : Kinematic Wave

LossRate 1: Scs	
Percent Impervious Area	0
Curve Number	84

Results: CH4	
Peak Discharge (CFS)	24.85
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.74
Precipitation Volume (AC - FT)	1.77
Loss Volume (AC - FT)	0.43
Excess Volume (AC - FT)	1.34
Direct Runoff Volume (AC - FT)	1.28
Baseflow Volume (AC - FT)	0



Subbasin: CH3

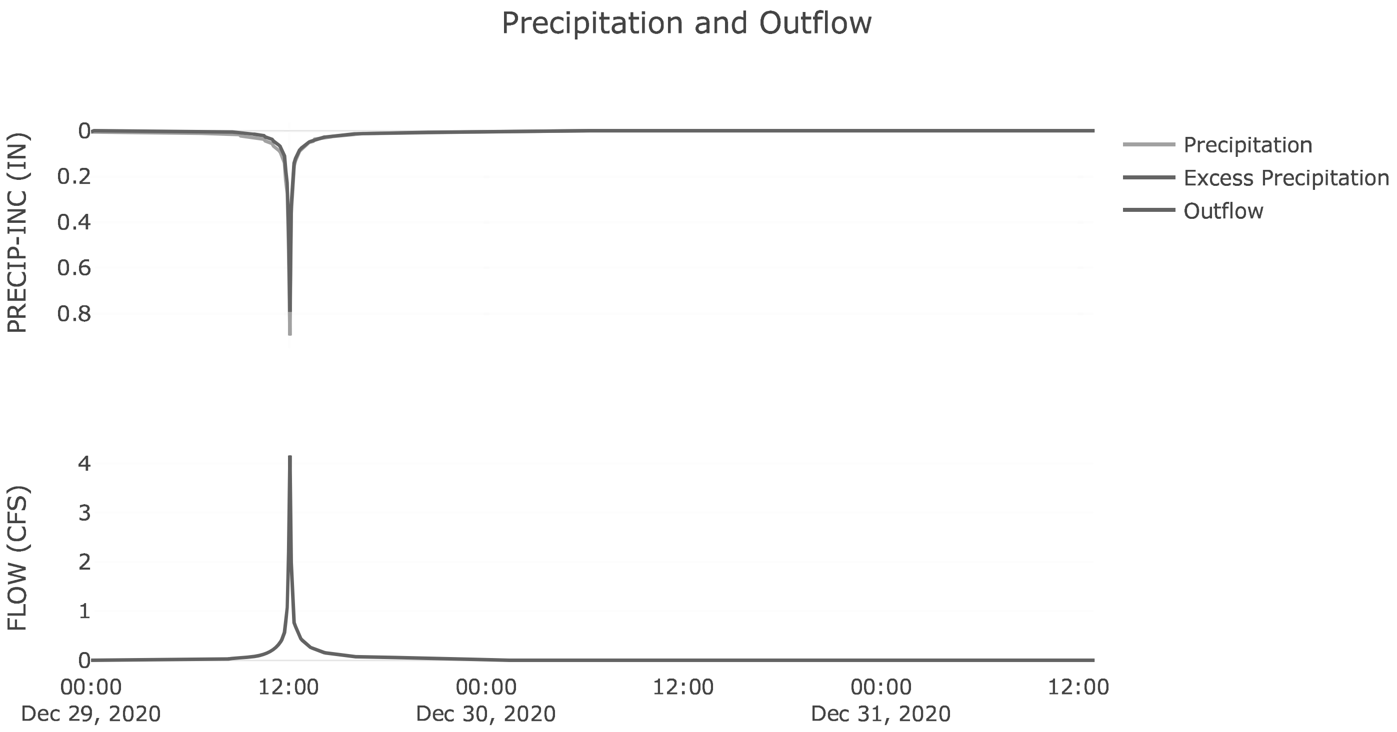
Area (MI2) : 0
Downstream : Ch5
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH3

Peak Discharge (CFS)	4.16
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.91
Precipitation Volume (AC - FT)	0.29
Loss Volume (AC - FT)	0.07
Excess Volume (AC - FT)	0.22
Direct Runoff Volume (AC - FT)	0.22
Baseflow Volume (AC - FT)	0



Subbasin: CH5

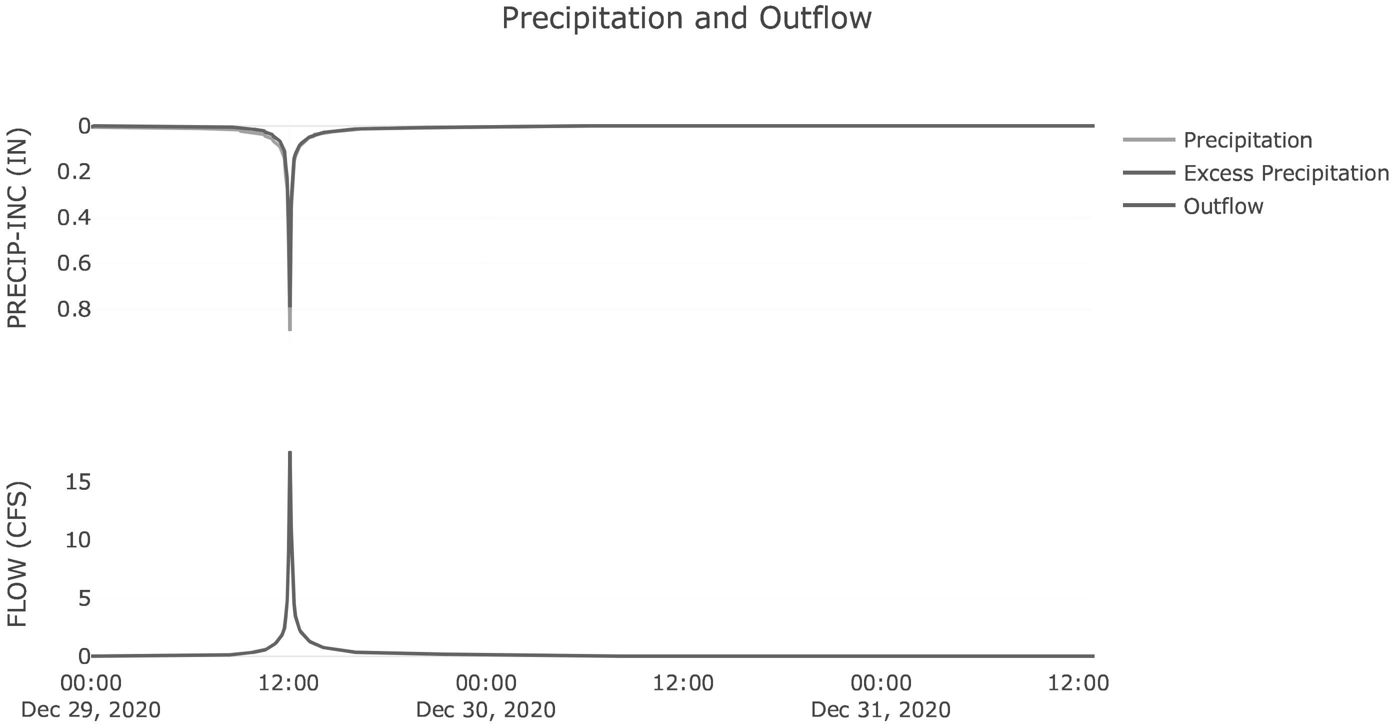
Area (MI2) : 0
Downstream : R/ch6
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH5

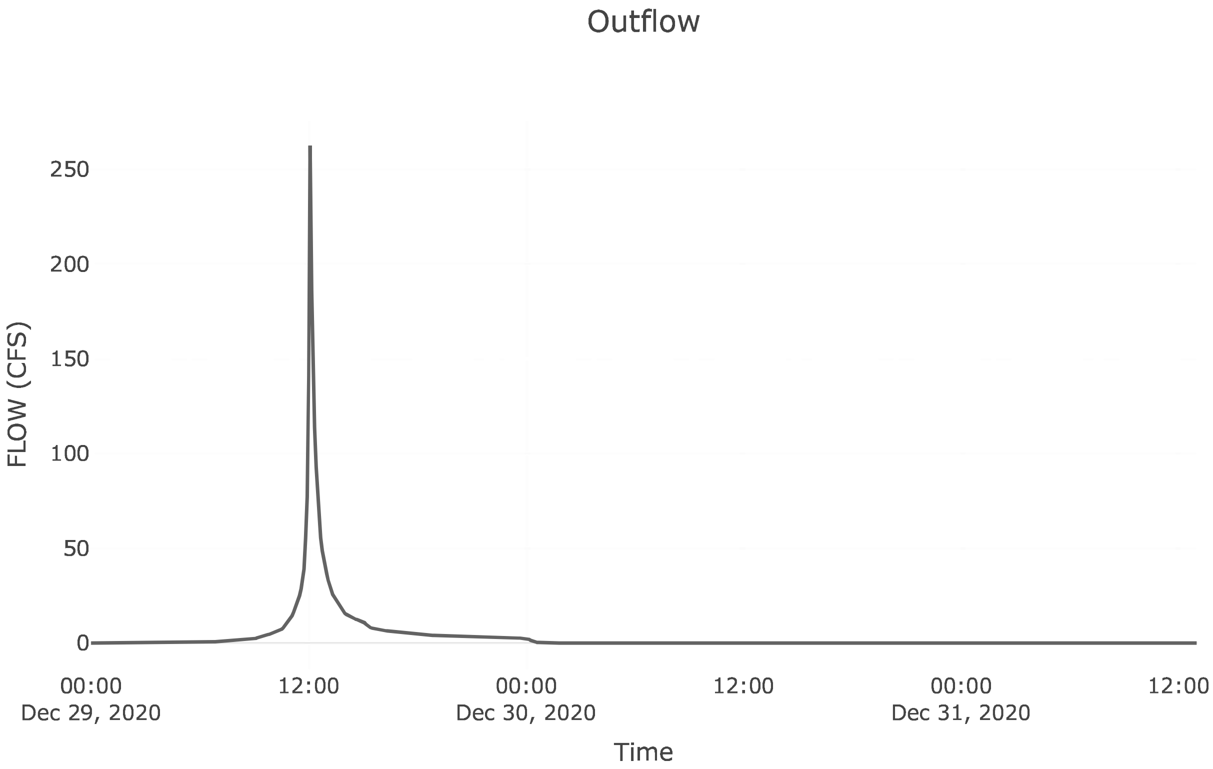
Peak Discharge (CFS)	17.64
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.99
Precipitation Volume (AC - FT)	1.34
Loss Volume (AC - FT)	0.32
Excess Volume (AC - FT)	1.02
Direct Runoff Volume (AC - FT)	1.02
Baseflow Volume (AC - FT)	0



Junction: R/CH6

Results: R/CH6

Peak Discharge (CFS)	262.5
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5



Subbasin: CH6

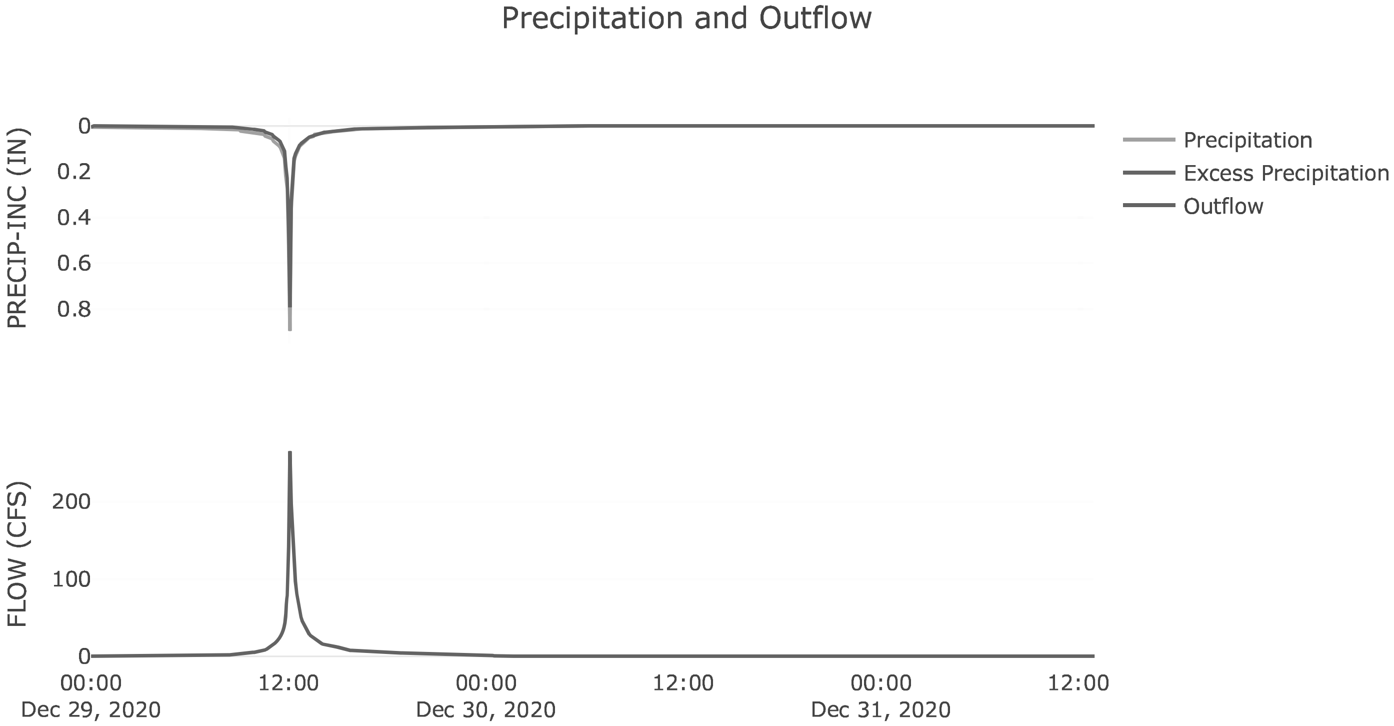
Area (MI2) : 0
Downstream : R/p3
Transform : Kinematic Wave

LossRate 1: Scs

Percent Impervious Area	0
Curve Number	84

Results: CH6

Peak Discharge (CFS)	265.06
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.03
Precipitation Volume (AC - FT)	30.72
Loss Volume (AC - FT)	7.41
Excess Volume (AC - FT)	23.31
Direct Runoff Volume (AC - FT)	19.61
Baseflow Volume (AC - FT)	0



Subbasin: S6

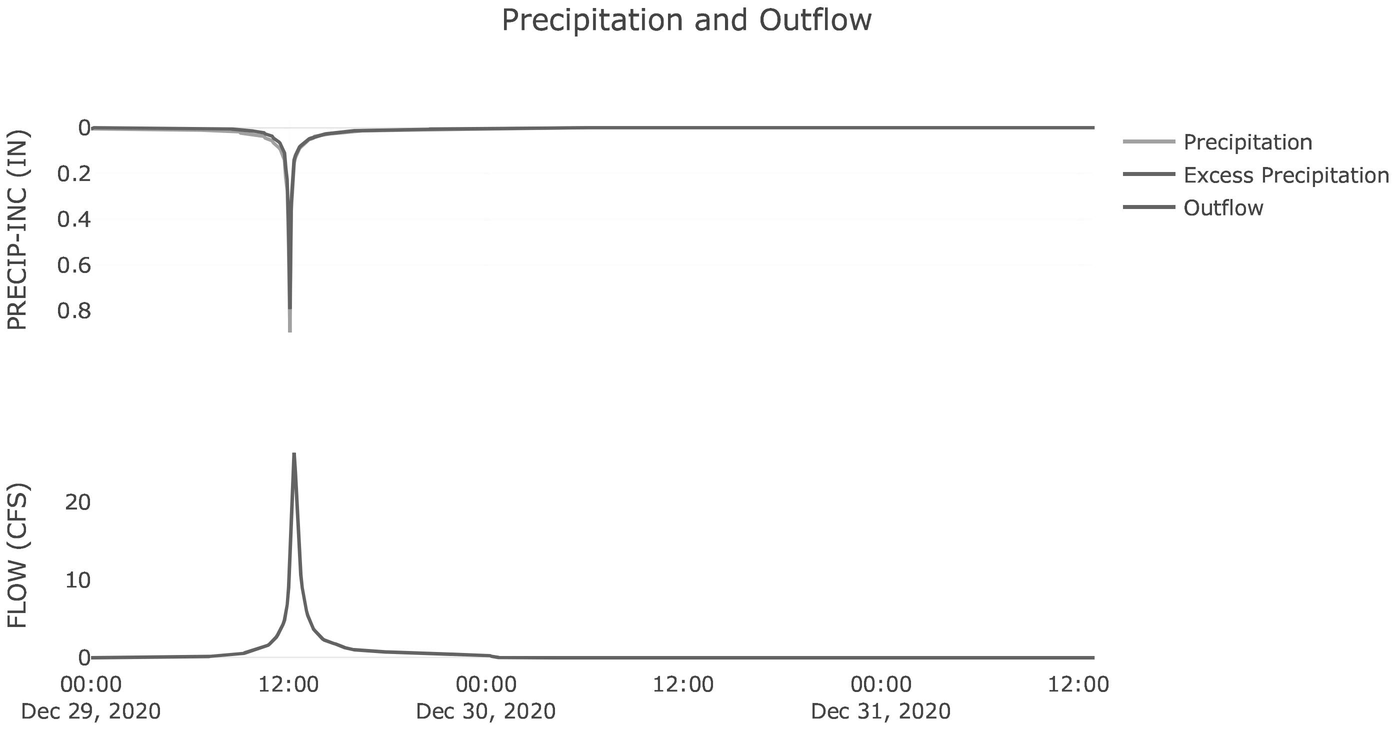
Area (MI2) : 0.01
Downstream : R/p3

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.27
Snyder Cp	0.7

Results: S6

Peak Discharge (CFS)	26.34
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.98
Precipitation Volume (AC - FT)	3.78
Loss Volume (AC - FT)	0.91
Excess Volume (AC - FT)	2.87
Direct Runoff Volume (AC - FT)	2.87
Baseflow Volume (AC - FT)	0



Subbasin: S8

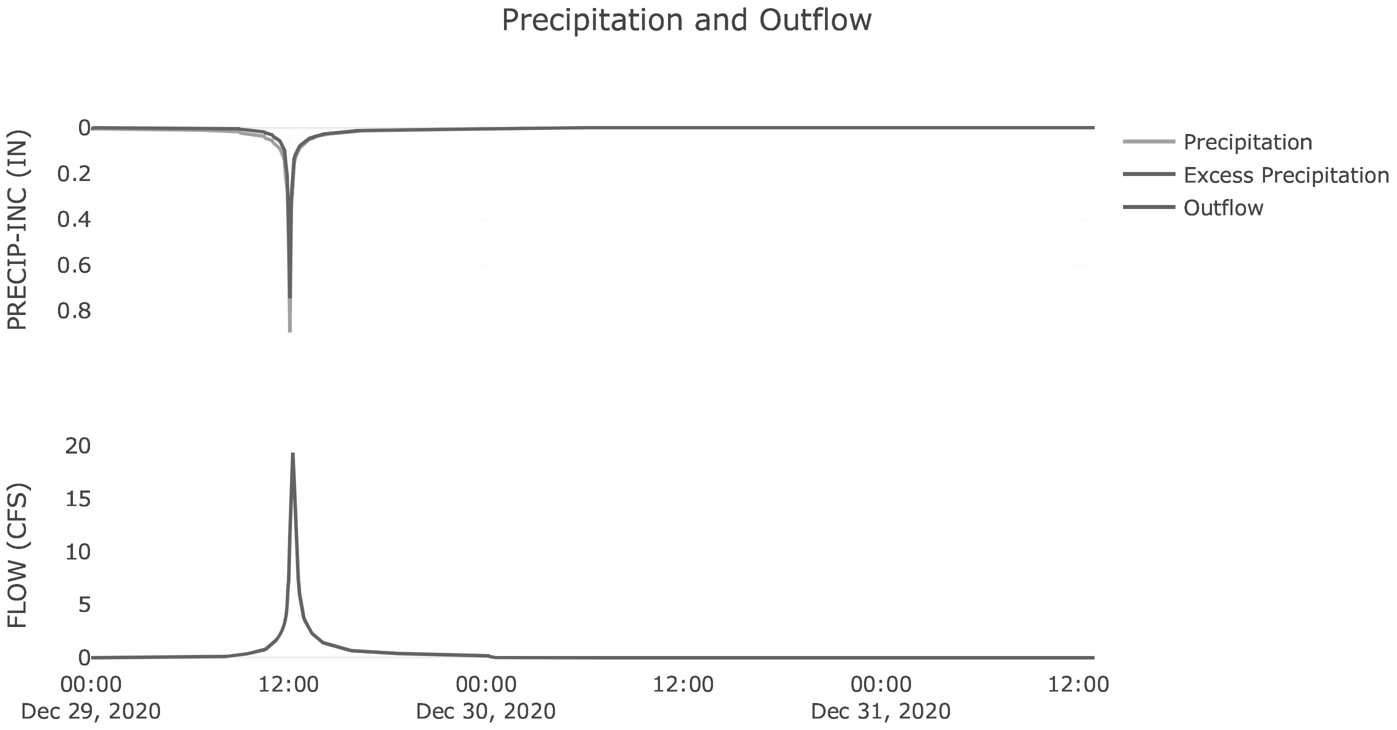
Area (MI2) : 0.01
Downstream : R/p3

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.19
Snyder Cp	0.69

Results: S8

Peak Discharge (CFS)	19.33
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.51
Precipitation Volume (AC - FT)	2.52
Loss Volume (AC - FT)	0.76
Excess Volume (AC - FT)	1.76
Direct Runoff Volume (AC - FT)	1.76
Baseflow Volume (AC - FT)	0



Subbasin: P3

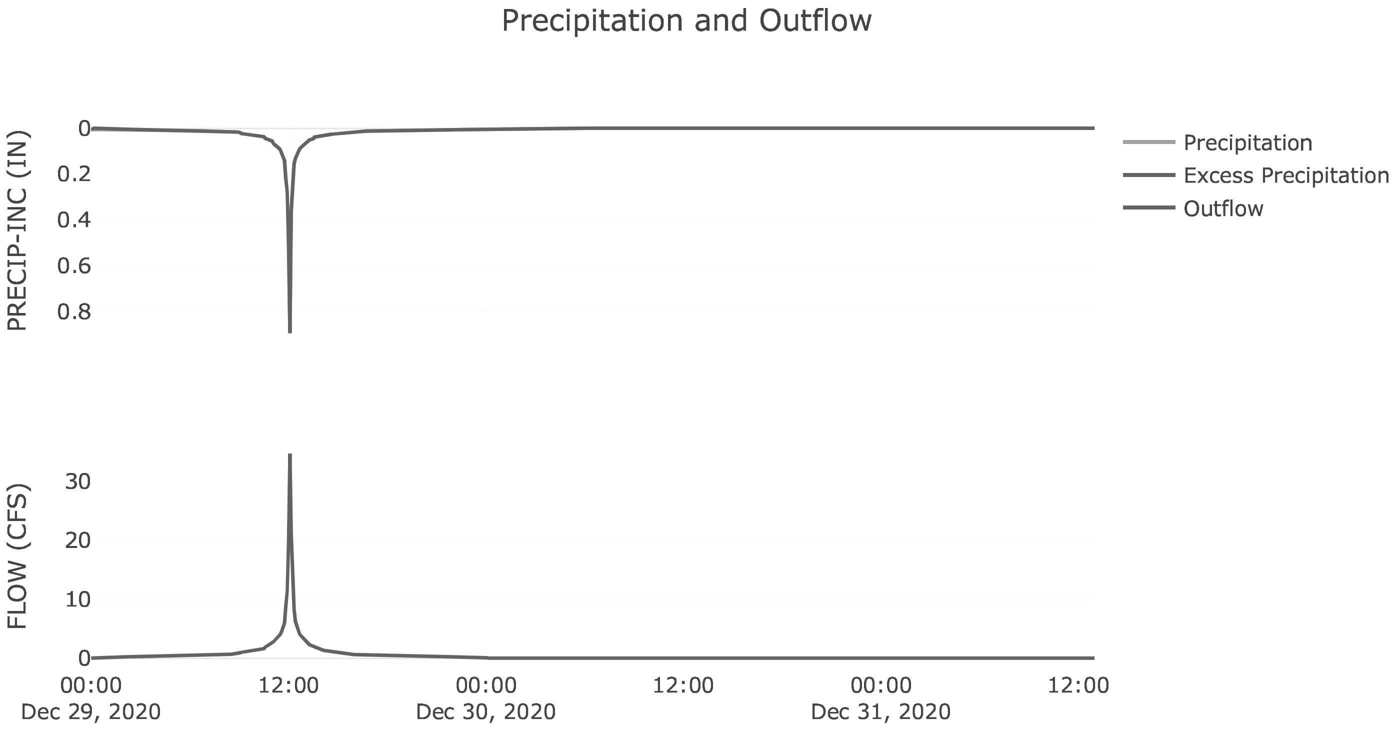
Area (MI2) : 0.01
Downstream : R/p3

Transform: Scs

Lag	0.1
Unitgraph Type	Standard

Results: P3

Peak Discharge (CFS)	34.7
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	7.76
Precipitation Volume (AC - FT)	2.4
Loss Volume (AC - FT)	0.04
Excess Volume (AC - FT)	2.36
Direct Runoff Volume (AC - FT)	2.36
Baseflow Volume (AC - FT)	0

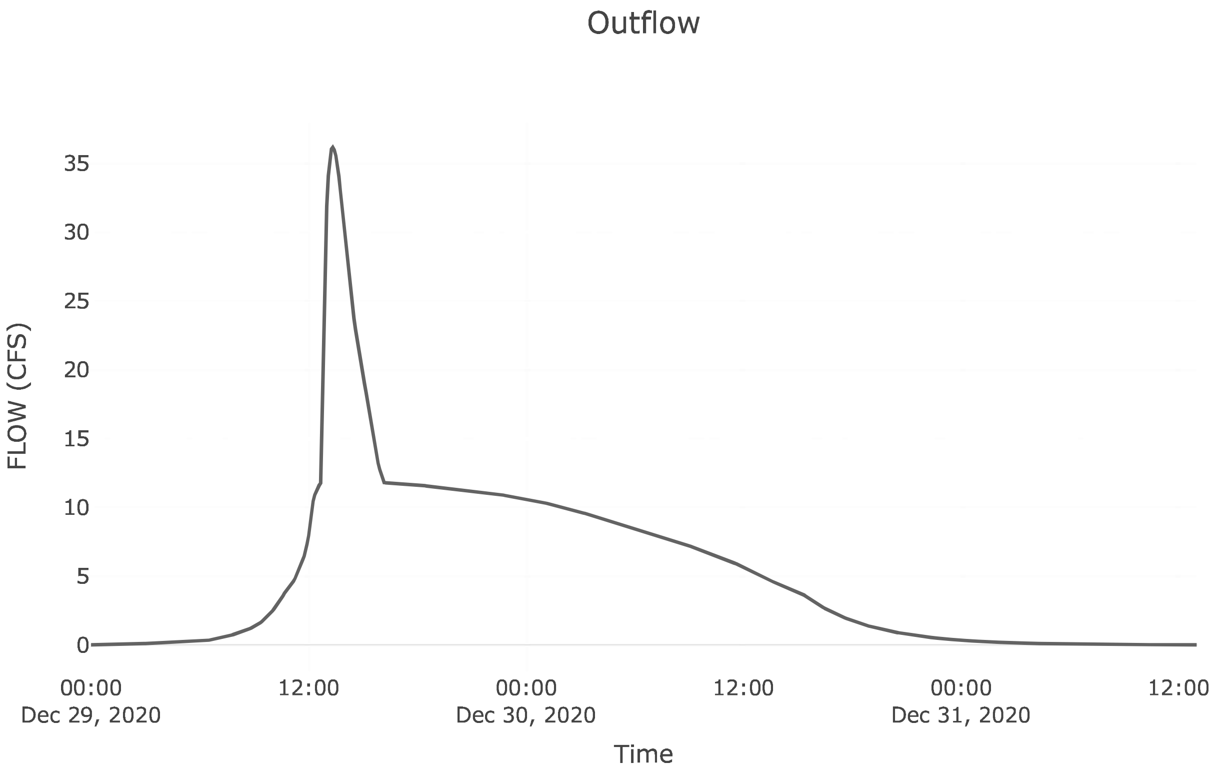


Reservoir: R/P3

Downstream : Dp5

Results: R/P3

Peak Discharge (CFS)	36.18
Time of Peak Discharge	29Dec2020, 13:20
Volume (IN)	5.32
Peak Inflow (CFS)	324.87
Time of Peak Inflow	29Dec2020, 12:05
Inflow Volume (AC - FT)	26.6
Maximum Storage (AC - FT)	15.66
Peak Elevation (FT)	544.67
Discharge Volume (AC - FT)	26.6



Subbasin: O3

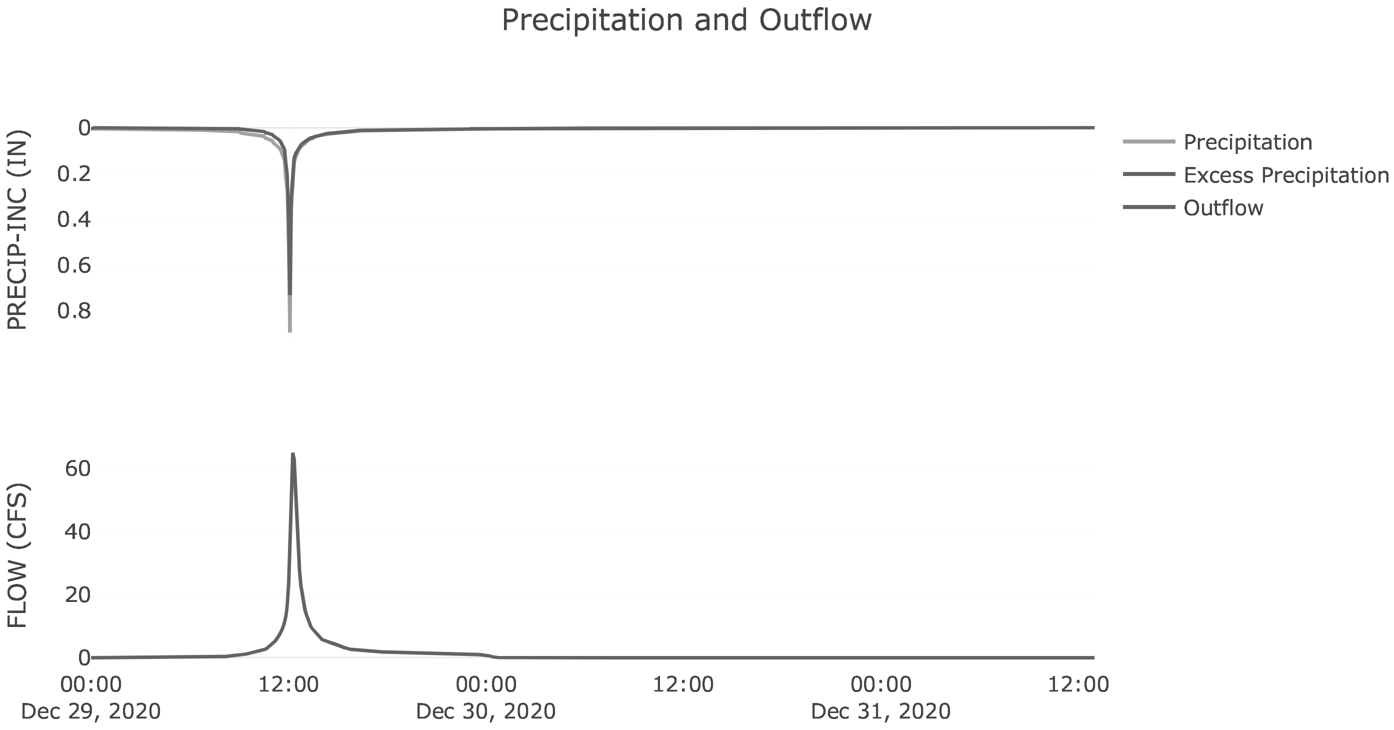
Area (MI2) : 0.02
Downstream : Dp5

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.23
Snyder Cp	0.67

Results: O3

Peak Discharge (CFS)	64.93
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.4
Precipitation Volume (AC - FT)	9.71
Loss Volume (AC - FT)	3.06
Excess Volume (AC - FT)	6.65
Direct Runoff Volume (AC - FT)	6.65
Baseflow Volume (AC - FT)	0



Subbasin: S7

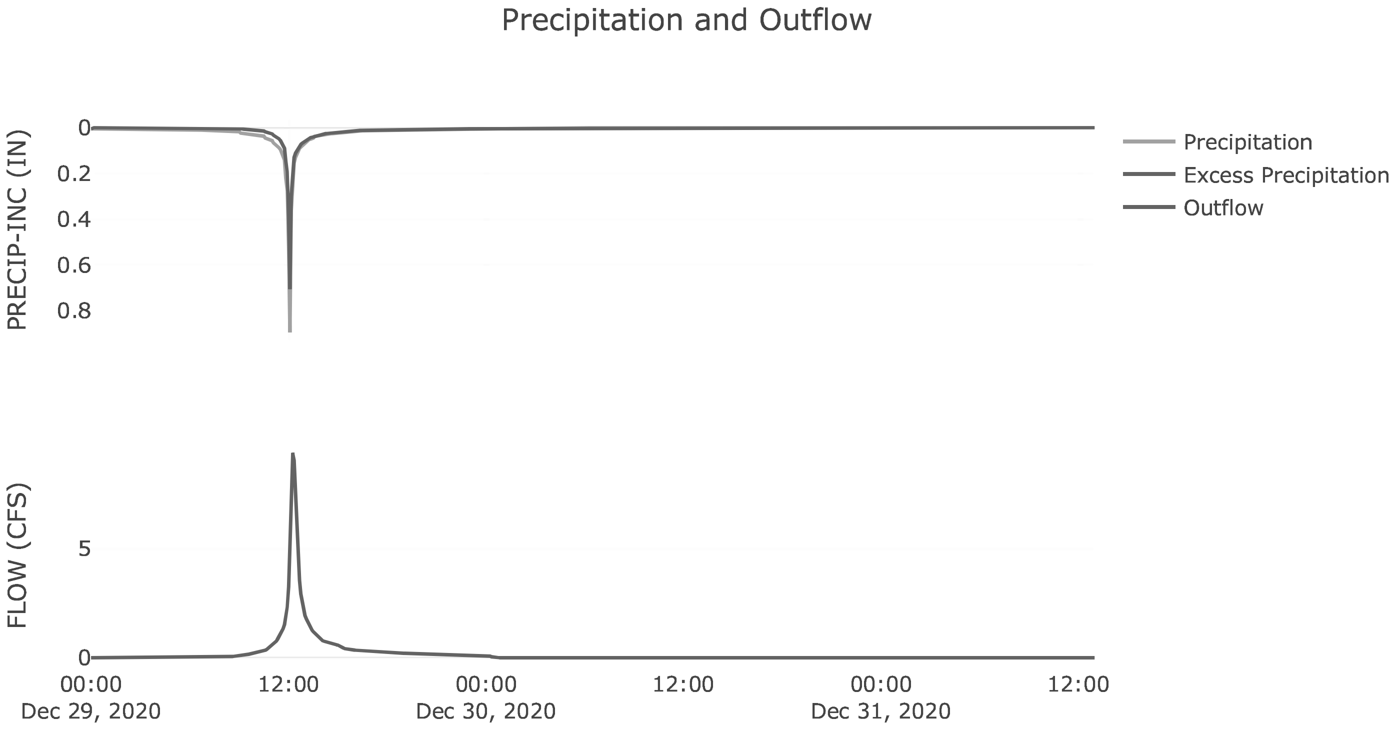
Area (MI2) : 0
Downstream : Dp5

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.23
Snyder Cp	0.72

Results: S7

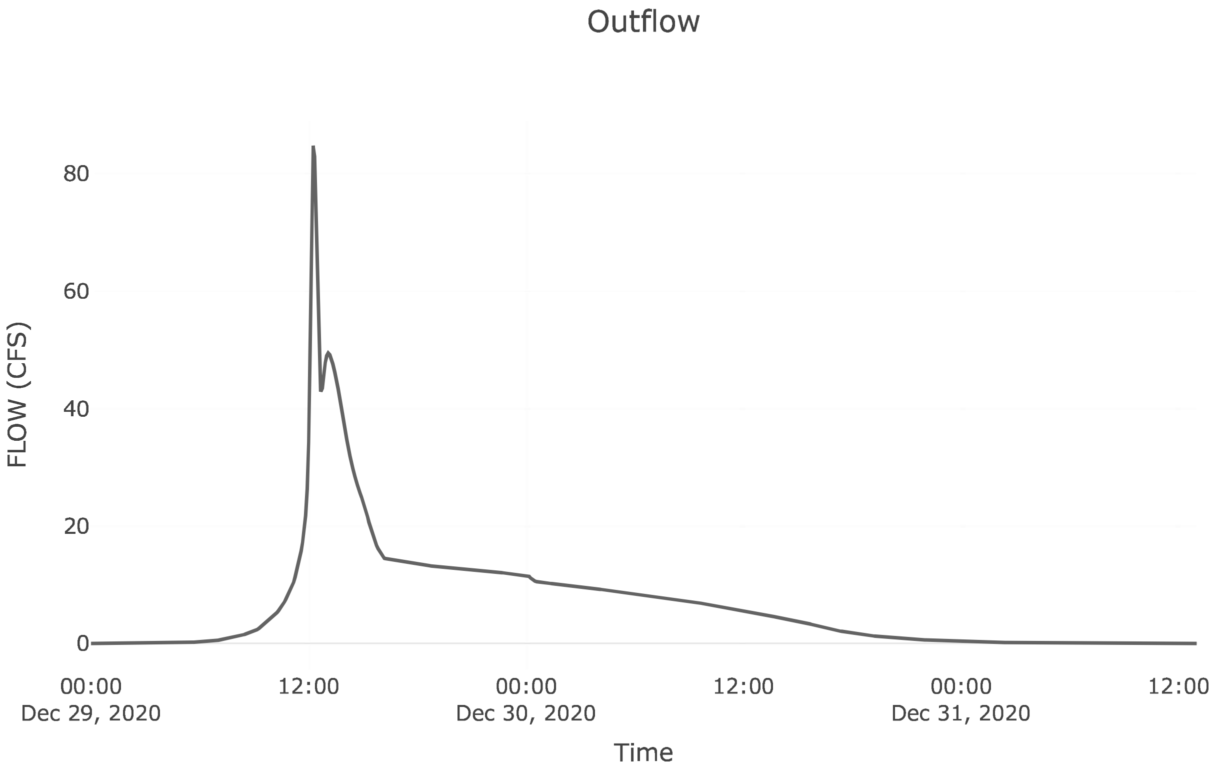
Peak Discharge (CFS)	9.4
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.16
Precipitation Volume (AC - FT)	1.39
Loss Volume (AC - FT)	0.48
Excess Volume (AC - FT)	0.91
Direct Runoff Volume (AC - FT)	0.91
Baseflow Volume (AC - FT)	0



Junction: DP5

Results: DP5

Peak Discharge (CFS)	84.78
Time of Peak Discharge	29Dec2020, 12:15
Volume (IN)	5.33



Subbasin: O5

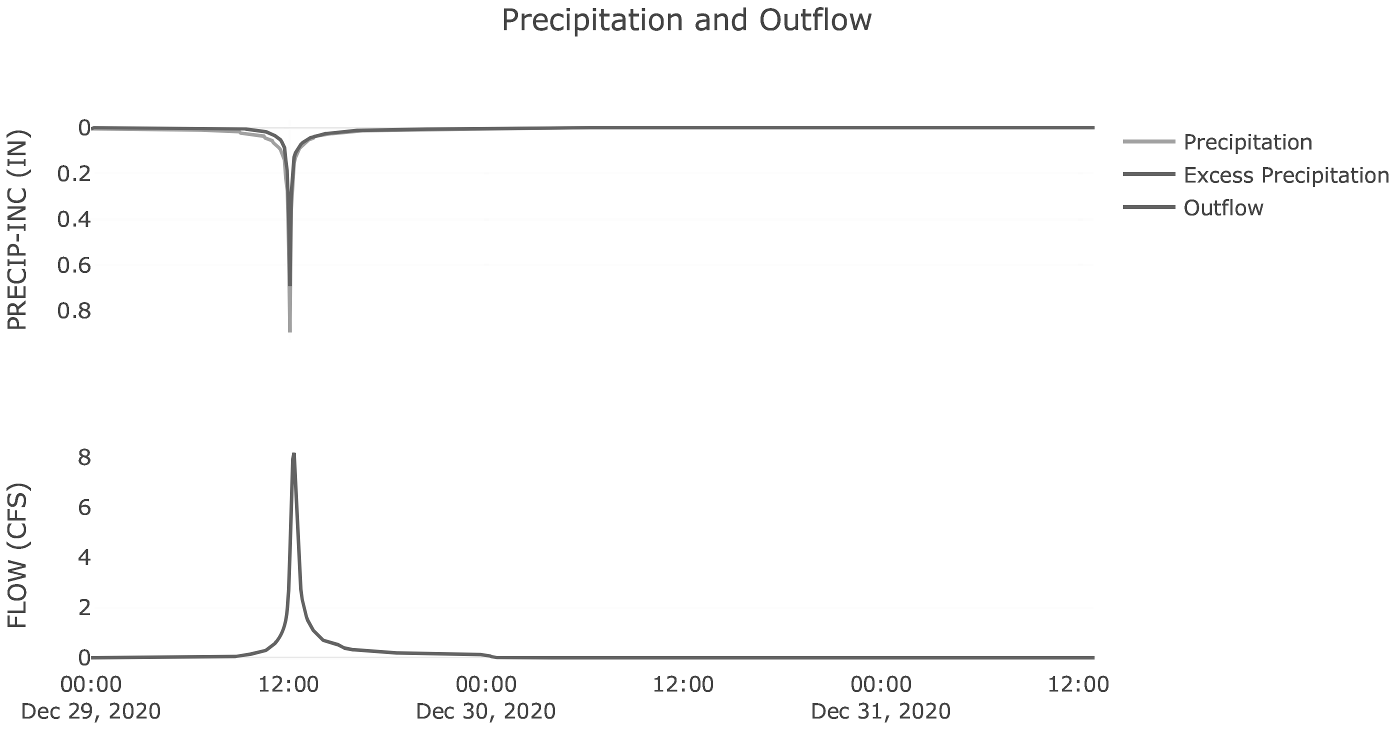
Area (MI2) : 0
Downstream : Dp4

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.25
Snyder Cp	0.73

Results: O5

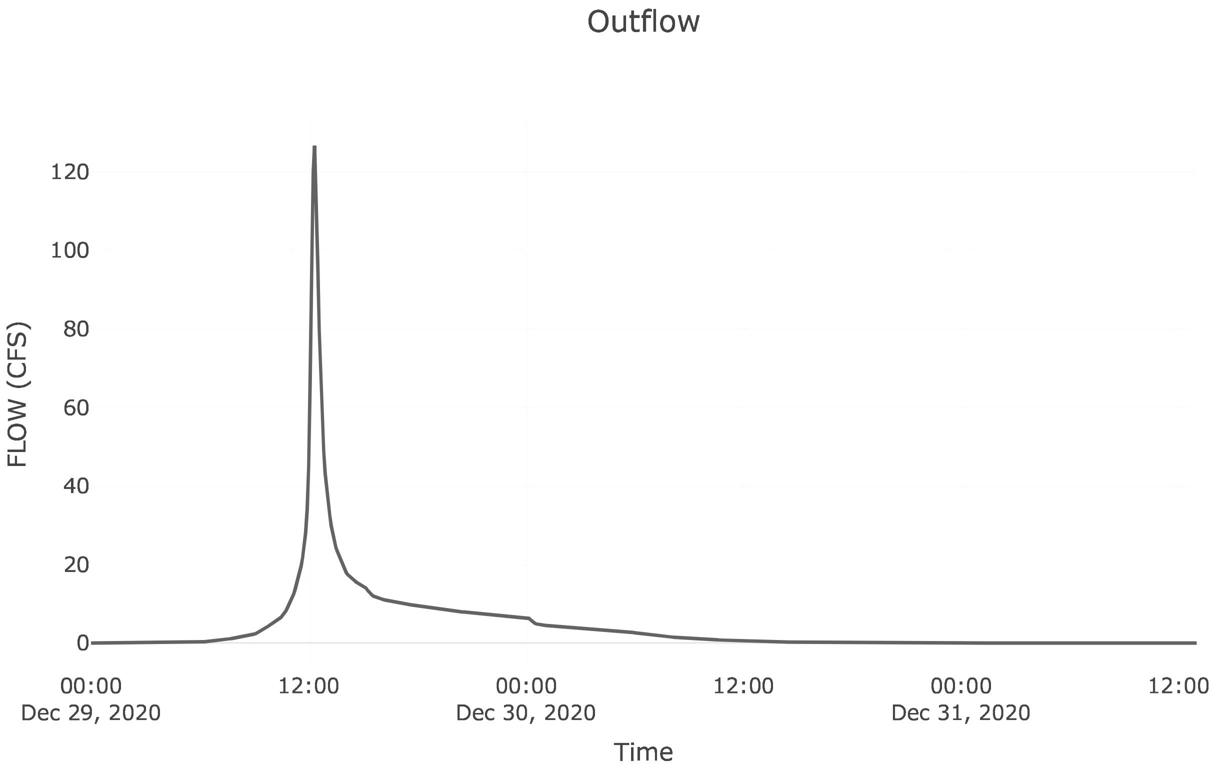
Peak Discharge (CFS)	8.18
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.05
Precipitation Volume (AC - FT)	1.26
Loss Volume (AC - FT)	0.45
Excess Volume (AC - FT)	0.81
Direct Runoff Volume (AC - FT)	0.81
Baseflow Volume (AC - FT)	0



Junction: DP4

Results: DP4

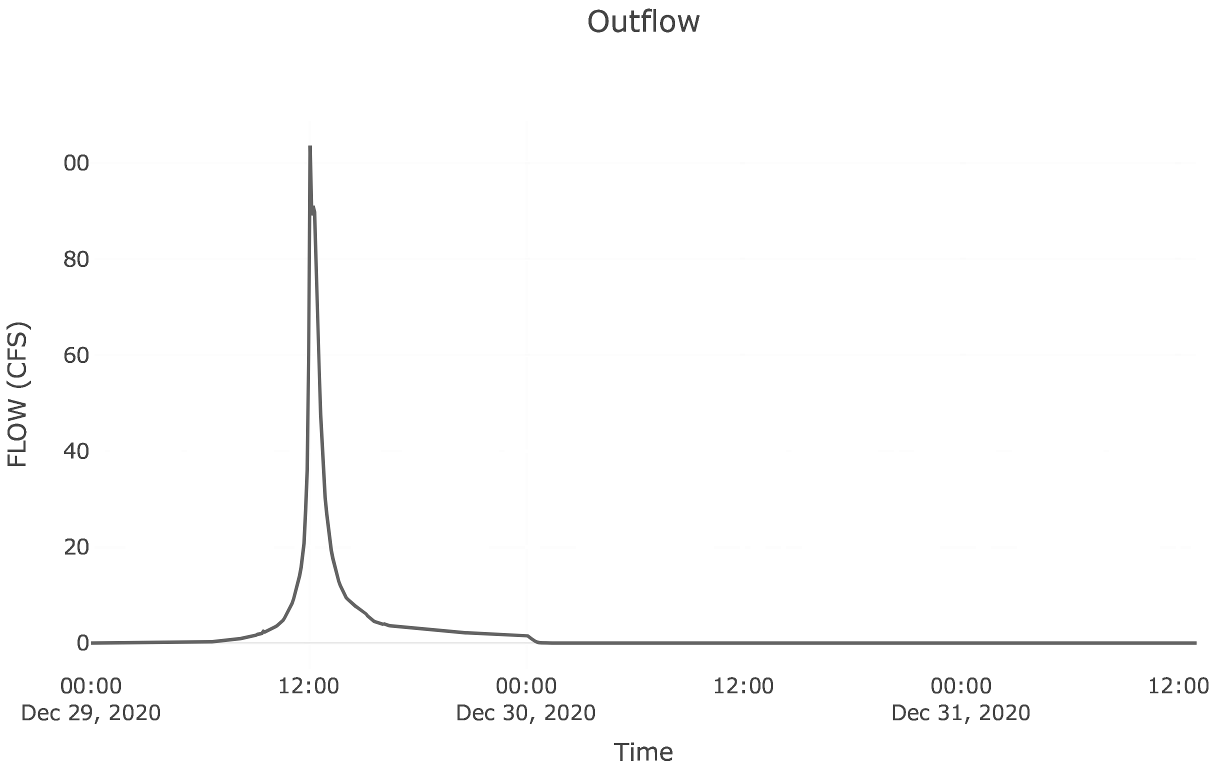
Peak Discharge (CFS)	126.65
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.77



Junction: DP2

Results: DP2

Peak Discharge (CFS)	103.58
Time of Peak Discharge	29Dec2020, 12:05
Volume (IN)	5.3



Subbasin: O4

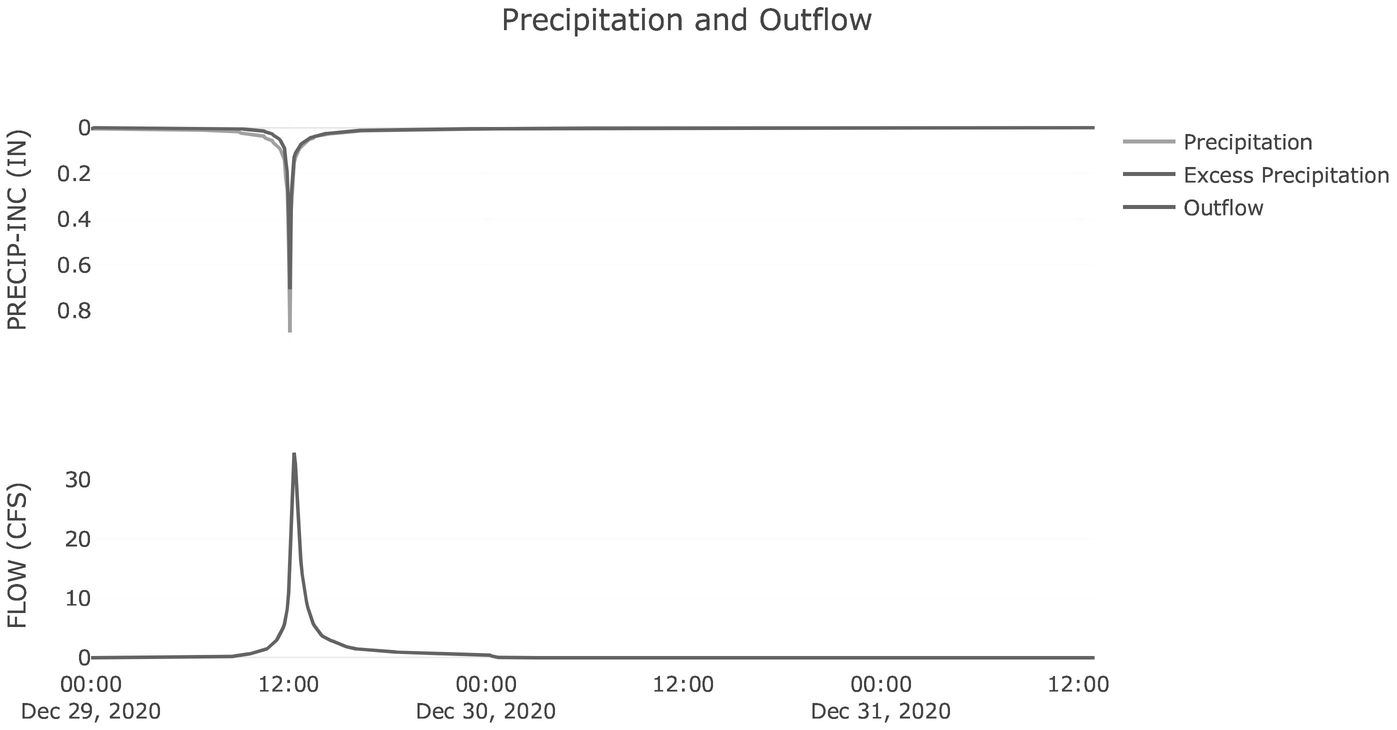
Area (MI2) : 0.01
Downstream : Dp3

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.29
Snyder Cp	0.69

Results: O4

Peak Discharge (CFS)	34.48
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.16
Precipitation Volume (AC - FT)	5.93
Loss Volume (AC - FT)	2.04
Excess Volume (AC - FT)	3.88
Direct Runoff Volume (AC - FT)	3.88
Baseflow Volume (AC - FT)	0



Subbasin: S11

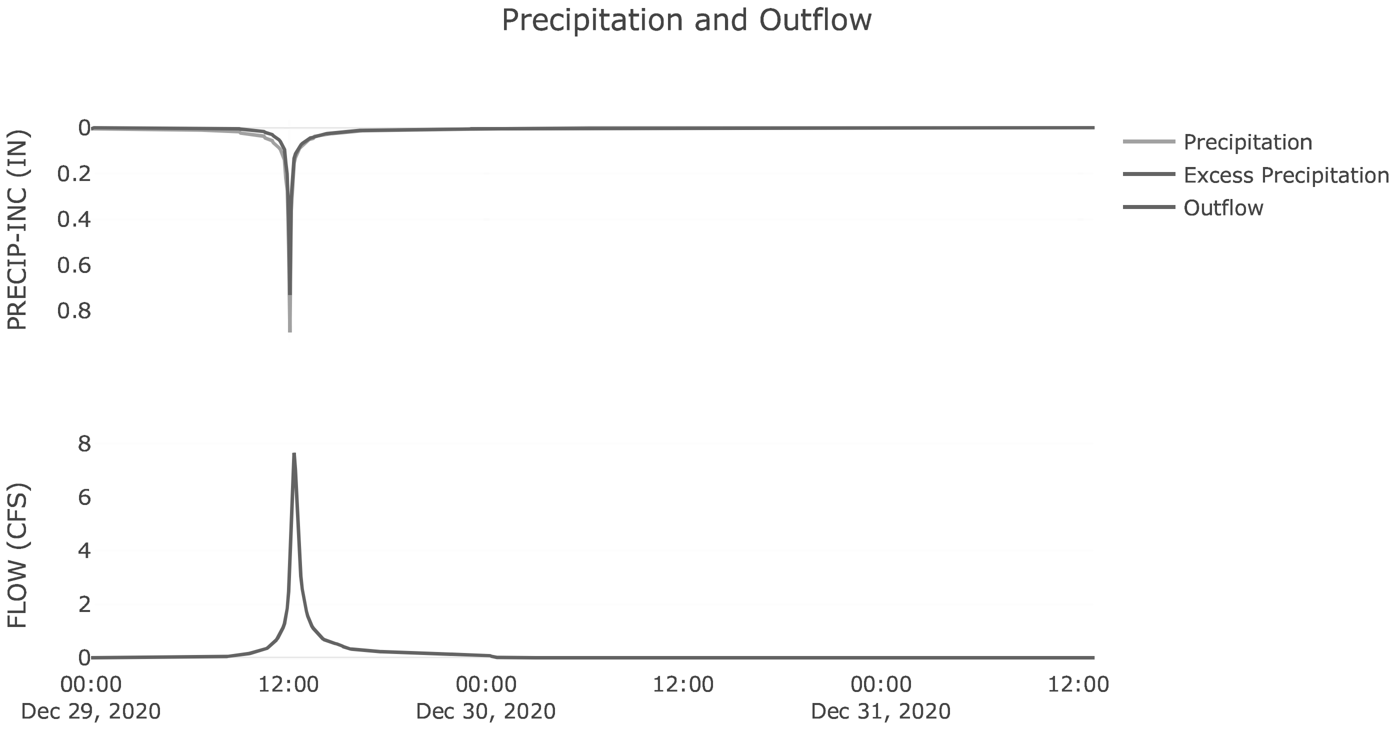
Area (MI2) : 0
Downstream : Dp3

Transform: Snyder

Snyder Method	Standard
Snyder Tp	0.28
Snyder Cp	0.74

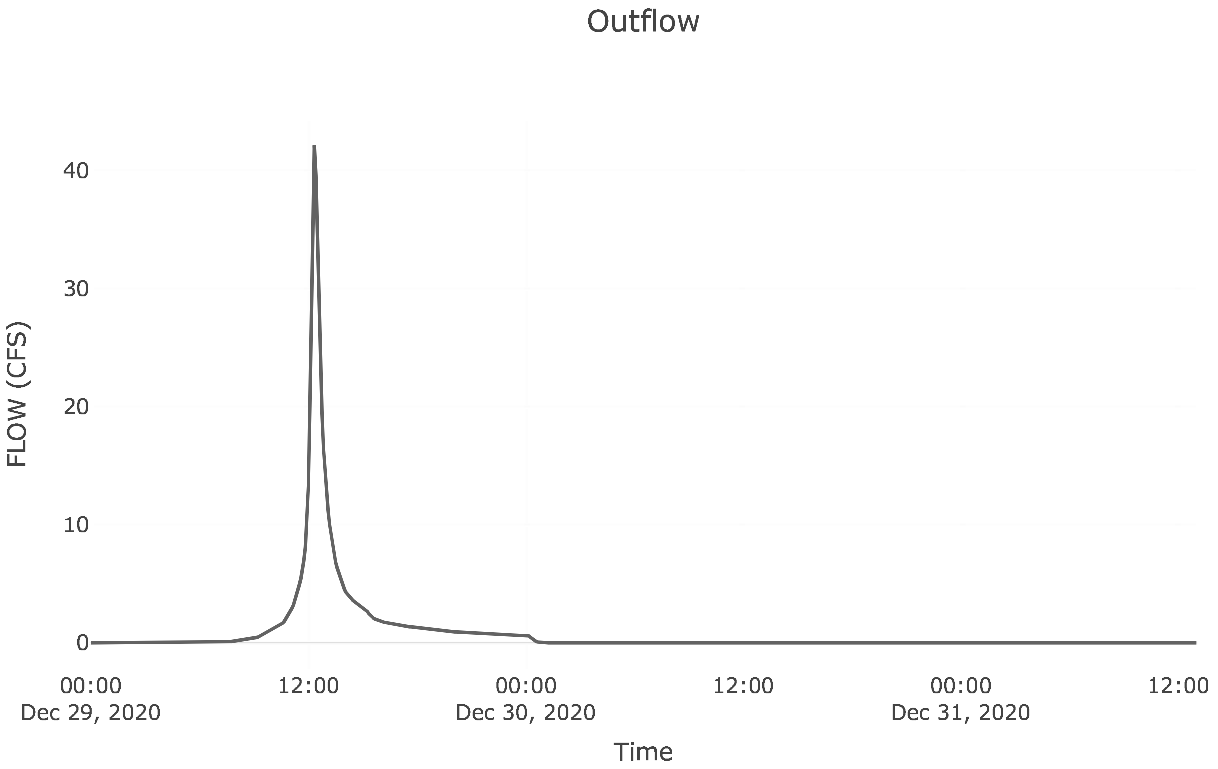
Results: S11

Peak Discharge (CFS)	7.65
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.4
Precipitation Volume (AC - FT)	1.18
Loss Volume (AC - FT)	0.37
Excess Volume (AC - FT)	0.81
Direct Runoff Volume (AC - FT)	0.81
Baseflow Volume (AC - FT)	0



Junction: DP3

Results: DP3	
Peak Discharge (CFS)	42.13
Time of Peak Discharge	29Dec2020, 12:20
Volume (IN)	5.2



VOLUME CALCULATIONS

EXCESS RAINFALL VOLUME CALCULATION

The volume generated by the site and the surrounding properties is calculated for the 25-year storm event. A summary of the design information that is included in this Appendix and related appendices are listed below.

- Excess rainfall and drainage areas used in the volume calculations were taken from the HEC-HMS analysis located on pages IIIF-E-18 through IIIF-E-68.
- Updated permitted condition volume information is summarized on pages IIIF-E-71 through IIIF-E-73.

ROYAL OAKS LANDFILL
0120-076-11-106
25- YEAR EXCESS RAINFALL
VOLUME CALCULATIONS

Required: Determine the volume generated by the site and offsite areas using the excess rainfall calculated in the HEC-HMS analysis of the post-development site conditions.

Method: 1. Use the excessive rainfall data generated by the HEC-HMS analysis (see pages IIIF-E-18 through IIIF-E-68) to determine the volume produced by the site for the post-development conditions.

1. Updated Permitted Condition

1. Volume Discharging at DP1

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
O1	**0.2607**	**4.02**	**166.84**	**55.92**
S1	**0.0129**	**5.86**	**8.24**	**4.02**
S2	**0.0108**	**5.75**	**6.92**	**3.32**
S10	**0.0021**	**5.98**	**1.32**	**0.66**
DA1	**0.0102**	**6.22**	**6.50**	**3.37**
DA6	**0.0083**	**6.22**	**5.28**	**2.74**
CH8	**0.0086**	**5.98**	**5.53**	**2.76**
P1	**0.0031**	**7.76**	**2.01**	**1.30**

Total Volume Discharging at DP1= **74.08** **ac-ft**

2. Volume Discharging at DP2

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
DA2	**0.0110**	**6.22**	**7.03**	**3.64**
S3	**0.0132**	**5.63**	**8.46**	**3.97**
O6	**0.0171**	**5.05**	**10.93**	**4.60**

Total Volume Discharging at DP2= **12.21** **ac-ft**

3. Volume Discharging at DP3

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
O4	**0.0141**	**5.16**	**9.00**	**3.87**
S11	**0.0028**	**5.40**	**1.77**	**0.80**

Total Volume Discharging at DP3= **4.67** **ac-ft**

4. Volume Discharging at DP4

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
CH1	**0.0020**	**5.98**	**1.28**	**0.64**
CH2	**0.0006**	**5.98**	**0.40**	**0.20**
S4	**0.0037**	**5.75**	**2.34**	**1.12**
S5	**0.0417**	**5.51**	**26.71**	**12.26**
P2	**0.0073**	**7.76**	**4.64**	**3.00**
DA3	**0.0141**	**6.22**	**9.01**	**4.67**
O5	**0.0030**	**5.05**	**1.93**	**0.81**

Total Volume Discharging at DP4= **22.71** **ac-ft**

5. Volume Discharging at DP5

Area No.	Area (sq mi)	Total Excess Rainfall (in)	Area (ac)	Volume (ac-ft)
S6	**0.0090**	**5.98**	**5.75**	**2.87**
S7	**0.0033**	**5.16**	**2.11**	**0.91**
S8	**0.0060**	**5.51**	**3.86**	**1.77**
S9	**0.0059**	**5.16**	**3.77**	**1.62**
CH3	**0.0007**	**5.98**	**0.46**	**0.23**
CH4	**0.0042**	**5.98**	**2.67**	**1.33**
CH5	**0.0025**	**5.98**	**1.58**	**0.79**
CH6	**0.0019**	**5.98**	**1.23**	**0.61**
CH7	**0.0101**	**5.98**	**6.45**	**3.21**
DA4	**0.0162**	**6.22**	**10.35**	**5.36**
DA5	**0.0078**	**6.22**	**5.02**	**2.60**
O2	**0.0238**	**3.35**	**15.24**	**4.26**
O3	**0.0231**	**5.40**	**14.76**	**6.64**
P3	**0.0057**	**7.76**	**3.64**	**2.35**

Total Volume Discharging at DP5= **34.56** **ac-ft**

Total Volume Discharging At Permit Boundary =	**148.23**	**ac-ft**

VELOCITY CALCULATIONS

Required: Determine the flow velocities entering and exiting the permit boundary using HYDROCALC HYDRAULICS (Version 2.01, 1996-2010) for the flows calculated for the 25-year storm event.

Method:
1. Use the flow data to determine velocity of runoff entering the landfill permit boundary.
2. Use the flow data to determine velocity of runoff exiting the landfill permit boundary.

1. Flow Velocity entering the landfill permit boundary

O1

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 318.9 cfs

Storm Year	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)
25	318.9	0.0316	0.04	5.6	3.3	9.37	2.09	8.16

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O2

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 40.7 cfs

Storm Year	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)
25	40.7	0.0444	0.04	4.1	6.2	51.44	0.25	3.07

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O3

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 64.9 cfs

Storm Year	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)
25	64.9	0.0802	0.04	4.2	5.1	14.06	0.58	6.63

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O4

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 34.5 cfs

Storm Year	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)
25	34.5	0.0871	0.04	1.7	1.9	5.08	0.72	7.54

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O5

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 8.2 cfs

Storm Year	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)
25	8.2	0.0907	0.04	100.0	100.0	100.00	0.05	1.51

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010)

O6

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 40.1 cfs

Storm Year	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)
25	40.1	0.0684	0.04	4.4	5.1	83.69	0.16	2.90

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

2. Flow Velocity exiting the landfill permit boundary

DP 1

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 338.5 cfs

Storm Year	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)
25	338.5	0.0155	0.04	10.6	6.4	130.88	0.70	3.54

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

DP 2

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 103.6 cfs

Storm Year	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)
25	103.6	0.0077	0.04	6.6	10.0	171.77	0.36	1.64

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

developed by Dodson and Associates (Version 2.01, 1996-2010)

DP 3

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 42.1 cfs

Storm Year	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)
25	42.1	0.0736	0.04	4.3	5.1	18.53	0.40	5.16

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

DP 4

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 126.6 cfs

Storm Year	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)
25	126.6	0.0360	0.04	1.6	2.0	3.71	2.07	8.22

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)

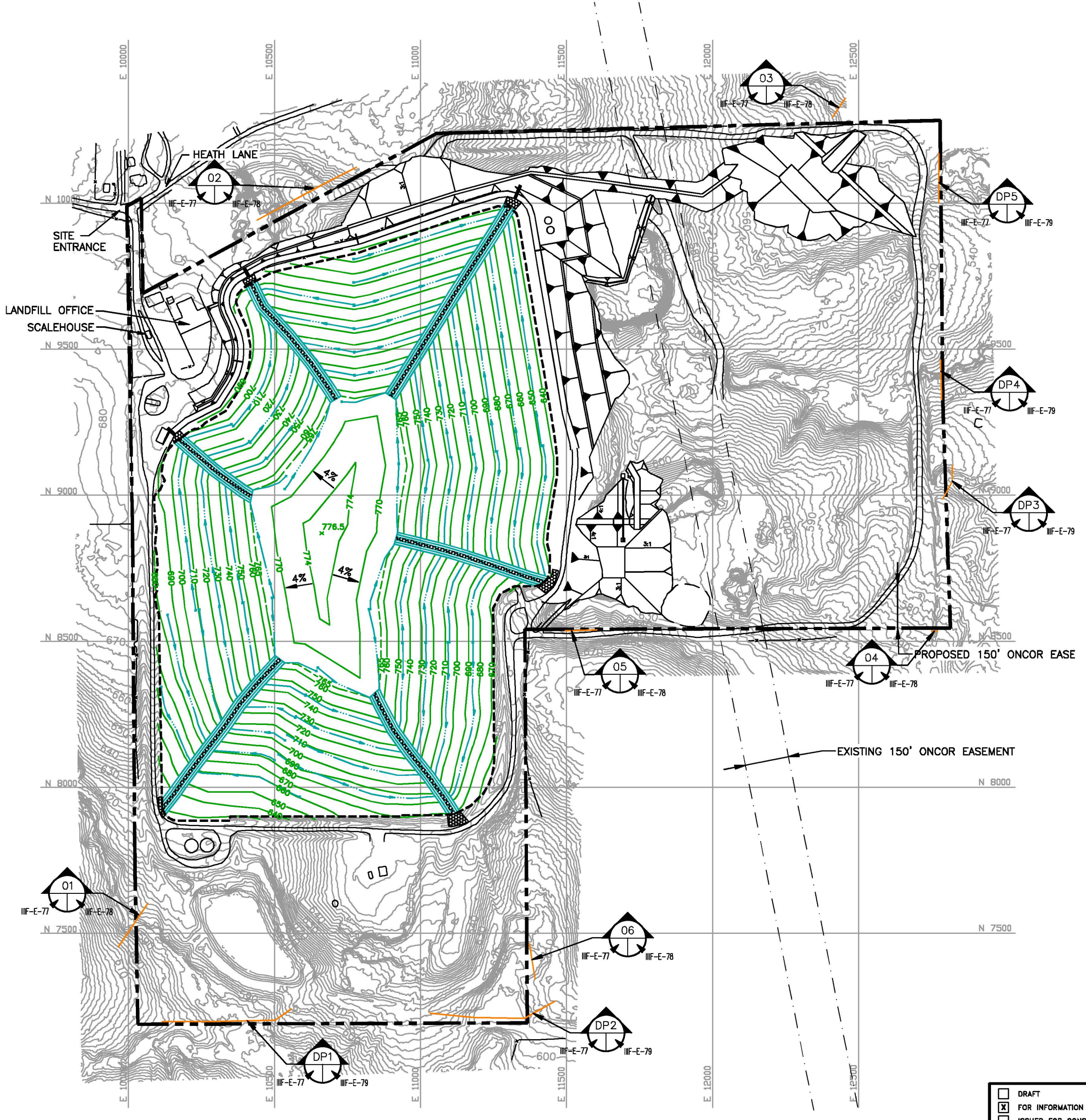
DP 5

Flows were obtained from the Hydrologic Calculations included in Appendix IIIF-E for the offsite areas and are summarized below.

Q25 = 84.8 cfs

Storm Year	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)
25	84.8	0.020	0.04	14.4	3.7	27.50	0.69	3.65

Note: Calculations were performed using the HYDROCALC HYDRAULICS for Windows program
developed by Dodson and Associates (Version 2.01, 1996-2010)



N

0 200 400
SCALE IN FEET

LEGEND

▬ ▪ ▬	PERMIT BOUNDARY
▬ ▬	LIMIT OF WASTE
E 10500	SITE GRID
610	EXISTING CONTOUR (SEE NOTE 1)
624	PERMITTED FINAL COVER CONTOUR
─·─	DRAINAGE SWALE
▨	DRAINAGE LETDOWN
─·─	CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS DEVELOPED BY FIRMATEK FROM AERIAL PHOTOGRAPHY FLOWN NOVEMBER 10, 2022.

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DATE: 05/2024
FILE: 0120-76-11
CAD: IIIF-E-77 VELOCITY CALCS.DWG

DRAWN BY: JDW
DESIGN BY: SAB
REVIEWED BY: KDG

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

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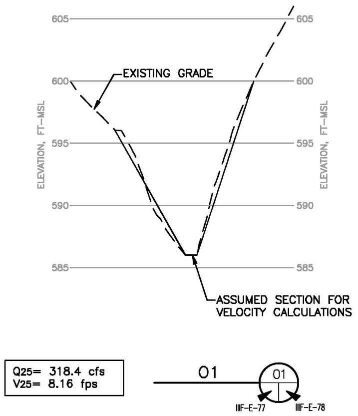

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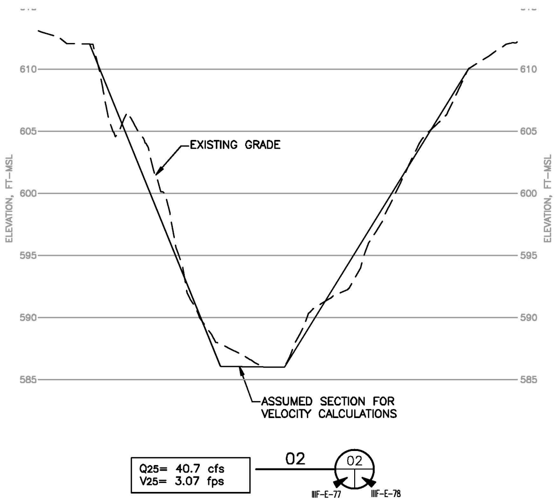

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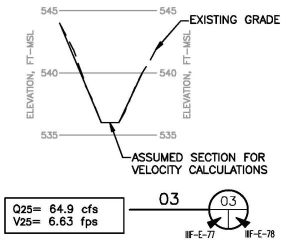

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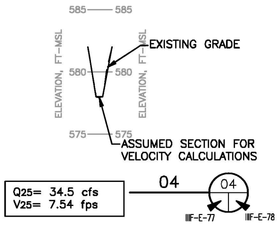

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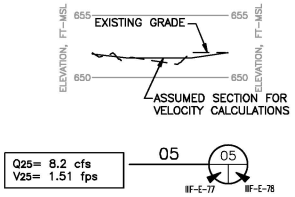

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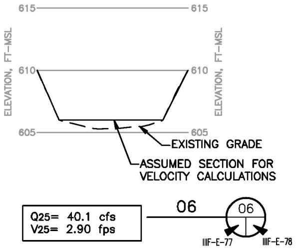

Q25= 40.1 cfs
V25= 2.90 fps

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DRAWN BY: JDW
DESIGN BY: SAB
REVIEWED BY: KDG

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

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NO.	DATE	DESCRIPTION

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ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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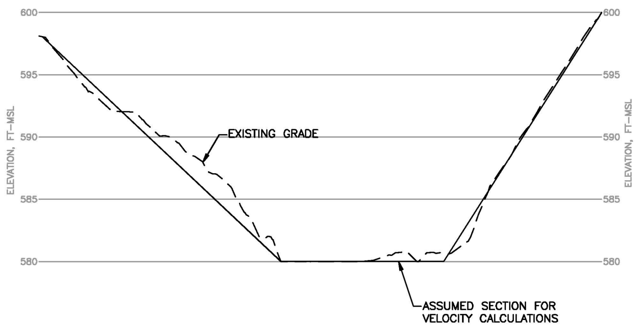

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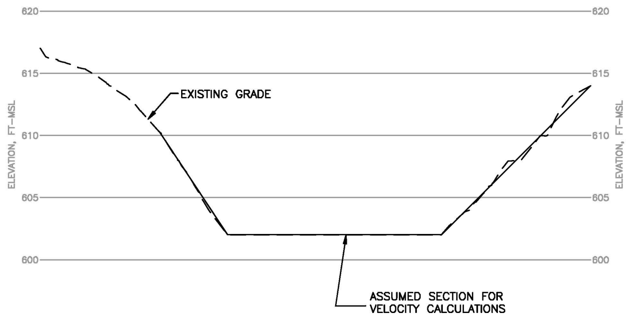
IIIF-E-77 IIIF-E-79



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IIIF-E-77 IIIF-E-79

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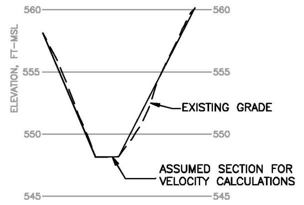
0 10 20
SCALE IN FEET (VERTICAL)



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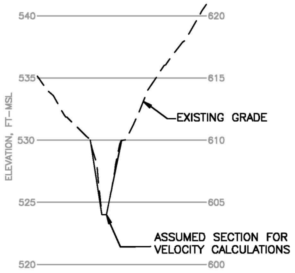

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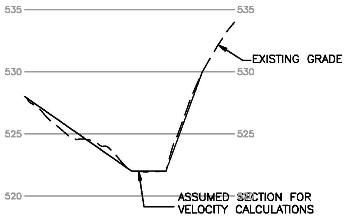

Q25= 84.8 cfs
V25= 3.65 fps

DISCHARGE POINT 5 DP5
IIIF-E-77 IIIF-E-79

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CAD: IIIF-E-79-VELOCITY SECTONS.DWG

DRAWN BY: JDW
DESIGN BY: SAB
REVIEWED BY: KDG

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

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ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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EXISTING PERMITTED DRAINAGE CALCULATION EXCERPTS

MAJOR
PERMIT
AMENDMENT
FOR THE

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS
JACKSONVILLE, TEXAS

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
MUNICIPAL SOLID WASTE FACILITY - TYPE I

PERMIT APPLICATION
NO. MSW 1614A

PART III

ATTACHMENT 6

GROUND WATER AND SURFACE WATER

PROTECTION PLAN AND DRAINAGE PLAN

GARY RUSSELL HORWITCH
48456
9-12-96

Applicant:

LAIDLAW WASTE SYSTEMS (TEXAS), INC.
9001 Airport Freeway, Suite 500
North Richland Hills, Texas 76180
(817) 485-9629

Prepared by:

HMA ENVIRONMENTAL SERVICES, INC.
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Houston, Texas 77014-1146
(713) 440-5503

May 10, 1996

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STATE OF TEXAS
GARY RUSSEL HORWITCH
48456
9-12-96

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GARY [illegible] HORWITCH
48456

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48156
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4845

9-12-96

LIST OF APPENDICES

Appendix

18456

9-12-96

LIST OF ACRONYMS

ac	acres
BMP	Best Management Practices
C	coefficient
cfs	cubic feet per second
CN	curve number
CFR	Code of Federal Regulations
FEMA	Federal Emergency Management Agency
ft	feet
ft-msl	feet mean sea level
ft/sec	feet per second
HDPE	high-density polyethylene
H:V	horizontal to vertical
Laidlaw	Laidlaw Waste Systems (Texas), Inc.
MLFCS	multi-layer final cover system
MPA	Major Permit Amendment
NPDES	National Pollutant Discharge Elimination System
MSW	Municipal Solid Waste
MSWLF	Municipal Solid Waste Landfill Facility
NWP26	Nationwide Permit 26
SCS	Soil Conservation Services
SOP	Site Operating Plan
Storm Water Plan	Ground Water and Storm Water Protection Plan and Drainage Plan
TAC	Texas Administrative Code
T_c	time of concentration
T_L	lag time

GARY RUSSELL HORWITCH
9-12-96

LIST OF ACRONYMS
(Continued)

TNRCC	Texas Natural Resource Conservation Commission
TR 55	Technical Release No. 55
TxDOT	Texas Department of Transportation
USACE	U. S. Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USLE	Universal Soil Loss Equation

GARY RUSSEL HORWITCH
48456
9-12-96

1.0 INTRODUCTION

This Ground Water and Surface Water Protection Plan and Drainage Plan (Storm Water Plan) has been developed as part of the Major Permit Amendment (MPA) that is being submitted for the Laidlaw Waste Systems (Texas), Inc. (Laidlaw) Royal Oaks Landfill, located in Jacksonville, Cherokee County, Texas. This Storm Water Plan has been developed in accordance with the requirements identified in Texas Administrative Code (TAC) §330.56(f).

1.1 SITE WATER MANAGEMENT

The Royal Oaks Landfill has been designed to segregate leachate, clean runoff, and contaminated water. The site design incorporates permanent and temporary berms, dikes and/or ditches to isolate leachate, contaminated water, and clean runoff. The overall storm water management system (e.g., storm water sedimentation ponds, perimeter ditches, and other drainage controls) will be constructed and additional temporary construction features (dikes, ditches, etc.) will be constructed as required during the operating life of the landfill. The following definitions are used to distinguish the types of waters which are generated at the site.

1. Leachate - Water which has come in direct contact with solid waste and is collected in the leachate collection system.
2. Contaminated water - Storm water runoff from landfill areas which have received daily cover and storm water runoff from constructed cells which has come in direct contact with waste or leachate.
3. Clean runoff - Storm water runoff from undeveloped areas, intermediate cover, or areas with a multi-layer final cover system (MLFCS).

This attachment describes the various components of the site storm water management system. Specific information concerning the control of leachate and contaminated water is provided in the Leachate and Contaminated Water Plan included as Attachment 15.

1.2 SITE INFORMATION

The Royal Oaks Landfill is an existing Municipal Solid Waste Landfill Facility (MSWLF) -Type I, Texas Natural Resource Conservation Commission (TNRCC) Municipal Solid Waste (MSW) Permit No. 1614. The Royal Oaks Landfill is located east of the city limits of Jacksonville, Cherokee County, Texas, and north of the closed City of Jacksonville Landfill (TNRCC Permit No. 501).

The site is located approximately 0.5 mile east of the intersection U. S. Highway 69 and Heath Lane. The 144-acre site was permitted on July 19, 1984, as a MSWLF-Type I by the City of Jacksonville. The City of Jacksonville operated the site until December 21, 1988, when Laidlaw began operating the site for the City.

The Subtitle D modifications for the site were submitted to the TNRCC on April 9, 1994, and were approved by the TNRCC on August 22, 1994.

1.3 PREDEVELOPMENT SITE TOPOGRAPHY

The Royal Oaks Landfill is located on a ridge between the headwaters of Keys Creek and Barber Branch. The predevelopment site topography is shown on the General Topographic Map (see Figure 1-1). The predevelopment elevation of the ridge ranged from an elevation of approximately 690 feet mean sea level (ft-msl) in the northwest portion of the site to an elevation of approximately 660 ft-msl in the southeast portion of the site. The predevelopment topography slopes from the ridge line to an elevation of

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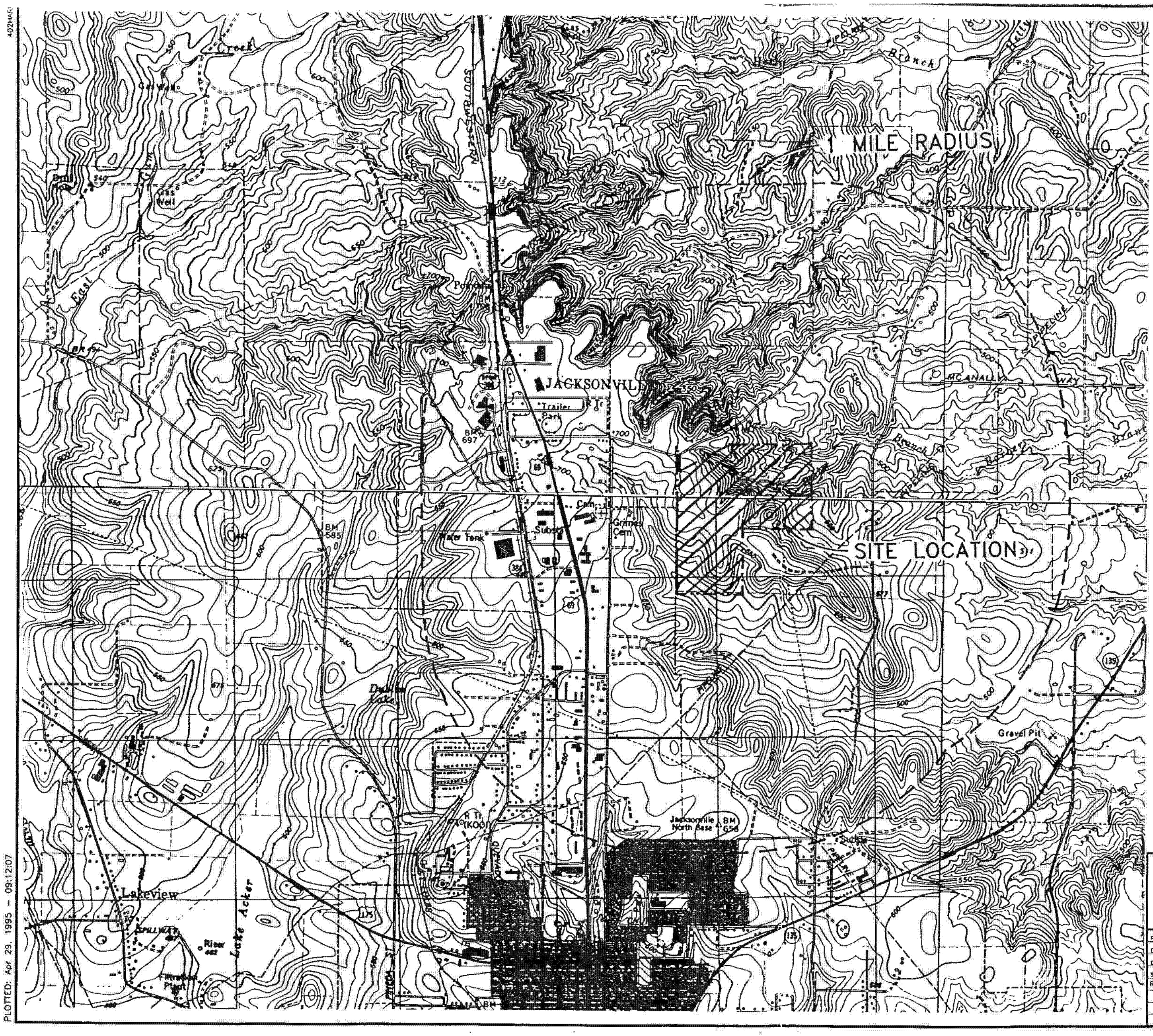

N

HORWITCH

LEGEND:

▨ SITE LOCATION

— — — — 1 MILE SITE BOUNDARY OFFSET

——550—— CONTOUR INTERVAL FT–MSL

BASE MAP SOURCE:

USGS 7 1/2 MINUTE
JACKSONVILLE EAST (1973),
JACKSONVILLE WEST (1982),
TECULA (1983) AND MOUNT
SELMAN (1973).

2000 1000 0 2000
SCALE FEET

Part III
Attachment 6
Figure
1–1

GENERAL TOPOGRAPHIC MAP

PROJECT NO: 022402-3
DRAWN BY: AMT 4/95
CHECKED BY: PRM 4/95
SUBMITTED BY:
REV NO. DESCRIPTION BY DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

HMA environmental
HMA Environmental
Services, Inc.
Houston, Texas

approximately 600 ft-msl in the southwest portion of the site and to an elevation of approximately 530 ft-msl in the eastern portion of the site.

1.4 DRAINAGE PATTERNS

Surface water drainage from the site is generally to the south and to the east as indicated on Figure 1-2. Surface water runoff from the southern half of the site flows south to Keys Creek, while surface water from the northern half of the site flows into the tributary of Barber Branch prior to flowing into Keys Creek. Keys Creek flows southeast into Mud Creek and ultimately into the Angelina River.

1.5 FLOODPLAIN AND FLOODWAY INFORMATION

The Royal Oaks Landfill site is not located within a Federal Emergency Management Agency (FEMA) designated 100-year floodplain or floodway. Certification of compliance with the floodplain restrictions indicated in TAC §330.301 for the entire Royal Oaks Landfill site (see Appendix F, Part II of the MPA) was submitted as part of the April 9, 1994, Subtitle D Upgrade, Class I Permit Modification for the site (EMCON, 1994a). This Class I Permit Modification was approved by the TNRCC on August 22, 1994. Additionally, as indicated in Appendix I, construction of expansion Cells 7, 8, and 9 will impact approximately 0.6 acres of the Barber Branch Creek headwaters. Therefore, under the terms and conditions of Nationwide Permit 26 (NWP26), notification to the U. S. Army Corps of Engineers (USACE) prior to commencement of construction activities is not required because the affected area is less than 1 acre.

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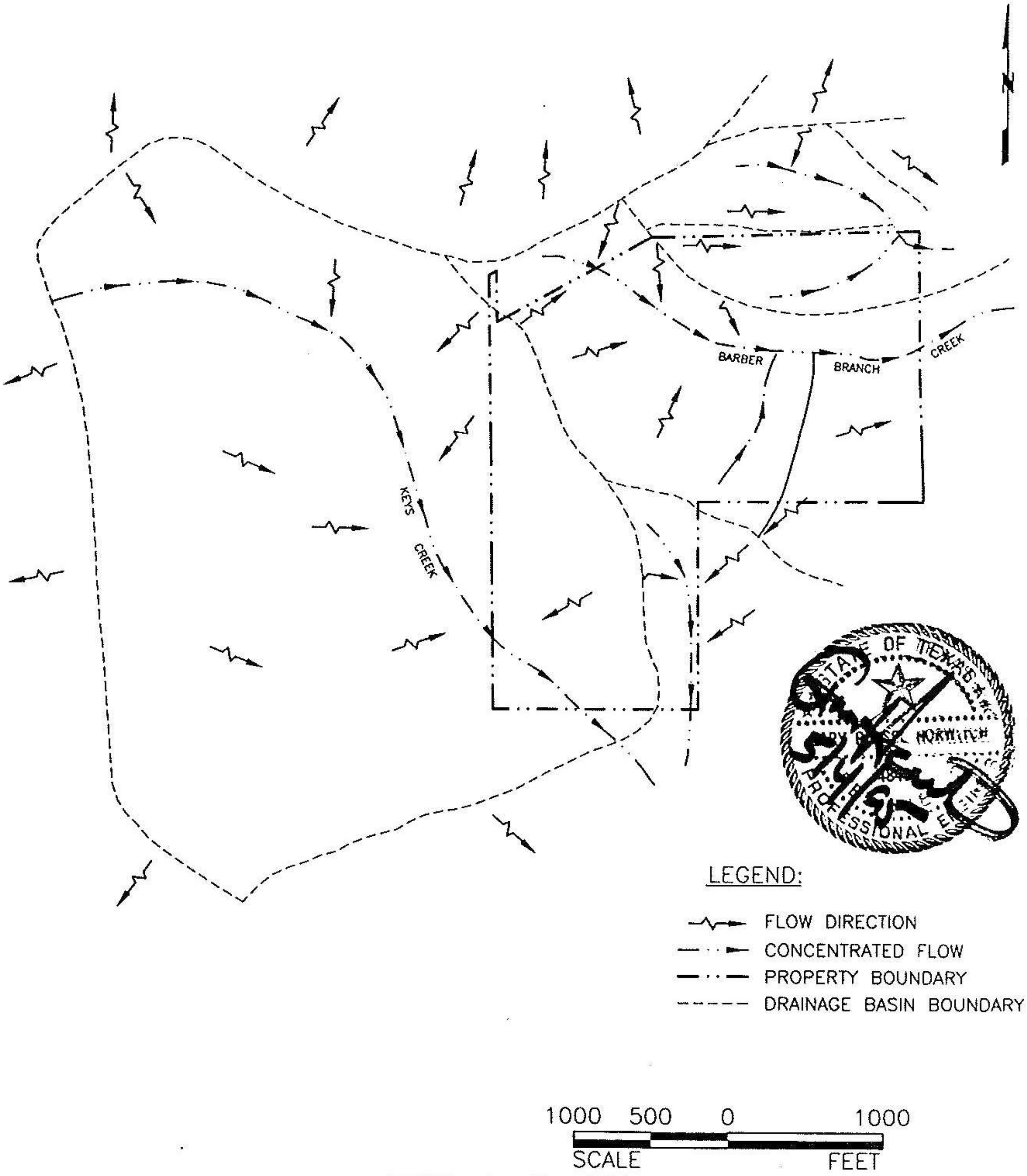

Part III
Attachment 6
Figure
1-2

PREDEVELOPMENT DRAINAGE PATTERNS

PROJECT NO.: 022402-3
DRAWN BY: JMT 4/95
CHECKED BY: PRM 4/95
SUBMITTED BY:

REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

HMA environmental
HMA Environmental
Services, Inc.
Houston, Texas

PLOTTED: May 02, 1995 – 09:44:59

1.6 STORM WATER DISCHARGE MONITORING

Storm water monitoring will not be performed at the site since the City of Jacksonville has a population of less than 100,000 persons (12,763 according to the 1990 census) and the Royal Oaks Landfill is exempt from the NPDES program as indicated in Title 40 of the Code of Federal Regulations (CFR) Part 122.26(e)(2)(I).

2.0 SITE DEVELOPMENT

2.1 GENERAL

The facilities associated with the development of the Royal Oaks Landfill are shown on Sheet 1.1 included in Attachment 1. The landfill footprint, site office/maintenance building, scalehouse, and other site operational features are located on the west side of the site. Storm water sedimentation ponds are located on the eastern and southern sides of the site.

2.2 LANDFILL DEVELOPMENT

The Royal Oaks Landfill is designed to operate as a multi-level, modified area fill landfill, with above and belowgrade filling. The general sequence of anticipated landfill operations is indicated on Sheet 1.13 included in Attachment 1. Detailed descriptions of the various design components are included in Section 3.0, Part III of the MPA, and a detailed description of the waste disposal activities is provided in the Site Operating Plan (SOP) included in Part IV of the MPA. Sheet 7.1 included in Attachment 7 shows the closed configuration of the site.

Closure of the site, which will be performed as portions of the landfill reach final grade, will include installation of the MLFCS and other activities as indicated in the Final Closure Plan (see Attachment 10).

The MLFCS (see Sheets 1.9 through 1.11 in Attachment 1) will provide a low maintenance cover, reduce rainfall percolation through the cover system, and subsequently minimize leachate generation within the landfill. As indicated on the landfill's completion plan (see Sheet 1.2 in Attachment 1), 4 percent topslopes, 4 horizontal to 1 vertical (4H:1V) side slopes, and side slope terraces are provided to minimize erosion and facilitate drainage of the landfill.

2.3 STORM WATER MANAGEMENT SYSTEM COMPONENTS

The major components of the storm water management system include:

1. Runoff control berms along the perimeter of the landfill topslope to divert the runoff to the storm water flumes and to prevent runoff from topslope areas from continuing over the side slope areas (see Sheet 1.10 in Attachment 1);
2. Side slope terraces to collect runoff from the landfill side slopes and divert the runoff to the storm water flumes (see Sheets 1.9 and 1.11 in Attachment 1);
3. Storm water flumes, constructed of riprap lined drainage channels, geosynthetic lined drainage channels, piping, or other flow conveyance alternatives to convey concentrated runoff from the landfill topslopes and terraces to the perimeter ditch system (see Sheet 1.15 in Attachment 1);
5. Culverts to convey runoff under perimeter roads (see Sheet 1.14 in Attachment 1);
6. Ditches along the perimeter of the landfill to direct runoff to the storm water sedimentation ponds (see Sheet 1.14 in Attachment 1); and
7. Storm water sedimentation ponds to provide for sediment removal from runoff (see Sheet 1.14 in Attachment 1).

3.0 DRAINAGE CALCULATIONS

3.1 GENERAL

The surface water management system is designed to convey peak discharges from the 25-year storm and to control the storm water runoff volume resulting in the 25-year, 24-hour storm in accordance with TAC §330.55(b)(5) and TAC §330.55(b)(3), respectively. Peak discharges used in the design of the runoff control berms, the side slope terraces, the storm water flumes, the culverts, and the ditches were determined using the Rational Method. Peak discharges and runoff volumes used in the design of the storm water sedimentation ponds, and peak discharges for comparison of predevelopment and post development discharges were determined using Soil Conservation Service (SCS) methodologies available in the HEC-1 computer model developed by the USACE, or in SCS Technical Release No. 55 (TR 55).

Flow depths for the runoff control berms, the side slope terraces, the storm water flumes, and the ditches were determined using Mannings Equation. Water surface profiles for the perimeter ditches were determined using the HEC-2 computer model developed by the USACE.

Culvert sizing was performed using nomographs provided in the Texas Department of Transportation (TxDOT) Bridge Division Hydraulic Manual (TxDOT, 1985). While culvert sizing calculations were performed for corrugated metal pipes, culverts constructed of other materials [concrete pipe, high-density polyethylene (HDPE) pipe, and box culverts] may be used, if sufficient flow capacity is provided.

3.2 HYDROLOGIC METHODS

3.2.1 RATIONAL METHOD - PEAK FLOW ESTIMATES

As indicated in Section 3.1, peak discharges used in the design of the runoff control berms, the side slope terraces, the storm water flumes, the culverts, and the ditches (flow conveyance structures) were determined using the Rational Method as identified in the TxDOT Bridge Division Hydraulic Manual (TxDOT, 1985). The formula used to compute the peak discharges was:

$$Q = C*I*A$$

with
Q = Discharge in cubic feet per second (cfs)
C = Runoff coefficient (unitless)
I = Rainfall intensity in inches per hour
A = Drainage area in acres (ac)
* = Multiplication

The runoff coefficient (C) was based upon various criteria including topography, soil type, and land use. A C value of 0.3 was used for landfill topslope areas while a C value of 0.7 was used for other areas. Rainfall intensity was determined using the formula:

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

where b, d, and e are constants identified in the TxDOT Hydraulic Manual. For Cherokee County, the values of the constants for the 25-year rainfall are:

$b = 85$

$d = 8.5$

$e = .751$

The time of concentration (T_c) is the time in minutes required for the runoff to flow from the most hydraulically remote location in the drainage basin to the point of interest. The T_c is based on slope, ground cover, and type of drainage (sheet flow or concentrated flow). A minimum T_c of ten minutes was used for determining rainfall intensity.

The drainage areas were determined based on the drainage subareas determined for the site.

3.2.2 SCS METHOD - PEAK FLOW AND RUNOFF VOLUME ESTIMATE

As indicated in Section 3.1, peak discharges and runoff volumes used in the design of the storm water sedimentation ponds and used in the comparison of predevelopment and post development site discharges were determined using SCS methodologies available in the HEC-1 computer model developed by the USACE, or in SCS TR 55.

Unit hydrographs were determined using a triangular distribution of precipitation data determined from TP-40 frequency-duration-depth data (Dodson, 1992).

Lag time (T_L) required for the SCS method was computed based on the T_c by the equation:

$$T_L = T_c \times 0.60$$

Where the T_c is the time in minutes required for the runoff to flow from the most hydraulically remote location in the drainage basin to the point of interest. The time of concentration is based on slope, ground cover, and type of drainage (sheet flow or concentrated flow). A minimum T_c of ten minutes was used for computing the T_L.

The curve number (CN) was based upon various criteria including topography, soil type, and land use; and the drainage areas were determined based on the drainage subareas determined for the site. An overall CN of 65 was used for predevelopment conditions and undeveloped portions of the site, and an overall CN of 80 was used for the drainage areas in the sedimentation pond analyses.

3.3 DESIGN CALCULATIONS

Design calculations are provided in Appendices B through I of this attachment. Separate calculations were provided for the flow conveyance structures, the storm water sedimentation ponds, and comparison of predevelopment and post development site discharges.

3.4 FLOW CONVEYANCE STRUCTURE CALCULATIONS

Drainage basins for the peak flow computations are identified on Figure 3-1. Peak flow computations for the flow conveyance structures (including flow from offsite drainage basins) are included in Appendix B and are summarized in Table 3-1. Side slope terraces, drainage flumes, culvert sizing computations are included in Appendices C through E.

3.5 STORM WATER SEDIMENTATION POND CALCULATIONS

Drainage basins for the storm water sedimentation pond computations are identified on Figure 3-2. As indicated on Figure 3-2, the drainage area (including the offsite drainage area) contributing to a specific storm water sedimentation pond was modeled using a single hydrograph. Low level outlets, primary outflow structures, and emergency spillways are provided for each storm water sedimentation pond.

Table 3-1 25-Year Storm, Peak Flow Computations (Page 1 of 2)

Drainage Area	Basin Area (AC)	Time of Conc. (min)	Runoff Coefficient	Storm Intensity (in/hr)	Peak Flow (cfs)
1	1.4	23.0	0.3	6.4	2.7
2	1.0	26.4	0.3	5.9	1.8
3	0.7	22.4	0.3	6.5	1.4
4	1.0	20.6	0.3	6.8	2.0
5	1.2	26.0	0.3	6.0	2.1
6	0.9	25.4	0.3	6.0	1.6
7	5.9	10.7	0.7	9.2	37.9
8	7.7	10.1	0.7	9.4	50.6
9	9.3	13.2	0.7	8.4	54.8
10	3.8	10.0	0.7	9.5	25.1
11	4.4	10.8	0.7	9.2	28.5
12	5.8	12.0	0.7	8.8	35.6
13	3.9	17.7	0.7	7.3	20.1
14	1.8	10.0	0.7	9.5	12.2
15	0.8	10.0	0.7	9.5	5.3
16	1.0	10.0	0.7	9.5	6.7
17	1.9	17.7	0.7	7.3	9.7
18	1.0	16.4	0.7	7.6	5.2
19	0.8	10.0	0.7	9.5	5.5
20	1.4	10.0	0.7	9.5	9.0
21	0.1	10.0	0.7	9.5	0.6
22	1.4	10.0	0.7	9.5	9.4
23	1.5	10.0	0.7	9.5	10.0

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Table 3-1 25-Year Storm, Peak Flow Computations (Page 2 of 2)

Drainage Area	Basin Area (AC)	Time of Conc. (min)	Runoff Coefficient	Storm Intensity (in/hr)	Peak Flow (cfs)
24	7.9	19.9	0.7	6.9	38.2
25	2.2	16.7	0.7	7.5	11.8
26	5.7	13.1	0.7	8.5	33.5
27	12.2	27.1	0.3	5.8	21.3
28	2.4	11.5	0.7	9.0	15.1
29	8.6	15.2	0.7	7.9	47.4
30	5.4	19.4	0.7	7.0	26.3
31	11.5	34.2	0.7	5.1	40.9

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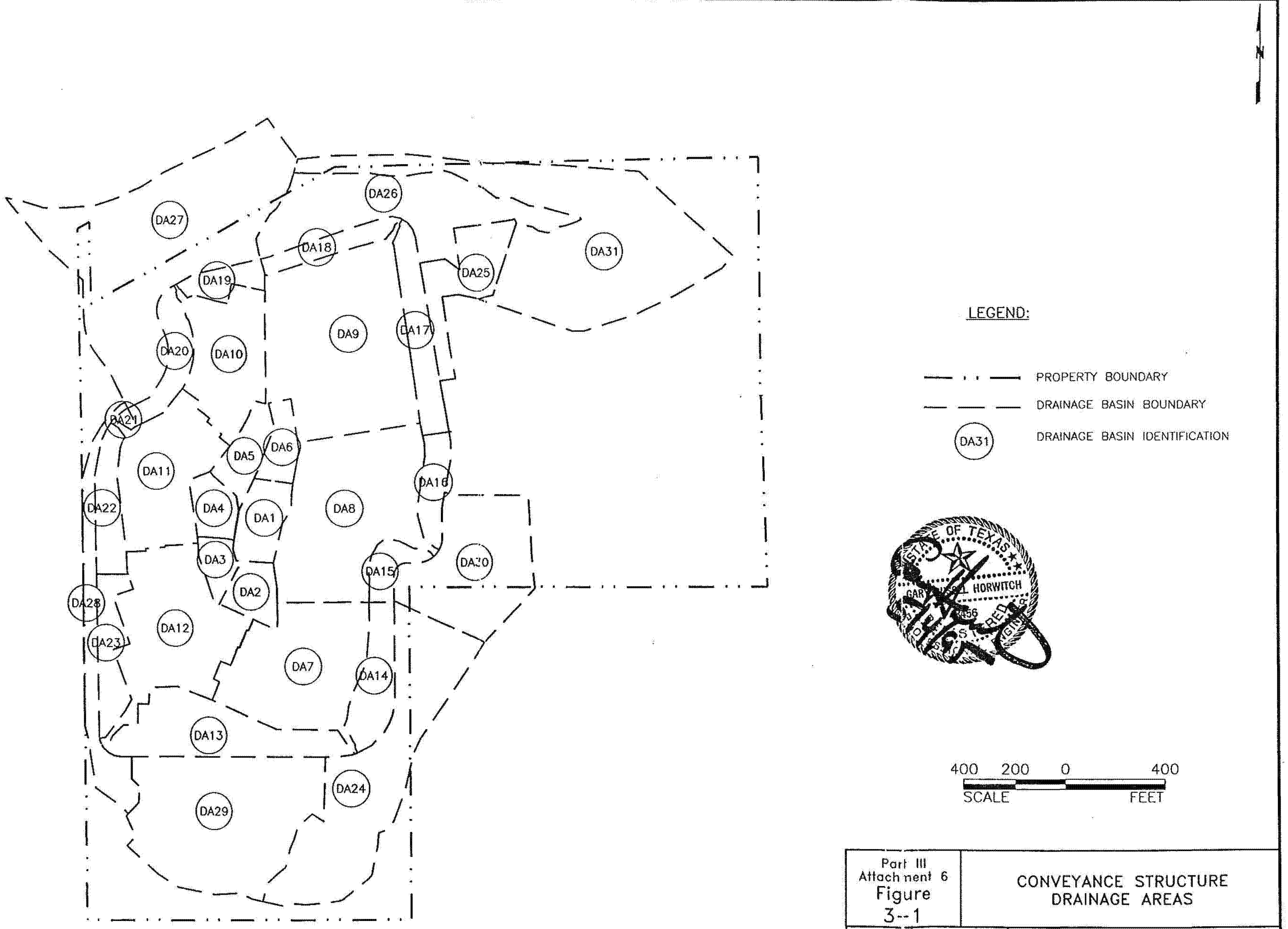
9-12-96

402070DR



GARY HORWITCH

Part III
Attachment 6
Figure
3--1

CONVEYANCE STRUCTURE DRAINAGE AREAS

PROJECT NO.: 072402-3
DRAWN BY: JMT 4/95
CHECKED BY: PHM 4/95
SUBMITTED BY:

REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

HMA environmental
HMA Environmental
Services, Inc.
Houston, Texas

PLOTTED: Apr 29, 1995 - 09:13:52

The storm water sedimentation ponds were designed to provide for storage of the runoff from the 2-year, 24-hour rainfall event and the release of this runoff within approximately 36 hours. The low level outlet for each storm water sedimentation pond was set such that a permanent 4-foot (ft) deep sedimentation area was provided.

The storm water sedimentation ponds were provided with primary outflow structures sized to convey the HEC-1 routed flows from the 25-year, 24-hour rainfall event without requiring use of the emergency spillway. Emergency spillways were provided to convey flows in excess of the 25-year, 24-hour rainfall event. Overflow elevations for the emergency spillways were indicated at 4 ft below the top of the sedimentation pond embankment and will convey the flow from the 100-year, 24-hour rainfall event (in the event of blockage of the primary outflow structure) without overtopping the embankment.

Detailed storm water sedimentation pond calculations, including HEC-1 computer results, are included in Appendix F and are summarized in Table 3-2.

3.6 PREDEVLOPMENT AND POST DEVELOPMENT PEAK FLOW COMPARISONS

Storm water discharges from the site for predevelopment and post development conditions were developed using SCS methods in HEC-1 and as described in Section 3.2.2.

Drainage basins for predevelopment flow computations are identified on Figure 3-3. As indicated on Figure 3-3, the drainage areas contributing to a specific discharge location were modeled using a single hydrograph. Drainage basins for post development flow computations are identified on Figure 3-4. Hydrographs from these drainage basins were

Table 3-2 Sedimentation Pond Data Summary

	Sedimentation Pond 1	**Sedimentation Pond 2**	**Sedimentation Pond 3**
Construction Time Requirement	Cell 1	Cell 5	Cell 7
Pond Bottom Elevation (ft-msl)	576.0	606.0	526.0
Low-Level Outlet			
Invert Elevation (ft-msl)	580.0	610.0	530.0
Diameter (in)	8	10	12
Emergency Spillway Elevation (ft-msl)	596.0	621.0	546.0
Emergency Spillway Width (ft)	20	20	40
Embankment Elevation (ft-msl)	600.0	625.0	550.0
Overflow Control Structure Pipe Outlet			
Overflow Weir Elevation (ft-msl)	594.0	619.0	544.0
Upstream Elevation (ft-msl)	580.0	610.0	530.0
Downstream Elevation (ft-msl)	578.0	590.0	526.0
Diameter (in)	48	36	48
Runoff Curve Number	80	80	80
T_L (hr)	.31	.23	.33
Drainage Area (ac)	46.5	16.2	51.8
25-Year, 24-Hour Storm			
Peak Inflow (cfs)	159 cfs	61	171
Peak Outflow (cfs)	61 cfs	6	30
Peak Stage (ft-msl)	595.30	618.02	544.50
100-Year, 24-Hour Storm			
Peak Inflow (cfs)	184 cfs	70	199
Peak Outflow (cfs)	128 cfs	16	88
Peak Stage (ft-msl)	596.25	619.27	545.6

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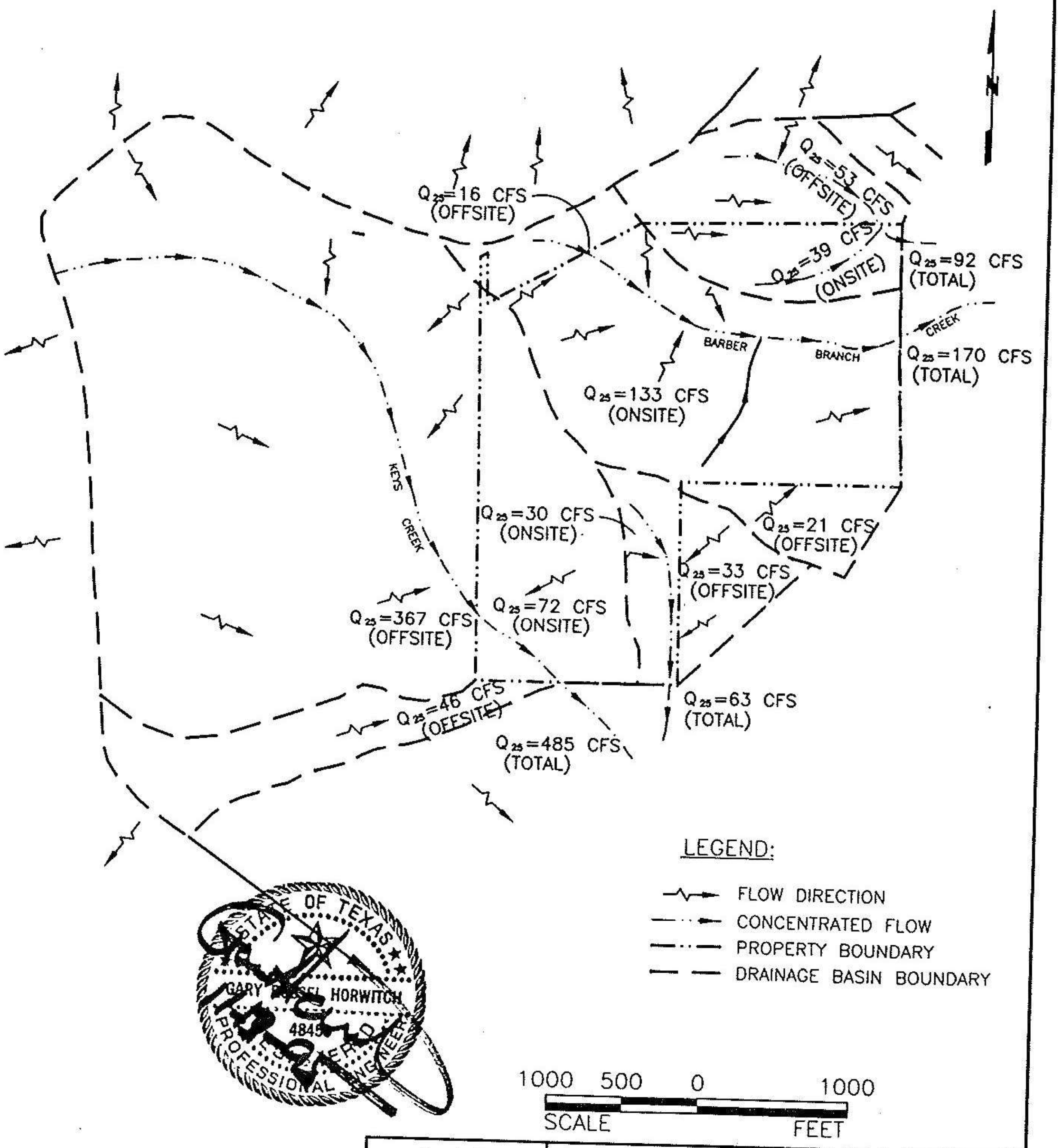
9-12-96



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Part III
Attachment 6
Figure
3-3

PREDEVELOPMENT DRAINAGE PATTERNS

PROJECT NO: 022402-3
DRAWN BY: JMT 10/95
CHECKED BY: JPR 10/95
SUBMITTED BY:

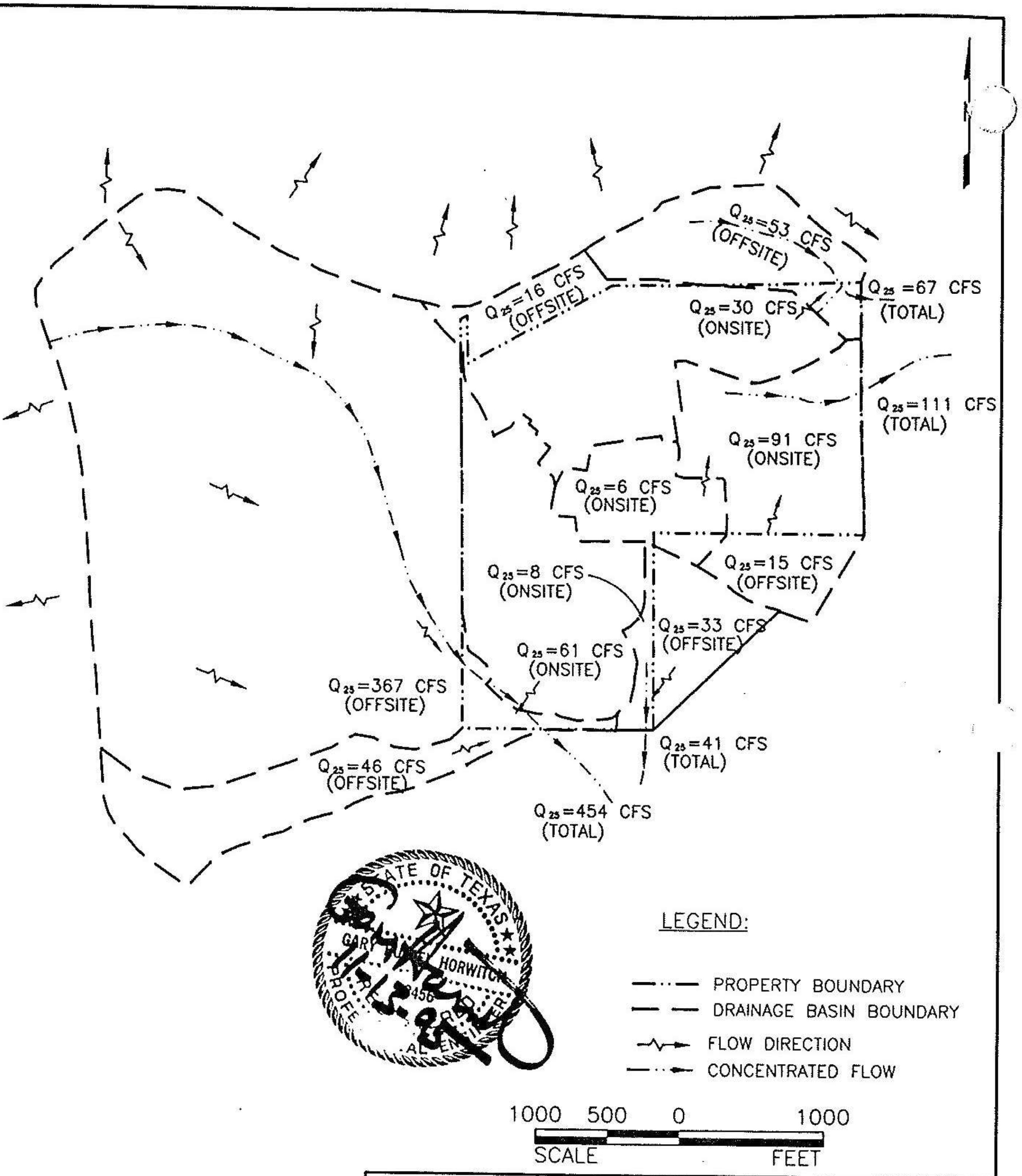
REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

HMA environmental
HMA Environmental
Services, Inc.
Houston, Texas

PLOTTED:Nov 06, 1995 - 08:26:49

402082DR



Part III
Attachment 6
Figure
3-4

POST DEVELOPMENT DRAINAGE PATTERNS

PROJECT NO: 022402-3
DRAWN BY: JMT 10/95
CHECKED BY: JPR 10/95
SUBMITTED BY

REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, IN

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Houston, Texas

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NOTE:

THE TIME OF PEAK FLOWS FROM DRAINAGE BASINS VARY DUE TO SEDIMENTATION POND ATTENUATION. SEE HEC-1 ANALYSES IN ATTACHMENT 6 TO PART III.

determined and routed through the sedimentation pond (see Section 3.5) for comparison at the predevelopment hydrograph locations. As indicated in Table 3-3, peak flows resulting from post development conditions at the Royal Oaks Landfill site are less than those for predevelopment conditions.

Detailed calculations, including HEC-1 computer results, are included in Appendix J.

3.7 PREDEVLOPMENT AND POST DEVELOPMENT DRAINAGE PATTERN COMPARISONS

As indicated in Section 1.4, surface water runoff from the southern portion of the site flows directly to Keys Creek, while surface water from the northern portion of the site flows into a tributary of Barber Branch. A comparison of predevelopment and post development drainage areas and CN's for the two watersheds is provided in Table 3-4. As indicated in Table 3-4, the drainage areas for the watersheds are not significantly altered by the landfill development. While the CN's for the drainage basins increase for post development conditions, the comparisons provided in Section 3.6 indicate the sedimentation basins will attenuate any increase in peak flows from the site. Therefore, the drainage patterns will not be significantly altered by the landfill development.

Table 3-3 Watershed Peak Flow Comparison

Watershed	**Predevelopment Flow (cfs)**	**Post Development Flow (cfs)**
Keys Creek		
Predevelopment Subbasin 1	485	454
Predevelopment Subbasin 2	63	41
Barber Branch		
Predevelopment Subbasin 3	170	111
Predevelopment Subbasin 4	92	67

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Table 3-4 Watershed Drainage Pattern Comparison

Watershed	Predevelopment	Post Development
Barber Branch		
Drainage Area (ac)	131	133
CN	65	73
Keys Creek		
Drainage Area (ac)	306	304
CN	65	67

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4.0 WATER SURFACE PROFILE COMPUTATIONS

Water surface profiles for the landfill ditch system for peak discharges resulting from the 25-year peak discharges (computed using the Rational Method as described in Section 3.2.1) were developed using the HEC-2 computer program developed by the Hydrologic Engineering Center of the USACE.

Hydraulic information, HEC-2 modeling data, and results (including ditch cross-section information, flow velocities, etc), and water surface profiles are included in Appendix G. Based on these evaluations, the landfill ditch system has sufficient capacity to convey the peak discharges from the 25-year storm event.

5.0 EROSION AND SEDIMENTATION CONTROL PLAN

As required by TAC §330.56(b)(E), the Royal Oaks Landfill has been designed to minimize soil erosion losses. Temporary grassing, silt fences, and other sedimentation control devices will be used to minimize soil erosion and sedimentation during construction and operation of the Royal Oaks Landfill. As areas of the landfill reach final grade, the MLFCS which includes permanent grassing will be installed. This erosion and sedimentation control plan, has been developed to include Best Management Practices (BMP's) identified in EPA reference documents (USEPA 1992a and USEPA 1992b).

5.1 SOIL LOSS MINIMIZATION

The long-term effects of erosion for the completed portions of the landfill have been evaluated using the Universal Soil Loss Equation (USLE) as indicated in the Final Closure Plan (see Attachment 12). Additionally, flow velocities have been estimated for the flow conveyance structures (see Table 5-1) to determine if erosion controls, other than grassing, are required (e.g., riprap, concrete lining, asphalt lining, geotextiles, etc.). For flow conveyance structures with velocities in excess of 5 feet per second (ft/sec) (Haan, 1994), calculations have been performed to determine the amount of riprap which would be required for erosion protection. Peak flow velocities in the various flow conveyance structures were computed as part of the conveyance structure sizing provided in Appendices C through E and the HEC-2 analyses included in Appendix G.

Calculations to determine riprap requirements (see Appendix H) are based on Federal Highway Administration methods (Haan, 1994). Riprap, or other erosion controls, is required for the storm water flumes, a substantial portion of the ditch system, and at culvert outlets as shown in Appendix H.

Table 5-1 Conveyance Structure Flow Velocities

Conveyance Structure	25-Year Storm Flow Velocity (ft)/sec
West Pond 1 Ditch	5.0 - 9.4
East Pond 1 Ditch	3.8 - 5.8
Pond 3 Ditch	4.7 - 14.6
North Leachate Storage Area Ditch	1.4
Sideslope Terraces	1.4
Runoff Control Berm	0.3
Interior Perimeter Ditch	0.4 - 5.6

Source: HMA 1995.

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5.2 STABILIZATION ACTIVITIES

Temporary and permanent stabilization will be used during the construction and operation of the Royal Oaks Landfill to minimize soil erosion and sedimentation. Temporary stabilization will be performed in disturbed portions of the site where construction or landfilling activities will not be performed within 21 days. These areas will be stabilized within 14 days from the last activity in the area. Temporary seeding will be performed using fast growing grasses, which will minimize the exposure of bare ground to rainfall.

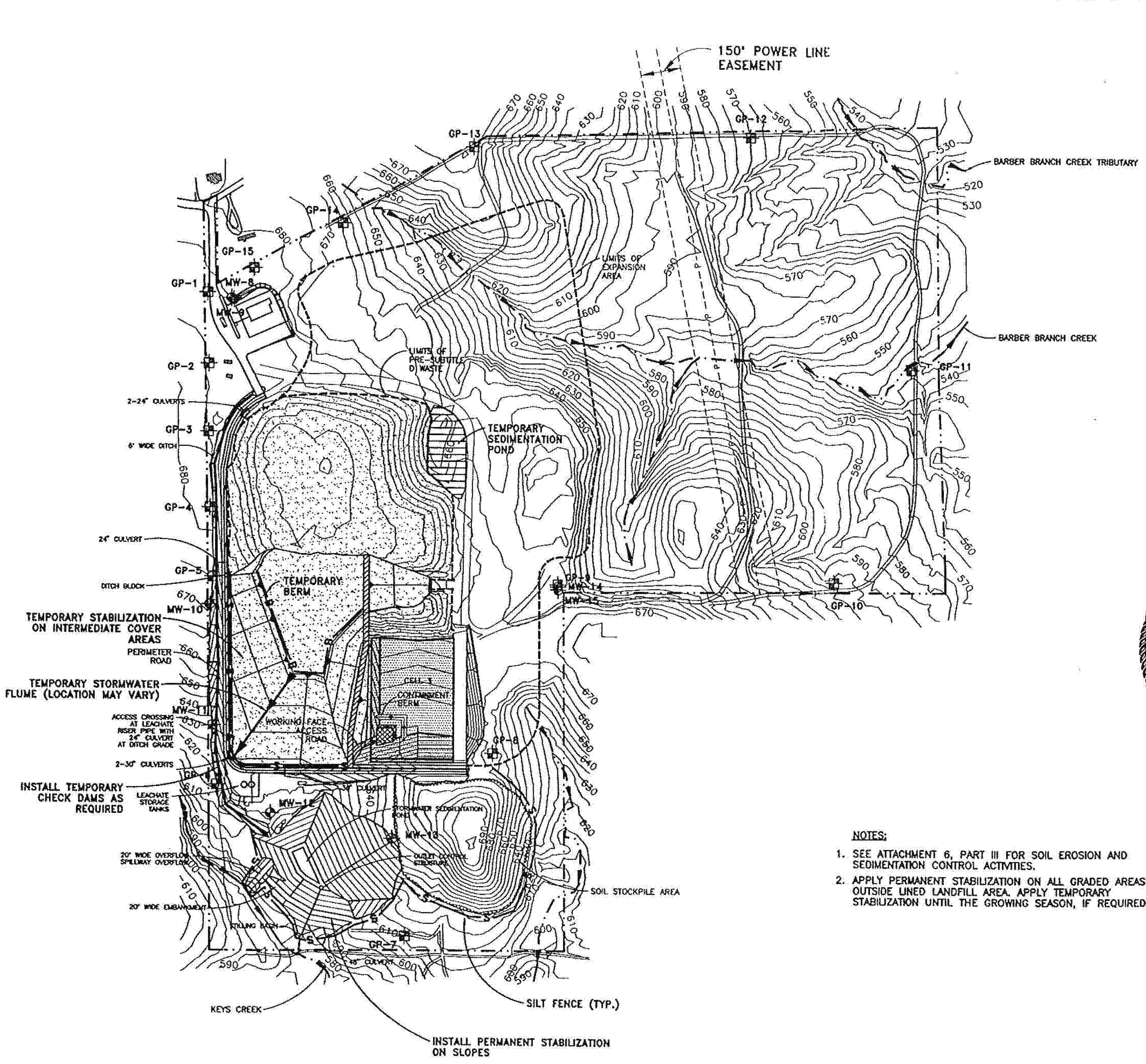
Permanent stabilization will be performed within 14 days after the last construction activity on portions of the site where the landfill has reached final grade or construction activities will permanently cease (e.g., sedimentation ponds, perimeter ditches, etc.). The permanent stabilization will consist of a mixture of grasses suited to permanent site conditions. Fertilizer and lime additions, if required, will be based on the analysis of the site soils. Special techniques including mulching, hydroseeding, installation of erosion control mats, or sodding may be used in areas with a higher potential for erosion (e.g., ditches, runoff control berms, landfill side slopes, etc.).

If construction activities end during a time of year outside the planting season for the permanent stabilization, temporary seeding will be performed to stabilize the area until the permanent stabilization is performed.

5.3 STRUCTURAL CONTROLS

Various structural controls will be installed to intercept and detain sediment from disturbed areas. These controls may include silt fences, straw bales, check dams, sediment traps, or interceptor swales an berms. Typical use of these types of structural controls is indicated on Figures 5-1, 5-2, and 5-3.

The primary method of sediment removal will be accomplished by the 3-sedimentation basins provided at the site. As indicated in Section 3.5, each sedimentation pond is provided with a permanent 4-ft deep sedimentation area, embankment, a low level outlet, a primary overflow structure, and an emergency spillway. These sedimentation ponds will be constructed as indicated in the sequence of operation drawings included as Sheets 1.17 through 1.21 in Attachment 1.



LEGEND

- GP-15 — EXISTING GAS PROBE
- MW-8 — EXISTING MONITOR WELL
- MW-16 — FUTURE MONITOR WELL
- ×650.5 — SPOT ELEVATION
- —— 570 —— — CONTOUR ELEVATION (FT-MSL)
- 〰〰〰 — VEGETATION LINE
- ——×—— — BARBED WIRE FENCE
- —·—·— — SITE BOUNDARY
- - - - - - — LIMITS OF CELL AREA
- ▨ — DAILY COVER
- ▨ — INTERMEDIATE COVER
- ▨ — MULTI LAYER FINAL COVER SYSTEM
- ▨ — LINED LANDFILL AREA
- ▩ — WORKING FACE
- ▨ — WORKING FACE ACCESS ROAD
- ←·· — — DRAINAGE PATH
- ▶— — FILL SLOPE
- ▷— — CUT SLOPE
- —B— — TEMPORARY BERM
- —S— — SILT FENCE

200 100 0 200
SCALE FEET

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NOTES:

1. SEE ATTACHMENT 6, PART III FOR SOIL EROSION AND SEDIMENTATION CONTROL ACTIVITIES.
2. APPLY PERMANENT STABILIZATION ON ALL GRADED AREAS OUTSIDE LINED LANDFILL AREA. APPLY TEMPORARY STABILIZATION UNTIL THE GROWING SEASON, IF REQUIRED.

PLANS FOR PERMIT PURPOSES ONLY

Part III
Attachment 6
Figure
5-1

TYPICAL SOIL EROSION
AND CONTROL
INITIAL ACTIVITIES

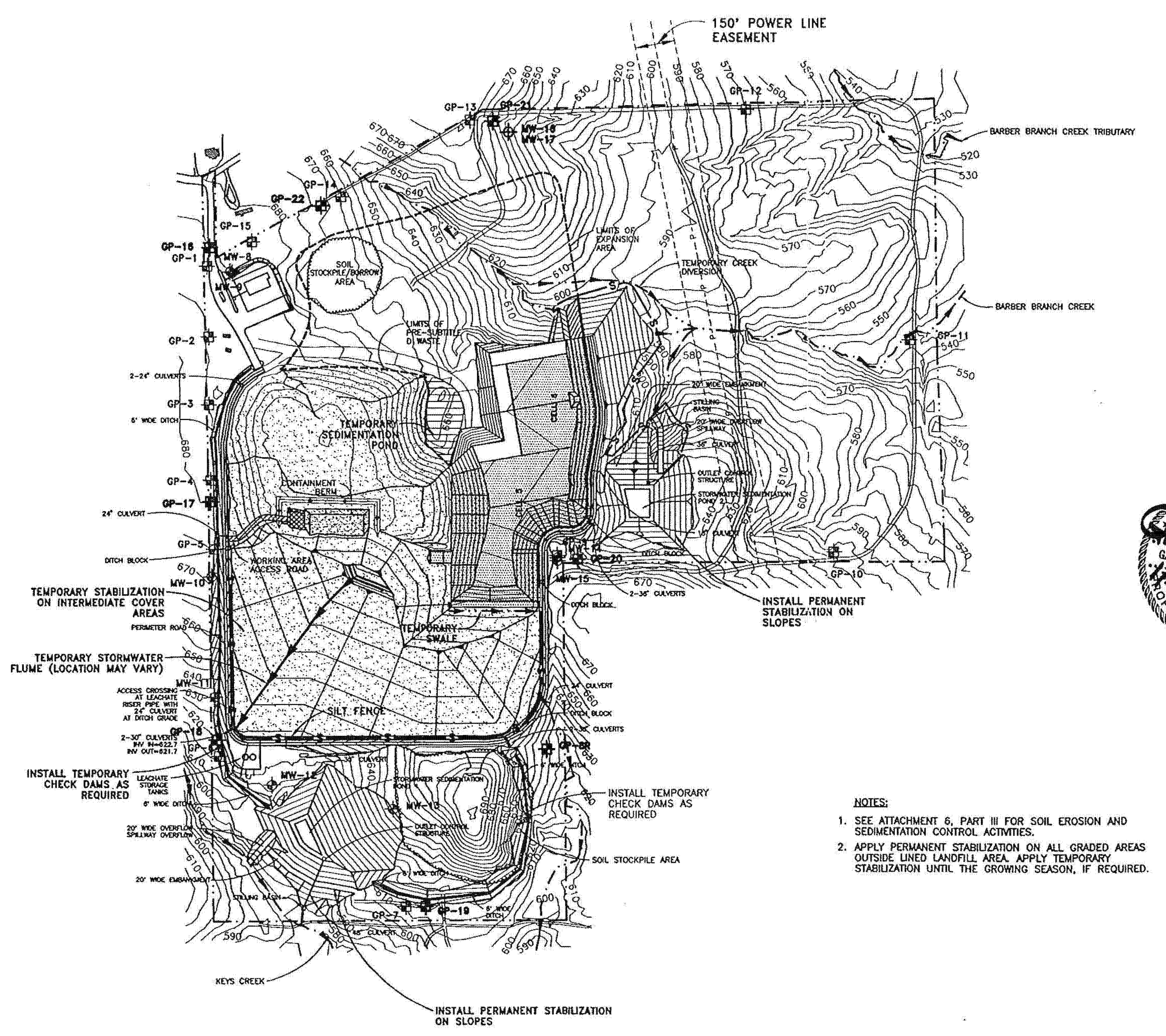
PROJECT NO: 022402-3
DRAWN BY: JHT 11/95
CHECKED BY: PRM 11/95
SUBMITTED BY:

REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

HMA environmental
HMA Environmental
Services, Inc.
Houston, Texas

402R0009



LEGEND

GP-15	EXISTING GAS PROBE
MW-8	EXISTING MONITOR WELL
MW-16	FUTURE MONITOR WELL
× 650.5	SPOT ELEVATION
—— 570 ——	CONTOUR ELEVATION (FT-MSL)
﹏﹏﹏	VEGETATION LINE
——×——	BARBED WIRE FENCE
—··—··—	SITE BOUNDARY
- - - - - -	LIMITS OF CELL AREA
▨	DAILY COVER
▨	INTERMEDIATE COVER
+ + +	MULTI LAYER FINAL COVER SYSTEM
▨	LINED LANDFILL AREA
▨	WORKING FACE
▨	WORKING FACE ACCESS ROAD
←·—·—	DRAINAGE PATH
▶—	FILL SLOPE
▷—	CUT SLOPE
—B—	TEMPORARY BERM
—S—	SILT FENCE

200 100 0 200
SCALE FEET

NOTES:

1. SEE ATTACHMENT 6, PART III FOR SOIL EROSION AND SEDIMENTATION CONTROL ACTIVITIES.
2. APPLY PERMANENT STABILIZATION ON ALL GRADED AREAS OUTSIDE LINED LANDFILL AREA. APPLY TEMPORARY STABILIZATION UNTIL THE GROWING SEASON, IF REQUIRED.

PLANS FOR PERMIT PURPOSES ONLY

Part III
Attachment 6
Figure
5-2

TYPICAL SOIL EROSION
AND CONTROL
INTERMEDIATE ACTIVITIES

PROJECT NO.: 022402-3
DRAWN BY: JMT 11/95
CHECKED BY: PRM 11/95
SUBMITTED BY:

REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

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HMA Environmental
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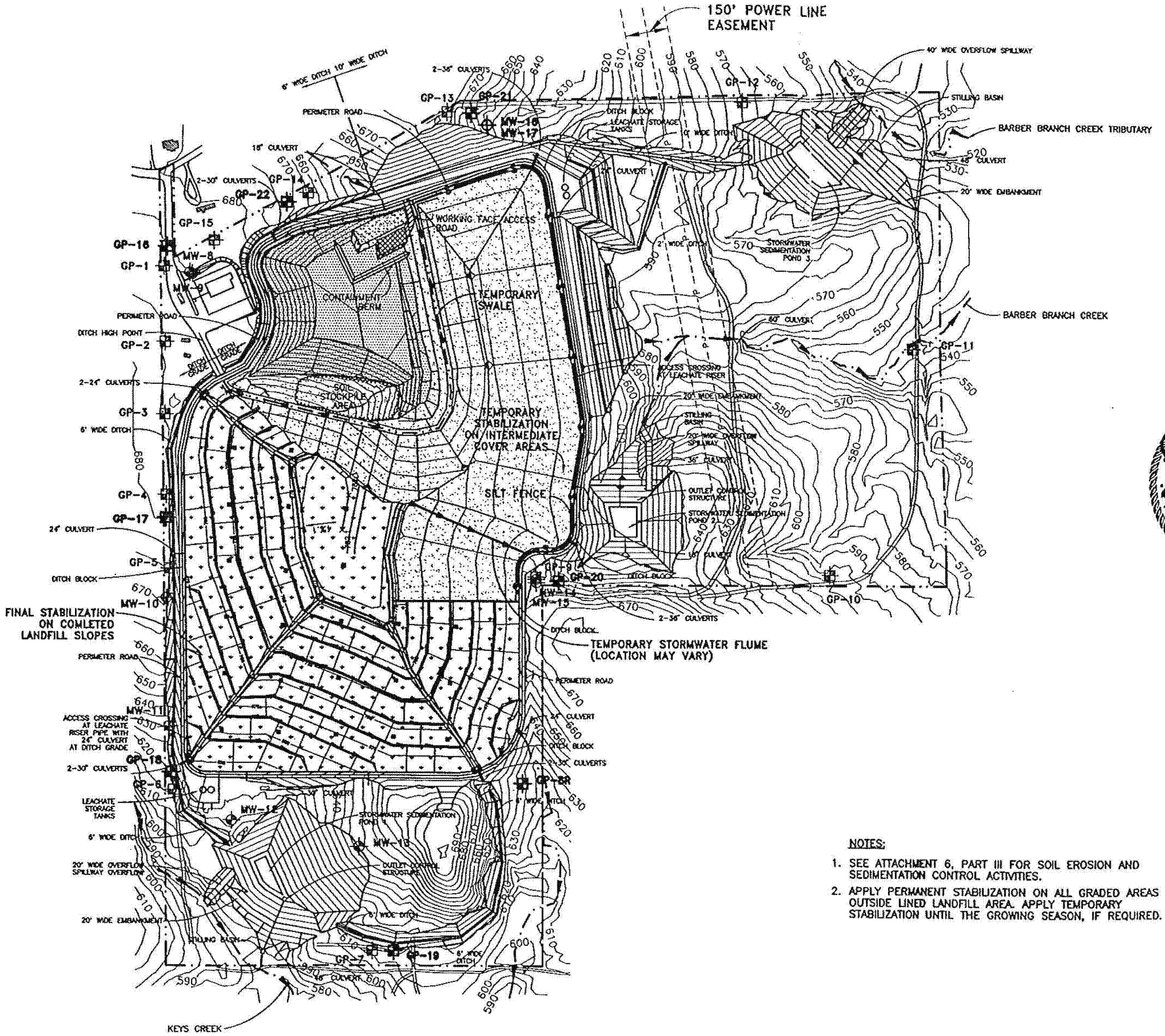
Houston, Texas

PLOTTED: Nov 5, 1995 - 14:33:48

402R0010



N

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11-13-95

LEGEND

GP-21	PROPOSED GAS PROBE
GP-15	EXISTING GAS PROBE
MW-8	EXISTING MONITOR WELL
MW-16	FUTURE MONITOR WELL
× 650.5	SPOT ELEVATION
—— 570 ——	CONTOUR ELEVATION (FT-MSL)
〰〰〰	VEGETATION LINE
——×——	BARBED WIRE FENCE
— · · — · · —	SITE BOUNDARY
– – – – – –	LIMITS OF CELL AREA
▨	DAILY COVER
▨	INTERMEDIATE COVER
▨	MULTI LAYER FINAL COVER SYSTEM
▨	LINED LANDFILL AREA
▩	WORKING FACE
▧	WORKING FACE ACCESS ROAD
← · · —	DRAINAGE PATH
▶—	FILL SLOPE
▷—	CUT SLOPE
—— B ——	TEMPORARY BERM
—— S ——	SILT FENCE

200 100 0 200
SCALE FEET

NOTES:

1. SEE ATTACHMENT 6, PART III FOR SOIL EROSION AND SEDIMENTATION CONTROL ACTIVITIES.
2. APPLY PERMANENT STABILIZATION ON ALL GRADED AREAS OUTSIDE LINED LANDFILL AREA. APPLY TEMPORARY STABILIZATION UNTIL THE GROWING SEASON, IF REQUIRED.

FLANS FOR PERMIT PURPOSES ONLY

Part III
Attachment 6
Figure
5-3

TYPICAL SOIL EROSION
AND CONTROL
FINAL ACTIVITIES

PROJECT NO.: C22402-3
DRAWN BY: JMT 11/95
CHECKED BY: FRM 11/95
SUBMITTED BY:

REV NO.	DESCRIPTION	BY	DATE

ROYAL OAKS LANDFILL
LAIDLAW WASTE SYSTEMS, INC.

HMA environmental
HMA Environmental
Services, Inc.
Houston, Texas

PLOTTED: Nov 13, 1995 - 14:31:10

6.0 STORM WATER INSPECTION AND MAINTENANCE PLAN

6.1 GENERAL

During site construction activities and site operations, inspection and maintenance will be conducted to ensure the storm water management system components and erosion and sedimentation control features are performing in accordance with design requirements. Written records of these inspection and maintenance activities will be maintained as part of the site operating record. Training for personnel performing the inspections will be provided as part of the overall training program for site personnel. During the post-closure care period for the Royal Oaks Landfill, inspections will be performed as indicated in Section 7.2 of the Closure and Post-Closure Care Plan (see Attachment 13). This Storm Water Inspection Plan has been prepared to include pollution prevention requirements identified in EPA reference documents (USEPA 1992a and USEPA 1992b).

6.2 SITE INSPECTION FREQUENCY AND RECORDKEEPING

Site inspections will be performed by the Landfill General Manager or other qualified personnel. Inspection of conditions which could affect the performance of the storm water management system or erosion and sedimentation control measures will be identified on an inspection report form, similar to that provided in Figure 6-1. The inspection form includes the inspectors name, a checklist of various inspection items, a space to indicate whether action is required, a space for comments regarding the severity of a inspection item, its specific location, or other details necessary of performance of appropriate maintenance activities.

Site inspections will be performed once every 7 days or within 24 hours of a rainfall event of 0.50 inches or more.

Figure 6-1 Storm Water Inspection Form

Facility: Royal Oaks Landfill

Type of Inspection: ____________________

Weather Conditions:
Rain ________ Temperature ________
Snow ________ Wind ________
Clear ________
Cloudy ________

Inspection Date: ____________ Arrival Time: ________ (AM/PM) Departure Time: ________ (AM/PM)

Inspector(s)/Affiliation: ____________________
____
____

Inspection Items	Inspected	N/A	Presence/ Absence of Inspected Item	Action Required	No Action Required	Comments
	(Check One)			(Check One)		
A. EROSION						
- Intermediate Cover Areas						
- Final Cover Areas						
- Perimeter Ditches						
- Storm Water Flumes						
- Side Slope Terraces						
- Sedimentation Pond Embankments						
- Berms						
- Other Drainage Features						
B. SETTLEMENT						
- Intermediate Cover Areas						
- Final Cover Areas						
- Perimeter Ditches						
- Storm Water Flumes						
- Side Slope Terraces						
- Other Drainage Features						

Figure

Storm Water Inspection Form

Facility: Royal Oaks Landfill

Inspection Items	Inspected	N/A	Presence/ Absence of Inspected Item	Action Required	No Action Required	Comments
	(Check One)			(Check One)		
C. SILT AND SEDIMENT BUILDUP						
- Perimeter Ditches						
- Storm Water Flumes						
- Side Slope Terraces						
- Sedimentation Ponds						
D. OBSTRUCTIONS						
- Drainage Features						
E. PRESENCE OF EROSION AND SEDIMENT DISCHARGE						
- Offsite Discharge Locations						
- Site Boundary in Disturbed Areas						
F. OTHER						

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6.3 SITE INSPECTION ACTIVITIES

The following items will be evaluated during the inspections:

1. Erosion of intermediate cover areas, final cover areas, perimeter ditches, storm water flumes, side slope terraces, sedimentation pond embankments, berms, or other drainage features;
2. Settlement of intermediate cover areas, final cover areas, perimeter ditches, storm water flumes, side slope terraces, or other drainage features;
3. Silt and sediment buildup in perimeter ditches, storm water flumes, side slope terraces, and sedimentation ponds;
4. Obstructions in drainage features;
5. Presence of erosion or sediment discharge at offsite storm water discharge locations; and
6. Presence of sediment discharges along the site boundary in areas which have been disturbed by site activities.

6.4 SITE MAINTENANCE ACTIVITIES

Maintenance activities will be performed to correct damaged or deficient items noted during the site inspections. These activities will be performed as soon as possible after the inspection. The time frame for correction of damaged or deficient items will vary based on weather, ground conditions, and other site specific conditions.

Maintenance activities may consist of the following activities:

1. Placement of additional temporary or permanent stabilization grassing;
2. Placement, grading, and stabilization of additional soils in eroded areas or in areas which have settled;
3. Replacement of riprap or other structural lining;

4. Placement of additional riprap in eroded areas or in areas which have settled;
5. Removal of obstructions from drainage features;
6. Removal of silt and sediment buildup from drainage features;
7. Repairs to erosion and sedimentation controls; and
8. Installation of additional erosion and sedimentation controls.

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SUBJECT Royal Oaks Landfill
Sed Pond Outlet Sizing
DESIGNER RRM
CHECKER JCR

AEP NO. 022YC2
SHEET 12 OF
DATE 4/29/95
DATE 5/2/95

SEDIMENTATION POND 1

OUTFLOW -

LOW FLOW FROM 8-INCH DIAMETER ORIFICE @ 580.0

PRIMARY FLOW FROM OVERFLOW WIER AT 594.0 FT-MSL

ELEVATION	STORAGE AC-FT	8" ϕ ORIFICE @ 580	OVERFLOW @594.0	TOTAL FLOW
580	0	0	0	0
582	.65	1.8	0	1.8
584	1.52	2.7	0	2.7
586	2.65	3.4	0	3.4
588	4.05	3.9	0	3.9
590	5.77	4.4	0	4.4
592	7.81	4.9	0	4.9
594	10.20	5.3	0	5.3
595	11.59	5.4	36	41.4
596*	12.97	5.6	101.8	107.4
597	14.59	5.8	187.1	192.9

* EMERGENCY SPILLWAY ELEVATION

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environmental

SUBJECT Royal Oaks Landfill AEP NO. 622402
Sed Pond Outlet Sizing SHEET 13 OF
DESIGNER 1DM DATE 4/29/95
CHECKER JPR DATE 5/3/95

SEDIMENTATION POND 2

OUTFLOW

LOW FLOW FROM 10 inch DIAMETER ORIFICE @ 610
PRIMARY FLOW FROM OVERFLOW WEIR @ 619.0

ELEVATION (FT-MSL)	STORAGE (AC-FT)	10" ϕ ORIFICE FLOW @ 610 (cfs)	OVERFLOW @ 619 (cfs)	TOTAL FLOW (cfs)
610	0	0	0	0
612	.85	2.7	0	2.7
614	1.91	4.2	0	4.2
616	3.21	5.2	0	5.2
618	4.78	6.1	0	6.1
619	5.71	6.5	0	6.5
620	6.63	6.9	36	42.9
621*	7.12	7.3	101.8	109.1

*. EMERGENCY SPILLWAY EL @ 621

HMA
environmental

SUBJECT ROYAL OAKS LANDFILL
SED POND OUTLET SIZING
DESIGNER RRM
CHECKER JPR

AEP NO 022402
SHEET 14 OF
DATE 4/29/95
DATE 5/2/95

GARY RUSSELL HORWITZ

SEDIMENTATION POND 3

OUTFLOW

LOW FLOW FROM 12-INCH DIAMETER ORIFICE @ 530 FT-MSL

PRIMARY FLOW FROM OVERFLOW WEIR @ 544 FT-MSL

ELEVATION (FT-MSL)	STORAGE (AC-FT)	12" ϕ ORIFICE FLOW @ 530 (cfs)	OVERFLOW @ 544 (cfs)	TOTAL FLOW (cfs)
530	0	0	0	0
532	1.16	3.8	0	3.8
534	2.57	5.9	0	5.9
536	4.28	7.5	0	7.5
538	6.29	8.7	0	8.7
540	8.64	9.9	0	9.9
542	11.36	10.9	0	10.9
544	14.47	11.8	0	11.8
545	16.25	12.2	36	48.2
546*	18.02	12.6	101.8	114.4

APPENDIX IIIF-F

EROSION CONTROL PLAN FOR ALL PHASES OF LANDFILL OPERATION

Includes pages IIIF-F-1 through IIIF-F-15

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED PROFESSIONAL ENGINEER

05/20/2024

CONTENTS

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EROSION CONTROL PLAN FOR ALL PHASES OF LANDFILL OPERATION

1.0 Introduction

The purpose of this appendix is to provide an Erosion Control Plan (ECP) to meet the requirements of Title 30 Texas Administrative Code (TAC) Chapter §330.305(d), which are listed below.

> *"The landfill design must provide effective erosional stability to top dome surfaces and external embankment side slopes during all phases of landfill operation, closure, and post-closure care in accordance with the following.*
>
> *(1) Estimated peak velocities for top surfaces and external embankment slopes should be less than the permissible non-erodible velocities under similar conditions.*
>
> *(2) The top surfaces and external embankment slopes of municipal solid waste landfill units must be designed to minimize erosion and soil loss through the use of appropriate side slopes, vegetation, and other structural and nonstructural controls, as necessary. Soil erosion loss (tons/acre) for the top surfaces and external embankment slopes may be calculated using the Soil Conservation Service of the United States Department of Agriculture's Universal Soil Loss Equation, in which case the potential soil loss should not exceed the permissible soil loss for comparable soil-slope lengths and soil-cover conditions."*

This ECP has also been developed to meet the requirements of the Texas Commission on Environmental Quality (TCEQ) guidance document titled, "Guidance for Addressing Erosional Stability During All Phases of Landfill Operation." As noted in the above guidance document, landfill cover phases are defined as daily cover, intermediate cover, and final cover. Top dome surfaces and external embankment side slopes are:

- Those above grade slopes that directly drain to the site perimeter stormwater management system (i.e., areas where the stormwater directly flows to a perimeter channel or detention pond designed in accordance with Title 30 TAC §330.63(c), §330.303, and §330.305);
- Above grade slopes that have received intermediate or final cover; and

- Above grade slopes that have either reached their permitted elevation, or will subsequently remain inactive for longer than 180 days. For example, after an above grade slope has reached the permitted elevation and intermediate cover has been placed, the structural erosion control features (e.g., drainage swales, letdown structures, and/or sedimentation ponds) will be in-place 180 days after intermediate cover has been placed.

Slopes which drain to ongoing waste placement areas, pre-excavated areas, areas that have received only daily cover, and areas under construction which have not received waste are not considered external side slopes.

The ECP for daily cover areas and top dome surfaces and external side slopes that drain directly to the site perimeter stormwater management system, have received intermediate cover, and either reached their permitted configuration or will remain inactive for longer than 180 days are addressed in the following sections. Erosion control measures for final cover areas are addressed in the currently TCEQ-approved Site Development Plan (SDP).

Inspection, maintenance, and recordkeeping requirements are included in the Site Operating Plan (SOP) and discussed in Section 2.4. The word “temporary” is used throughout the ECP to describe any erosion control feature that is not a permanent erosion control feature that is included in the approved Site Development Plan. Additionally, “temporary” is defined as the time between construction of intermediate cover and the construction of final cover. Temporary erosion controls are those controls which are installed or constructed within 180 days from when the intermediate cover is constructed and in place until permanent controls are constructed for the final cover.

2.0 Erosion Control Plan for Top Dome Surfaces and External Side Slopes with Intermediate Cover

Erosion control for above grade top dome surfaces and external embankment side slopes that drain directly to the site perimeter stormwater management system, have received intermediate cover, and either reached their permitted configuration or will remain inactive for longer than 180 days will be managed using a system of nonstructural and structural erosion and sediment controls to meet rule requirements for the intermediate cover phase of landfill construction.

The structural controls will consist of a combination of vegetation, temporary add-on swales, and letdown structures. These structural controls will be configured in a manner that will result in a net soil loss of 50 tons/acre/year or less from the external slope area. As shown on Sheet IIIF-F-10, stormwater runoff will be collected in swales and conveyed to drainage letdown structures down the 25 percent slopes to the perimeter drainage system. The primary goal will be to establish the vegetative cover percentage and swale spacing distance indicated in the swale design summary table on Sheet IIIF-F-11 on all external top dome surfaces and external embankment slopes. These criteria will result in a net soil loss of 50 tons/acres/year or less for each drainage swale and letdown combination specified on Sheets IIIF-F-10 and IIIF-F-11 (refer to Section 2.1 for additional information).

Mulch, woodchips, compost or straw/hay will be used as a layer placed over the intermediate cover to protect the exposed soil surface from erosive forces and conserve soil moisture until vegetation can be established. The mulch, woodchips, compost or straw/hay will be used to stabilize recently graded or seeded areas. If needed, the mulch, woodchips, compost or straw/hay will be spread evenly over a recently seeded area and tracked into the surface to protect the soil from erosion and moisture loss, and provide additional erosional stability to the intermediate cover surface during the establishment of vegetation. These materials are not required for the establishment of vegetation on the intermediate cover unless they are needed to provide additional erosional stability to the intermediate cover surface. These materials will vary in thickness but the mulch, woodchips, compost or straw/hay will be placed so as not to inhibit the growth of vegetation. In the event that the indicated vegetative ground cover required for a specific swale spacing distance is not obtained within 180 days after intermediate cover is placed on a top dome or external side slope, mulch, woodchips, compost or straw/hay will be used as a secondary measure to limit soil loss to 50 tons/acre/year or less until vegetation is established. Stormwater discharge from the site must comply with the current TPDES for the site. The discharge locations for the site are identified in Appendix IIIF as a part of the final drainage design and cannot be revised based on this ECP. Design and use of temporary erosion control measures can not result in offsite discharge exceeding the peak flow rates, volumes, or velocities listed in Table 4-1 of Appendix IIIF.

As an alternative to mulch, wood chips, compost, or straw/hay, a detention/ sedimentation pond may be used as a secondary measure to limit the discharge of eroded soil loss to 50 tons/acre/year or less (refer to Section 2.2 for additional information) if the required percent vegetation goal is not obtained within 180 days after intermediate cover is placed on the top dome or external side slopes. In this case, the detention/sedimentation pond will remain in place until the specified percent vegetation goal is met (e.g., 60 percent vegetation on the external embankment slopes and top dome surfaces).

2.1 Drainage Swale and Letdown Structure Requirements

Sheet IIIF-F-10 shows a typical layout for erosion control structures, including temporary add-on swales and drainage letdowns. Sheet IIIF-F-11 provides a swale design summary, which includes spacing and vegetative cover requirements for the swales. Supporting calculations for the specifications listed on Sheet IIIF-F-11 are provided in Appendix IIIF-F-1 – Temporary Add-on Swale Design. Appendix IIIF-F-1 also includes a demonstration to show that sheet flow velocities for the grass established surfaces for all swale spacings are less than 5 ft/sec and sheet flow velocity for "nearly bare ground" is less than 3.5 ft/sec (consistent with Title 30 TAC §330.305(d)(1)).

Letdown structures will be located and constructed in a manner that minimizes erosion loss. The letdowns are designed to convey runoff from the 25-year frequency storm event (refer to Appendix IIIF-F-2 – Temporary Letdown Design for more information). Sheet IIIF-F-12 shows letdown details and the letdown design summary. As shown on Sheet IIIF-F-12, the letdowns will consist of either a lined open channel structure or a pipe letdown. The type, size, and number of letdowns will be determined based on the size of the drainage area using the design information specified on Sheet IIIF-F-12. As noted on Sheet IIIF-F-12, the use of pipe letdowns will be limited to 1 inlet per letdown.

As noted on Sheet IIIF-F-10, the acceptable soil loss is determined for each acre on the top dome surfaces and external embankment side slopes. The soil loss for top dome surfaces and external embankment side slopes will vary depending on swale spacing and percent vegetative cover (refer to Sheet IIIF-F-11 for soil loss estimates). If certain percent vegetation cover is not achieved, a sediment control pond will be temporarily used for sediment capture to reduce the discharge of eroded soil from the external slopes to a rate that is equal to or less than 50 tons/acre/year. Sediment will be removed when necessary. The swale spacing as shown on Sheet IIIF-F-11 for top dome and side slope surfaces is based on the limiting soil loss of 50 tons/acres/year. If a vegetative coverage and swale spacing configuration results in a soil loss greater than 50 tons/acre/year, the following procedure will be used to verify that an acceptable intermediate cover thickness is maintained.

- Intermediate cover areas will be inspected to detect erosion gullies and vegetation loss.
- After identifying the areas requiring additional soil, these areas will be replenished with additional soil and graded to provide uniform surfaces prior to reseeding.
- Any damaged concentrated flow drainage structures such as swales will be repaired to eliminate uncontrolled concentrated flow.

Temporary open channel letdowns will be inspected for erosion/hollowing through and under the lining materials (e.g., gabions, grouted riprap, and turf reinforcement) and repaired as necessary to ensure the letdown is functioning as designed. Numerous erosion control structures have been installed at the site that conform to the requirements of this ECP, and these structures will remain in place and continue to serve as erosion control measures until they are decommissioned.

As stated previously, the primary goal is to obtain the required vegetation coverage percentage for each condition (e.g., swale spacing).

2.2 Sedimentation Pond Design

As noted on Sheets IIIF-F-10 and IIIF-F-11, if vegetative cover for any surface is maintained at or above the percentages given for swale spacing distances, the estimated soil loss is less than 50 tons/acre/year. In the event that certain percent ground cover that limits the soil loss to 50 tons/acre/year is not achieved and soil loss is temporarily greater than 50 tons/acre/year, a sedimentation pond will be used along with other structural and non-structural BMPs approved as part of this plan to limit the discharge of eroded soil. Sheet IIIF-F-13 provides a procedure for determining the required pond size. Supporting calculations for the procedure listed on Sheet IIIF-F-13 are included in Appendix IIIF-F-3 – Sediment Control Pond Design. If a sediment control pond is used to limit the off-site discharge of eroded soil to 50 tons/acre/year or less from the external slope area, a demonstration noting how the pond was sized will be documented and maintained in the Site Operating Record. This document will also include a statement that notes how the temporary sedimentation pond, the pond outlet, and any related perimeter channels were constructed consistent with the requirements of the Site Development Plan. Sheet IIIF-F-14 shows the different options for typical pond outlet structures.

The sedimentation pond option is a secondary erosion control option, similar to mulch, wood chips, compost, or straw/hay, and will only be used if the required percent vegetation specification is not met. If the sedimentation pond option is implemented, the swales and letdowns specified will remain in-place. The sedimentation pond option simply allows for the control of sediment while vegetation is being established.

For example, if intermediate cover is placed over a 20-acre external side slope area that is at the permitted elevation on December 31, then the operator will install swales and letdowns on the 20-acre slope consistent with the design and specifications listed in Section 2.1. The operator then has 180 days (which for this example would be June 29) to obtain the required vegetation coverage on the 20-acre area. If in early June it becomes apparent that the percent vegetation will be less than the required coverage on June 29, then the operator may install a sedimentation pond downstream of the 20-acre area, consistent with the requirements shown on Sheet IIIF-F-13. Consistent with Section II.D of the TCEQ guidance document titled, "Guidance for Addressing Erosional Stability During All Phases of Landfill Operation," the sedimentation pond will remain in-place so that the net annual soil loss from the 20-acre area that could leave the facility boundary is less than 50 tons/acre/year until the required percent vegetation specification is met.

If a sedimentation pond is used as a source to maintain a soil loss equal to or less than 50 tons/acre/year, the following procedure will be used to verify that an acceptable intermediate cover thickness is maintained.

- Intermediate cover areas will be inspected to detect erosion gullies and vegetation loss.
- After identifying the areas requiring additional soil, these areas will be replenished with additional soil and graded to provide uniform surfaces prior to reseeding.
- Any damaged concentrated flow drainage structures such as swales will be repaired to eliminate uncontrolled concentrated flow.

As stated previously, the primary goal is to obtain the specified vegetation coverage percentage on top dome surfaces and external embankments. The sedimentation pond will only be used until the specified vegetation coverage percentage is obtained. The sedimentation pond may only be used for a period of 12 months after the 180-day period has expired (e.g., 12 months after the June 29th date used in the above example). Once the required vegetation percentage is achieved, then the sedimentation pond will no longer be needed (but may remain in-place as an additional BMP until the site reaches the permitted final configuration). If the percent vegetation does not meet the required specification within the 12-month period, then additional erosion control measures will be implemented. These measures will include: (1) adjusting the swale spacing, (2) applying mulch, wood chips, compost, or straw/hay, or similar TCEQ approved materials, or (3) the submittal of a permit modification to revise this erosion control plan to provide additional erosion protection measures that will allow the site to meet the goals of this plan.

2.3 Other Erosion Control BMPs

Other best management practices (BMPs) used in conjunction with the above erosion control measures are listed below.

- Check Dams – These structures will be used in channels to slow down flow velocities and improve sediment capture.
- Silt Fences – These structures will be used in capturing sediment transported by sheet flow and for diversion of flow for controlling sediment discharge.
- Compost Filter Berms – These structures may be used in capturing sediment transported by sheet flow and for diversion of flow for controlling sediment discharge.
- Erosion Booms – These structures may be used in capturing sediment and for diversion of flow for controlling sediment discharge.

These erosion control measures will be used on slopes to help control erosion loss. Rock check dams will be used in the detention/sedimentation pond. Refer to Sheet IIIF-F-15 for details of typical BMPs.

Nonstructural controls that will be used at the site to minimize erosion loss include: plans and designs to minimize disruption of the natural features, drainage, topography, and vegetative cover features; phased development to minimize the area of bare soil exposed at any given time; plans to disturb only the smallest area necessary to perform current activities; scheduling of construction activities during the time of year with the least erosion potential; and specific plans for the stabilization of exposed surfaces in a timely manner.

2.4 Schedule and Recordkeeping Requirements

After an external side slope or top dome surface reaches the final permitted grade or will remain inactive for longer than 180 days, the structural erosion control features and letdown structures will be in place within 180 days from when intermediate cover is placed. During this 180 day period, the structural erosion control structures will be constructed and vegetation established. Structural erosion control measures consist of drainage swales, letdown structures, and detention ponds.

At the end of this 180-day period, the cover log will be updated to document the external side slope and top dome surface area, the structural controls that were installed, and a demonstration showing how the structural controls meet the 50 tons/acre/year or less soil loss requirement (e.g., percent vegetation coverage, swale spacing, and letdowns installed). Inspection requirements and schedules are listed in the SOP for all drainage features, including intermediate cover areas. If the required percent vegetation coverage is not achieved within the 180-day period, secondary erosion control measures such as mulch, wood chips or compost will be used to limit the soil loss to the 50 tons/acre/year or less. Other erosion protection measures will only be utilized upon prior written authorization (e.g., permit modification) by TCEQ. In addition, a detention/sedimentation pond may also be used until the required vegetation coverage is achieved. Any secondary measure used will be documented in the Site Operating Record at the end of the 180-day period to document compliance with this plan. In addition, the date the required vegetation cover is achieved and the date that the secondary measure is no longer needed will also be documented in the Site Operating Record. The dates and locations of installation of erosion and sediment control will also be documented in the Site Operating Record. Inspection requirements and schedules are listed in the SOP for all drainage features, including intermediate cover areas. Inspection and maintenance of the erosion and sediment control structures of the top dome surfaces and external embankment side slopes will follow the same schedule and methods as described in Section 4.24 of the facility's SOP.

For example, as stated in Section 4.18.3 of the current Site Operating Plan (SOP), intermediate cover areas are inspected weekly and within 72 hours of a rainfall event of 0.5 inches or more, or as soon as the areas are accessible, for proper placement, thickness, erosion, and compaction. Additionally, Section 4.23 of the SOP also requires inspections of perimeter channels and ponds to ensure they are functioning as designed (e.g., excess sediment removed, outlet structures intact, and erosion control measures intact, etc.) on a weekly basis and after a rainfall event of 0.5 inches or more, or as soon as the areas are accessible.

During the inspection of structural controls (e.g., vegetation over intermediate cover areas), if significant soil loss is identified in a given intermediate cover area, impacted areas will be replenished with additional soil. Prior to application of temporary erosion controls and seeding, the area will be graded to eliminate preferential path ways or any other uneven surface due to settlement to prevent concentrated flow over the intermediate cover areas. Soil for replenishment of cover areas will be borrowed from sedimentation ponds or any other soil source. If sediment collected from wet retention pond(s) (e.g., Pond NP or temporary sedimentation ponds) is used for erosion layer replenishment, it will be stockpiled outside the ponds to dry out prior to being used for intermediate cover layer replenishment. Soil borrowed from other soil sources may be used as intermediate cover layer and erosion layer replenishment soil.

2.5 Construction Activities on Top Dome Surfaces and External Side Slopes with Intermediate Cover

Occasionally, top dome surfaces and external side slopes that have been stabilized through the use of swales, letdown structures, and compliance with the minimum required vegetation cover specification will be disturbed due to various construction activities such as the installation or repair of a landfill gas system, regrading of an area due to ponded water caused by uneven waste settlement, the repair of erosion rills, or damage due to an extreme storm event or natural disaster. Each of these events will be documented in the Site Operating Record. Recorded information will include the date of construction, approximate area disturbed, and the date re-seeding of the disturbed area occurred. In accordance with Title 30 TAC §330.165(g), previously stabilized surfaces will be repaired within 5 days of detection of the disturbance of these surfaces.

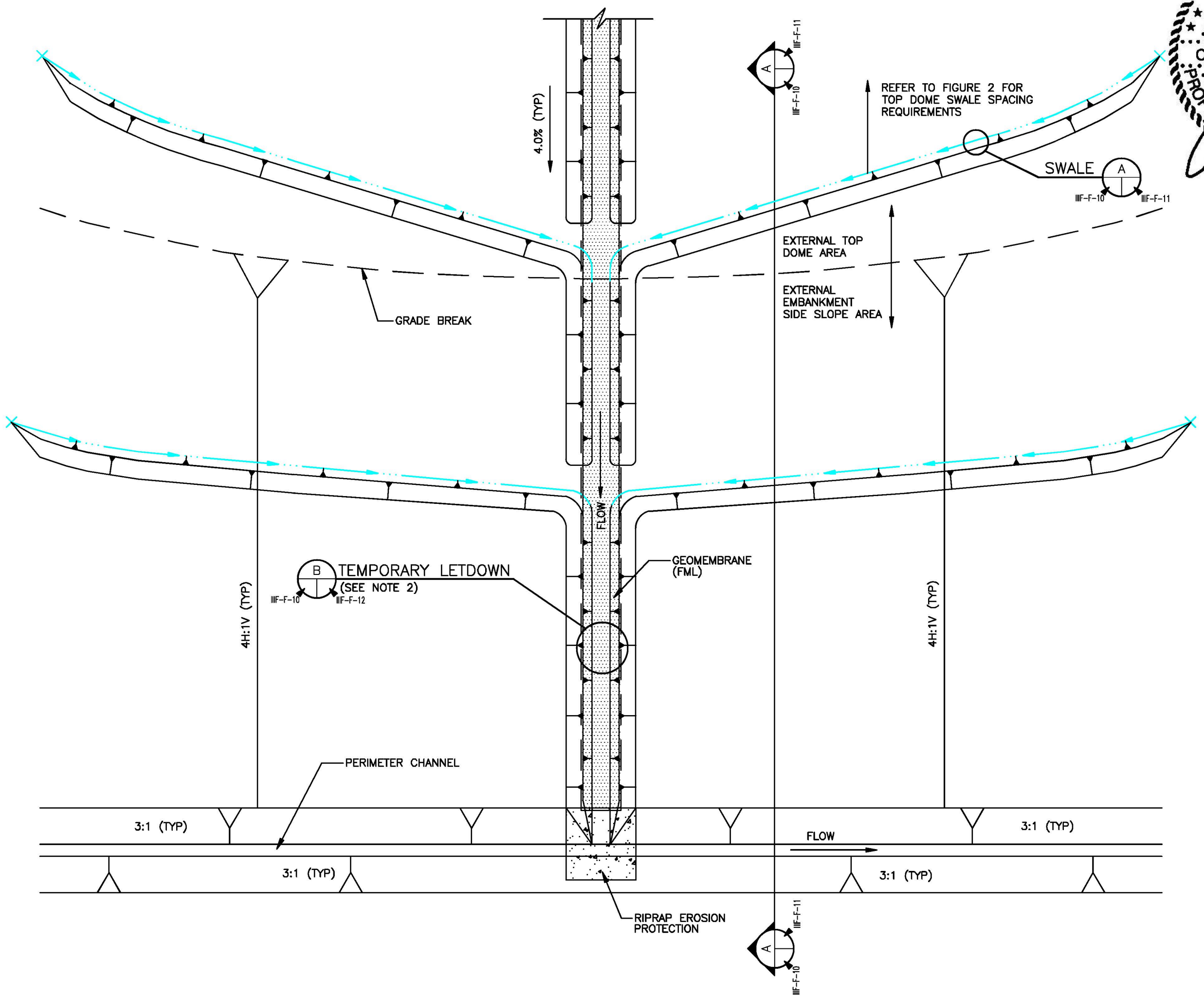
3.0 Erosion Control Plan for Daily Cover Areas and Intermediate Cover Areas for Non-External Side Slopes

BMPs will be employed to control erosion. BMPs will include the use of temporary rock riprap, silt fences, straw bales, check dams, interceptor swales and berms, temporary and permanent seeding and sodding, surface roughening, matting and mulching, sediment traps, and surface wetting for dust control.

Examples of erosion and sedimentation control features that will be used during the phased development of the site are shown in Appendix IIIA-A of the Site Development Plan. The following provides general guidelines of how the erosion control features will minimize sediment discharge from the site.

- As noted in the SOP, vegetation will be established on above-grade intermediate cover areas that remain inactive. The temporary vegetative cover will minimize erosion potential.
- Typically, uncontaminated stormwater runoff from the site will be channeled through the perimeter channel system to detention ponds before being discharged from the site. Sediment that collects in the channels and detention ponds will be removed consistent with the stormwater system maintenance plan presented in Section 2.3 of Appendix IIIF.
- Erosion will be controlled by vegetation in drainage structures with flow velocities less than or equal to 5 ft/sec. For drainage structures with flow velocities greater than 5 ft/sec, rock riprap or gabions will be used for surface reinforcement. Other erosion protection measures may be utilized if equivalent erosion protection is met.

Typical erosion control features are shown on Sheet IIIF-F-15. Inspection items and schedules are listed in the SOP for all drainage features, daily cover, and intermediate cover areas.



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05/20/2024

LEGEND

- DRAINAGE SWALE FLOWLINE
- LETDOWN
- ▨ GEOMEMBRANE LINING WITHIN LETDOWN (SEE NOTE 2)
- ▨ RIPRAP EROSION PROTECTION

NOTES:

1. THE ACCEPTABLE SOIL LOSS IS LESS THAN OR EQUAL TO 50 TONS/ACRE/YEAR. THE SOIL LOSS FOR TOP DOME SURFACES AND EXISTING EXTERNAL EMBANKMENT SIDE SLOPES WILL VARY DEPENDING ON SWALE SPACING AND PERCENT VEGETATIVE COVER (REFER TO SHEET IIIF–F–11 FOR SOIL LOSS ESTIMATES).
2. TEMPORARY LETDOWN IS SHOWN AS AN OPEN CHANNEL WITH A GEOMEMBRANE LINER. AS NOTED ON SHEET IIIF–F–12, OTHER CHANNEL LININGS MAY BE USED (e.g., GABIONS, GROUT, GROUTED CONCRETE RIPRAP, AND TURF REINFORCEMENT MAT). IN ADDITION, PIPE LETDOWNS MAY ALSO BE USED. HOWEVER, IF PIPE LETDOWNS ARE USED THEY WILL BE LIMITED TO 1–INLET AS SHOWN ON SHEET IIIF–F–12.

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☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 05/2024
FILE: 0120–76–11
CAD: IIIF–F–10–EROS. CONTROL.DWG

DRAWN BY: JDW
DESIGN BY: CRM
REVIEWED BY: RJS

Weaver Consultants Group
TBPE REGISTRATION NO. F–3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

EROSION CONTROL PLAN TYPICAL EROSION CONTROL STRUCTURE LAYOUT

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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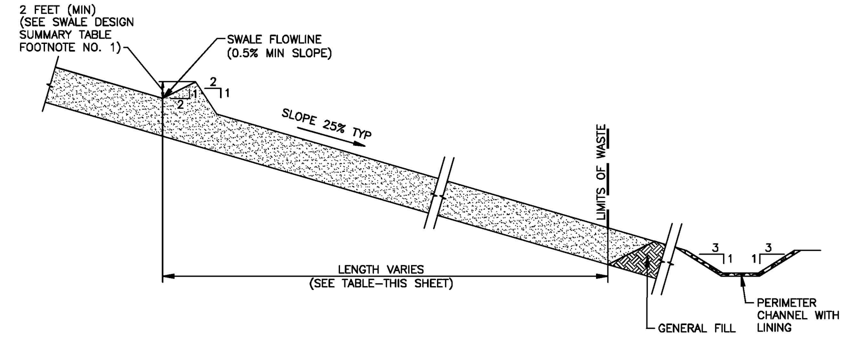
SHEET IIIF–F–10

0:\0120\76\EXPANSION 2023\PART III\IIIF\IIIF–F\IIIF–F–10–TYPICAL SWALE SPACING.dwg, byoung, 1:2



A
IIIF-F-10 IIIF-F-11
SIDE SLOPE DRAINAGE SWALE

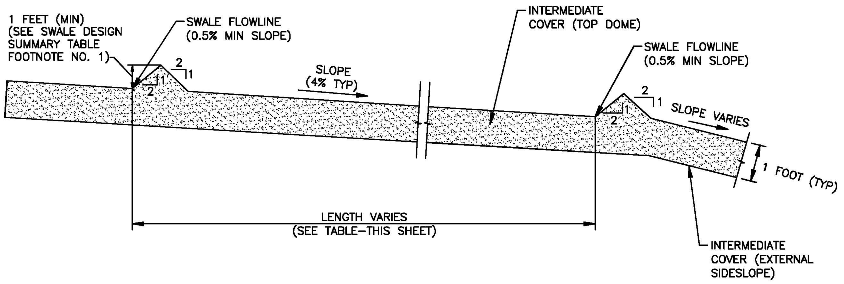
SWALE DESIGN SUMMARY[1]

SIDE SLOPE (25%)				TOP SLOPE (4%)			
VEGETATIVE COVER PERCENTAGE	DISTANCE BETWEEN SWALES (FT)	ESTIMATED SOIL LOSS (TONS/ACRE/YEAR)	ADDITIONAL SEDIMENT CAPTURE REQUIRED[2]	VEGETATIVE COVER PERCENTAGE	DISTANCE BETWEEN SWALES[3](FT)	ESTIMATED SOIL LOSS (TONS/ACRE/YEAR)	ADDITIONAL SEDIMENT CAPTURE REQUIRED[2]
60	100	18.6	NO	60	200	1.7	NO
70	100	7.7	NO	70	200	0.7	NO
80	100	5.8	NO	80	200	0.5	NO
85	100	3.6	NO	85	200	0.3	NO
60	500	40.4	NO	60	500	2.4	NO
70	500	16.7	NO	70	500	1.0	NO
80	500	12.5	NO	80	500	0.7	NO
85	500	7.9	NO	85	500	0.5	NO

[1] REFER TO APPENDIX IIIF–F–1 FOR SUPPORTING CALCULATIONS.

[2] IF SITE SPECIFIC CONDITIONS YIELD A MAXIMUM HORIZONTAL DISTANCE BETWEEN THE TOE OF THE SLOPE AND GRADE BREAK OF LESS THAN 300 FEET FOR SIDE SLOPES AND A DISTANCE OF 500 FEET FROM THE GRADE BREAK TO THE PEAK OF THE TOP SLOPES, ESTABLISHMENT OF 60% VEGETATION WILL BE SUFFICIENT MEANS OF EROSION CONTROL WITHOUT THE ADDITION OF TEMPORARY SWALES AND LETDOWNS GIVEN THAT THE TOTAL SOIL LOSS FOR THE SIDE SLOPE IS LESS THAN 50 TONS/ACRE/YEAR AND THE TOP SLOPE IS LESS THAN 50 TONS/ACRE/YEAR.

[3] NUMBERS INDICATE THE MAXIMUM SWALE SPACING FOR A GIVEN VEGETATIVE COVER PERCENTAGE.



A
IIIF-F-10 IIIF-F-11
TOP DOME SURFACE DRAINAGE SWALE

SWALE DRAINAGE AREA SUMMARY

CONDITION (SWALE HEIGHT)	MAXIMUM DRAINAGE AREA (ACRES)	MINIMUM SWALE SPACING[1] (FEET)	MAXIMUM SWALE LENGTH[2] (FEET)
TOP SLOPE (2 FT SWALE, 4%)	31.3	200	6,800
TOP SLOPE (1.5 FT SWALE, 4%)	14.5	200	3,150
TOP SLOPE (1 FT SWALE, 4%)	4.4	200	1,060
SIDE SLOPE (2 FT SWALE, 25%)	6.7	100	2,460
SIDE SLOPE (1.5 FT SWALE, 25%)	3.1	100	1,350
SIDE SLOPE (1 FT SWALE, 25%)	1.1	100	430

[1] THE MINIMUM SWALE SPACING IS USED TO DETAIN THE MAXIMUM SWALE LENGTH GIVEN THAT THE AREA IS FIXED. MINIMUM SWALE SPACING IS OBTAINED FROM THE CALCULATIONS PROVIDED ON PAGE IIIF–F–1–10.

[2] MAXIMUM SWALE LENGTH CALCULATED USING THE FOLLOWING EQUATION:

MAXIMUM DRAINAGE AREA x (43,560 SF/ACRE)/MINIMUM SWALE SPACING

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CAD: IIIF-F-11-SWALE DESIGN.DWG

DRAWN BY: JDW
DESIGN BY: CRM
REVIEWED BY: RJS

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

EROSION CONTROL PLAN SWALE DESIGN SUMMARY

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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SHEET IIIF–F–11

OPEN CHANNEL GEOMEMBRANE LETDOWN DESIGN SUMMARY

DESIGN IS APPLICABLE FOR A DRAINAGE AREA UP TO 30.0 ACRES (TOP DECK AND SIDE SLOPE).

25% SLOPE
MAXIMUM FLOW DEPTH = 0.48 FT.
BOTTOM WIDTH = 8 FT.

4% SLOPE
MAXIMUM FLOW DEPTH = 0.82 FT.
BOTTOM WIDTH = 8 FT.

OPEN CHANNEL GABION AND ROCK RIPRAP LETDOWN DESIGN SUMMARY

DESIGN IS APPLICABLE FOR A DRAINAGE AREA UP TO 30.0 ACRES (SIDE SLOPE AND TOP DECK).

25% SLOPE
MAXIMUM FLOW DEPTH = 1.07 FT.
BOTTOM WIDTH = 8 FT.

4% SLOPE
MAXIMUM FLOW DEPTH = 1.78 FT.
BOTTOM WIDTH = 8 FT.

OPEN CHANNEL GROUTED RIPRAP LETDOWN DESIGN SUMMARY

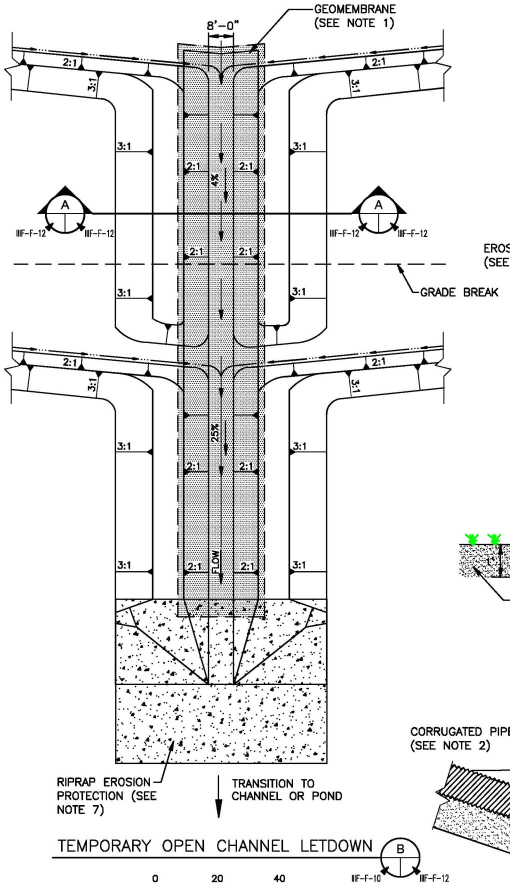
DESIGN IS APPLICABLE FOR A DRAINAGE AREA UP TO 30.0 ACRES (TOP DECK AND SIDE SLOPE).

25% SLOPE
MAXIMUM FLOW DEPTH = 0.91 FT.
BOTTOM WIDTH = 8 FT.

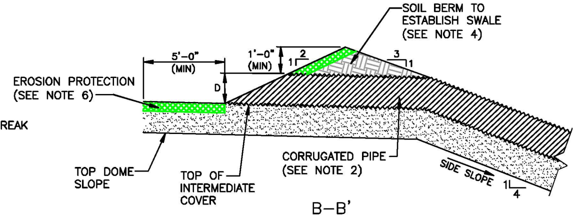
4% SLOPE
MAXIMUM FLOW DEPTH = 1.52 FT.
BOTTOM WIDTH = 8 FT.

OPEN CHANNEL TURF REINFORCEMENT LETDOWN DESIGN SUMMARY

SEE GROUTED RIPRAP LETDOWN DESIGN.



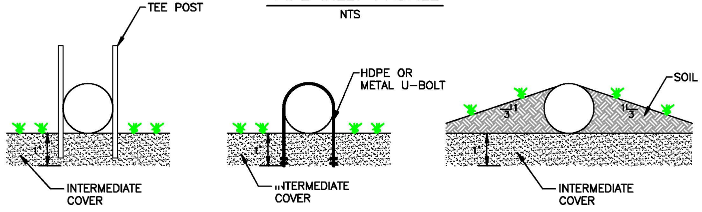
TEMPORARY OPEN CHANNEL LETDOWN



B–B'

PIPE INLET PROFILE

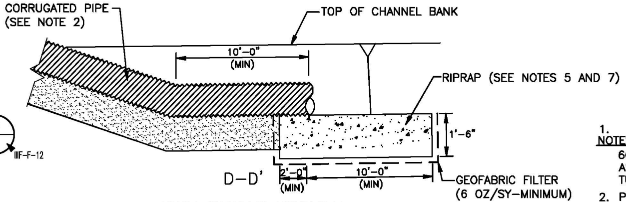
NTS



C–C'

ANCHORING DETAILS

NTS



D–D'

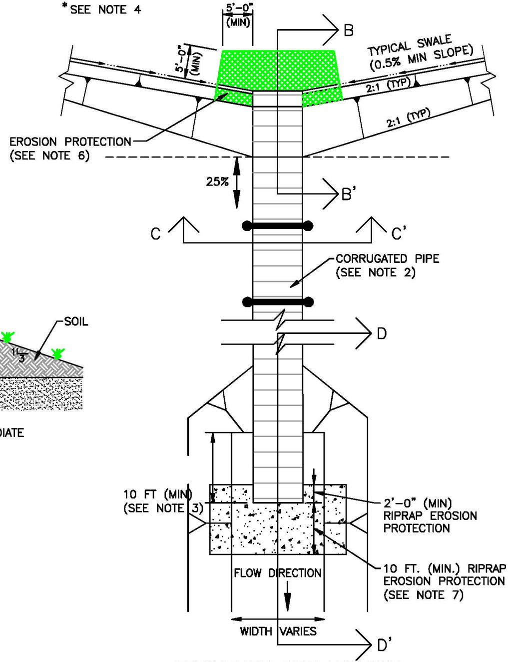
PIPE OUTLET PROFILE
(SEE NOTE 3)

NTS

25% PIPE LETDOWN DESIGN SUMMARY*
(USE OF PIPE LETDOWN IS LIMITED TO 1-INLET)

DRAINAGE AREA (ACRE)	DESIGN FLOW RATE (CFS)	REQUIRED PIPE DIAMETER (FT)
2.5	15.0	1.5
3.0	30.2	3
5.0	30.2	3

*SEE NOTE 4



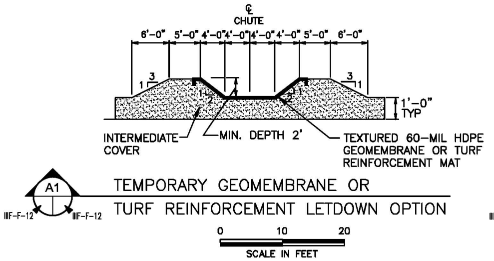
TEMPORARY PIPE LETDOWN

NTS

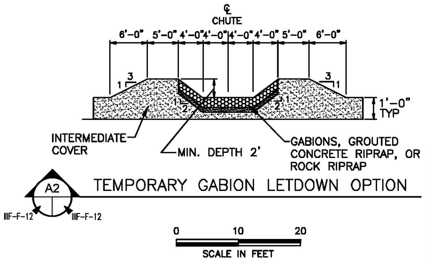
1.
NOTES:

60 MIL HDPE GEOMEMBRANE TEXTURED BOTH SIDES WILL BE USED FOR GEOMEMBRANE LETDOWN LINING. AS AN ALTERNATIVE, TEMPORARY LETDOWN CAN BE LINED WITH GABIONS, GROUTED CONCRETE RIPRAP, TURF REINFORCEMENT MAT, OR ROCK RIPRAP.

2. PIPE DRAINAGE LETDOWN WILL BE ANCHORED BY USING SOIL BERM AT THE INLET LOCATED WITHIN THE SWALE. ADDITIONAL ANCHORING ON THE SIDE SLOPE MAY BE PROVIDED USING SOIL, HDPE OR METAL U-BOLTS, T-POSTS OR EQUIVALENT MATERIALS.
3. PIPE WILL BE EXTENDED INTO THE CHANNEL TO MINIMIZE EROSION.
4. PIPE LETDOWNS WILL BE LIMITED TO 1 INLET PER LETDOWN. SOIL BERMS AROUND THE PIPE INLET WILL BE EXTENDED A MINIMUM 1-FOOT ABOVE THE LETDOWN PIPE INLET. REFER TO PAGE IIIF-F-2-22 FOR HYDRAULIC ANALYSIS.
5. RIPRAP APRON DESIGN IS PROVIDED ON PAGES IIIF-F-2-33 AND 34. D_{50} FOR RIPRAP 8-INCHES IS MINIMUM.
6. RIPRAP, GROUT, GROUTED RIPRAP, GABIONS, GEOMEMBRANE, EXISTING VEGETATION OR TURF REINFORCEMENT MAY BE USED FOR EROSION PROTECTION.
7. OTHER EROSION PROTECTION (e.g., RIPRAP, GROUT, GROUTED RIPRAP, GABIONS OR TURF REINFORCEMENT) MAY BE USED AT TEMPORARY LETDOWN OUTFALLS.
8. REFER TO PAGE IIIF-F-2-35 FOR EROSION PROTECTION DESIGN. IF LETDOWN DISCHARGES TO A POND, 10 FEET OF RIPRAP WILL BE SUFFICIENT.



TEMPORARY GEOMEMBRANE OR TURF REINFORCEMENT LETDOWN OPTION



TEMPORARY GABION LETDOWN OPTION

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REVIEWED BY: RJS

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PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

NO.	DATE	DESCRIPTION

EROSION CONTROL PLAN
LETDOWN DESIGN SUMMARY

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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SHEET IIIF-F-12

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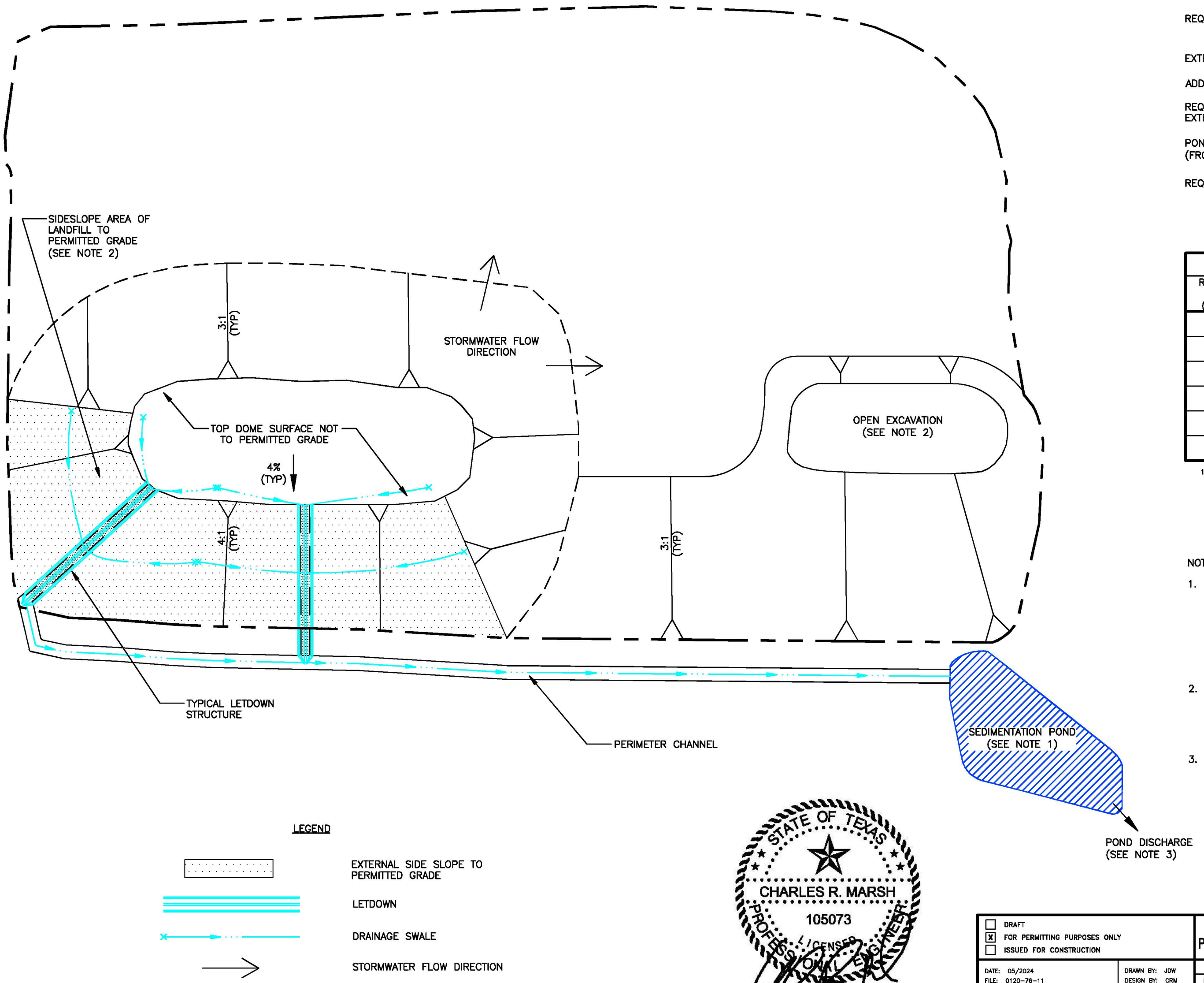

EXAMPLE CALCULATION

REQUIRED POND SIZE = EXTERNAL EMBANKMENT AREA (ACRES) X POND AREA REQUIRED/UNIT DRAINAGE AREA FACTOR

EXTERNAL EMBANKMENT AREA DRAINING TO POND = 50 ACRES

ADDITIONAL UPLAND AREA DRAINING TO POND = 0 ACRES (SEE NOTE 1)

REQUIRED SEDIMENT REMOVAL FROM EXTERNAL SIDE SLOPE AREA = 80 TONS/ACRE/YEAR TO 50 TONS/ACRE/YEAR

POND AREA REQUIRED/UNIT DRAINAGE AREA FACTOR = 0.060 (FROM TABLE BELOW)

REQUIRED POND SIZE = 50 ACRES X 0.060 = 3.00 ACRES

SIZE OF POND REQUIRED[1]

REQUIRED SEDIMENT REMOVAL (TONS/ACRE/YEAR)	POND AREA REQUIRED/ UNIT DRAINAGE AREA FACTOR	EFFICIENCY OF POND (DYNAMIC AND QUIESCENT)
60 TO 50	0.025	16.9%
70 TO 50	0.040	29.2%
80 TO 50	0.060	37.9%
90 TO 50	0.075	45.3%
100 TO 50	0.110	50.7%
200 TO 50	0.300	75.6%

[1] REFER TO APPENDIX IIIF-F-3 FOR MORE INFORMATION. THE POND DESIGN AND DEMONSTRATION ARE PROVIDED TO ENSURE THAT SEDIMENT DISCHARGE FROM THE SITE WILL BE PREVENTED DURING INITIAL ESTABLISHMENT OF VEGETATION OVER THE SIDE SLOPES AND TOP DOME SURFACES.

NOTES:

1. EXAMPLE POND CONFIGURATION IS SHOWN. A DEMONSTRATION WILL BE INCLUDED IN THE SITE OPERATING RECORD TO SHOW THAT THE POND HAS THE CAPABILITY TO CAPTURE SEDIMENT SUCH THAT DISCHARGE IS LESS THAN OR EQUAL TO 50 TONS/ACRE/YEAR FROM THE EXTERNAL SIDE SLOPE AND TOP DOME AREA. THE DEMONSTRATION WILL ACCOUNT FOR THE ADDITIONAL SEDIMENT CREATED BY THE UPLAND AREA THAT FLOWS TO THE POND. FOR DEMONSTRATION PURPOSES, THE POND DEPTH WILL BE AN AVERAGE OF 4 FEET. OVERALL SEDIMENT DISCHARGE FROM THE SITE MUST COMPLY WITH THE CURRENT TPDES PERMIT FOR THE SITE.
2. EXCAVATED FUTURE CELL AREAS OR SOIL BORROW AREAS CAN ALSO BE USED AS SEDIMENTATION PONDS. IF THESE AREAS ARE USED FOR PONDS, A DEMONSTRATION NOTING THAT THE EXCAVATED FUTURE CELL AREA OR SOIL BORROW AREA HAS MORE CAPACITY THAN THE VOLUME PRODUCED BY THE 25-YEAR, 24-HOUR STORM WILL BE DOCUMENTED AND MAINTAINED IN THE SITE OPERATING RECORD.
3. AS STATED IN SECTION 2.2, A STATEMENT WILL BE ADDED TO THE SITE OPERATING RECORD EACH TIME A SEDIMENTATION POND IS INSTALLED TO NOTE HOW THE TEMPORARY SEDIMENTATION POND AND THE POND OUTLET WERE CONSTRUCTED CONSISTENT WITH THE REQUIREMENTS OF THE SITE DEVELOPMENT PLAN.

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EROSION CONTROL PLAN
SEDIMENT CONTROL POND PLAN

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CHEROKEE COUNTY, TEXAS

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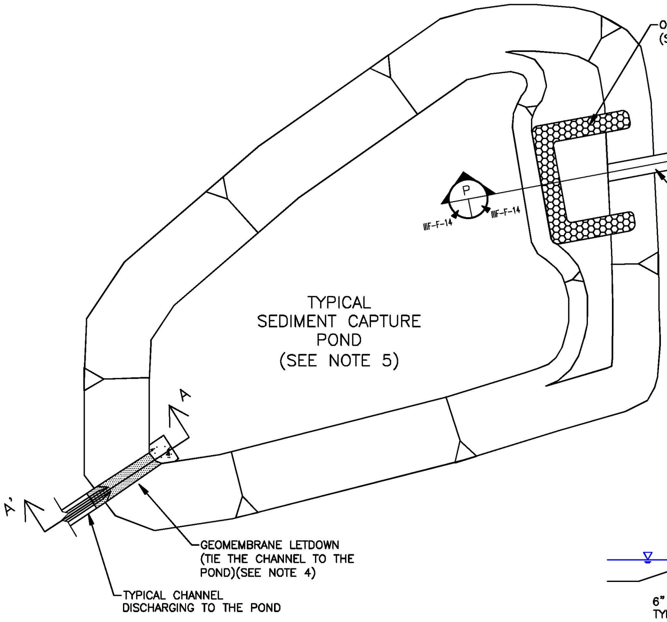
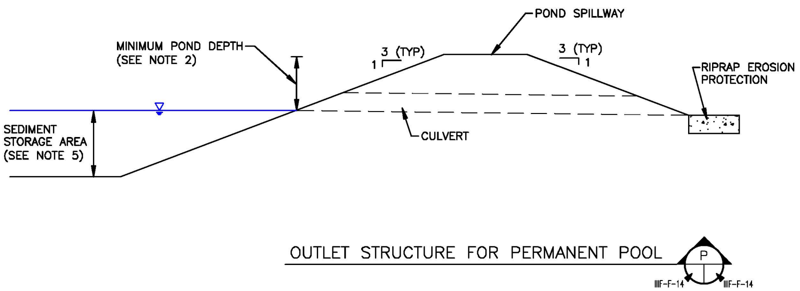
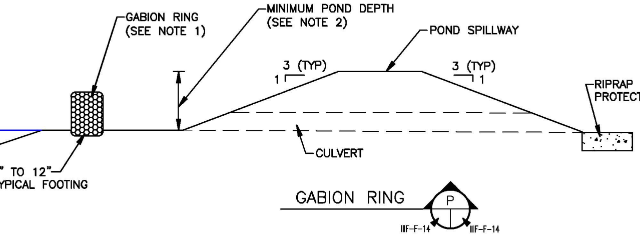
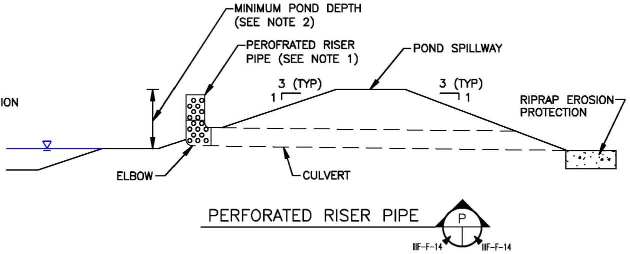




OUTLET STRUCTURE FOR PERMANENT POOL



GABION RING

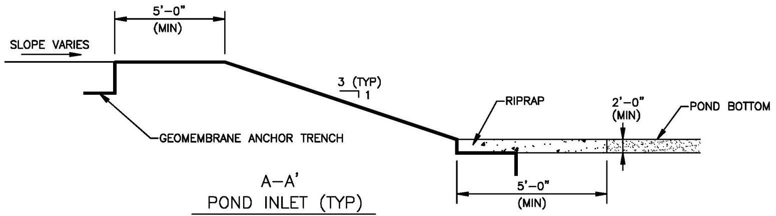


PERFORATED RISER PIPE

OPTIONS FOR DRY PONDS

NOTES:

1. AS AN OPTION TO THE GABION RING, A PERFORATED RISER PIPE (SHOWN ON THIS SHEET) MAY ALSO BE USED, AS WELL AS A ROCK CHECK DAM.
2. MINIMUM POND DEPTH IS 4 FEET BETWEEN THE LOW FLOW OUTLET FLOW LINE AND POND SPILLWAY ELEVATION.
3. IF THE POND IS INSTALLED WITHOUT A LOW FLOW OUTLET, THEN SEE NOTE 2 ON SHEET IIIF-F-13.
4. VEGETATIVE SURFACING, GROUTED RIPRAP, RIPRAP, GABIONS, OR TURF REINFORCEMENT MAY BE USED TO ENSURE THE STABILITY OF THE POND INLET.
5. POND BOTTOM AREAS WILL BE EXCAVATED BELOW THE LOW FLOW OUTLET FLOW LINE ELEVATION TO PROVIDE SEDIMENT STORAGE. SEDIMENT ACCUMULATED IN POND WILL BE REMOVED AS NEEDED TO ENSURE SEDIMENT STORAGE CAPACITY BELOW THE FLOWLINE ELEVATION OF LOW FLOW OUTLET (REFER TO SECTION 2.4 FOR ADDITIONAL INFORMATION REGARDING SEDIMENT REMOVAL).



A-A'
POND INLET (TYP)
NTS

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TYPICAL POND OUTLET
STRUCTURES
ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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SHEET IIIF-F-14

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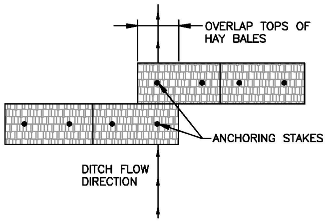
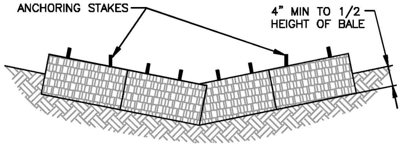
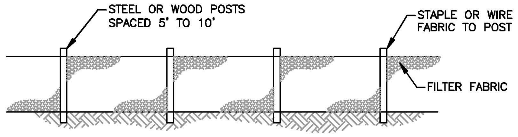


PLAN VIEW

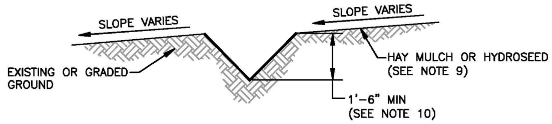


PROFILE VIEW

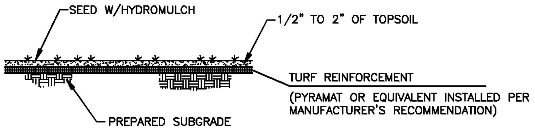
BALED HAY FOR EROSION CONTROL
NTS
(SEE NOTE 1)



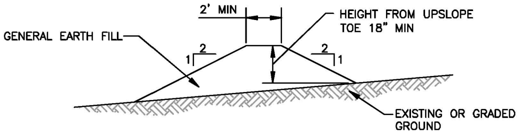
TEMPORARY SEDIMENT CONTROL FENCE
NTS
(SEE NOTE 3)



TEMPORARY DIVERSION CHANNEL
NTS
(SEE NOTE 6)

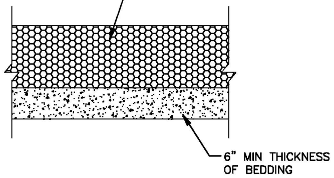


TURF REINFORCEMENT
NTS
(SEE NOTE 4)

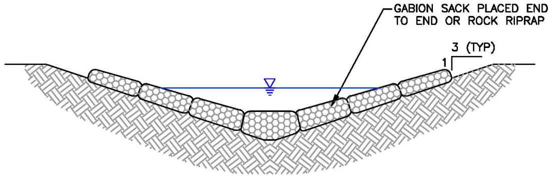


TEMPORARY DIVERSION BERM
NTS
(SEE NOTE 7)

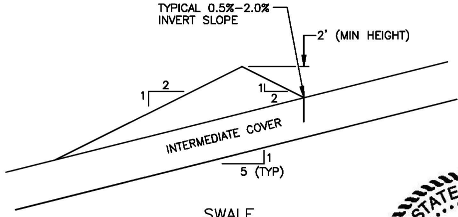
24" THICKNESS OF RIPRAP	
SIEVE SIZE SQUARE MESH	PERCENT PASSING
30 INCH	100
24 INCH	65–100
18 INCH	45–75
12 INCH	25–50
8 INCH	10–30
6 INCH	0–15



ROCK RIPRAP
NTS
(SEE NOTE 2)



ROCK CHECK DAM
NTS
(SEE NOTE 5)



SWALE
NTS
(SEE NOTE 8)

NOTES:

1. BALED HAY MAY BE USED IN NEWLY ESTABLISHED COVER AREAS OR DISTURBED/REGRADED SURFACES TO MAINTAIN SHEET FLOW UNTIL VEGETATION IS ESTABLISHED.
2. ROCK RIPRAP MAY BE USED IN AREAS WHERE CONCENTRATED FLOW WITH HIGH VELOCITIES MAY OCCUR (e.g., CULVERT INLETS/OUTLETS).
3. A TEMPORARY SEDIMENT CONTROL FENCE MAY BE USED IN CAPTURING SEDIMENT TRANSPORTED BY SHEET FLOW AND FOR DIVERSION OF FLOW FOR CONTROLLING SEDIMENT DISCHARGE.
4. TURF REINFORCEMENT MAY BE USED ON NEWLY ESTABLISHED SURFACES SUCH AS INTERMEDIATE COVER AND IN CHANNELS WHERE MODERATELY HIGH FLOW VELOCITIES ARE EXPECTED.
5. A ROCK CHECK DAM MAY BE USED IN CHANNELS TO SLOW DOWN FLOW VELOCITIES AND IMPROVE SEDIMENT CAPTURE.
6. A TEMPORARY DIVERSION CHANNEL MAY BE USED FOR SHORTENING SHEET FLOW DISTANCES IN UNDEVELOPED AREAS OR IN LARGER CHANNELS TO PROVIDE MEANDERING AND SLOWER FLOW VELOCITIES TO PREVENT IN-CHANNEL EROSION.
7. A TEMPORARY DIVERSION BERM MAY BE USED IN AREAS TO DIVERT FLOW FROM ENTERING STEEP SLOPED AREAS (e.g., TOP OF EXCAVATION) AND TO REDUCE SHEET FLOW LENGTHS.
8. A SWALE MAY BE USED IN AREAS TO DIVERT FLOW FROM ENTERING STEEP SLOPED AREAS (e.g., TOP OF EXCAVATION) AND TO REDUCE SHEET FLOW LENGTHS.
9. HAY MULCH AND HYDROSEED MAY ALSO BE USED FOR NEWLY ESTABLISHED SURFACES TO PROMOTE VEGETATION ESTABLISHMENT AND PREVENT EROSION.
10. THE VALUE SHOWN IS AT THE TIME OF CHANNEL INSTALLATION; CHANNEL WIDTH AND DEPTH MAY VARY.

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05/20/2024

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PREPARED FOR
PINE HILL FARMS LANDFILL TX, LP

REVISIONS

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EROSION CONTROL PLAN
TYPICAL BMPs

ROYAL OAKS LANDFILL
CHEROKEE COUNTY, TEXAS

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SHEET IIIF-F-15

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APPENDIX IIIF-F-1

TEMPORARY ADD-ON SWALE DESIGN

Includes pages IIIF-F-1-1 through IIIF-F-1-12

STATE OF TEXAS
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PROFESSIONAL ENGINEER

05/20/2024

SWALE DESIGN

This appendix includes the expected soil loss calculations for various swale spacing intervals on the side slopes and top dome surfaces. An example calculation is provided on pages IIIF-F-1-2 through IIIF-F-1-4 for a vegetative cover of 60 percent. For the results of various percent vegetative covers and swale spacing intervals, refer to the table on page IIIF-F-1-5 and to Sheet IIIF-F-11 – Swale Design Summary. If the required percent vegetation coverage is not achieved within the 180-day period, secondary erosion control measures such as mulch, wood chips, compost or straw/hay will be used to limit the soil loss to 50 tons/acre/year or less. In addition, a detention/sedimentation pond may also be used until the required vegetation coverage is achieved. Any secondary measure used will be documented in the Site Operating Record at the end of the 180-day period to document compliance with this plan. In addition, the date the required percent vegetation coverage is achieved and the secondary measure is no longer needed will also be documented in the Site Operating Record.

Also included in this appendix are the sheet flow velocities for all swale spacing intervals on the side slopes and top dome surfaces. As noted in these calculations (pages IIIF-F-1-6 through IIIF-F-1-8), all velocities are acceptable.

Additionally, this appendix includes a calculation for the maximum drainage area that each swale can drain, as well as the maximum swale length. These calculations are included on pages IIIF-F-1-9 through IIIF-F-1-12.

ROYAL OAKS LANDFILL
0120-076-11-106
TEMPORARY EROSION LAYER EVALUATION

Required: Determine the required spacing of the drainage swales for different percentages of vegetative cover for top dome surfaces and external embankment side slopes.

Method:

1. Estimate soil loss per acre based on percent ground cover and swale spacing for top dome surface and external side slope.
2. Summary.

Notes:

1. The following example calculation procedure has been developed for 60 percent ground cover.
2. The table on page IIIF-F-1-5 includes the results of the following procedure for 60, 70, 80, and 85 percent ground cover and various swale spacings. The results are also summarized on Figure 2 in Appendix IIIF-F.

References:

1. SCS National Engineering Handbook, Chapter 3 - Erosion.
2. TNRCC, *Use of the USLE in Final Cover/Configuration Design* , 1993.
3. United States Department of Agriculture, National Resource Conservation Service, Web Soil Survey for Cherokee County, Texas (http://websoilsurvey.nrcs.usda.gov).
4. United States Environmental Protection Agency, *Solid Waste Disposal Facility Criteria Technical Manual* , 1993.

Solution:

1. Estimate soil loss per acre based on percent ground cover and swale spacing for top dome surface and external side slope.

Soil Loss Equation: $A=RKL_SCP$

Where:

$A=$ Soil loss (tons/ac/yr)
$R=$ Rainfall factor
$K=$ Soil erodibility factor
$L_S=$ Slope length/slope gradient factor
$C=$ Plant cover or cropping management factor
$P=$ Erosion practice factor

The rainfall factor, R, represents the average intensity for the maximum intensity, 30 minute storms over a 22 year period of record compiled by the SCS. Using Figure 1 (Ref 2), Average Annual Values of the R Factor, the R factor for Cherokee County is:

R = 370

The soil erodibility factor, K, factor represents the resistance of a soil surface to erosion as a function of the soil's physical and chemical properties. Assume an organic matter content of 2% to determine the K factor. The intermediate soil will consist of soils comparable to sandy clay. Additionally, compost will be added to intermediate soil as necessary to protect against erosion. Therefore, the following is a conservative K value for the site (Table 1 on page 6, Ref. 2).

K = 0.20

The slope length/slope gradient factor, L_s, represents the erosion of the soil due to both slope length and degree of slope.

Case 1.	Top Slope			Case 2.	Top Slope		
	slope =	4	%		slope =	4	%
	length =	200	ft		length =	500	ft
Case 4.	Side Slope			Case 4.	Side Slope		
	slope =	25	%		slope =	25	%
	length =	100	ft		length =	500	ft

Using the above information and Figure 4 (Ref 2, p.13), the L_s factors are determined.

Case	Slope (%)	Slope Length (ft)	L_s
1. Top Slope	4	200	0.54
2. Top Slope	4	500	0.76
3.Side Slope	25	100	6.00
4.Side Slope	25	500	13.00

The plant cover or 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. C Factor for Permanent Pasture, Range, and Idle Land with No Appreciable Canopy has the following relation with percent ground cover (GC) (from Ref 2, p.7) .

% GC	C Factor:
0	0.45
20	0.20
40	0.10
60	0.042
80	0.013
85	0.0082

[1] Linear Interpolation was utilized for % GC between reported values.

C Factor= 0.0420 (for 60% ground cover)

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. Contouring for this site will be done only to establish vegetation.

P = 1.00

ROYAL OAKS LANDFILL
0120-076-11-106
TEMPORARY EROSION LAYER EVALUATION

Slope Condition	R	K	L_s	C	P	A (tons/ac/yr)
1. Top Slope 4% slope 200 ft length	370	0.20	0.54	0.0420	1.0	1.68
2. Top Slope 4% slope 500 ft length	370	0.20	0.76	0.0420	1.0	2.36
3.Side Slope 25% slope 100 ft length	370	0.20	6.00	0.0420	1.0	18.65
4.Side Slope 25% slope 500 ft length	370	0.20	13.00	0.0420	1.0	40.40

2. Summary
   For a summary of soil loss rates for various percentages of ground cover, see Figure 2 in Appendix IIIF-F and page IIIF-F-1-5.

SOIL LOSS ESTIMATE SUMMARY TABLE

Case	Slope (%)	Length (ft)	L_s	Percent Ground Cover	C Factor	A (tons/ac/yr)
Top Slope	4	200	0.54	60	0.042	1.7
Top Slope	4	200	0.54	70	0.017	0.7
Top Slope	4	200	0.54	80	0.013	0.5
Top Slope	4	200	0.54	85	0.0082	0.3
Top Slope	4	500	0.76	60	0.042	2.4
Top Slope	4	500	0.76	70	0.017	1.0
Top Slope	4	500	0.76	80	0.013	0.7
Top Slope	4	500	0.76	85	0.0082	0.5
Top Slope	25	100	6.00	60	0.042	18.6
Top Slope	25	100	6.00	70	0.017	7.7
Top Slope	25	100	6.00	80	0.013	5.8
Top Slope	25	100	6.00	85	0.0082	3.6
Top Slope	25	500	13.00	60	0.042	40.4
Top Slope	25	500	13.00	70	0.017	16.7
Top Slope	25	500	13.00	80	0.013	12.5
Top Slope	25	500	13.00	85	0.0082	7.9

ROYAL OAKS LANDFILL
0120-076-11-106
SHEET FLOW VELOCITY

Required: Determine the sheet flow velocity for the top dome surfaces and external embankment side slopes and compare to the permissible non-erodible flow velocity.

Method:

1. Determine the peak velocities for the cases listed on page IIIF-F-1-2.
2. Compare to permissible velocities.
3. Conclusion.

References:

1. Raudkivi, A.J., *Hydrology - An Advanced Introduction to Hydrological Processes and Modeling*, 1979.
2. Texas Department of Transportation, *Bridge Division Hydraulic Manual*, December 2019.
3. United States Soil Conservation Service, *TR-55 Hydrology for Small Watersheds*, December 1989.

Solution: Use the typical case scenarios from the USLE calculation to determine the expected peak sheet flow velocity.

Case 1. Top Slope
slope = 4 %
length = 200 ft

Case 2. Top Slope
slope = 4 %
length = 500 ft

Case 3. Side Slope
slope = 25 %
length = 100 ft

Case 4. Side Slope
slope = 25 %
length = 500 ft

1. Determine the peak velocities for the cases listed on page IIIF-F-1-2.

Cultivated Straight Row (Overland Flow)

From Figure 15.2 (page 15-8 in Ref. 1), determine the velocities for all cases.

Case 1. V = 1.7 ft/s
Case 2. V = 1.7 ft/s
Case 3. V = 4.5 ft/s
Case 4. V = 4.5 ft/s

Note: Figure 15.2 is reproduced on page IIIF-F-1-8.

2. Compare to permissible velocities.

Summary of Velocities

	Condition	Equivalent Percent Ground Coverage	Peak Velocity (ft/s)	Permissible Velocity[1] (ft/s)
Cultivated Straight Row	4%, 200 ft	>60%	1.7	5.0
	4%, 500 ft	>60%	1.7	5.0
	25%, 200 ft	>60%	4.5	5.0
	25%, 500 ft	>60%	4.5	5.0

[1] Permissible velocity information is from USACE EM 1110-0-1418, Chapter 5 - Evaluation of Stability.

3. Conclusion.
The peak velocities for each case are listed in the above summary table. As shown peak velocities are below permissible velocities for the conditions analyzed. After 180 days, at least 60 percent vegetation will be established in order to maintain permissible non-erodible velocities.

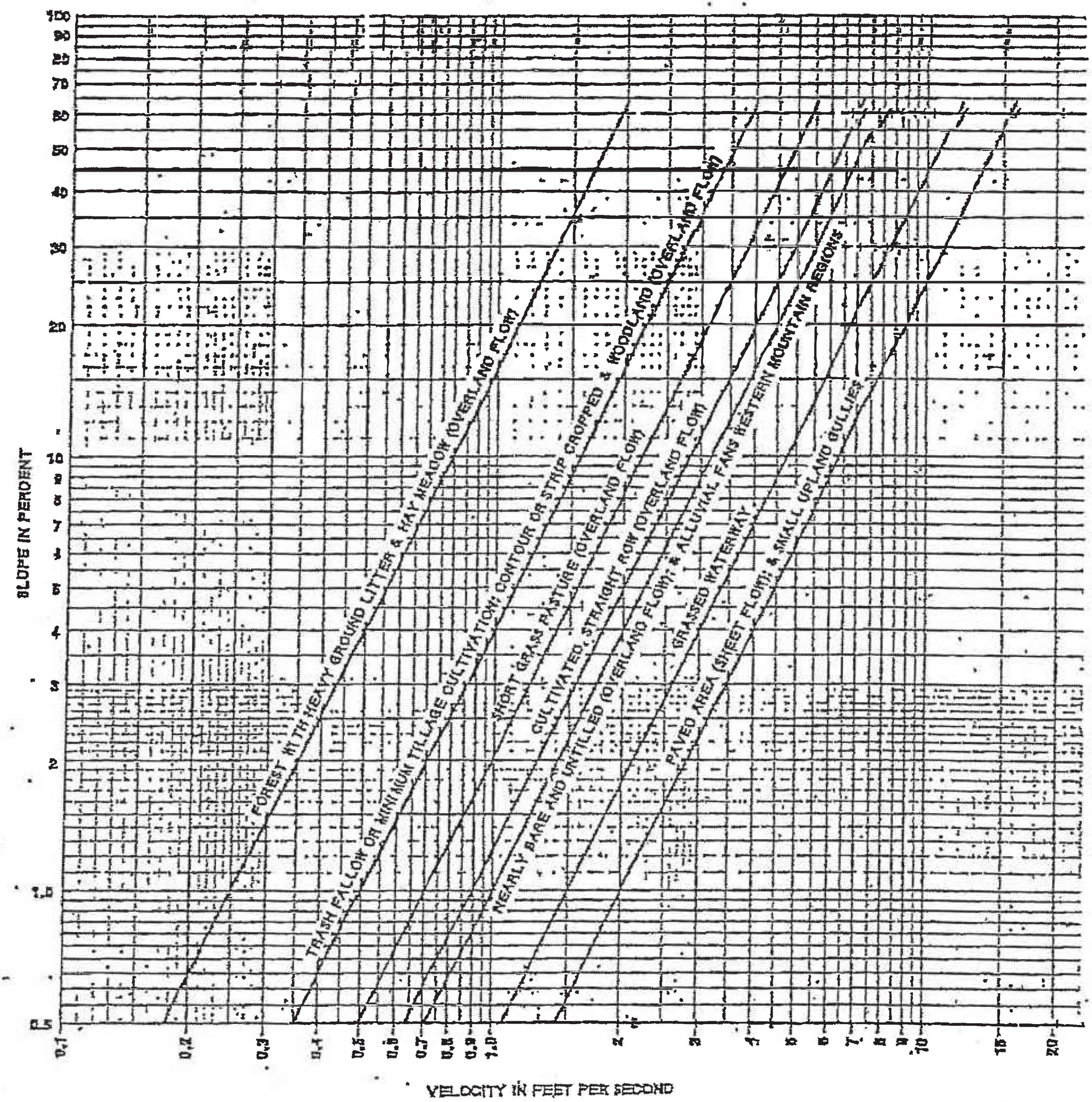


Figure 15.2.—Velocities for upland method of estimating T_c

ROYAL OAKS LANDFILL
0120-076-11-106
SWALE ANALYSIS

Required: Analyze swales to determine the adequacy of the swale design.

Method:

1. Determine the 25-year, 24-hour flow rates for a maximum swale drainage area for top slopes and side slopes using the Rational Method.
2. Determine maximum swale length that corresponds to the maximum swale drainage area.

Reference:

1. State of Texas, Department of Transportation, Bridge Division, Hydraulic Manual, September 2019.
2. National Oceanic and Atmospheric Administration's Atlas 14 Point Precipitation Frequency Estimates.

Solution:

1. Determine the 25-year intensity flow rates.

$$Q = CIA$$

Where:
C= 0.7 (runoff coefficient, Ref 1.)
I = intensity in/hr
A= drainage area, ac

From Ref. 2, for
25-year storm event

t_c is assumed to be 10 min.

I = 8.59 in/hr

For Top Slope (4%):

Maximum Drainage Area (2 ft swale) = 31.3 acres
Maximum Drainage Area (1.5 ft swale) = 14.5 acres
Maximum Drainage Area (1 ft swale) = 4.9 acres

Flow Rate (2 ft swale) =	188.0	cfs
Flow Rate (1.5 ft swale) =	87.2	cfs
Flow Rate (1 ft swale) =	29.5	cfs

For Side Slope (25%):

Maximum Drainage Area (2 ft swale) = 6.7 acres
Maximum Drainage Area (1.5 ft swale) = 3.1 acres
Maximum Drainage Area (1 ft swale) = 1.1 acres

Flow Rate (2 ft swale) =	40.4	cfs
Flow Rate (1.5 ft swale) =	18.8	cfs
Flow Rate (1 ft swale) =	6.4	cfs

2. Determine maximum swale length that corresponds to the maximum swale drainage area.

Condition (swale height)	Maximum Drainage Area (acres)	Minimum Swale Spacing[1] (ft)	Maximum Swale Length[2] (ft)
4% Top Slope (2 ft swale)	31.3	200	6,800
4% Top Slope (1.5 ft swale)	14.5	200	3,150
4% Top Slope (1 ft swale)	4.9	200	1,060
25% Side Slope (2 ft swale)	6.7	100	2,900
25% Side Slope (1.5 ft swale)	3.1	100	1,350
25% Side Slope (1 ft swale)	1.1	100	470

[1] Minimum swale spacing is taken from calculations provided on page IIIF-F-1-2.

[2] Maximum swale length calculated using the following equation:

Maximum Drainage Area x (43,560 sf/acre) / Minimum Swale Spacing

Prep By: VG
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
SWALE ANALYSIS

Chkd By: BPY/CRM
Date: 5/9/2024

Flow Rate (cfs)	Bottom Slope (ft/ft)	n-value	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude No.	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq. ft.)	Top Width of Flow (ft)
2 ft Top Slope (4%) Swale												
188.0	0.005	0.03	2	25	0	2.00	3.48	0.614	0.19	2.19	53.96	53.98
1.5 ft Top Slope (4%) Swale												
87.2	0.005	0.03	2	25	0	1.50	2.87	0.585	0.13	1.63	30.34	40.48
1 ft Top Slope (4%) Swale												
29.5	0.005	0.03	2	25	0	1.00	2.19	0.546	0.07	1.07	13.48	26.98
2 ft Side Slope (25%) Swale												
40.4	0.005	0.03	2	4	0	2.00	3.37	0.595	0.18	2.18	11.98	11.99
1.5 ft Side Slope (25%) Swale												
18.8	0.005	0.03	2	4	0	1.50	2.78	0.567	0.12	1.62	6.75	9.00
1.0 ft Side Slope (25%) Swale												
6.4	0.005	0.03	2	4	0	1.00	2.13	0.531	0.07	1.07	3.01	6.01

Note: Calculations were performed using the HYDROCALC HYDRAULICS program developed by Dodson and Associates (Version 2.01, 1996-2010).

Maximum flow depth is 2.0 ft (swale height).

Design is acceptable.

Example Calculation: Calculate the normal depth for the swale for the maximum size 4% top slope drainage area.

List of Symbols

Q_d = design flow rate for channel, cfs
R = hydraulic radius, ft
n = Manning's roughness coefficient
S = channel slope, ft/ft
b = bottom width of channel, ft
z_r = z-ratio (ratio of run to rise for channel sideslope) for right side slope of swale
z_l = z-ratio (ratio of run to rise for channel sideslope) for left side slope of swale
A_f = flow area, sf
g = gravitational acceleration = 32.2 ft/s^2
T = top width of flow, ft
d = normal depth of swale, ft

The program uses an iterative process to calculate the normal depth of the swale to satisfy Manning's Equation

$$Q = \frac{1.486}{n} A R^{0.67} S^{0.5}$$

Design Inputs:

Q_d = 188.0 cfs
S = 0.005 ft/ft
b = 0 ft
z_r = 25 (H) : 1 (V)
z_l = 2 (H) : 1 (V)
n = 0.03

Step 1 - Based on the geometry of the swale cross-section, solve for R and A_f

$$R = \frac{bd + 1/2d^2(z_r + z_l)}{b + d((z_l^2 + 1)^{0.5} + (z_r^2 + 1))}$$

$$A_f = bd + 1/2d^2(z_r + z_l)$$

assume: d = 2.00 ft

R = 0.991 ft

A_f = 53.96 sf

solve for Q: $Q = 188.0$

if Q is not equal to Q_d, select a new d and repeat calculations

Step 2 - solve for velocity, T, Froude number, velocity head, and energy head

$Q = VA \Rightarrow \quad V = Q/A$

$V = 3.48$ ft/s

$T = b + d(z_l + z_r)$

$T = 53.98$ ft

$$F_r = \frac{V}{(gA/T)^{0.5}}$$

$F_r = 0.614$

$$\text{Velocity Head} = \frac{V^2}{2g}$$

Velocity Head = 0.19 ft

Energy Head = water elevation + velocity head

Energy Head = 2.19 ft

APPENDIX IIIF-F-2

TEMPORARY LETDOWN DESIGN

Includes pages IIIF-F-2-1 through IIIF-F-2-35

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

05/20/2024

LETDOWN (OR CHUTE) DESIGN

The temporary letdown structure options include open channel flow letdowns and pipe letdowns. Open channel flow letdowns will be lined with either geomembrane, turf reinforcement mat, gabions, grouted concrete riprap, or rock riprap. The pipe letdowns are typically corrugated plastic pipe. Both types of letdowns may have an energy dissipator structure at the bottom of the letdown. Typical letdown details are shown on Sheet IIIF-F-12 – Letdown Design Summary.

This appendix includes a demonstration to show that the letdown structure sizes shown on Sheet IIIF-F-12 will contain the peak flow rate produced by the 25-year storm event. The geomembrane-lined and gabion-lined chutes (as well as turf reinforcement, rock riprap, and grouted riprap-lined chutes) were analyzed for peak flow rates generated from drainage areas ranging from 5 acres to 30 acres. This analysis (pages IIIF-F-2-2 through IIIF-F-2-5) is summarized on Sheet IIIF-F-12 and shows the maximum drainage areas that the 2-foot-deep chutes (8 feet minimum bottom width) are adequate to handle (i.e., the maximum flow depth calculated is less than 2.00 feet).

Also included in this appendix is an analysis for the 18-inch-, 24-inch-, and 36-inch-diameter temporary pipe letdowns for 25 percent slopes. The maximum flow that these pipes were capable of conveying was determined, and from this design flow rate a maximum drainage area size was calculated. The drainage area corresponds to the area that could drain to the pipe at each inlet. As noted on Sheet IIIF-F-12, the use of pipe letdowns will be limited to 1 inlet per letdown. The design summary for geomembrane-lined letdowns and pipe letdowns is provided on Sheet IIIF-F-12.

ROYAL OAKS LANDFILL
0120-076-11-106
CHUTE ANALYSIS

Required: Analyze chutes to determine chute sizes for drainage areas that range from 1.81 acres to 32.4 acres.

Method:

1. Determine the 25-year, 24-hour flow rates for various sizes of chute drainage areas using the Rational Method.

Reference:

1. State of Texas, Department of Transportation, Bridge Division, Hydraulic Manual, September 2019.
2. National Oceanic and Atmospheric Administration's Atlas 14 Point Precipitation Frequency Estimates.

Solution:

1. Determine the 25-year intensity flow rates.

$$Q = CIA$$

Where:
C= 0.7 (runoff coefficient, Ref 1.)
I = intensity in/hr
A= drainage area, ac

From Ref. 2, for
25-year storm event

t_c is assumed to be 10 min.

I = 8.59 in/hr

Area (ac)	Flow (cfs)
5.00	30.1
10.0	60.1
15.0	90.2
20.0	120.3
25.0	150.3
30.0	180.4

2. Demonstrate that the normal depth of flow for the maximum 25-year flow rate will be contained within the chute.

Please refer to Page IIIF-F-2-3 for chute hydraulic analysis output.

Prep By: VG
Date: 5/9/2024

Chkd By: BPY/CRM
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
EROSION CONTROL STRUCTURE DESIGN
GEOMEMBRANE-LINED CHUTE

Uniform flow design for the geomembrane-lined chutes on 4% slope.

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
30.1	0.04	0.01	2	2	8	0.29	12.26	4.170	2.33	2.62	2.46	9.15
60.1	0.04	0.01	2	2	8	0.43	15.76	4.435	3.86	4.29	3.81	9.72
90.2	0.04	0.01	2	2	8	0.55	18.15	4.581	5.12	5.67	4.97	10.19
120.3	0.04	0.01	2	2	8	0.65	20.02	4.684	6.23	6.87	6.01	10.59
150.3	0.04	0.01	2	2	8	0.74	21.56	4.764	7.23	7.96	6.97	10.94
180.4	0.04	0.01	2	2	8	0.82	22.90	4.829	8.15	8.97	7.88	11.27

Uniform flow design for the geomembrane-lined chutes on 25% slope.

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
30.1	0.25	0.01	2	2	8	0.17	21.85	9.659	7.42	7.58	1.38	8.66
60.1	0.25	0.01	2	2	8	0.25	28.21	10.221	12.36	12.61	2.13	9.00
90.2	0.25	0.01	2	2	8	0.32	32.74	10.592	16.16	16.98	2.75	9.28
120.3	0.25	0.01	2	2	8	0.38	36.33	10.856	20.51	20.89	3.31	9.51
150.3	0.25	0.01	2	2	8	0.43	39.40	11.088	24.12	24.55	3.82	9.72
180.4	0.25	0.01	2	2	8	0.48	42.00	11.252	27.41	27.89	4.30	9.92

Conclusions: Maximum normal depth is 0.82 feet. Chute design depth is 2.0 feet; therefore, design is acceptable.

1. Calculations were performed using the HYDROCALC Hydraulics for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010).

Prep By: VG
Date: 5/9/2024

Chkd By:BPY/CRM
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
EROSION CONTROL STRUCTURE DESIGN
GABION, TURF REINFORCEMENT MAT, ROCK RIPRAP, OR CONCRETE GROUTED RIPRAP-LINED CHUTE

Chute flow design for the gabion and rock riprap-lined chutes on 4% slope.

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
30.1	0.04	0.04	2	2	8	0.65	5.01	1.171	0.39	1.04	6.01	10.59
60.1	0.04	0.04	2	2	8	0.96	6.28	1.233	0.61	1.58	9.56	11.85
90.2	0.04	0.04	2	2	8	1.21	7.14	1.268	0.79	2.00	12.64	12.85
120.3	0.04	0.04	2	2	8	1.42	7.79	1.294	0.94	2.37	15.44	13.69
150.3	0.04	0.04	2	2	8	1.61	8.33	1.313	1.08	2.69	18.05	14.40
180.4	0.04	0.04	2	2	8	1.78	8.79	1.329	1.20	2.98	20.53	15.11

Chute flow design for the gabion and rock riprap-lined chutes on 25% slope.

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
30.1	0.25	0.04	2	2	8	0.38	9.09	2.714	1.28	1.66	3.31	9.51
60.1	0.25	0.04	2	2	8	0.57	11.60	2.887	2.09	2.66	5.18	10.27
90.2	0.25	0.04	2	2	8	0.72	13.30	2.968	2.75	3.47	6.78	10.88
120.3	0.25	0.04	2	2	8	0.85	14.62	3.032	3.32	4.17	8.23	11.39
150.3	0.25	0.04	2	2	8	0.96	15.71	3.083	3.84	4.80	9.57	11.85
180.4	0.25	0.04	2	2	8	1.07	16.63	3.119	4.30	5.37	10.85	12.28

Conclusions: Maximum calculated normal depth is 1.78 feet, resulting from a peak flow from 30 acres. Chute design depth is 2.0 feet; therefore, 30.0 acres is the maximum allowable drainage area for a gabion or rock rip-rap lined chute.

Maximum velocity is 16.63 fps. As noted in footnote No. 2 below, the lining material will be selected so that the permissible velocity is not exceeded for erosion control.

1. Calculations were performed using the HYDROCALC Hydraulics for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010).
2. Permissible velocities are listed below, and lining material will be selected so that these are not exceeded.

Description	Permissible Velocity (fps)
Turf Reinforcement Mat (based on Pyramat or equivalent. Refer to Sheet IIIF-F-2-19.)	25
Rock Riprap (based on Sheet IIIF-F-2-20 and a D_{50} of 12 inches. If other riprap is used, it will meet the D_{50} requirements listed on Sheet IIIF-F-2-21.)	9
Gabion/Concrete Grouted Riprap (based on Sheet IIIF-F-2-21 and a D_{50} of 1 ft. If other gabion is used, it will meet the D_{50} requirements listed on Sheet IIIF-F-2-21. (The permissible velocity for concrete grouted riprap will actually be greater than 21 fps because it is classified as a rigid channel lining material.)	21

ROYAL OAKS LANDFILL
0120-076-11-106
EROSION CONTROL STRUCTURE DESIGN
GABION, TURF REINFORCEMENT MAT, ROCK RIPRAP, OR CONCRETE GROUTED RIPRAP-LINED CHUTE

Chute flow design for the concrete grouted riprap and turf reinforcement-lined chutes on 4% slope.

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
30.1	0.04	0.03	2	2	8	0.55	6.05	1.527	0.57	1.12	4.97	10.19
60.1	0.04	0.03	2	2	8	0.82	7.63	1.609	0.91	1.72	7.88	11.27
90.2	0.04	0.03	2	2	8	1.03	8.69	1.657	1.17	2.21	10.38	12.12
120.3	0.04	0.03	2	2	8	1.21	9.52	1.691	1.41	2.62	12.64	12.85
150.3	0.04	0.03	2	2	8	1.37	10.19	1.717	1.61	2.99	14.76	13.49
180.4	0.04	0.03	2	2	8	1.52	10.76	1.738	1.80	3.32	16.76	14.07

Chute flow design for the concrete grouted riprap and turf reinforcement-lined chutes on 25% slope.

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	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
30.1	0.25	0.03	2	2	8	0.32	10.92	3.531	1.85	2.17	2.76	9.28
60.1	0.25	0.03	2	2	8	0.48	14.00	3.750	3.04	3.52	4.29	9.92
90.2	0.25	0.03	2	2	8	0.61	16.10	3.872	4.03	4.63	5.60	10.43
120.3	0.25	0.03	2	2	8	0.72	17.73	3.958	4.89	5.60	6.78	10.88
150.3	0.25	0.03	2	2	8	0.82	19.08	4.024	5.66	6.48	7.88	11.27
180.4	0.25	0.03	2	2	8	0.91	20.25	4.078	6.37	7.28	8.91	11.63

Conclusions: Maximum calculated normal depth is 1.52 feet, resulting from a peak flow from 30 acres. Chute design depth is 2.0 feet; therefore, 30.0 acres is the maximum allowable drainage area for a grouted riprap or turf reinforcement mat-lined chute.

Maximum velocity is 20.25 fps. As noted in footnote No. 2 below, the lining material will be selected so that the permissible velocity is not exceeded for erosion control.

1. Calculations were performed using the HYDROCALC Hydraulics for Windows program developed by Dodson and Associates (Version 2.01, 1996-2010).
2. Permissible velocities are listed below, and lining material will be selected so that these are not exceeded.

Description	Permissible Velocity (fps)
Turf Reinforcement Mat (based on Pyramat or equivalent. Refer to Sheet IIIF-F-2-19.)	25
Rock Riprap (based on Sheet IIIF-F-2-20 and a D_{50} of 12 inches. If other riprap is used, it will meet the D_{50} requirements listed on Sheet IIIF-F-2-21.)	9
Gabion/Concrete Grouted Riprap (based on Sheet IIIF-F-2-21 and a D_{50} of 1 ft. If other gabion is used, it will meet the D_{50} requirements listed on Sheet IIIF-F-2-21. (The permissible velocity for concrete grouted riprap will actually be greater than 21 fps because it is classified as a rigid channel lining material.)	21

Prep by: VG
Date: 5/9/2024

Chkd by: BPY/CRM
Date: 5/9/2024

ROYAL OAKS LANDFILL
0120-076-11-106
OPEN CHANNEL LETDOWN
RIPRAP EROSION PROTECTION DESIGN

Required: Design the riprap erosion protection at the downstream end of the open channel letdown.

Method: Use HEC-RAS to model the open channel geomembrane-lined letdown to determine the hydraulic characteristics of the hydraulic jump that will occur at the downstream end of the letdown. Based on the results, design the riprap erosion protection area.

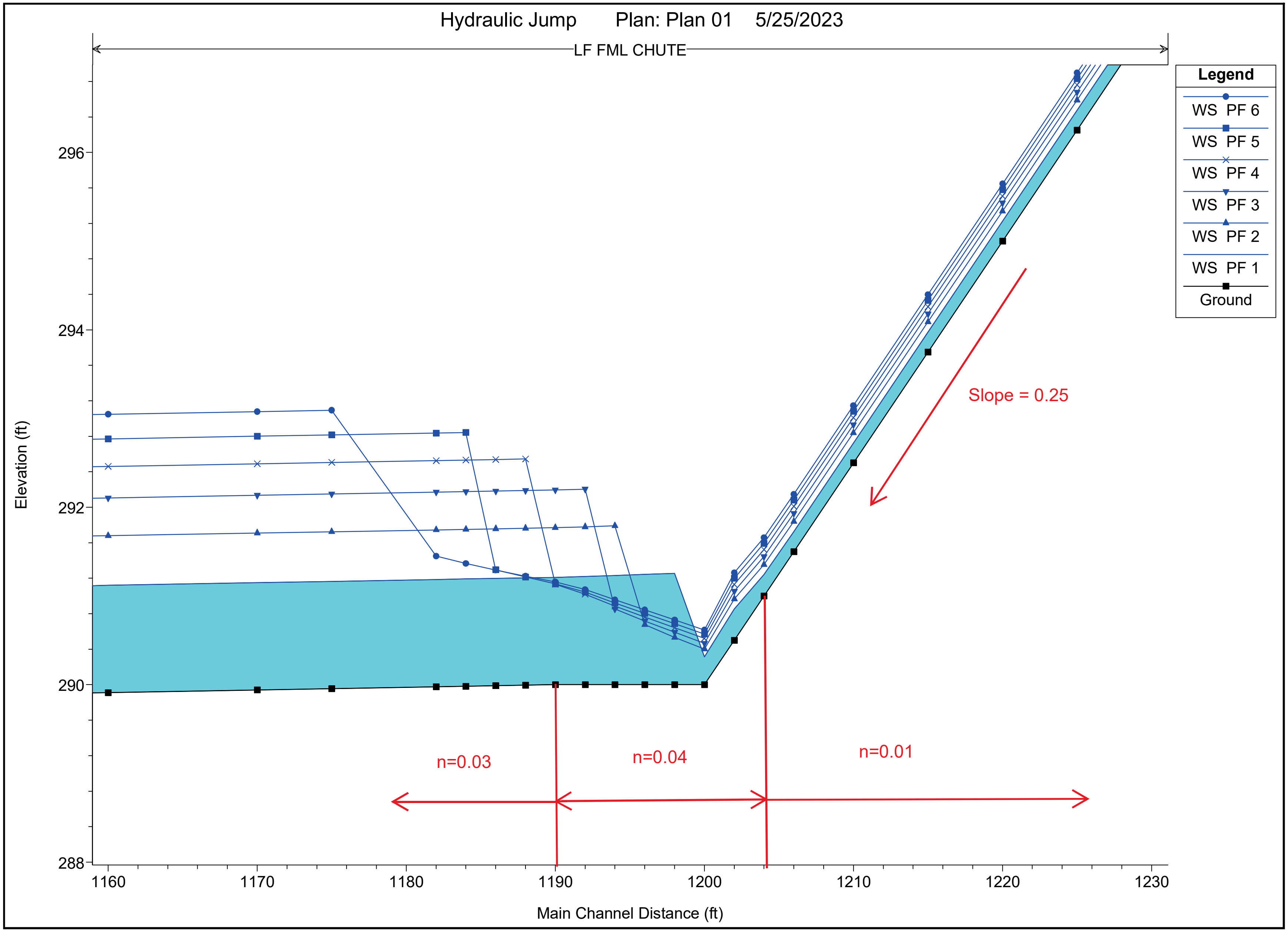
Note: This example calculation is shown for geomembrane-lined letdowns to conservatively estimate the length of riprap needed. As seen on pages IIIF-F-2-3 through IIIF-F-2-5, the geomembrane-lined letdowns have the highest velocities and represent the worst-case scenario. Therefore, this riprap design is applicable to all lined letdowns.

Solution: Page IIIF-F-2-7 shows the water surface profile for incremental flows up to 300 cfs for the geomembrane letdown into a channel, as modeled in HEC-RAS. The modeling output is presented on pages IIIF-F-2-8 through IIIF-F-2-18. The following table summarizes the erosion protection design for the various flows.

Flow (cfs)	Drainage Area* (ac)	Length of Hydraulic Jump (ft)	Specified Runout of Riprap (ft)
50	8	2	10
100	17	6	10
150	25	8	10
200	33	10	10
250	42	16	16
300	50	25	25

* Drainage areas are approximated based on corresponding flows/drainage areas listed on page IIIF-F-2-2.

The values listed in the above table are specified riprap lengths for letdowns terminating into a perimeter channel. If the letdown terminates into a pond, 10 feet of riprap erosion control will be sufficient because the water in the pond will provide additional energy dissipation.


Hydraulic Jump Plan: Plan 01 5/25/2023
LF FML CHUTE
Legend
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
296
294
292
290
288
1160
1170
1180
1190
1200
1210
1220
1230
Main Channel Distance (ft)
Slope = 0.25
n=0.03
n=0.04
n=0.01

```
                  HEC-RAS HEC-RAS 6.3.1 September 2022
                    U.S. Army Corps of Engineers
                   Hydrologic Engineering Center
                          609 Second Street
                          Davis, California


      X     X  XXXXXX   XXXX        XXXX      XX      XXXX
      X     X  X       X    X       X   X    X  X    X
      X     X  X       X            X   X   X    X   X
      XXXXXXX  XXXX    X       XXX  XXXX    XXXXXX    XXXX
      X     X  X       X            X  X    X    X        X
      X     X  X       X    X       X   X   X    X        X
      X     X  XXXXXX   XXXX        X    X  X    X   XXXXX




PROJECT DATA
Project Title: Hydraulic Jump
Project File : HydraulicJump.prj
Run Date and Time: 5/25/2023 1:44:08 PM

Project in English units



PLAN DATA

Plan Title: Plan 01
Plan File : p:\Solid waste\Allied\Royal Oaks\Expansion 2022\Part III\IIIF\IIIF-F\HEC-RAS\HydraulicJump.p01

           Geometry Title: FML CHUTE with 4' RUNUP .003
           Geometry File : p:\Solid waste\Allied\Royal Oaks\Expansion 2022\Part III\IIIF\IIIF-F\HEC-RAS\HydraulicJump.g01

           Flow Title     : FML CHUTE 0.3%
           Flow File      : p:\Solid waste\Allied\Royal Oaks\Expansion 2022\Part III\IIIF\IIIF-F\HEC-RAS\HydraulicJump.f01

Plan Summary Information:
Number of:  Cross Sections =   36     Multiple Openings  =     0
            Culverts       =    0     Inline Structures  =     0
            Bridges        =    0     Lateral Structures =     0

Computational Information
    Water surface calculation tolerance   =  0.01
    Critical depth calculation tolerance  =  0.01
    Maximum number of iterations          =  20
    Maximum difference tolerance          =  0.3
    Flow tolerance factor                 =  0.001

Computation Options
    Critical depth computed only where necessary
    Conveyance Calculation Method: At breaks in n values only
    Friction Slope Method:         Average Conveyance
    Computational Flow Regime:     Mixed Flow



FLOW DATA

Flow Title: FML CHUTE 0.3%
Flow File : p:\Solid waste\Allied\Royal Oaks\Expansion 2022\Part III\IIIF\IIIF-F\HEC-RAS\HydraulicJump.f01

Flow Data (cfs)

  River           Reach           RS                    PF 1           PF 2            PF 3            PF 4           PF 5            PF 6
  LF              FML CHUTE       5000                    50            100             150             200            250             300


Boundary Conditions

  River           Reach           Profile                    Upstream                 Downstream

  LF              FML CHUTE       PF 1                      Normal S = 0.25         Normal S = 0.003
  LF              FML CHUTE       PF 2                      Normal S = 0.25         Normal S = 0.003
  LF              FML CHUTE       PF 3                      Normal S = 0.25         Normal S = 0.003
  LF              FML CHUTE       PF 4                      Normal S = 0.25         Normal S = 0.003
  LF              FML CHUTE       PF 5                      Normal S = 0.25         Normal S = 0.003
  LF              FML CHUTE       PF 6                      Normal S = 0.25         Normal S = 0.003



GEOMETRY DATA

Geometry Title: FML CHUTE with 4' RUNUP .003
Geometry File : p:\Solid waste\Allied\Royal Oaks\Expansion 2022\Part III\IIIF\IIIF-F\HEC-RAS\HydraulicJump.g01

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 5000

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     500       20     490       28      490       48      500

Manning's n Values         num=        3
     Sta   n Val      Sta    n Val      Sta    n Val
       0     .01        0     .01       48      .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48               100     100     100              .1       .5

CROSS SECTION
```

```
RIVER: LF
REACH: FML CHUTE           RS: 4900

INPUT
Description:
Station Elevation Data     num=       4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     475       20     465       28      465       48      475


Manning's n Values         num=       3
      Sta   n Val      Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48               100     100     100              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4800

INPUT
Description:
Station Elevation Data     num=       4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     450       20     440       28      440       48      450

Manning's n Values         num=       3
     Sta  n Val       Sta   n Val      Sta    n Val
       0     .01        0     .01       48     .01

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48               100     100     100              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4700

INPUT
Description:
Station Elevation Data     num=       4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     425       20     415       28      415       48      425

Manning's n Values         num=       3
     Sta  n Val       Sta   n Val      Sta    n Val
       0     .01        0     .01       48     .01

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48               100     100     100              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4600

INPUT
Description:
Station Elevation Data     num=       4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     400       20     390       28      390       48      400

Manning's n Values         num=       3
      Sta   n Val      Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48               100     100     100              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4500

INPUT
Description:
Station Elevation Data     num=       4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     375       20     365       28      365       48      375

Manning's n Values         num=       3
     Sta  n Val       Sta   n Val      Sta    n Val
       0     .01        0     .01       48     .01

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48               100     100     100              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4400

INPUT
Description:
Station Elevation Data     num=       4
     Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
       0     350       20     340       28      340       48      350

 Manning's n Values         num=       3
      Sta   n Val      Sta   n Val      Sta    n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
            0      48               100     100     100              .1       .5
```

```
CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4300

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
       0     325       20     315       28     315       48     325

Manning's n Values         num=        3
     Sta  n Val       Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                75      75      75              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4225

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
       0  306.25       20  296.25       28  296.25       48  306.25

Manning's n Values         num=        3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 5       5       5              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4220

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
       0     305       20     295       28     295       48     305

Manning's n Values         num=        3
     Sta  n Val       Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 5       5       5              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4215

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
       0  303.75       20  293.75       28  293.75       48  303.75

Manning's n Values         num=        3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 5       5       5              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4210

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
       0   302.5       20   292.5       28   292.5       48   302.5

Manning's n Values         num=        3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 4       4       4              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4206

INPUT
Description:
Station Elevation Data     num=        4
     Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
       0   301.5       20   291.5       28   291.5       48   301.5

Manning's n Values         num=        3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .01        0     .01       48     .01
```

```
 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 2       2       2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4204

INPUT
Description:
Station Elevation Data     num=       4
      Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
        0     301       20     291       28      291       48      301

Manning's n Values         num=       3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .04        0     .04       48     .04

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 2       2       2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4202

INPUT
Description:
Station Elevation Data     num=       4
      Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
        0   300.5       20   290.5       28    290.5       48    300.5

Manning's n Values         num=       3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .04        0     .04       48     .04

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      48                 2       2       2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4200

INPUT
Description:
Station Elevation Data     num=       4
      Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
        0     300       30     290       42      290       72      300

Manning's n Values         num=       3
      Sta  n Val       Sta   n Val      Sta   n Val
        0     .04        0     .04       72     .04

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      72                 2       2       2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4198

INPUT
Description:
Station Elevation Data     num=       4
      Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
        0     300       30     290       42      290       72      300

Manning's n Values         num=       3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .04        0     .04       72     .04

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      72                 2       2       2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4196

INPUT
Description:
Station Elevation Data     num=       4
      Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
        0     300       30     290       42      290       72      300

Manning's n Values         num=       3
      Sta  n Val       Sta   n Val      Sta   n Val
        0     .04        0     .04       72     .04

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0      72                 2       2       2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4194

INPUT
Description:
Station Elevation Data     num=       4
      Sta    Elev      Sta    Elev      Sta     Elev      Sta     Elev
        0     300       30     290       42      290       72      300
```

```
Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .04        0     .04       72     .04

 Bank Sta: Left   Right     Lengths: Left Channel    Right      Coeff Contr.   Expan.
             0      72                  2       2        2              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4192

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0     300       30     290       42     290       72     300

Manning's n Values          num=       3
     Sta  n Val       Sta   n Val      Sta   n Val
       0     .04        0     .04       72     .04

 Bank Sta: Left   Right     Lengths: Left Channel    Right      Coeff Contr.   Expan.
             0      72                  2       2        2              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4190

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0     310       60     290       72     290      132     310

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

  Bank Sta: Left   Right     Lengths: Left Channel    Right     Coeff Contr.   Expan.
              0     132                  2       2        2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4188

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0 309.994       60 289.994       72 289.994      132 309.994

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

  Bank Sta: Left   Right     Lengths: Left Channel    Right     Coeff Contr.   Expan.
              0     132                  2       2        2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4186

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0 309.988       60 289.988       72 289.988      132 309.988

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

  Bank Sta: Left   Right     Lengths: Left Channel    Right     Coeff Contr.   Expan.
              0     132                  2       2        2             .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4184

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0 309.982       60 289.982       72 289.982      132 309.982

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                  2       2       2              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4182

INPUT
Description:
Station Elevation Data     num=        4
```

```
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0 309.976       60 289.976       72 289.976      132 309.976

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                  7       7       7              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4175

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0 309.955       60 289.955       72 289.955      132 309.955

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                  5       5       5              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4170

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.94       60  289.94       72  289.94      132  309.94

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4160

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.91       60  289.91       72  289.91      132  309.91

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4150

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.88       60  289.88       72  289.88      132  309.88

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4140

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.85       60  289.85       72  289.85      132  309.85

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4130
```

```
INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.82       60  289.82       72  289.82      132  309.82

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4120

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.79       60  289.79       72  289.79      132  309.79

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4110

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.76       60  289.76       72  289.76      132  309.76

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                 10      10      10              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4100

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.73       60  289.73       72  289.73      132  309.73

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132                100     100     100              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 4000

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  309.43       60  289.43       72  289.43      132  309.43

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Lengths: Left Channel   Right      Coeff Contr.   Expan.
             0     132               1000    1000    1000              .1       .5

CROSS SECTION


RIVER: LF
REACH: FML CHUTE           RS: 3000

INPUT
Description:
Station Elevation Data     num=        4
      Sta    Elev      Sta    Elev      Sta    Elev      Sta    Elev
        0  306.43       60  286.43       72  286.43      132  306.43

Manning's n Values         num=        3
      Sta   n Val      Sta   n Val      Sta   n Val
        0     .03        0     .03      132     .03

 Bank Sta: Left   Right     Coeff Contr.   Expan.
             0     132              .1       .5

Profile Output Table - Standard Table 1

  Reach         River Sta     Profile   Q Total   Min Ch El   W.S. Elev   Crit W.S.   E.G. Elev   E.G. Slope   Vel Chnl   Flow Area   Top Width   Froude # Chl
```

			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
FML CHUTE	5000	PF 1	50.00	490.00	490.22	490.98	501.00	0.250199	26.33	1.90	8.90	10.05
FML CHUTE	5000	PF 2	100.00	490.00	490.34	491.48	508.29	0.250152	33.98	2.94	9.36	10.68
FML CHUTE	5000	PF 3	150.00	490.00	490.43	491.87	514.43	0.250103	39.30	3.82	9.72	11.06
FML CHUTE	5000	PF 4	200.00	490.00	490.51	492.21	519.88	0.250072	43.47	4.60	10.04	11.32
FML CHUTE	5000	PF 5	250.00	490.00	490.58	492.50	524.85	0.250091	46.96	5.32	10.32	11.53
FML CHUTE	5000	PF 6	300.00	490.00	490.65	492.77	529.44	0.250043	49.96	6.00	10.58	11.69
FML CHUTE	4900	PF 1	50.00	465.00	465.98	465.98	466.39	0.001646	5.14	9.73	11.91	1.00
FML CHUTE	4900	PF 2	100.00	465.00	465.34	466.48	483.28	0.249924	33.97	2.94	9.36	10.68
FML CHUTE	4900	PF 3	150.00	465.00	465.43	466.87	489.42	0.249922	39.29	3.82	9.72	11.05
FML CHUTE	4900	PF 4	200.00	465.00	465.51	467.21	494.87	0.249919	43.46	4.60	10.04	11.32
FML CHUTE	4900	PF 5	250.00	465.00	465.58	467.50	499.83	0.249911	46.95	5.33	10.32	11.52
FML CHUTE	4900	PF 6	300.00	465.00	465.65	467.77	504.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4800	PF 1	50.00	440.00	440.16	440.98	463.50	0.865896	38.76	1.29	8.62	17.66
FML CHUTE	4800	PF 2	100.00	440.00	440.34	441.48	458.28	0.249924	33.97	2.94	9.36	10.68
FML CHUTE	4800	PF 3	150.00	440.00	440.43	441.87	464.42	0.249922	39.29	3.82	9.72	11.05
FML CHUTE	4800	PF 4	200.00	440.00	440.51	442.21	469.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4800	PF 5	250.00	440.00	440.58	442.50	474.83	0.249911	46.95	5.33	10.32	11.52
FML CHUTE	4800	PF 6	300.00	440.00	440.65	442.77	479.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4700	PF 1	50.00	415.00	415.25	415.98	423.64	0.167972	23.23	2.15	9.01	8.38
FML CHUTE	4700	PF 2	100.00	415.00	415.34	416.48	433.28	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4700	PF 3	150.00	415.00	415.43	416.87	439.42	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4700	PF 4	200.00	415.00	415.51	417.21	444.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4700	PF 5	250.00	415.00	415.58	417.50	449.84	0.249956	46.95	5.32	10.32	11.53
FML CHUTE	4700	PF 6	300.00	415.00	415.65	417.77	454.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4600	PF 1	50.00	390.00	390.22	390.98	401.87	0.283401	27.38	1.83	8.87	10.64
FML CHUTE	4600	PF 2	100.00	390.00	390.34	391.48	408.28	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4600	PF 3	150.00	390.00	390.43	391.87	414.42	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4600	PF 4	200.00	390.00	390.51	392.21	419.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4600	PF 5	250.00	390.00	390.58	392.50	424.84	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4600	PF 6	300.00	390.00	390.65	392.77	429.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4500	PF 1	50.00	365.00	365.23	365.98	375.54	0.233381	25.76	1.94	8.92	9.74
FML CHUTE	4500	PF 2	100.00	365.00	365.34	366.48	383.28	0.249924	33.97	2.94	9.36	10.68
FML CHUTE	4500	PF 3	150.00	365.00	365.43	366.87	389.42	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4500	PF 4	200.00	365.00	365.51	367.21	394.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4500	PF 5	250.00	365.00	365.58	367.50	399.84	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4500	PF 6	300.00	365.00	365.65	367.77	404.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4400	PF 1	50.00	340.00	340.22	340.98	351.12	0.254706	26.48	1.89	8.89	10.13
FML CHUTE	4400	PF 2	100.00	340.00	340.34	341.48	358.28	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4400	PF 3	150.00	340.00	340.43	341.87	364.42	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4400	PF 4	200.00	340.00	340.51	342.21	369.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4400	PF 5	250.00	340.00	340.58	342.50	374.84	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4400	PF 6	300.00	340.00	340.65	342.77	379.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4300	PF 1	50.00	315.00	315.23	315.98	325.92	0.247365	26.24	1.91	8.90	10.00
FML CHUTE	4300	PF 2	100.00	315.00	315.34	316.48	333.28	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4300	PF 3	150.00	315.00	315.43	316.87	339.42	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4300	PF 4	200.00	315.00	315.51	317.21	344.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4300	PF 5	250.00	315.00	315.58	317.50	349.84	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4300	PF 6	300.00	315.00	315.65	317.77	354.43	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4225	PF 1	50.00	296.25	296.47	297.23	307.25	0.250314	26.34	1.90	8.90	10.05
FML CHUTE	4225	PF 2	100.00	296.25	296.59	297.73	314.53	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4225	PF 3	150.00	296.25	296.68	298.12	320.67	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4225	PF 4	200.00	296.25	296.76	298.46	326.12	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4225	PF 5	250.00	296.25	296.83	298.75	331.09	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4225	PF 6	300.00	296.25	296.90	299.02	335.68	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4220	PF 1	50.00	295.00	295.22	295.98	306.00	0.250314	26.34	1.90	8.90	10.05
FML CHUTE	4220	PF 2	100.00	295.00	295.34	296.48	313.28	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4220	PF 3	150.00	295.00	295.43	296.87	319.42	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4220	PF 4	200.00	295.00	295.51	297.21	324.87	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4220	PF 5	250.00	295.00	295.58	297.50	329.84	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4220	PF 6	300.00	295.00	295.65	297.77	334.43	0.250003	49.96	6.00	10.58	11.69

FML CHUTE	4215	PF 1	50.00	293.75	293.97	294.73	304.75	0.250314	26.34	1.90	8.90	10.05
FML CHUTE	4215	PF 2	100.00	293.75	294.09	295.23	312.03	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4215	PF 3	150.00	293.75	294.18	295.62	318.17	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4215	PF 4	200.00	293.75	294.26	295.96	323.62	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4215	PF 5	250.00	293.75	294.33	296.25	328.59	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4215	PF 6	300.00	293.75	294.40	296.52	333.18	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4210	PF 1	50.00	292.50	292.72	293.48	303.50	0.250314	26.34	1.90	8.90	10.05
FML CHUTE	4210	PF 2	100.00	292.50	292.84	293.98	310.78	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4210	PF 3	150.00	292.50	292.93	294.37	316.92	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4210	PF 4	200.00	292.50	293.01	294.71	322.37	0.249970	43.47	4.60	10.04	11.32
FML CHUTE	4210	PF 5	250.00	292.50	293.08	295.00	327.34	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4210	PF 6	300.00	292.50	293.15	295.27	331.93	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4206	PF 1	50.00	291.50	291.72	292.48	302.50	0.250314	26.34	1.90	8.90	10.05
FML CHUTE	4206	PF 2	100.00	291.50	291.84	292.98	309.78	0.250000	33.98	2.94	9.36	10.68
FML CHUTE	4206	PF 3	150.00	291.50	291.93	293.37	315.92	0.250042	39.29	3.82	9.72	11.06
FML CHUTE	4206	PF 4	200.00	291.50	292.01	293.71	321.36	0.249766	43.46	4.60	10.04	11.32
FML CHUTE	4206	PF 5	250.00	291.50	292.08	294.00	326.34	0.250046	46.95	5.32	10.32	11.53
FML CHUTE	4206	PF 6	300.00	291.50	292.15	294.27	330.93	0.250003	49.96	6.00	10.58	11.69
FML CHUTE	4204	PF 1	50.00	291.00	291.24	291.98	300.55	3.170161	24.47	2.04	8.96	9.04
FML CHUTE	4204	PF 2	100.00	291.00	291.35	292.48	307.78	3.483114	32.51	3.08	9.41	10.03
FML CHUTE	4204	PF 3	150.00	291.00	291.44	292.87	313.91	3.612651	38.02	3.95	9.78	10.55
FML CHUTE	4204	PF 4	200.00	291.00	291.52	293.21	319.33	3.680324	42.30	4.73	10.09	10.90
FML CHUTE	4204	PF 5	250.00	291.00	291.59	293.50	324.31	3.729965	45.88	5.45	10.37	11.16
FML CHUTE	4204	PF 6	300.00	291.00	291.66	293.77	328.90	3.761742	48.95	6.13	10.63	11.37
FML CHUTE	4202	PF 1	50.00	290.50	290.85	291.48	294.95	0.868746	16.24	3.08	9.41	5.01
FML CHUTE	4202	PF 2	100.00	290.50	290.97	291.98	299.93	1.359147	24.01	4.16	9.86	6.52
FML CHUTE	4202	PF 3	150.00	290.50	291.05	292.37	304.76	1.691206	29.70	5.05	10.22	7.45
FML CHUTE	4202	PF 4	200.00	290.50	291.13	292.71	309.34	1.930498	34.23	5.84	10.52	8.10
FML CHUTE	4202	PF 5	250.00	290.50	291.20	293.00	313.69	2.116497	38.04	6.57	10.80	8.60
FML CHUTE	4202	PF 6	300.00	290.50	291.26	293.27	317.81	2.262648	41.33	7.26	11.05	8.99
FML CHUTE	4200	PF 1	50.00	290.00	290.31	290.76	292.69	0.578378	12.36	4.05	13.88	4.04
FML CHUTE	4200	PF 2	100.00	290.00	290.40	291.17	295.90	0.980860	18.81	5.32	14.42	5.46
FML CHUTE	4200	PF 3	150.00	290.00	290.47	291.48	299.37	1.324084	23.93	6.27	14.81	6.49
FML CHUTE	4200	PF 4	200.00	290.00	290.52	291.75	302.90	1.611426	28.22	7.09	15.13	7.27
FML CHUTE	4200	PF 5	250.00	290.00	290.57	291.99	306.40	1.852150	31.92	7.83	15.43	7.90
FML CHUTE	4200	PF 6	300.00	290.00	290.62	292.21	309.84	2.055611	35.17	8.53	15.70	8.41
FML CHUTE	4198	PF 1	50.00	290.00	291.26	290.76	291.35	0.004674	2.53	19.79	19.53	0.44
FML CHUTE	4198	PF 2	100.00	290.00	290.53	291.17	293.48	0.374126	13.78	7.26	15.20	3.51
FML CHUTE	4198	PF 3	150.00	290.00	290.59	291.48	295.85	0.589871	18.40	8.15	15.55	4.48
FML CHUTE	4198	PF 4	200.00	290.00	290.64	291.75	298.41	0.790326	22.36	8.95	15.85	5.25
FML CHUTE	4198	PF 5	250.00	290.00	290.69	291.99	301.06	0.972850	25.83	9.68	16.13	5.88
FML CHUTE	4198	PF 6	300.00	290.00	290.73	292.21	303.74	1.137985	28.93	10.37	16.38	6.41
FML CHUTE	4196	PF 1	50.00	290.00	291.24		291.35	0.004834	2.56	19.56	19.46	0.45
FML CHUTE	4196	PF 2	100.00	290.00	290.68	291.17	292.39	0.163384	10.50	9.53	16.07	2.40
FML CHUTE	4196	PF 3	150.00	290.00	290.72	291.48	294.10	0.302236	14.76	10.16	16.31	3.30
FML CHUTE	4196	PF 4	200.00	290.00	290.76	291.75	295.99	0.435149	18.35	10.90	16.58	3.99
FML CHUTE	4196	PF 5	250.00	290.00	290.80	291.99	298.03	0.565010	21.56	11.59	16.83	4.58
FML CHUTE	4196	PF 6	300.00	290.00	290.84	292.21	300.14	0.687924	24.46	12.26	17.06	5.09
FML CHUTE	4194	PF 1	50.00	290.00	291.23		291.34	0.005008	2.59	19.32	19.39	0.46
FML CHUTE	4194	PF 2	100.00	290.00	291.79	291.17	291.95	0.005097	3.21	31.12	22.75	0.48
FML CHUTE	4194	PF 3	150.00	290.00	290.86	291.48	293.11	0.164298	12.04	12.45	17.13	2.49
FML CHUTE	4194	PF 4	200.00	290.00	290.89	291.75	294.57	0.257354	15.39	12.99	17.32	3.13
FML CHUTE	4194	PF 5	250.00	290.00	290.92	291.99	296.17	0.350863	18.38	13.61	17.53	3.68
FML CHUTE	4194	PF 6	300.00	290.00	290.96	292.21	297.86	0.442214	21.08	14.23	17.74	4.15
FML CHUTE	4192	PF 1	50.00	290.00	291.22		291.33	0.005189	2.62	19.09	19.31	0.46
FML CHUTE	4192	PF 2	100.00	290.00	291.78		291.94	0.005231	3.24	30.83	22.67	0.49
FML CHUTE	4192	PF 3	150.00	290.00	292.21	291.48	292.41	0.005248	3.65	41.05	25.23	0.51
FML CHUTE	4192	PF 4	200.00	290.00	291.02	291.75	293.65	0.156717	13.02	15.37	18.12	2.49
FML CHUTE	4192	PF 5	250.00	290.00	291.04	291.99	294.94	0.226314	15.84	15.78	18.26	3.00
FML CHUTE	4192	PF 6	300.00	290.00	291.07	292.21	296.33	0.295497	18.39	16.32	18.43	3.45
FML CHUTE	4190	PF 1	50.00	290.00	291.21		291.32	0.002999	2.64	18.91	19.26	0.47
FML CHUTE	4190	PF 2	100.00	290.00	291.77		291.94	0.003001	3.27	30.62	22.62	0.49
FML CHUTE	4190	PF 3	150.00	290.00	292.20		292.41	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4190	PF 4	200.00	290.00	291.13	291.75	293.18	0.060806	11.47	17.44	18.80	2.10
FML CHUTE	4190	PF 5	250.00	290.00	291.14	291.99	294.30	0.093516	14.26	17.53	18.83	2.60
FML CHUTE	4190	PF 6	300.00	290.00	291.16	292.21	295.50	0.125916	16.72	17.94	18.95	3.03

FML CHUTE	4188	PF 1	50.00	289.99	291.20		291.31	0.002999	2.64	18.91	19.26	0.47
FML CHUTE	4188	PF 2	100.00	289.99	291.76		291.93	0.003001	3.27	30.62	22.62	0.49
FML CHUTE	4188	PF 3	150.00	289.99	292.19		292.40	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4188	PF 4	200.00	289.99	292.54	291.75	292.79	0.003004	3.99	50.13	27.30	0.52
FML CHUTE	4188	PF 5	250.00	289.99	291.21	291.99	293.88	0.072799	13.09	19.10	19.32	2.32
FML CHUTE	4188	PF 6	300.00	289.99	291.22	292.21	294.98	0.101908	15.55	19.29	19.38	2.75
FML CHUTE	4186	PF 1	50.00	289.99	291.20		291.31	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4186	PF 2	100.00	289.99	291.76		291.92	0.003001	3.27	30.62	22.62	0.49
FML CHUTE	4186	PF 3	150.00	289.99	292.18		292.39	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4186	PF 4	200.00	289.99	292.54		292.79	0.003004	3.99	50.13	27.30	0.52
FML CHUTE	4186	PF 5	250.00	289.99	291.30	291.98	293.54	0.056683	12.01	20.82	19.85	2.07
FML CHUTE	4186	PF 6	300.00	289.99	291.29	292.20	294.55	0.082769	14.48	20.72	19.82	2.50
FML CHUTE	4184	PF 1	50.00	289.98	291.19		291.30	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4184	PF 2	100.00	289.98	291.75		291.92	0.003001	3.27	30.62	22.62	0.49
FML CHUTE	4184	PF 3	150.00	289.98	292.18		292.39	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4184	PF 4	200.00	289.98	292.53		292.78	0.003004	3.99	50.13	27.30	0.52
FML CHUTE	4184	PF 5	250.00	289.98	292.84	291.98	293.12	0.003003	4.25	58.88	29.16	0.53
FML CHUTE	4184	PF 6	300.00	289.98	291.37	292.19	294.16	0.066438	13.42	22.36	20.31	2.25
FML CHUTE	4182	PF 1	50.00	289.98	291.19		291.29	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4182	PF 2	100.00	289.98	291.75		291.91	0.003001	3.27	30.62	22.61	0.49
FML CHUTE	4182	PF 3	150.00	289.98	292.17		292.38	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4182	PF 4	200.00	289.98	292.53		292.77	0.003004	3.99	50.12	27.30	0.52
FML CHUTE	4182	PF 5	250.00	289.98	292.84		293.12	0.003003	4.25	58.88	29.16	0.53
FML CHUTE	4182	PF 6	300.00	289.98	291.45	292.19	293.84	0.053073	12.41	24.17	20.83	2.03
FML CHUTE	4175	PF 1	50.00	289.96	291.16		291.27	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4175	PF 2	100.00	289.96	291.72		291.89	0.003001	3.27	30.62	22.62	0.49
FML CHUTE	4175	PF 3	150.00	289.96	292.15		292.36	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4175	PF 4	200.00	289.96	292.51		292.75	0.003004	3.99	50.12	27.30	0.52
FML CHUTE	4175	PF 5	250.00	289.96	292.82		293.10	0.003003	4.25	58.88	29.16	0.53
FML CHUTE	4175	PF 6	300.00	289.96	293.09	292.17	293.40	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4170	PF 1	50.00	289.94	291.15		291.26	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4170	PF 2	100.00	289.94	291.71		291.87	0.003001	3.27	30.62	22.61	0.49
FML CHUTE	4170	PF 3	150.00	289.94	292.14		292.35	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4170	PF 4	200.00	289.94	292.49		292.74	0.003005	3.99	50.12	27.30	0.52
FML CHUTE	4170	PF 5	250.00	289.94	292.80		293.08	0.003003	4.25	58.88	29.16	0.53
FML CHUTE	4170	PF 6	300.00	289.94	293.08		293.39	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4160	PF 1	50.00	289.91	291.12		291.23	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4160	PF 2	100.00	289.91	291.68		291.84	0.003002	3.27	30.62	22.61	0.49
FML CHUTE	4160	PF 3	150.00	289.91	292.11		292.32	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4160	PF 4	200.00	289.91	292.46		292.71	0.003005	3.99	50.12	27.30	0.52
FML CHUTE	4160	PF 5	250.00	289.91	292.77		293.05	0.003003	4.25	58.88	29.16	0.53
FML CHUTE	4160	PF 6	300.00	289.91	293.05		293.36	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4150	PF 1	50.00	289.88	291.09		291.20	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4150	PF 2	100.00	289.88	291.65		291.81	0.003002	3.27	30.62	22.61	0.49
FML CHUTE	4150	PF 3	150.00	289.88	292.08		292.29	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4150	PF 4	200.00	289.88	292.43		292.68	0.003005	3.99	50.12	27.30	0.52
FML CHUTE	4150	PF 5	250.00	289.88	292.74		293.02	0.003003	4.25	58.88	29.16	0.53
FML CHUTE	4150	PF 6	300.00	289.88	293.02		293.33	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4140	PF 1	50.00	289.85	291.06		291.17	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4140	PF 2	100.00	289.85	291.62		291.78	0.003002	3.27	30.62	22.61	0.49
FML CHUTE	4140	PF 3	150.00	289.85	292.05		292.26	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4140	PF 4	200.00	289.85	292.40		292.65	0.003006	3.99	50.12	27.30	0.52
FML CHUTE	4140	PF 5	250.00	289.85	292.71		292.99	0.003004	4.25	58.87	29.16	0.53
FML CHUTE	4140	PF 6	300.00	289.85	292.99		293.30	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4130	PF 1	50.00	289.82	291.03		291.14	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4130	PF 2	100.00	289.82	291.59		291.75	0.003002	3.27	30.62	22.61	0.49
FML CHUTE	4130	PF 3	150.00	289.82	292.02		292.23	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4130	PF 4	200.00	289.82	292.37		292.62	0.003006	3.99	50.11	27.30	0.52
FML CHUTE	4130	PF 5	250.00	289.82	292.68		292.96	0.003004	4.25	58.87	29.16	0.53
FML CHUTE	4130	PF 6	300.00	289.82	292.96		293.27	0.003000	4.46	67.21	30.83	0.53

FML CHUTE	4120	PF 1	50.00	289.79	291.00		291.11	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4120	PF 2	100.00	289.79	291.56		291.72	0.003003	3.27	30.61	22.61	0.49
FML CHUTE	4120	PF 3	150.00	289.79	291.99		292.20	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4120	PF 4	200.00	289.79	292.34		292.59	0.003006	3.99	50.11	27.30	0.52
FML CHUTE	4120	PF 5	250.00	289.79	292.65		292.93	0.003004	4.25	58.87	29.16	0.53
FML CHUTE	4120	PF 6	300.00	289.79	292.93		293.24	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4110	PF 1	50.00	289.76	290.97		291.08	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4110	PF 2	100.00	289.76	291.53		291.69	0.003003	3.27	30.61	22.61	0.49
FML CHUTE	4110	PF 3	150.00	289.76	291.96		292.17	0.003001	3.68	40.81	25.17	0.51
FML CHUTE	4110	PF 4	200.00	289.76	292.31		292.56	0.003007	3.99	50.11	27.30	0.52
FML CHUTE	4110	PF 5	250.00	289.76	292.62		292.90	0.003004	4.25	58.87	29.16	0.53
FML CHUTE	4110	PF 6	300.00	289.76	292.90		293.21	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4100	PF 1	50.00	289.73	290.94		291.05	0.003000	2.64	18.91	19.26	0.47
FML CHUTE	4100	PF 2	100.00	289.73	291.50		291.66	0.003003	3.27	30.61	22.61	0.49
FML CHUTE	4100	PF 3	150.00	289.73	291.93		292.14	0.003002	3.68	40.81	25.17	0.51
FML CHUTE	4100	PF 4	200.00	289.73	292.28		292.53	0.003007	3.99	50.11	27.30	0.52
FML CHUTE	4100	PF 5	250.00	289.73	292.59		292.87	0.003004	4.25	58.87	29.16	0.53
FML CHUTE	4100	PF 6	300.00	289.73	292.87		293.18	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	4000	PF 1	50.00	289.43	290.64		290.75	0.002994	2.64	18.92	19.26	0.47
FML CHUTE	4000	PF 2	100.00	289.43	291.20	290.60	291.36	0.003008	3.27	30.60	22.61	0.50
FML CHUTE	4000	PF 3	150.00	289.43	291.63	290.91	291.84	0.003003	3.68	40.80	25.17	0.51
FML CHUTE	4000	PF 4	200.00	289.43	291.98	291.18	292.23	0.003013	3.99	50.07	27.29	0.52
FML CHUTE	4000	PF 5	250.00	289.43	292.29		292.57	0.003007	4.25	58.85	29.16	0.53
FML CHUTE	4000	PF 6	300.00	289.43	292.57		292.88	0.003000	4.46	67.21	30.83	0.53
FML CHUTE	3000	PF 1	50.00	286.43	287.64	287.19	287.75	0.003001	2.64	18.91	19.26	0.47
FML CHUTE	3000	PF 2	100.00	286.43	288.20	287.60	288.36	0.003002	3.27	30.62	22.61	0.49
FML CHUTE	3000	PF 3	150.00	286.43	288.63	287.91	288.84	0.003004	3.68	40.80	25.17	0.51
FML CHUTE	3000	PF 4	200.00	286.43	288.98	288.18	289.23	0.003001	3.99	50.14	27.31	0.52
FML CHUTE	3000	PF 5	250.00	286.43	289.29	288.42	289.57	0.003000	4.24	58.90	29.17	0.53
FML CHUTE	3000	PF 6	300.00	286.43	289.57	288.64	289.88	0.003004	4.47	67.18	30.82	0.53

PROPEX
GEOSYNTHETICS

Pyramat® Turf Reinforcement Mat
Technical Data Sheet

Roll Sizes - 8.5 ft x 90 ft, 85 sq yd (2.6m x 27.4m, 8.44 sq m)

PYRAMAT high performance turf reinforcement mat (HPTRM) is a three-dimensional, lofty, woven polypropylene geotextile that is available in green or tan which is specially designed for erosion control applications on steep slopes and vegetated waterways. The matrix is composed of polypropylene monofilament yarns featuring X3® technology woven into a uniform configuration of resilient pyramid-like projections. The material exhibits very high interlock and reinforcement capacity with both soil and root systems, demonstrates superior UV resistance, and enhances seedling emergence.

PYRAMAT conforms to the property values listed below[1] and is manufactured at a Propex facility having achieved ISO 9001:2000 certification. Propex performs internal Manufacturing Quality Control (MQC) tests that have been accredited by the Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP).

PRODUCT TEST DATA		
Property	Test Method	MARV[2]
Physical		
Mass Per Unit Area	ASTM D-6566	13.5 oz sq yd (455 g sq m)
Thickness	ASTM D-6525	.4 in (10.2 mm)
Light Penetration (% Passing)	ASTM D-6567	10% (10%)
Color	Visual	Green, Tan
Mechanical		
Tensile Strength (Grab)	ASTM D-6818	4000 x 3000 lbs/ft (58.4 x 43.8 kN/m)
Elongation	ASTM D-6818	65% max (65% max)
Resiliency	ASTM D-6524	80% (80%)
Flexibility	ASTM D-6575	.534 in/lbs (615000 mg-cm) avg
Endurance		
UV Resistance @ 6000 hrs	ASTM D-4355	90% (90%)
Performance		
Velocity[3] (Vegetated)	Large Scale	25 ft/sec (7.6 m/sec)
Shear Stress[3] (Vegetated)	Large Scale	15 lbs sq ft (718 Pa)
Manning's "n"[4] (Unvegetated)	Calculated	.028 (.028)
Seedling Emergence	ECTC Draft Method #4	296% (296%)

NOTES

1. The property values listed are effective 08/2006 and are subject to change without notice.
2. MARV indicates minimum average roll value calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any sample taken during quality assurance testing will exceed the value reported.
3. Maximum permissible velocity and shear stress has been obtained through vegetated testing programs featuring specific soil types, vegetation classes, flow conditions, and failure criteria. These conditions may not be relevant to every project nor are they replicated by other manufacturers. Please contact Propex for further information.
4. Calculated as typical values from large-scale flexible channel lining test programs with a flow depth of 6 to 12 inches.

Distributed by:

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P.O. Box 810 Johnson City, NY 13790
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www.ivlindustries.com

IVI-EC-3442-0407-0147

Type	Thickness m ft	Size mm	d_{50} m ft	velocity m/s ft/sec	velocity m/s ft/sec
Reno mattress	0.15 - 0.17	70 - 100	0.085	3.5	4.2
		70 - 150	0.110	4.2	4.5
	0.23 - 0.25	70 - 100	0.085	3.6	5.5
		70 - 150	0.120	4.5	6.1
	0.30	70 - 120	0.100	4.2	5.5
		100 - 150	0.125	5.0	6.4
Gabions	0.50 1.64	100 - 200	0.150 0.49	5.8 19	7.6 25
		120 - 250	0.190 0.62	6.4 21	8.0 26

Where the revetment has to be placed under water the thickness of the Reno mattress remains the same since it can be launched from a pontoon whereas rip rap has to be increased by 50% [12, 13, 49, 50, 51].

The big reduction in the revetment thickness, which is achieved using Reno mattress instead of rip rap, is of economic significance in protection projects in large rivers, given the same area of work, and, therefore, the quantity of material used.

2.2 Semi permeable and impermeable linings with sand asphalt mastic.

a) General characteristics of sand asphalt mastic grouted Reno mattress.

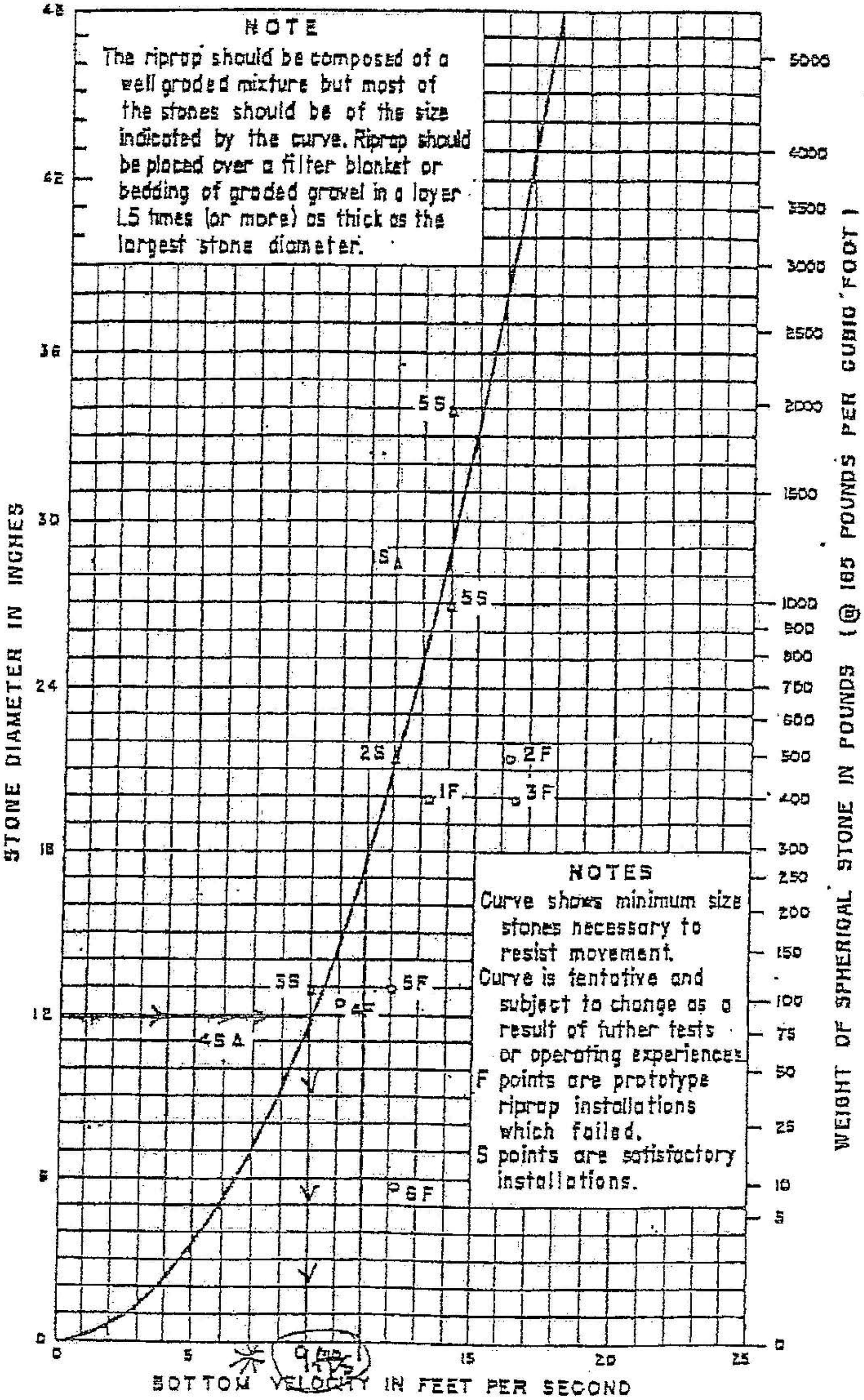
The combination of the stone filled Reno mattress and sand asphalt mastic has the characteristics of both gabion work and asphalt concrete. The addition of bituminous mastic to the Reno mattress produces a structure which combines the properties and performance of both materials. The mattress retains its flexibility, while the density of the filling is increased and therefore the efficiency of the protection. If all the voids between the stones in the layer are filled and the surface of the mattress covered, the lining will be completely impervious. The mastic also protects the wire mesh against corrosion and from abrasion by transported material.

The wire mesh reinforces the grouted stone layer and gives it strength in tension. Hence, the thickness of the combined structure can be considerably less than that of ordinary mastic grouted stone to withstand the same stresses. The resulting saving in bitumen and aggregate, and the increased flexibility due to the reduced thickness, have given rise to extensive use of this type of lining for protection in a variety of waterways.

b) Mix design of sand asphalt mastic.

To avoid excessive detail, only the fundamental data on mix design is given here. For fuller information, reference should be made to the specific publications listed in the bibliography [5, 6].

SIZE OF RIPRAP TO BE USED DOWNSTREAM FROM STILLING BASINS



NOTE

The riprap should be composed of a well graded mixture but most of the stones should be of the size indicated by the curve. Riprap should be placed over a filter blanket or bedding of graded gravel in a layer 1.5 times (or more) as thick as the largest stone diameter.

NOTES

Curve shows minimum size stones necessary to resist movement.

Curve is tentative and subject to change as a result of futher tests or operating experiences.

F points are prototype riprap installations which failed.

S points are satisfactory installations.

FIGURE 165.—Curve to determine maximum stone size in riprap mixture.

SOURCE: HYDRAULIC DESIGN OF STILLING BASINS AND ENERGY DISSIPATORS. US DEPT OF THE INTERIOR - BUREAU OF LAND RECLAMATION, 1964.

ROYAL OAKS LANDFILL
0120-076-11-106
PIPE LETDOWN DESIGN

Required: Determine the maximum drainage area for 18-inch, 24-inch and 36-inch diameter letdown pipes using the BCAP computer program.

Method:

1. Determine the maximum flow for 18-inch, 24-inch and 36-inch diameter letdown pipes on the 25% side slope.
2. Determine the maximum drainage areas for the flows calculated in Step 1.

Reference:

1. State of Texas, Department of Transportation, Bridge Division, Hydraulic Manual, September 2019.
2. National Oceanic and Atmospheric Administration's Atlas 14 Point Precipitation Frequency Estimates.

Note: The pipe letdown analysis has been performed using "Broken-Back" Culvert Analysis Program (BCAP) which is available from the Federal Highway Administration Web Page:

http://www.dor.state.ne.us/roadway-design/ [follow link to downloadable files and info]

The program was developed to analyze culverts with changing slopes.

Solution:

1. Determine the maximum flow for 18-inch, 24-inch and 36-inch diameter letdown pipes on the 25% side slope.

The following pages include the program outputs for the 18-in dia culvert, 24-in dia culvert and 36-in diameter culvert. Pages IIIF-F-2-24 and IIIF-F-2-29 include rating tables that show if the hydraulic jump occurs within the pipe or not [YES/NO]. The results also include pipe outlet velocity for each flow rate as well as the tailwater depth and velocity in the channel ("Tailwater Velocity").

The flow ratings are used to calculate the maximum allowable top dome drainage area for each pipe size analyzed (Step 2). The maximum flow rate that has hydraulic jump within the culvert is used for allowable drainage area calculations on page IIIF-F-2-33. The computer program does not have corrugated plastic pipe option; therefore, the corrugated metal pipe option has been used with a Manning's Coefficient of 0.024.

Results:

Q18 = 15.0 cfs maximum allowable flow in 18-in-dia pipe
Q24 = 17.8 cfs maximum allowable flow in 24-in-dia pipe
Q36 = 30.2 cfs maximum allowable flow in 36-in-dia pipe

```
NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO
Project:                                   Royal Oaks Landfill
Station or Location:
Date:                                           11 / 22 / 2023

DISCHARGE DATA
Minimum:                                              5.00 cfs
Design Discharge:                                    10.00 cfs
Maximum:                                             15.00 cfs
Number of Barrels:                                           1

TAILWATER DATA
Type:                                               Downstream
Channel Shape:                                       Trapezoid
Bottom Slope:                                            ft/ft
Roughness Coefficient:

CULVERT DATA
Type:                                            Circular Pipe
Pipe Diameter:                                          1.5 ft
Culvert Material:                             Corr. Metal Pipe
Inlet Type:                              Mitered to Conform to Slope
Roughness Coefficient:                                   0.024
Outlet Section Roughness Coeff.:                         0.024
Inlet Section Slope:                                0.04 ft/ft
Steep Section Slope:                                0.25 ft/ft
Outlet Section Slope:                                  0 ft/ft

CULVERT PROFILE DATA
Type:                                       Double Broken-Back
Inlet Station:                                         0.00 ft
Inlet Elevation:                                     765.40 ft
Upper Break Station:                                  10.00 ft
Upper Break Elevation:                               765.00 ft
Lower Break Station:                                1170.00 ft
Lower Break Elevation:                               475.00 ft
Outlet Station:                                     1201.00 ft
Outlet Elevation:                                    475.00 ft
```

NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

Project: Royal Oaks Landfill
Station or Location:
Date: 11/22/2023

Discharge cfs	Headwater Depth ft	Inlet Control Elevation ft	Break Control Elevation ft	Critical Depth ft	Outlet Depth ft	Outlet Velocity ft/s	Outlet Froude Number	Tailwater Depth ft	Tailwater Velocity ft/s	Hydraulic Jump
6.0	1.49	766.89	766.60	.93	.93	5.22	1.0	.27	1.07	YES
7.0	1.70	767.10	766.81	1.00	1.00	5.57	1.0	.29	1.16	YES
8.0	1.95	767.35	767.03	1.07	1.07	5.91	1.0	.33	1.16	YES
9.0	2.22	767.62	767.26	1.14	1.14	6.26	1.0	.35	1.22	YES
10.0	2.54	767.94	767.51	1.20	1.20	6.60	1.0	.37	1.28	YES
11.0	2.88	768.28	767.78	1.26	1.26	6.95	1.0	.39	1.33	YES
12.0	3.25	768.65	768.12	1.31	1.31	7.31	1.0	.41	1.38	YES
13.0	3.64	769.04	768.35	1.37	1.37	7.69	1.0	.43	1.42	YES
14.0	4.05	769.46	768.69	1.42	1.42	8.09	1.0	.45	1.46	YES
15.0	4.48	769.88	769.06	1.47	1.47	8.53	1.0	.47	1.49	YES

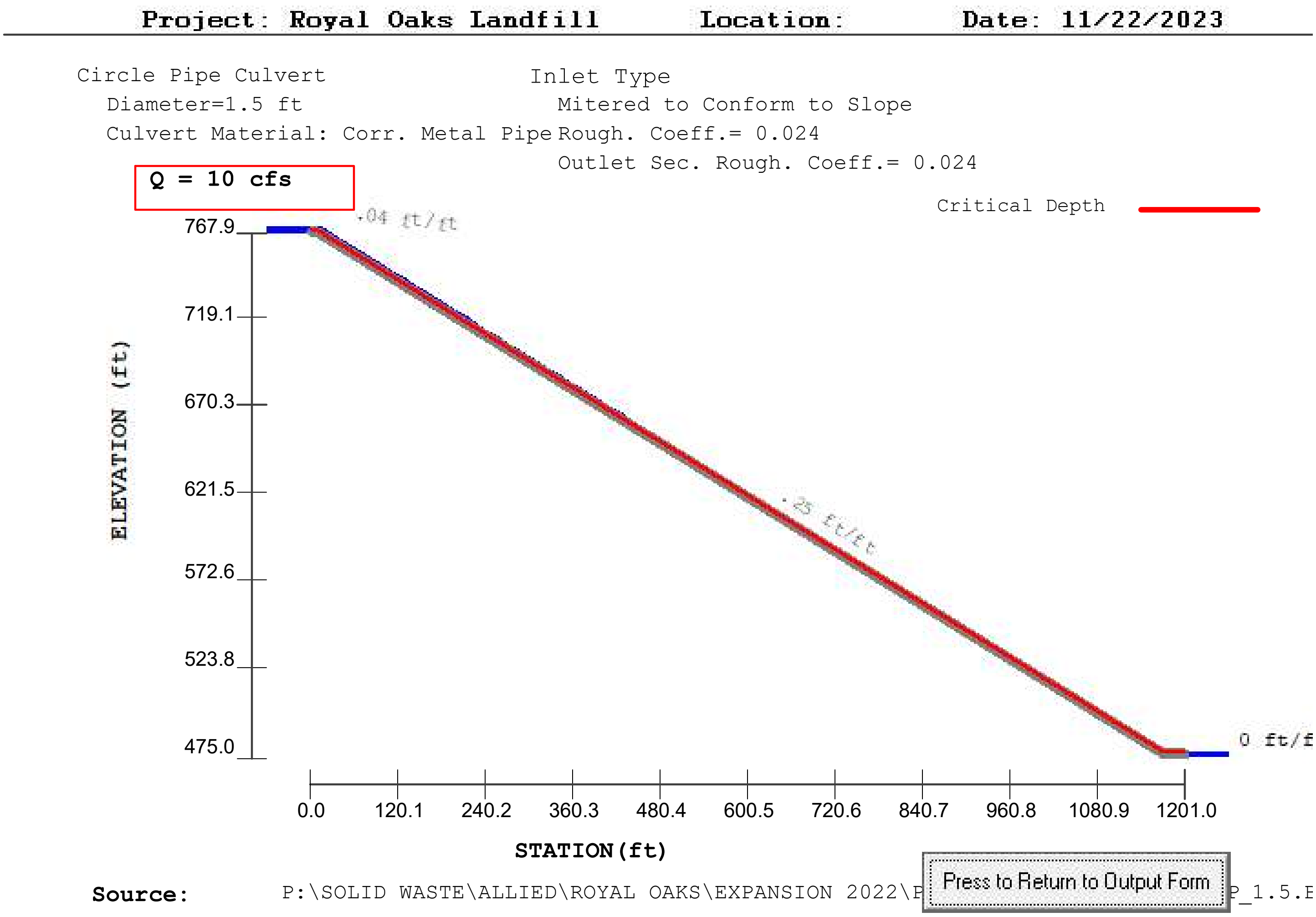
```
NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO
Project:                                           Royal Oaks Landfill
Station or Location:
Date:                                                       11/22/2023

CULVERT DATA
Discharge:                                                    10.0 cfs
Shape:                                                        Circular
Material:                                             Corr. Metal Pipe
Size:                                                1-1.5 ft x 1.5 ft
Inlet Type:                                          Mitered to Conform to Slope

WATER SURFACE PROFILE
Inlet Depth:                                                   1.50 ft
Inlet Velocity:                                              5.66 ft/s
Upper Break Depth:                                             1.20 ft
Upper Break Velocity:                                        6.60 ft/s
Lower Break Depth:                                             0.61 ft
Lower Break Velocity:                                       14.82 ft/s
Depth at End of Hydraulic Jump:                                1.50 ft
Velocity at End of Hydraulic Jump:                           5.66 ft/s
Depth at End of Hydraulic Jump:                                0.37 ft
Velocity at End of Hydraulic Jump:                           1.28 ft/s

OUTPUT DATA
Head Water Depth:                                              2.54 ft
Inlet Control Elevation:                                     767.94 ft
Break Control Elevation:                                     767.51 ft
Critical Depth:                                                1.20 ft
Tailwater Depth:                                               0.37 ft
Hydraulic Jump?                                                    YES
  Jump Station:                                             1183.39 ft
  Jump Length:                                                 9.38 ft
Outlet Depth:                                                  1.20 ft
Outlet Velocity:                                             6.60 ft/s
Outlet Froude No.:                                                 1.0
```



Project: Royal Oaks Landfill **Location:** **Date: 11/22/2023**

Circle Pipe Culvert
Diameter=1.5 ft
Culvert Material: Corr. Metal Pipe

Inlet Type
Mitered to Conform to Slope
Rough. Coeff.= 0.024
Outlet Sec. Rough. Coeff.= 0.024

Q = 10 cfs

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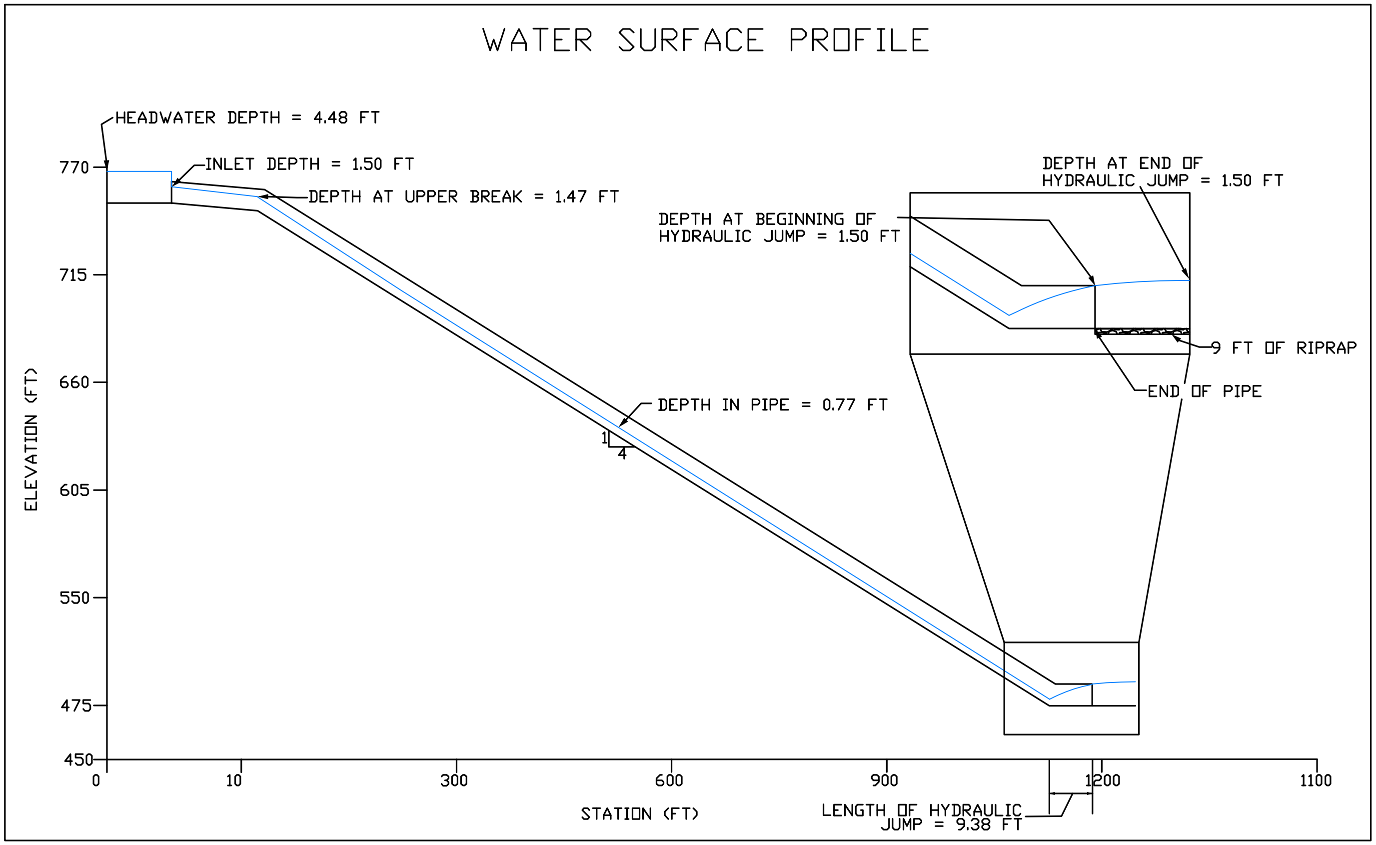

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NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO
Project:                                   Royal Oaks Landfill
Station or Location:
Date:                                           11 / 22 / 2023

DISCHARGE DATA
Minimum:                                              1.00 cfs
Design Discharge:                                    15.00 cfs
Maximum:                                             25.00 cfs
Number of Barrels:                                           1

TAILWATER DATA
Type:                                               Downstream
Channel Shape:                                       Trapezoid
Left Side Slope:                                        3 H:1V
Right Side Slope:                                       3 H:1V
Bottom Width:                                            20 ft
Bottom Slope:                                      0.005 ft/ft
Roughness Coefficient:                                    0.04

CULVERT DATA
Type:                                            Circular Pipe
Pipe Diameter:                                            2 ft
Culvert Material:                             Corr. Metal Pipe
Inlet Type:                              Mitered to Conform to Slope
Roughness Coefficient:                                   0.024
Outlet Section Roughness Coeff.:                         0.024
Inlet Section Slope:                                0.04 ft/ft
Steep Section Slope:                                0.25 ft/ft
Outlet Section Slope:                                  0 ft/ft

CULVERT PROFILE DATA
Type:                                       Double Broken-Back
Inlet Station:                                         0.00 ft
Inlet Elevation:                                     765.40 ft
Upper Break Station:                                  10.00 ft
Upper Break Elevation:                               765.00 ft
Lower Break Station:                                1170.00 ft
Lower Break Elevation:                               475.00 ft
Outlet Station:                                     1201.00 ft
Outlet Elevation:                                    475.00 ft
```

NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

Project: Royal Oaks Landfill
Station or Location:
Date: 11/22/2023

Discharge cfs	Headwater Depth ft	Inlet Control Elevation ft	Break Control Elevation ft	Critical Depth ft	Outlet Depth ft	Outlet Velocity ft/s	Outlet Froude Number	Tailwater Depth ft	Tailwater Velocity ft/s	Hydraulic Jump
3.4	.90	766.30	765.97	.65	.65	3.83	1.0	.19	.87	YES
5.8	1.24	766.64	766.31	.85	.85	4.56	1.0	.27	1.03	YES
8.2	1.51	766.91	766.61	1.01	1.01	5.15	1.0	.33	1.18	YES
10.6	1.78	767.18	766.90	1.15	1.15	5.67	1.0	.37	1.36	YES
15.0	2.36	767.76	767.43	1.37	1.37	6.56	1.0	.47	1.49	YES
15.4	2.43	767.83	767.48	1.39	1.39	6.63	1.0	.47	1.53	YES
17.8	2.84	768.24	767.82	1.49	1.80	5.98	.7	.51	1.62	YES
20.2	3.31	768.71	768.18	1.59	1.89	6.56	.7	.55	1.70	NO
22.6	3.84	769.24	768.56	1.68	2.00	7.19	.7	.59	1.76	NO
25.0	4.43	769.83	768.96	1.77	2.00	7.96	.8	.63	1.81	NO

```
NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO
Project:                                           Royal Oaks Landfill
Station or Location:
Date:                                                       11/22/2023

CULVERT DATA
Discharge:                                                    15.0 cfs
Shape:                                                        Circular
Material:                                             Corr. Metal Pipe
Size:                                                1-2.0 ft x 2.0 ft
Inlet Type:                                          Mitered to Conform to Slope

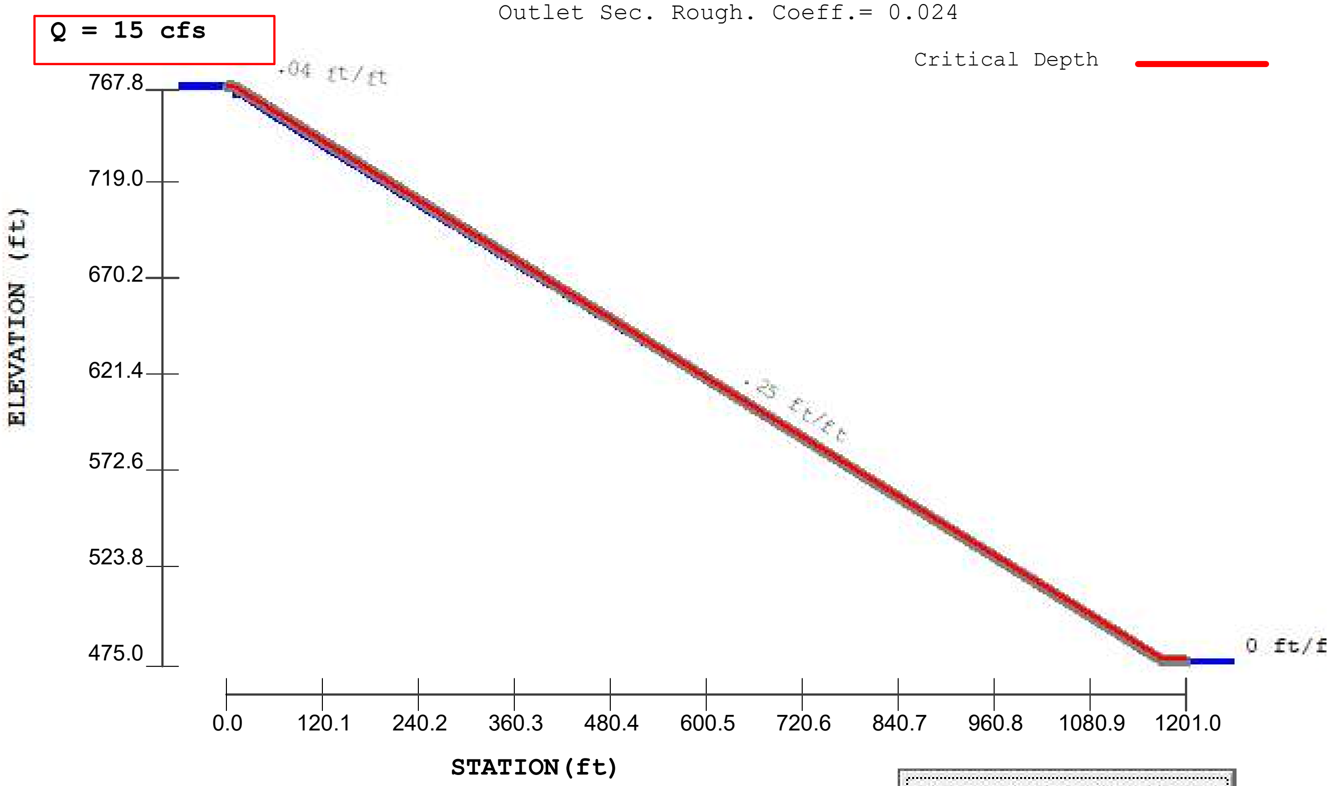
WATER SURFACE PROFILE
Inlet Depth:                                                   1.98 ft
Inlet Velocity:                                              4.78 ft/s
Upper Break Depth:                                             1.37 ft
Upper Break Velocity:                                        6.56 ft/s
Lower Break Depth:                                             0.68 ft
Lower Break Velocity:                                       15.93 ft/s
Depth at End of Hydraulic Jump:                                1.78 ft
Velocity at End of Hydraulic Jump:                           5.08 ft/s
Depth at End of Hydraulic Jump:                                0.47 ft
Velocity at End of Hydraulic Jump:                           1.49 ft/s

OUTPUT DATA
Head Water Depth:                                              2.36 ft
Inlet Control Elevation:                                     767.76 ft
Break Control Elevation:                                     767.43 ft
Critical Depth:                                                1.37 ft
Tailwater Depth:                                               0.47 ft
Hydraulic Jump?                                                    YES
  Jump Station:                                             1189.21 ft
  Jump Length:                                                10.68 ft
Outlet Depth:                                                  1.37 ft
Outlet Velocity:                                             6.56 ft/s
Outlet Froude No.:                                                 1.0
```

Project: Royal Oaks Landfill **Location:** **Date: 11/22/2023**

Circle Pipe Culvert
Diameter=2 ft
Culvert Material: Corr. Metal Pipe

Inlet Type
Mitered to Conform to Slope
Rough. Coeff.= 0.024
Outlet Sec. Rough. Coeff.= 0.024



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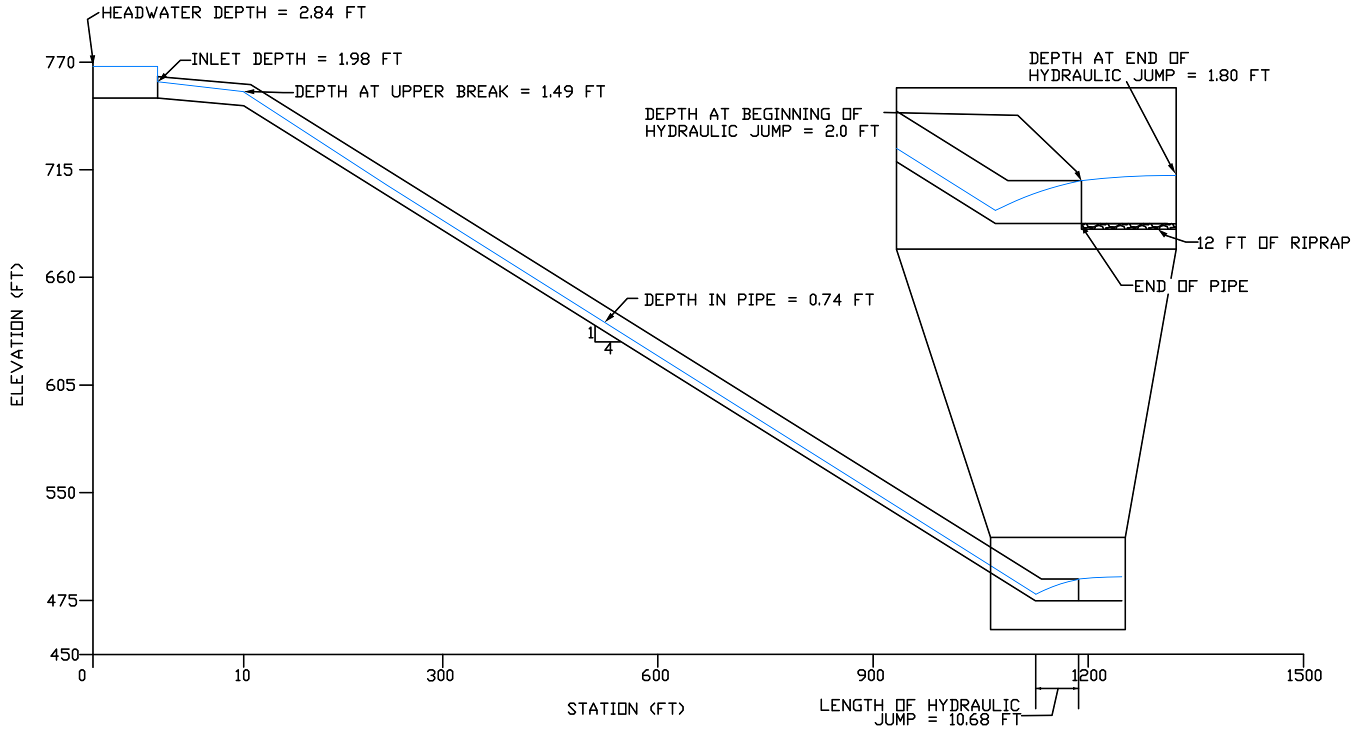
Press to Return to Output Form

WATER SURFACE PROFILE



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NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO
Project:                                   Royal Oaks Landfill
Station or Location:
Date:                                           11 / 22 / 2023

DISCHARGE DATA
Minimum:                                             23.00 cfs
Design Discharge:                                    25.00 cfs
Maximum:                                             35.00 cfs
Number of Barrels:                                           1

TAILWATER DATA
Type:                                               Downstream
Channel Shape:                                       Trapezoid
Left Side Slope:                                        3 H:1V
Right Side Slope:                                       3 H:1V
Bottom Width:                                            20 ft
Bottom Slope:                                      0.005 ft/ft
Roughness Coefficient:                                    0.04

CULVERT DATA
Type:                                            Circular Pipe
Pipe Diameter:                                            3 ft
Culvert Material:                             Corr. Metal Pipe
Inlet Type:                              Mitered to Conform to Slope
Roughness Coefficient:                                   0.024
Outlet Section Roughness Coeff.:                         0.024
Inlet Section Slope:                                0.04 ft/ft
Steep Section Slope:                                0.25 ft/ft
Outlet Section Slope:                                  0 ft/ft

CULVERT PROFILE DATA
Type:                                       Double Broken-Back
Inlet Station:                                         0.00 ft
Inlet Elevation:                                     765.40 ft
Upper Break Station:                                  10.00 ft
Upper Break Elevation:                               765.00 ft
Lower Break Station:                                1170.00 ft
Lower Break Elevation:                               475.00 ft
Outlet Station:                                     1216.00 ft
Outlet Elevation:                                    475.00 ft
```

NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

Project: Royal Oaks Landfill
Station or Location:
Date: 11/22/2023

Discharge cfs	Headwater Depth ft	Inlet Control Elevation ft	Break Control Elevation ft	Critical Depth ft	Outlet Depth ft	Outlet Velocity ft/s	Outlet Froude Number	Tailwater Depth ft	Tailwater Velocity ft/s	Hydraulic Jump
25.0	2.41	767.81	767.57	1.59	1.59	6.55	1.0	.63	1.81	YES
25.4	2.43	767.83	767.59	1.61	1.61	6.59	1.0	.63	1.84	YES
26.6	2.51	767.91	767.67	1.65	1.65	6.70	1.0	.65	1.87	YES
27.8	2.58	767.98	767.75	1.68	1.68	6.82	1.0	.67	1.89	YES
29.0	2.66	768.06	767.82	1.72	1.72	6.93	1.0	.69	1.91	YES
30.2	2.73	768.13	767.89	1.75	1.94	6.26	.8	.71	1.92	YES
31.4	2.81	768.21	767.97	1.79	1.97	6.40	.8	.71	2.00	NO
32.6	2.89	768.29	768.04	1.82	1.99	6.55	.8	.73	2.01	NO
33.8	2.97	768.37	768.12	1.85	2.02	6.68	.8	.75	2.03	NO
35.0	3.06	768.46	768.19	1.89	2.05	6.80	.8	.77	2.04	NO

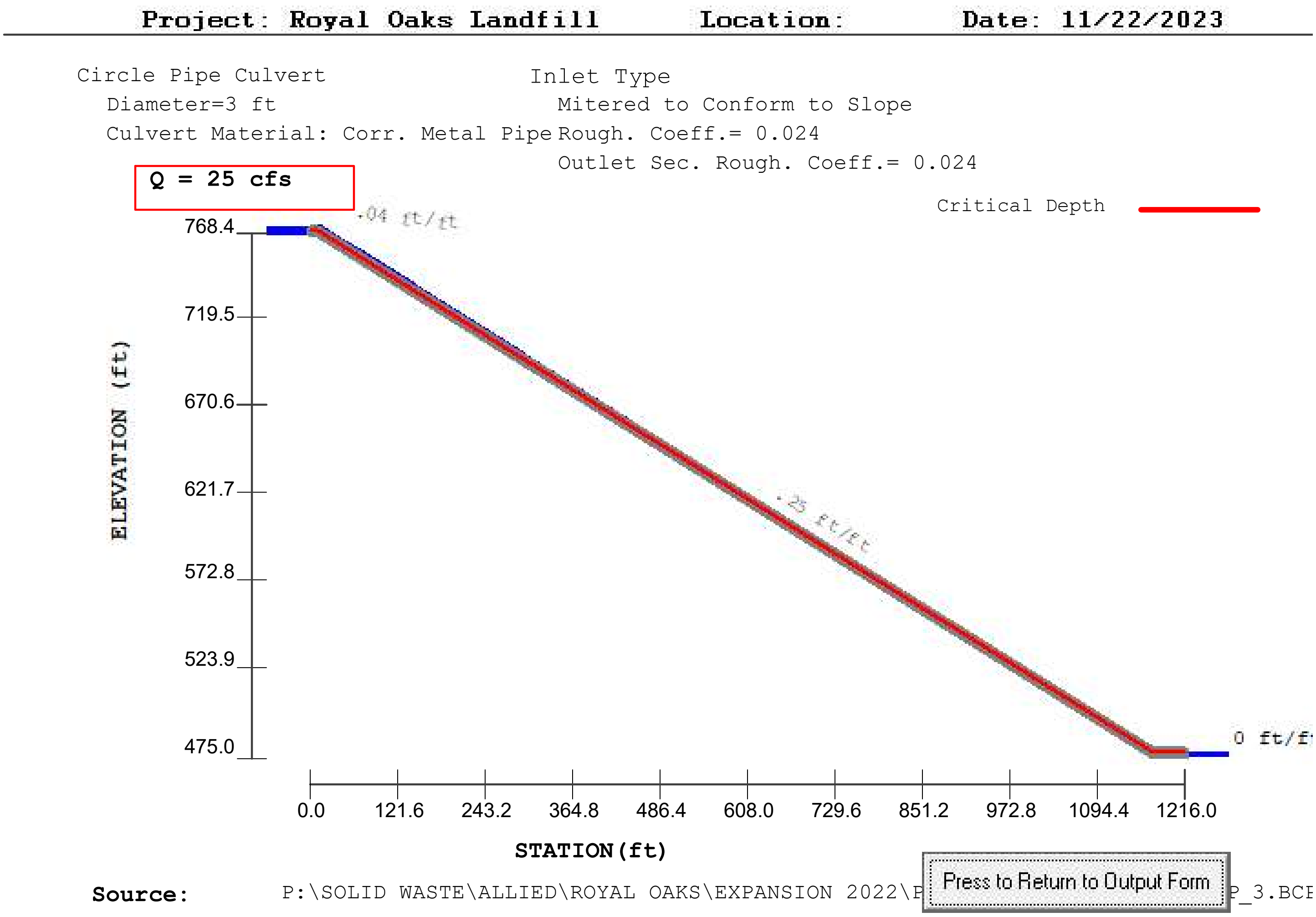
```
NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO
Project:                                           Royal Oaks Landfill
Station or Location:
Date:                                                       11/22/2023

CULVERT DATA
Discharge:                                                    25.0 cfs
Shape:                                                        Circular
Material:                                             Corr. Metal Pipe
Size:                                                1-3.0 ft x 3.0 ft
Inlet Type:                                          Mitered to Conform to Slope

WATER SURFACE PROFILE
Inlet Depth:                                                   2.21 ft
Inlet Velocity:                                              4.47 ft/s
Upper Break Depth:                                             1.59 ft
Upper Break Velocity:                                        6.55 ft/s
Lower Break Depth:                                             0.76 ft
Lower Break Velocity:                                       17.76 ft/s
Depth at End of Hydraulic Jump:                                2.08 ft
Velocity at End of Hydraulic Jump:                           4.79 ft/s
Depth at End of Hydraulic Jump:                                0.63 ft
Velocity at End of Hydraulic Jump:                           1.81 ft/s

OUTPUT DATA
Head Water Depth:                                              2.41 ft
Inlet Control Elevation:                                     767.81 ft
Break Control Elevation:                                     767.57 ft
Critical Depth:                                                1.59 ft
Tailwater Depth:                                               0.63 ft
Hydraulic Jump?                                                    YES
  Jump Station:                                             1200.15 ft
  Jump Length:                                                12.46 ft
Outlet Depth:                                                  1.59 ft
Outlet Velocity:                                             6.55 ft/s
Outlet Froude No.:                                                 1.0
```



Project: Royal Oaks Landfill **Location:** **Date: 11/22/2023**

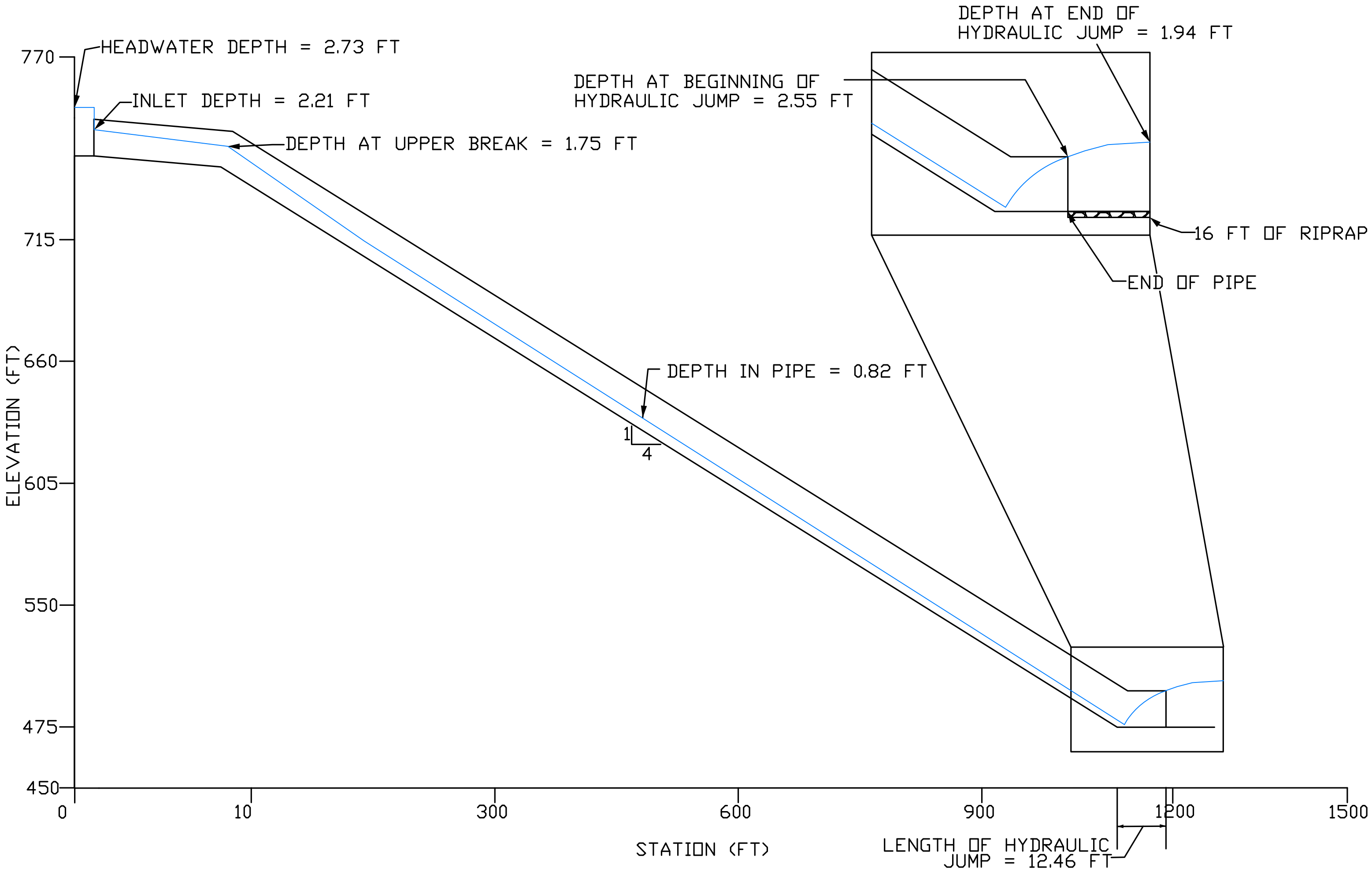
Circle Pipe Culvert
Diameter=3 ft
Culvert Material: Corr. Metal Pipe

Inlet Type
Mitered to Conform to Slope
Rough. Coeff.= 0.024
Outlet Sec. Rough. Coeff.= 0.024

Q = 25 cfs

Source: P:\SOLID WASTE\ALLIED\ROYAL OAKS\EXPANSION 2022\P P_3.BC

WATER SURFACE PROFILE



2. Determine the maximum drainage areas for the flows calculated in Step 1.

$Q = CIA$

Where: C= 0.7 (runoff coefficient, Ref 1.)
I = intensity in/hr
A= drainage area, ac

From Ref. 2, for
25-year storm event

t_c is assumed to be 10 min.

I = 8.59 in/hr

$A = Q / (CI)$

Pipe Diameter (in)	Flow (cfs)	Area (ac)
18	15.0	2.5
24	17.8	3.0
36	30.2	5.0

Conclusion: The maximum allowable drainage area for a 18-inch diameter letdown pipe is 2.5 acres for each inlet, for a 24-inch diameter letdown pipe is 3.0 acres for each inlet and for a 36-inch diameter letdown pipe is 5.0 acres for each inlet. The minimum berm height is 3 feet for a 24-inch diameter pipe and 4 feet for 36-inch diameter pipe. (Figure 3 details indicate 1 foot berm above the pipe).

ROYAL OAKS LANDFILL
0120-076-11-106
PIPE LETDOWN RIPRAP DESIGN

Required: Determine the Riprap size and Dimensions for 18-inch, 24-inch and 36-inch diameter letdown pipes using Riprap Apron Design provided by the Reference 1.

Method:

1. Determine the hydraulic conditions at the outlet of 18-inch, 24-inch and 36-inch diameter letdown pipes using the hydraulic design developed using the BCAP computer simulation.
2. Determine the riprap size and apron dimensions for each pipe letdown

Reference:

1. U.S. Department of Transportation - Federal Highway Administration. Hydraulic Engineering Circular No. 14, Third Edition. *Hydraulic Design of Energy Dissipators for Culverts and Channels*. Publication No. FHWA-NHI-06-086, July 2006.

Solution:

1. Determine the hydraulic parameters from pages IIIF-F-2-25 (pipe diameter 24-inches) and IIIF-F-2-30 (pipe diameter 36-inches):

Parameter	Symbol	18-inch Dia. Culvert	24-inch Dia. Culvert	36-inch Dia. Culvert
Design flow rates, cfs	Q=	15.0	17.8	30.2
Pipe Diameters, ft	D=	1.5	2	3
Depth at the pipe outlet, ft	y_n=	1.47	1.80	1.94
Adjusted culvert rise, ft	D'=	1.10	1.80	2.91
Tailwater Depth[1], ft	TW=	0.47	0.51	0.71

[1] Tailwater depth is the pipe diameter when the calculated tailwater depth is higher per Reference 1.

$$D_{50} = 0.2 \times D\left[\frac{Q}{\sqrt{g} \times D^{2.5}}\right]^{4/3} \times \left[\frac{D}{TW}\right]$$ Eq. 10.4 (page 10-17 of Ref. 1)

$$D' = \frac{D \times y_n}{2}$$ Eq. 10.5 (page 10-17 of Ref. 1)

D_{50} = Riprap Size in feet

ROYAL OAKS LANDFILL
0120-076-11-106
PIPE LETDOWN RIPRAP DESIGN

Riprap Classes and Apron Dimensions[1]

Class	D_{50} (in)	Apron Length[2] (ft)	Apron Depth (ft)
1	5	4xD	3.5xD_{50}
2	6	4xD	3.3xD_{50}
3	10	5xD	2.4xD_{50}
4	14	6xD	2.2xD_{50}
5	20	7xD	2.0xD_{50}
6	22	8xD	2.0xD_{50}

[1] This table has been reproduced from Table 10.1 included on page 10-18 of Reference 1.

[2] D is the culvert rise.

Design Parameter	18-inch Dia. Culvert	24-inch Dia. Culvert	36-inch Dia. Culvert
D_{50}, calculated, inches =	16.4	9.9	7.6
D_{50}, selected, inches =	18	12	12
Apron Length, calculated, feet =	7.7	10.8	14.6
Apron Length, selected, feet =	8	12	16
Apron Depth, calculated, inches =	43.2	28.8	28.8
Apron Depth, selected, inches =	44	30	30

Conclusion:

Riprap sizes for pipe diameters of 18-inches, 24-inches and 36-inches are selected conservatively. The calculated apron length is increased to 30 feet in the design. The apron depth used is higher than the calculated apron depth. Therefore, the design of the pipe letdown outlet energy dissipater calculations are acceptable and channels at the pipe outlets will be stable.

APPENDIX IIIF-F-3

SEDIMENT CONTROL POND DESIGN

Includes pages IIIF-F-3-1 through IIIF-F-3-7

STATE OF TEXAS
CHARLES R. MARSH
105073
LICENSED
PROFESSIONAL ENGINEER

05/20/2024

SEDIMENT CONTROL POND DESIGN

This appendix includes supporting information for the sedimentation pond sizing procedure presented on Sheet IIIF-F-13 (refer to Section 2.2 of the Erosion Control Plan for All Phases of Development). In the event that certain percent ground cover that limits the soil loss to 50/tons/acres/year is not achieved and soil loss is temporarily greater than 50 tons/acre/year, a sedimentation pond will be used along with other structural and non-structural BMPs approved as part of this plan to limit the discharge of eroded soil. The sedimentation pond option is a secondary erosion control option, similar to mulch, wood chips, compost, or straw/hay, and will only be used if the required percent vegetation specification is not met. If the sedimentation pond option is implemented, the swales and letdowns specified will remain in-place. The sedimentation pond option simply allows for the control of sediment while vegetation is being established. The pond design procedure has been developed for reducing discharge of eroded soil to less than the allowable amount for external side slopes (i.e., 50 tons/acre/year) if the required percent vegetation coverage is not obtained soil loss is greater than 50 tons/acre/year. The stormwater sedimentation pond design provided is for a 25-year frequency storm event. This provides for a conservative design because the efficiency of the pond will be higher for more frequent storms (e.g., one year frequency). The example calculation included on pages IIIF-F-3-2 through IIIF-F-3-6 demonstrates that a 0.5-acre detention pond is capable of reducing the discharge of 60 tons/acre/year of soil to less than 50 tons/acre/year of soil from the external slopes for a 20-acre area. A factor has been calculated that will be used to determine the required pond size for a specified external slope area. For a summary of the efficiencies of ponds for various required soil loss reduction amounts, refer to Sheet IIIF-F-13 – Sediment Control Pond Plan as well as the table on page IIIF-F-3-7.

Required: Develop a procedure to size a sedimentation pond to reduce sediment discharge from the external embankment area to 50 tons/acre/year or less.

Method:

1. Determine the 25-year frequency peak flow rate upstream of the sediment control pond using the Rational Method.
2. Calculate the settling velocity of sediment particles using Stokes equation.
3. Calculate the fraction of sediment trapped under dynamic conditions.
4. Calculate the fraction of sediment trapped under quiescent conditions.
5. Calculate the total fraction of sediment trapped under combined conditions.
6. Verify that pond design is adequate to reduce given soil loss to 50 tons/acre/year or less.

Reference:

1. State of Texas, Department of Transportation, Bridge Division, Hydraulic Manual, September 2019.
2. Chin, David. A. Water-Resources Engineering, Prentice Hall, Inc., 2000.
3. Haan, C.T., et al. Design Hydrology and Sedimentology for Small Catchments, 1994.
4. Cooperative Studies Section, Hydrologic Serices Division. U.S. Department of Commerence. *Technical Paper No. 40.*

Solution:

1. Determine the 25-year intensity flow rates.

$Q = CIA$

Where:

C= 0.7 (runoff coefficient, Ref 1.)
I = intensity in/hr
A= drainage area, ac

From Ref. 2, for
25-year storm event

t_c is assumed to be 10 min.

I = 8.59 in/hr From Ref. 1, for Cherokee County

A = 20.0 acres

Q = 120.26 cfs

2. Calculate the settling velocity, V_s (ft/hr), of sediment particles using Stokes equation.

$$V_s = \frac{\alpha\ (\rho_s/\rho_w - 1)\ g\phi^2}{18 v_w} \qquad \text{(Ref. 2)}$$

Where:

α = factor that measures the effect of particle shape (assume spherical, $\alpha = 1$)
ρ_s = density of sediment particle (pcf)
ρ_w = density of ambient water (62.4 pcf)
g = gravity (32.2 ft/s^2)
ϕ = particle diameter (ft)
v_w = kinematic viscosity of the ambient water (ft^2/s)

α = 1
ρ_s = 165 pcf
v_w = 1.08E-05 ft^2/s

Particle Class[1]	Percent in Class	Particle Diameter[2] (ft)	Settling Velocity, V_s (ft/hr)
1	10	1.31E-05	0.17
2	20	1.97E-05	0.38
3	30	2.62E-05	0.68
4	20	3.28E-05	1.06
5	20	3.94E-05	1.52
Total	**100**		

[1] Particle class corresponds to particle diameter.

[2] Particle diameter ranges from 4μm to 12μm, which is typical for clay and silt particles.

3. Calculate the fraction of sediment trapped under dynamic conditions.

a. Determine the overflow rate.

$V_c = Q/A_p$ (EPA Pond Performance Model from Ref. 3)

Where:

V_c = overflow rate
A_p = area of sediment control pond (ac)

Q = 120.26 cfs (from Step 2)
A_p = 0.50 acre

V_c = 19.88 ft/hr

b. Determine the fraction of sediment removed.

$F = 1 - (1 + 1/\beta * V_s/V_c)^{-\beta}$ (Ref. 3)

Where:

F = single-storm trapping of sediment
β = turbulence or short-circuiting parameter reflecting non-ideal performance of pond (assume good performance, $\beta = 3$)

β = 3

$D_R = L_F\,[(1/CV_Q^2) / (1/CV_Q^2 - \ln (E_m/L_F))]^{(1/CVQ\text{^}2) +1}$ (Ref. 3)

Where:

D_R = long-term dynamic removal fraction for stormwater
L_F = removal ratio for very low flow rates
E_m = mean storm removal fraction
CV_Q = coefficient of variation of flows

L_F = 1
E_m = assume equals single-storm trapping, F
CV_Q = 1.74 (from Table 9B.1, p. 570, Ref. 3)

Table 1 - Summary for Dynamic Conditions

Particle Class	Percent in Class	Particle Diameter (ft)	Settling Velocity, V_s (ft/hr)	Single-storm Trapping, F	Fraction Removed Over All Storms, D_R	Fraction Captured Under Dynamic Conditions, E_D[1]
1	10	1.31E-05	0.17	0.008	0.026	0.26
2	20	1.97E-05	0.38	0.019	0.033	0.66
3	30	2.62E-05	0.68	0.033	0.040	1.19
4	20	3.28E-05	1.06	0.051	0.047	0.94
5	20	3.94E-05	1.52	0.073	0.054	1.09
Total	**100**					**4.1**

[1] E_D is the product of percent in class and D_R.

4. Calculate the fraction of sediment trapped under quiescent conditions.

$$RR = \frac{T_{IA} V_s A_Q}{V_R}$$ (Ref. 3)

$V_R = RA$

Where:

RR = removal ratio
T_{IA} = average time interval between storms (hr)
V_s = settling velocity (ft/hr) from Step 2
A_Q = average surface area under quiescent conditions (ft^2)
V_R = mean runoff volume (ft^3)
R = runoff depth for 25-year, 24-hour storm (ft)
A = upstream drainage area (ac)

A_Q =	21,780	ft^2	(assume equal to A_p)
T_{IA} =	108	hrs	(from Table 9B.1, p. 570 of Ref. 3)
R =	0.61	ft	(Ref. 4)
A =	20.0	ac	(from Step 1)

V_R = 529,980 ft^3

Table 2 - Summary for Quiescent Conditions

Particle Class	Percent in Class	Settling Velocity, V_s (ft/hr)	Removal Ratio, RR (ft^3/hr)	Effective Volume Ratio, V_E/V_R[1]	Fraction Removed Under Quiescent Conditions[2]	Fraction Captured Under Quiescent Conditions, E_Q
1	10	0.17	0.75	0.120	0.12	1.20
2	20	0.38	1.69	0.130	0.12	2.40
3	30	0.68	3.00	0.140	0.13	3.90
4	20	1.06	4.68	0.145	0.14	2.80
5	20	1.52	6.74	0.150	0.15	3.00
Total	**100**					**13.3**

[1] Based on Figure 9.29 from Ref. 3, using RR and V_B/V_R.

V_B = reservoir volume = 87,120 ft^3, assuming a 0.5-acre pond with an average depth of 4 feet.
V_B/V_R = 0.164

[2] Based on Figure 9.30 from Ref. 3 with $CV_R = 1.74$.

5. Calculate the total fraction of sediment trapped under combined conditions, E_T.

$$E_T = 1 - (1 - E_D) * (1 - E_Q)$$ (Ref. 3)

E_T = 16.9 %

Refer to page IIIF-F-3-7 for the total efficiency of ponds for different soil loss reduction amounts.

6. Verify that pond design is adequate to reduce given soil loss to 50 tons/acre/year or less.

a. Calculate net soil loss (i.e., sediment not captured by pond).

Total Soil Loss =	60.0	tons/ac/yr	
E_T =	16.9	%	(from Step 5)

Net Soil Loss = Total Soil Loss x (1 - E_T/100)

Net Soil Loss = 49.9 tons/ac/yr

Refer to page IIIF-F-3-7 for the net soil loss for different soil loss reduction amounts.

b. Calculate the required pond size per unit drainage area factor.

Drainge Area =	20.0	acres	(from Step 1)
Pond Area =	0.5	acres	(from Step 3)

Required Pond Size / Unit Drainage Area Factor = 0.025

This factor was calculated using a drainage area of 20 acres and a pond area of 0.5 acres. If a 40-acre drainage area drains to the pond, then a 1.0-acre pond will be required to achieve the above efficiency and net soil loss estimate (40 acres x 0.025 = 1.0 acre). Refer to page IIIF-F-3-7 for the required pond size/unit drainage area factor for different soil loss reduction amounts.

Conclusion:

A 0.5-acre pond will sufficiently capture enough sediment from a 20-acre drainage area so that no more than 50 tons/acre/year of net soil loss occurs on external embankment slopes. If the size of the drainage area changes, this procedure will need to be updated. Refer to the table on page IIIF-F-3-7 for a summary of the pond efficiencies and net soil loss estimates for different soil loss reduction amounts.

SEDIMENT CONTROL POND SUMMARY

External Slope Area Soil Loss (Tons/Acre/Year)	Percent Efficiency of Pond (Dynamic Conditions)	Percent Efficiency of Pond (Quiescent Conditions)	Total Efficiency of Pond (%)	Net Soil Loss (Tons/Acre/Year)	Pond Area Required Per Unit Drainage Area[1]	50 Tons/Acre/Year or Less?
60	4.1	13.3	16.9	49.9	0.025	YES
70	5.0	25.5	29.2	49.6	0.040	YES
80	5.9	34.0	37.9	49.7	0.060	YES
90	6.6	41.5	45.4	49.2	0.075	YES
100	8.1	46.4	50.7	49.3	0.110	YES
200	15.5	71.2	75.7	48.7	0.300	YES

[1] This factor multiplied by a given drainage area will give the required pond size to achieve the efficiencies shown in the table.