TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

VOLUME 2 OF 4

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY, INC.

February 2025
Revised March 2025

STATE OF TEXAS
DAVID L. CLARK
81905
LICENSED
PROFESSIONAL ENGINEER
3-31-25

Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

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TEXAS BOARD OF PROFESSIONAL ENGINEERS
FIRM REGISTRATION NO. F-256

TEXAS BOARD OF PROFESSIONAL GEOSCIENTISTS
FIRM REGISTRATION NO. 50222

TASWA DISPOSAL AND RECYCLING FACILITY
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VOLUME 2 OF 4

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TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN

ATTACHMENT A
SITE DEVELOPMENT PLAN NARRATIVE

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

STATE OF TEXAS
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CONTENTS

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1 INTRODUCTION

30 TAC §330.63(a)

Consistent with 30 TAC §330.63(a), this site development plan narrative is included as Attachment A. Attachment A provides the criteria used in the design of this facility for safeguarding the health, welfare, and physical property of the public and environment. The site development plan narrative includes discussion of the geology, soil conditions, drainage, land use, zoning, adequacy of access roads and highways, and other considerations specific to this facility.

1.1 Site Location and History

Texoma Area Solid Waste Authority (TASWA) owns and operates the TASWA Disposal and Recycling Facility (TASWA DRF), an existing Type I Municipal Solid Waste Disposal Facility, under Permit No. MSW 2290 issued by the TCEQ on October 31, 2003. The TASWA DRF is located approximately 3 miles east of Whitesboro, 2 miles southeast of Sadler, and 3 miles west of Southmayd on State Highway 56 in Grayson County, Texas.

1.2 Facility Description

TASWA owns the 920.49-acre property, of which 689.7 acres is designated as the MSW 2290A permit boundary. Within the permit boundary, the MSW 2290A landfill footprint is 475.3 acres. The remaining area within the permit boundary is buffer zone and entrance facilities. The entrance to the TASWA DRF is off State Highway 56 and entrance facilities include an office building, a scalehouse and scales, a maintenance building, and a citizen convenience center.

The landfill method will be below-grade fill with 4H:1V sidewall slopes and aerial fill with 4H:1V final cover side slopes and a 4 percent final cover top slope. The drainage system is designed to meet or exceed TCEQ and EPA requirements for runon and runoff. The landfill liner, leachate collection, final cover, gas monitoring, and groundwater monitoring systems are designed to meet the TCEQ requirements.

The landfill will receive an estimated 270,000 tons of waste (approximately 865 tons per day) in the initial year following construction of the facility. The waste acceptance rate will vary over the life of the facility depending on market conditions. The maximum rate of waste disposal is expected to be approximately 1,342,700 tons per year (approximately 4,300 tons per day).

The major classifications of solid waste to be accepted for disposal at TASWA DRF include household waste, yard waste, commercial waste, Class 2 and Class 3 nonhazardous industrial waste, construction-demolition waste, and some special wastes. The TASWA DRF will not accept Class 1 industrial wastes.

1.3 Land Use and Zoning

An analysis of land use and potential impact on the area surrounding the facility was prepared by Integrated Environmental Solutions. The Land Use Analysis is included in Part II, Appendix IIB. The TASWA DRF is not located within the limits of any city and is not within the limits of extraterritorial jurisdiction of any city. The facility does not require zoning or other approval from any local government, nor does it require a special use permit.

1.4 Adequacy of Access Roads and Highways

A transportation study was prepared by Biggs and Mathews Environmental to provide information related to access roads and vehicular traffic with respect to the facility expansion. The transportation study is included in Part II, Appendix IIC. There are no existing or planned restrictions on the main access roadways within one mile of the site that would preclude safe and efficient operations for landfill vehicles and other traffic in the area.

Access will be provided to the TASWA DRF via State Highway 56 (SH56). The primary local and regional access routes to the facility will be SH 56 and US Highway 82. There are no known weight restrictions on the local or regional roads in the proximity of the facility other than the maximum legal weight limit of 80,000 pounds.

2 GENERAL FACILITY DESIGN

30 TAC §330.63(a)

Consistent with 30 TAC §330.63(b), the general facility design information is included in Attachment B. Attachment B includes narrative and drawings that provide the required general facility design information including a discussion on facility access control as required by §330.63(b)(1), a generalized process design and working plan of the facility that describes waste movement as required by §330.63(b)(2), a description of how solid waste processing facilities will be designed to facilitate proper cleaning as required by §330.63(b)(3), a description of how liquids resulting from the operation of solid waste processing facilities will be disposed of in a manner that will not cause surface water or groundwater pollution as well as the treatment of wastewaters resulting from the process or from cleaning and washing as required by §330.63(b)(4), and a general discussion of how the facility is designed to protect endangered and threatened species as required by §330.63(b)(5).

3 FACILITY SURFACE WATER DRAINAGE DESIGN

Consistent with 30 TAC §330.63(c), the facility surface water drainage design information is included in Attachment C. Attachment C includes a narrative discussion, drawings, and calculations that demonstrate how the facility is designed to meet the drainage and flood control requirements of §330.63(c) and §§330.303, 330.305, and 330.307. The surface water drainage design report includes analyses of the existing conditions, postdevelopment conditions, and design of the surface water management system including final cover drainage facilities, perimeter drainage channels, and detention and sedimentation ponds; and also includes an erosion and sediment control plan for all phases of landfill development. The facility surface water drainage design report demonstrates that existing drainage patterns will not be adversely altered. In addition, a demonstration that the proposed landfill footprint and proposed processing facilities are not located within the 100-year floodplain is included.

4 WASTE MANAGEMENT UNIT DESIGN

Consistent with 30 TAC §330.63(d), the waste management unit design information is included in Attachment D. Attachment D includes a narrative, drawings, and calculations that demonstrate how the facility is designed to meet §330.63(d)(1) for storage and transfer units and §330.63(d)(4) for landfill units.

The storage and transfer units located within the facility boundary may include a large item storage area, reusable materials staging area, citizen's convenience center, and woodwaste/brush mulching area. Attachment B provides details on these storage and transfer units. Attachment B also includes a narrative and drawings that demonstrate how the facility is designed to meet §330.63(b) and §330.63(d)(1) for general facility design and waste management unit design.

The landfill unit has been designed to meet the requirements of §330.63(d)(4), §330.331(a)(2) and §330.331(b) for a composite liner and the requirements of §330.333 for a leachate collection system. The landfill unit design includes provisions for all-weather operations, proposed landfill method, elevation of deepest excavation, maximum elevation of waste and final cover, waste disposal rate and operating life of the landfill, landfill unit cross sections, and construction and design details of the landfill unit. In addition, Attachment D includes the geotechnical design report for the facility, the liner quality control plan, the leachate and contaminated water management plan, and the final cover quality control plan.

5 GEOLOGY REPORT

Consistent with 30 TAC §330.63(e), the geology and soil information is included in Attachment E. Attachment E includes a narrative discussion, evaluations, and figures that provide the information required by §330.63(e). The geology report includes descriptions of the regional geology and hydrogeology, geologic process, regional aquifers, subsurface investigations, geotechnical properties of subsurface soils, and fault and seismic conditions. The geology report includes the evaluation and demonstrations which confirm that the geology and soil conditions are suitable for operations as a municipal solid waste disposal facility.

6 GROUNDWATER SAMPLING AND ANALYSIS PLAN

Consistent with 30 TAC §330.63(f), the groundwater sampling and analysis plan is included as Attachment F. Attachment F includes a narrative discussion, evaluations, and figures that provide the information required by §330.63(f) and §§330.401 through 330.421. The groundwater monitoring plan includes, among other things, the point of compliance, contaminant pathway analysis, groundwater monitoring program, detection monitoring program, and groundwater sampling and analysis plan.

7 LANDFILL GAS MANAGEMENT PLAN

Consistent with 30 TAC §330.63(g), the landfill gas management plan is included as Attachment G. Attachment G includes narrative, evaluations, and drawings that provide the information required by §330.63(g) and §330.371. The landfill gas management plan includes the requirements for landfill gas monitoring at the landfill perimeter and in on-site structures, a landfill gas control system, and procedures to be implemented in the event that concentrations of methane in excess of the regulatory limits are measured at the facility boundary or in on-site structures.

8 CLOSURE PLAN

Consistent with 30 TAC §330.63(h), the closure plan is included as Attachment H. Attachment H includes narrative, evaluations, and maps and drawings that provide the information required by §330.63(h), §330.457, §330.459 and §330.461. The closure plan includes the procedures to be taken for ongoing closure of the facility and following final acceptance of waste and certification of final closure. The closure plan describes the final cover system, closure procedures, and a closure schedule.

9 POSTCLOSURE PLAN

Consistent with 30 TAC §330.63(i), the postclosure plan is included as Attachment I. Attachment I includes a narrative discussion that provides the information required by §330.63(i), §330.463 and §330.465. The postclosure plan includes the procedures to be taken for postclosure care maintenance of the facility following closure including postclosure care certification. The postclosure plan describes the postclosure care activities, persons responsible for conducting postclosure care activities, and postclosure land use.

10 COST ESTIMATES FOR CLOSURE AND POSTCLOSURE CARE

Consistent with 30 TAC §330.63(j), the cost estimates for closure and postclosure care are included as Attachment J. Attachment J includes a narrative discussion, evaluations, calculations, and drawings that provide the information required by §330.63(j). The detailed cost estimate for closure meets the requirements of §330.503. The detailed cost estimate for postclosure care meets the requirements of §330.507. This plan also provides procedures to adjust the cost estimates during the life of the facility and describes the evidence of financial assurance, as required.

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN

ATTACHMENT B
GENERAL FACILITY DESIGN

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

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CONTENTS

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1 FACILITY ACCESS

30 TAC §330.63(b)(1)

Access to the TASWA Disposal and Recycling Facility (TASWA DRF) is provided from State Highway 56 (SH56). Entrance to the landfill is monitored by the scale attendant during site operating hours. Access to the TASWA DRF is controlled by a perimeter fence located along the facility boundary and a locking gate at the site entrance. The fence and gate prevent the entry of livestock, protect the public from exposure to potential health and safety hazards, discourages unauthorized public access to the disposal operations, and discourages unauthorized entry or uncontrolled disposal of solid waste or prohibited materials.

Perimeter fencing consisting of barbed wire, woven wire, wooden fencing, plastic fencing, pipe fencing, or other suitable material will be provided. A gate constructed of suitable fencing materials will be located on the entrance road. The gate will be locked when the landfill is not accepting waste. The perimeter fence and gate will be inspected monthly. Maintenance will be performed as necessary. Should a breach be detected during inspection or at any other time, every reasonable effort will be made to make repairs within 24 hours of detection. Should repairs require more than 24 hours, temporary repairs will be performed within the time specified to the TCEQ region office following notification. The TCEQ region office will be notified of the breach within 24 hours of detection unless repairs are made within eight hours of detection.

Entry to the active portion of the site will be restricted to designated personnel, approved waste haulers, properly identified persons whose entry is authorized by site management, and regulatory personnel. Visitors may be allowed on the active area only when accompanied by a site representative. The scale attendant will restrict site access to authorized vehicles and direct these vehicles appropriately.

Waste hauling vehicles will be directed to appropriate fill areas by signs located along the landfill haul road and access road. These vehicles will deposit their loads and depart the site. Site personnel will provide traffic directions as necessary to facilitate safe movement of vehicles. Within the site, signs will be placed along the landfill haul road and access road at a frequency adequate for users to be able to determine the disposal area locations and which roads are to be used. Roads not being used for access to disposal areas will be blocked or otherwise marked for no entry.

2 WASTE MOVEMENT

30 TAC §330.63(b)(2)

Waste enters the facility via the site entrance. The scale attendant observes the incoming waste at the gatehouse, conducts waste screening and weighing, and documents the incoming waste. The scale attendant is familiar with the rules and regulations governing the various types of waste that can or cannot be accepted into this facility and will direct the waste hauler to the appropriate waste disposal, storage, or processing area. The scalehouse personnel will also have the authority to reject prohibited wastes and have the rejected waste removed by the waste haul vehicle or transporter immediately upon discovery.

Trained personnel will observe waste unloading at the active working face, citizen's convenience center, large item staging area, and reusable materials and woodwaste/brush storage areas if utilized. Personnel will have the authority and responsibility to reject loads that contain prohibited wastes and to have prohibited waste removed by the waste haul vehicle or transporter immediately upon discovery.

Appendix B1 includes schematic drawings and details that depict disposal, waste processing, and storage activities that are part of the TASWA DRF. Drawing B.1 is a flow diagram that provides the storage, processing, and disposal sequences for the various wastes accepted. Drawing B.2 is a schematic drawing of the facility that depicts the location of the various phases of collection, processing, and disposal for the types of wastes accepted at the facility. Drawing B.3 depicts generalized construction details of storage facilities. Drawing B.4 depicts generalized layout and schematic of the Citizen's Convenience Center processing area. No waste processing will be done in an enclosed building.

Waste Disposal

The proposed landfill liner, leachate collection, and final cover systems will meet all applicable TCEQ rules and guidelines. Provisions addressing design and construction are addressed in the liner quality control plan, the leachate and contaminated water management plan, and the final cover quality control plan.

The waste disposal area will be excavated with side slopes no steeper than 4H:1V. The liner system will be constructed following excavation of a new waste disposal area. The proposed liner system for the facility is generally described below with layers listed from top to bottom.

COMPOSITE LINER SYSTEM (TOP TO BOTTOM)
24-inch Soil Protective Cover
Drainage Geocomposite LCS Layer
HDPE Geomembrane Liner
24-inch Compacted Clay Liner ($\leq 1 \times 10^{-7}$ cm/sec)

Information regarding materials and construction quality assurance are included in Attachment D7. Liner system details are included in Attachment D3.

A leachate collection system (LCS) has been designed with a geocomposite drainage layer, leachate collection trenches, and leachate collection sumps to remove leachate from the landfill. The LCS layout and details are shown in Part III, Attachment D3. Design of the LCS is discussed in Part III, Attachment D6. Information regarding materials and construction quality assurance are included in Part III, Attachment D7.

The proposed landfill development method for the site is a combination of the area-excavation fill followed by aerial fill to the proposed landfill completion height. Landfill development will generally follow the sequence of development as shown on Drawing B.2.

Waste accepted for disposal will be directed to the active working face. Waste will be unloaded within the active working face, spread in layers and thoroughly compacted. Daily cover of waste will be applied to control disease vectors, windblown waste, odors, fires, scavenging, and to promote runoff from the fill area.

The aerial fill side slopes will not be steeper than 4H:1V, and the aerial fill top slope will be approximately four percent. A composite final cover will be constructed over the entire landfill. As shown in Part III, Attachment D3, the final cover is generally described below with layers from top to bottom.

COMPOSITE FINAL COVER SYSTEM (TOP TO BOTTOM)
24-inch Erosion Layer
Drainage Geocomposite Layer – Sideslope Only
Cushion Geotextile Layer – Topslope only
Flexible Membrane (40-mil LLDPE)
18-inch Compacted Clay Layer ($\leq 1 \times 10^{-5}$ cm/sec)

Final cover placement will generally follow the sequence of development as shown on Drawing B.2 and will be ongoing as the site is developed. Sectors will be closed according to the closure plan provided in Part III, Attachment H.

Large Item Staging Area

A staging area for large items and white goods may be provided near the active working face or may be provided at the citizen's convenience center. Large items and white goods include ovens, dishwashers, freezers, air conditioners, scrap metal and other large items. Typically, large items and white goods are received in source-separated loads. Should large items or white goods be received in mixed loads, they will be removed from the active face and staged on the ground near the active working face, or citizen's convenience center. These items may be recycled to prevent a nuisance and to preclude discharge but will not be stored in excess of 180 days. Large items that are not recycled will be disposed of at the working face.

The large item staging area, when located within the waste disposal footprint will be placed only over areas that have received intermediate cover. Surface water runoff will be diverted around the storage area. Surface water from the large item staging area will be contained by containment and diversion berms consistent with Part III, Attachment D6.

Reusable Materials Staging Area

Inert materials such as brick, concrete, etc., and non-inert materials such as asphalt may be stockpiled for use on facility access roads and staging areas or for erosion control in drainage structures. Asphalt will not be used for erosion control in drainage structures. The reusable materials staging area will be located within the waste disposal footprint and will be relocated periodically as the active working face moves. The size of the stockpiles may vary depending on the amount of materials received at any given time. Since the brick and concrete materials are inert, runon and runoff from rainfall will not be controlled in a special manner and odor control measures are not required for these materials. Since asphalt is not an inert material, if received, it will be managed in a manner that will prevent runoff of contaminated water, discharge of waste, or the creation of nuisance conditions. These inert and non-inert materials will continuously be reused for site operations, and there is no time limit on the storage of these materials.

Citizen's Convenience Center

A citizen's convenience center for waste and recyclable material drop-off will be located within the site entrance facilities, as shown on Drawing B.2. General construction details of the Citizen's Convenience Center are provided on Drawing B.4. Thirty to forty cubic yard roll-off containers, as well as containers for recycled goods, may be provided. Containers with waste will be emptied at the active working face at the end of each day. The control of contaminated water within the roll-off containers will minimize the potential for generating odors within the area. Containers with waste will be emptied at the end of each day, also minimizing the potential for odors. Recycle containers will periodically be transported to an appropriate recycling facility. Large items and white goods may be stored at the citizen's convenience center and will be periodically transported to an appropriate recycling facility.

Woodwaste/Brush Mulching Area

The woodwaste/brush mulching area may be located within the landfill footprint and may process incoming yard trimmings, clean wood materials and vegetative materials, including trees and brush, into wood chips and mulch. The wood chips and mulch will be managed to prevent fire, safety, or health hazards in accordance with 30 TAC §330.209(a).

3 SANITATION

30 TAC §330.63(b)(3)

The solid waste processing and/or storage facilities include the large item storage area, reusable materials staging area, citizen's convenience center, and woodwaste/brush mulching area. Each of the solid waste processing facilities has been designed to facilitate proper cleaning. Operational requirements for each facility are described in Part IV, including a discussion of surface water controls, cleaning facilities, and contaminated water.

Large Item Storage Area

Large items and white goods received are transferred into steel roll-off containers or staged in the citizen's convenience center for storage. If used, roll-off containers will be tarped to prevent rainfall from accumulating inside the containers. Containers will be cleaned by removing loose material for disposal at the working face and washing down the containers with water. Wash water will be treated as contaminated water and disposed of in accordance with Part III, Attachment D6.

Reusable Materials Staging Area

Inert and non-inert materials will be stockpiled and reused for site operations. Surface water runon and runoff controls are not required for inert materials such as brick and concrete but will be required for non-inert materials such as asphalt. Stockpiles of non-inert materials will be located in areas with positive drainage away from the stockpiles to prevent runon of surface water. Runoff of contaminated water will be prevented by containment berms as shown on Drawing B.6. Any contaminated water that is collected will be disposed of in accordance with Part III, Attachment D6.

Citizen's Convenience Center

The citizen's convenience center will receive municipal solid waste and recyclables from the public. Any waste received will be loaded into steel roll-off containers. Full containers will be disposed of at the working face. Should waste materials spill onto the concrete surface, the materials will be picked up and disposed of at the working face. The concrete surfaces will be cleaned as needed by washing down with water. Wash water from the steel roll-off containers or concrete surfaces will be treated as contaminated water and disposed of in accordance with Part III, Attachment D6.

Woodwaste/Brush Mulching Area

Wood wastes received will be chipped and stockpiled only to be used for site operations. The area will consist of small piles managed to prevent litter and control fire, health hazards and safety in accordance with §330.209(a). There are no water runon and runoff control, or additional sanitation controls required.

4 WATER POLLUTION CONTROL

30 TAC §330.63(b)(4)

The processing and/or storage facilities will be maintained and operated to manage runon and runoff during the peak discharge from the 25-year, 24-hour storm event to prevent the off-site discharge of waste and feedstock material, including, but not limited to, processed or stored materials. Surface water in and around each processing and/or storage facility will be controlled to minimize surface water running onto, into, and off the processing and/or storage area. Since all contaminated water will be managed in a controlled manner, as discussed above, groundwater will be protected. Should the discharge of contaminated water become necessary, the facility will obtain specific written authorization from the TCEQ prior to discharge. The landfill and its processing and/or storage facilities will be operated consistent with §330.15(h)(1)-(4) regarding discharge of solid wastes or pollutants into waters of the United States or waters of the state.

The design of the landfill itself and the surface water management system for the facility will prevent the discharge of solid waste, pollutants, dredged or fill material and nonpoint source pollution that would violate any of the provisions referenced in 30 TAC §330.15(h). The facility has been designed to keep contaminated surface water (water that may have come into contact with waste at the landfill) separated from uncontaminated stormwater runoff and to store and discharge contaminated water in accordance with Part III, Attachment D6. Uncontaminated stormwater discharge will be pursuant to a general stormwater discharge permit for industrial activity.

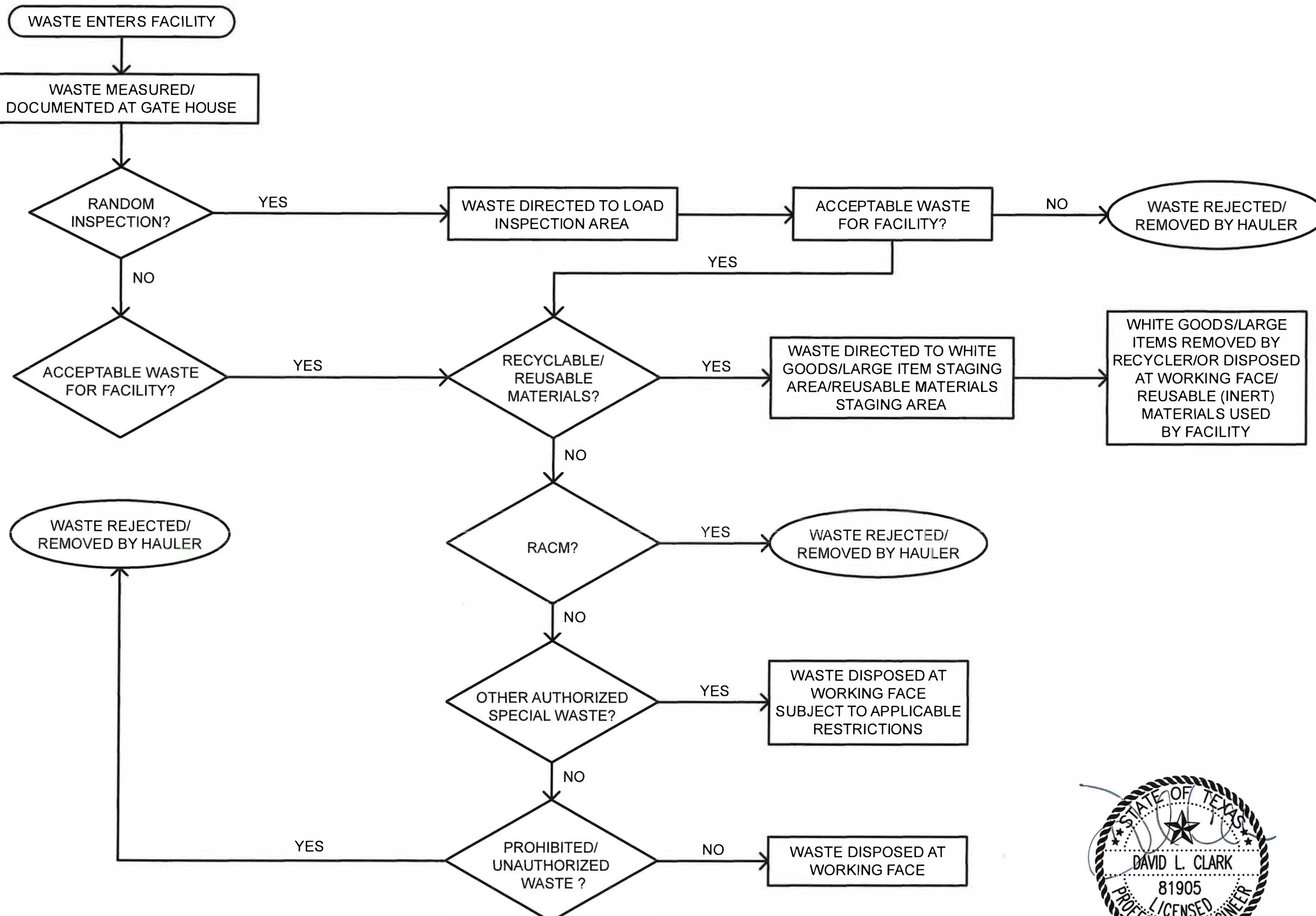
5 ENDANGERED SPECIES PROTECTION

30 TAC §330.63(b)(5)

A detailed threatened and endangered species survey and assessment was conducted by a qualified biologist. The survey and assessment along with coordination with the United States Fish and Wildlife Service (USFWS) and the Texas Parks and Wildlife Department (TPWD) regarding endangered and threatened species is provided in Part II, Appendix IIE. No adverse impact to threatened or endangered species is anticipated as a result of construction or operation of the TASWA DRF.

Development of the facility shall be conducted to minimize potential impacts to endangered or threatened species. The facility and the operation of the facility will not result in the destruction or adverse modification of the critical habitat of endangered or threatened species, or cause or contribute to the taking of any endangered or threatened species.

APPENDIX B1



STATE OF TEXAS
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WASTE MOVEMENT FLOW DIAGRAM

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

BME

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MANSFIELD, TEXAS 76063
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
B.1

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0 400 800
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A WASTE BOUNDARY
- N 7278000 — STATE PLANE COORDINATES
- (14) SECTOR NUMBER (DEVELOPMENT SEQUENCE)
- LINED AREA (AS OF SEPT. 2022)

NOTES:

1. EXISTING GROUND CONTOURS PROVIDED BY BIGGS AND MATHEWS ENVIRONMENTAL FROM DRONE SURVEY FLOWN ON JUNE 1, 2022.
2. THE ACTIVE DISPOSAL AREA WILL MOVE AS LANDFILLING PROGRESSES. THE SEQUENCE OF DEVELPOMENT WILL GENERALLY FOLLOW SECTOR NUMBERING.
3. THE LARGE ITEM STAGING AREA, IF USED, WILL GENERALLY BE ADJACENT TO THE ACTIVE FILL AREA WITHIN THE LANDFILL FOOTPRINT.
4. THE REUSABLE ITEM STAGING AREA WILL BE LOCATED ADJACENT TO THE ACTIVE AREA AND RELOCATED AS THE SITE IS DEVELOPED.
5. THERE IS A MINIMUM SEPARATING DISTANCE OF AT LEAST 50 FEET BETWEEN ALL STORAGE AND PROCESSING AREAS AND THE FACILITY BOUNDARY.

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WASTE DISPOSAL, PROCESSING, AND STORAGE SCHEMATIC PLAN

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

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DRAWING
B.2

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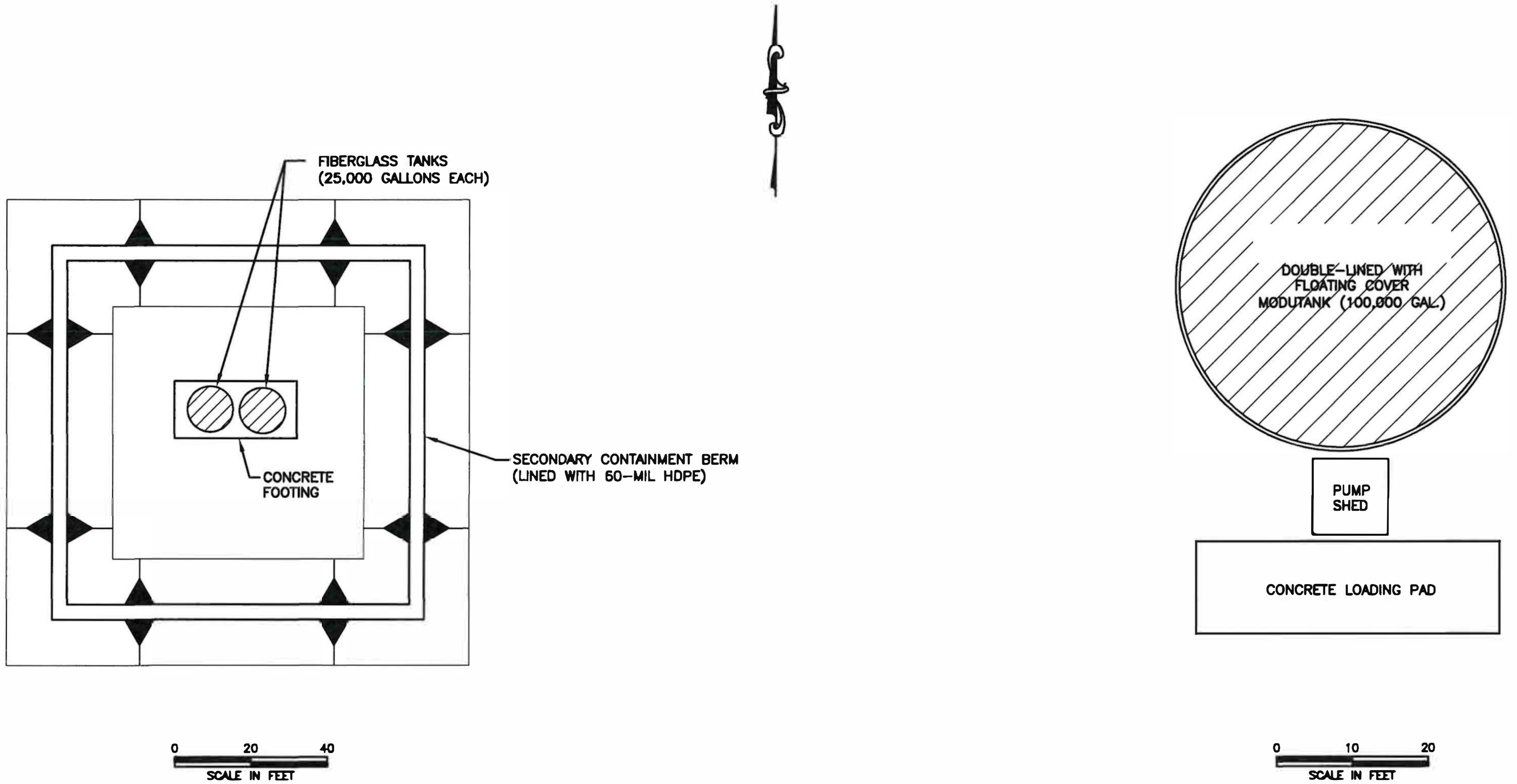

LEACHATE STORAGE FACILITY PLAN 1 B.3

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STORAGE FACILITIES SCHEMATIC	
TEXOMA AREA SOLID WASTE AUTHORITY TASWA DRF PERMIT AMENDMENT	
BME	BIGGS & MATHEWS ENVIRONMENTAL 1700 ROBERT ROAD, STE. 100 MANSFIELD, TEXAS 76063 817-563-1144
TBPE FIRM NO. F-256 TBPG FIRM NO. 50222	DRAWING B.3

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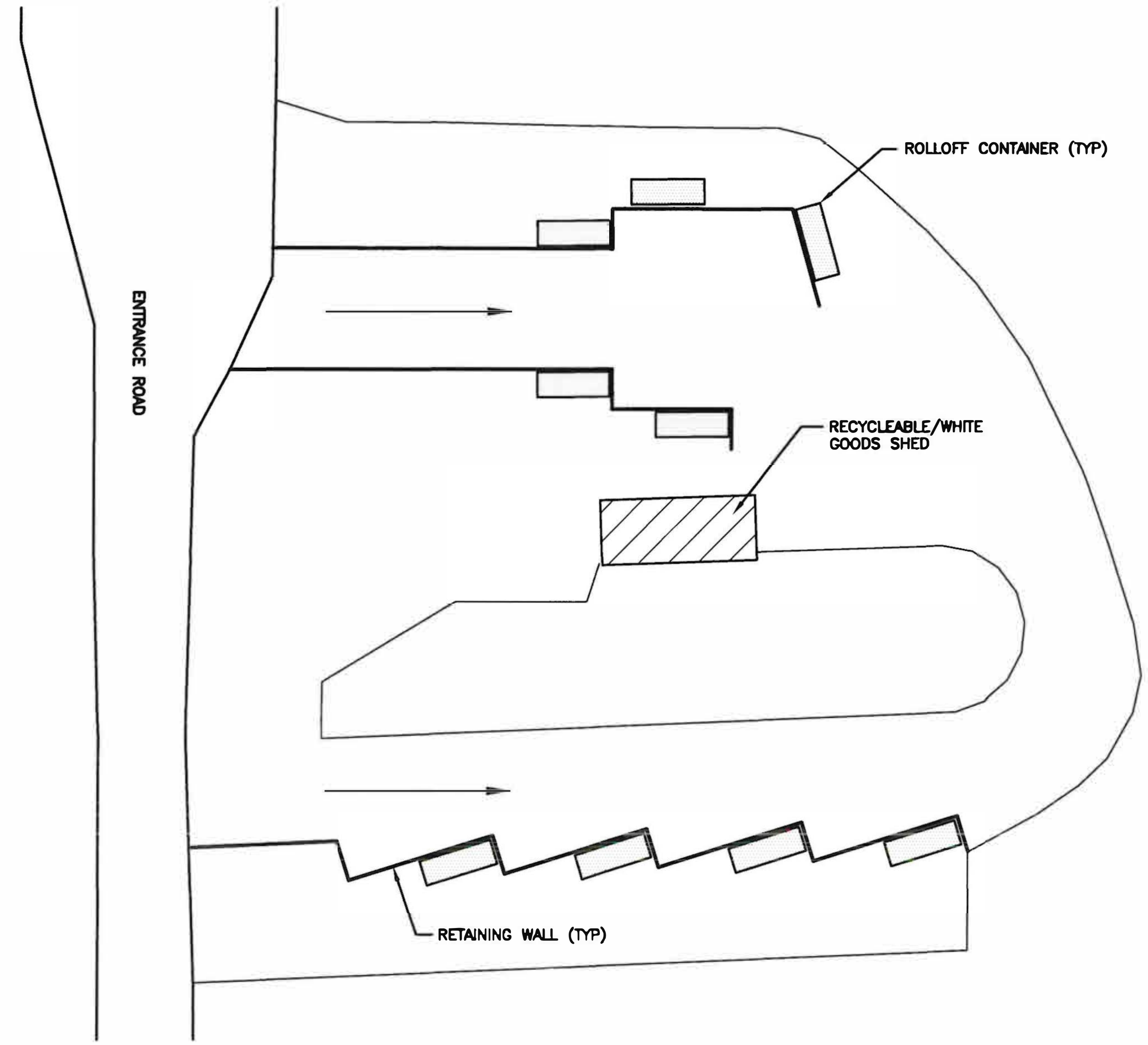

CITIZEN'S CONVENIENCE CENTER 1 B.4

0 25 50
SCALE IN FEET

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CITIZEN'S CONVENIENCE CENTER SCHEMATIC

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
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TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT C
FACILITY SURFACE WATER DRAINAGE REPORT

Prepared for

Texoma Area Solid Waste Authority, Inc.

February 2025

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED
PROFESSIONAL ENGINEER
2/28/2025

Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

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TEXAS BOARD OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS
FIRM REGISTRATION NO. F-256 AND NO. 10194895

TEXAS BOARD OF PROFESSIONAL GEOSCIENTISTS
FIRM REGISTRATION NO. 50222

STATE OF TEXAS
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CONTENTS

1 NARRATIVE

30 TAC §330.63(c) and §§330.301-330.307

The facility surface water drainage report is prepared as part of a permit application for the TASWA Disposal and Recycling Facility (TASWA DRF), consistent with 30 TAC Chapter 330. This facility surface water drainage report is prepared consistent with the requirements of §330.63(c) and §§330.301 through 330.307. Attachment C is organized to include the drainage analysis and design, flood control and analysis, and drainage system plans and details. The facility design complies with the requirements of §330.303(a)-(b) concerning the management of runon and runoff during peak discharge of a 25-year rainfall event, the prevention of off-site discharge of waste and feedstock materials, and the control of surface water discharge in and around the facility. The following is a brief description of each of the attachments.

Attachment C1 –Drainage Analysis and Design

Attachment C1 is the drainage analysis and design of the facility, which includes calculations and demonstrations consistent with the requirements of §330.63(c), and §§330.301-330.305. This attachment includes a comparison of surface water runoff from the current permitted condition to the postdevelopment condition at each location where surface water enters or exits the permit boundary for the 25-year, 24-hour rainfall event. The current permitted condition for this evaluation is defined as the permitted landfill completion plan for the TASWA DRF MSW Permit No. 2290 (2290). The postdevelopment condition for this evaluation is defined as the landfill completion plan for the TASWA DRF MSW Permit No. 2290A (2290A). The comparison between the current permitted condition and the postdeveloped condition demonstrates that the proposed expansion (2290A) of the TASWA DRF will not adversely alter the current permitted (2290) drainage patterns. In addition, this attachment includes the drainage design for the final cover system, drainage swales, chutes, perimeter channels, and detention ponds.

Attachment C2 – Flood Control Analysis

Attachment C2 is the flood control analysis, which includes calculations and demonstrations consistent with the requirements of §330.63(c)(2) and §§330.301-330.307. The flood control analysis demonstrates that the proposed expansion of the TASWA DRF will not adversely impact the flooding conditions of the receiving channel and that the landfill footprint will not be located within the 100-year floodplain. Since the landfill footprint will not be located within the 100-year floodplain, the levees required by §330.307 are not necessary to protect the facility from a 100-year frequency flood or to otherwise prevent the washout of solid waste from the facility.

Attachment C3 – Drainage System Plans and Details

This attachment includes site plans and details for the drainage system consistent with §330.63(c) and §§330.301-330.305.

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT C1
DRAINAGE ANALYSIS AND DESIGN

Prepared for

Texoma Area Solid Waste Authority

February 2025

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CONTENTS

1 INTRODUCTION

30 TAC §330.63(c) and §§330.301-330.305

1.1 Purpose

The drainage analysis and design is prepared as part of a permit amendment application for the TASWA Solid Waste Disposal and Recycling Facility (TASWA DRF) and includes the demonstrations consistent with the requirements of 30 TAC Chapter 330, §330.63(c) and §§330.301-305. The drainage analysis and design is organized to include a narrative description of the current permitted and postdevelopment conditions, the proposed drainage system design, the erosion and sedimentation control plan, and a discussion of the current permitted/postdevelopment comparison at the permit boundary. Drainage calculations are included in the appendices. Drainage design plans and details are included in Attachment C3. The following is a brief description of each of the appendices.

Appendix C1A – Current Permitted/Postdevelopment Comparison

Appendix C1A includes drainage area maps that delineate the drainage areas that contribute surface water runon and runoff at the permit boundary and provide a summary of the peak flow rate, volume of runoff, and runoff velocity at locations along the permit boundary for the current permitted and postdevelopment conditions. Appendix C1A also includes a table summarizing the current permitted/postdevelopment boundary analysis comparison.

Appendix C1B – Current Permitted Hydrologic Calculations

The current permitted hydrologic and hydraulic evaluation included in Appendix C1B represents the current permitted final closure configuration. The current permitted analysis includes delineations of drainage areas that contribute surface water runon and runoff at comparison locations along the current permit boundary. The current permitted hydrologic analysis represents the hydrologic calculations as defined by the landfill completion plan for the TASWA DRF MSW Permit No. 2290.

The results of the current permitted hydrologic evaluation are provided on the current permitted boundary analysis summary, which shows the 25-year peak flow rate, volume of runoff, and runoff velocity at comparison locations along the current permit boundary.

Appendix C1C – Postdevelopment Hydrologic Calculations

The postdevelopment hydrologic and hydraulic evaluation included in Appendix C1C represents the proposed final closure landfill configuration. The postdevelopment analysis includes delineations of drainage areas that contribute surface water runon and runoff at comparison points along the proposed permit boundary. The postdevelopment hydrologic analysis represents the hydrologic calculations as defined by the landfill completion plan for the TASWA DRF MSW Permit No. 2290A.

The results of the postdevelopment hydrologic evaluation are provided on the postdevelopment boundary analysis summary, which shows the 25-year peak flow rate, volume of runoff, and runoff velocity at the comparison locations along the proposed permit boundary.

Appendix C1D – Perimeter Drainage System Design

Appendix C1D presents the hydraulic design of the perimeter drainage system. The perimeter drainage plan shows the locations of the perimeter drainage channels, detention ponds, and surface water impoundments. The detention ponds are designed to provide the necessary storage and outlet control to mitigate impacts to the receiving channels downstream of the TSAWA Facility. The perimeter channels are designed for the 25-year, 24-hour storm event.

Appendix C1E – Final Cover Drainage Structure Design

Appendix C1E is limited to the design of the permanent final cover drainage structures (i.e., chute and swale system). The calculations demonstrate that the structures are designed to convey runoff produced from the 25-year storms, to provide erosion protection, and to minimize sediment loss from the final cover condition.

Appendix C1F – Intermediate Cover Erosion and Sedimentation Control Plan

Appendix C1F provides a detailed erosion and sediment control plan during the intermediate cover phase of development.

Appendix C1G – Intermediate Cover Erosion Control Structure Design

Appendix C1G provides the supporting documentation to evaluate and design temporary erosion and sediment control structures for the intermediate cover phase of landfill development.

2 METHODOLOGY

30 TAC §330.305(f) and §330.305

2.1 Concepts and Methods

The hydrologic and hydraulic methods employed in this study are consistent with the TCEQ regulations. The United States Army Corps of Engineers (COE) HEC-HMS computer program was used to compute peak flow rates and to determine water surface profiles. The Rational Method and the methods defined in the TxDOT *Hydraulic Design Manual*, September 2019, were used to design the final cover drainage system and erosion control features. Analyses of the peak flow rates, water surface profiles, and drainage design for these conditions proceeded in the following sequence:

- Maps were prepared that provided information about the surface water runoff characteristics of the current permitted final cover drainage conditions and contributing drainage areas. These maps are included in Appendix C1B.

- Surface water runoff hydrographs for the current permitted condition, including the perimeter drainage channels, detention ponds, and surface water impoundments, were developed using HEC-HMS. The current permitted HEC-HMS evaluation is included in Appendix C1B.

- Maps were prepared that provide information about the surface water runoff characteristics of the postdeveloped final cover drainage conditions for the expansion of the TASWA DRF. These maps are included in Appendix C1C.

- Surface water hydrographs for the postdeveloped condition, including the perimeter drainage channels, detention ponds, and surface water impoundments, were evaluated using HEC-HMS. The postdeveloped evaluation is included in Appendix C1C.

- The existing perimeter channels were modeled using HEC-HMS and Manning's Equation. Runoff hydrographs from drainage areas that contribute surface water runoff to the perimeter drainage system were routed through the existing perimeter channels, which include ponds and surface water impoundments, using HEC-HMS. Peak flow rates at specific stations were taken directly from HEC-HMS. Narrative discussing the perimeter drainage system design, which includes the evaluation of the existing and proposed surface water drainage features, is included in Appendix C1D.

- Final cover drainage systems were evaluated for capacity and erosion loss using the Rational Method and the methods defined in the TxDOT *Hydraulic Design*

Manual, September 2019. Final cover drainage systems calculations are included in Appendix C1E.

- Intermediate cover erosion and sediment control plan and structure design were evaluated for capacity and erosion loss using the Rational Method and the methods defined in the TxDOT *Hydraulic Design Manual*, September 2019. Intermediate cover erosion and sediment control plans are included in Appendix C1F and C1G.

2.2 Hydrologic and Hydraulic Modeling

2.2.1 HEC-HMS

The COE HEC-HMS program was developed to simulate the surface water 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 following assumptions were made as part of the hydrologic modeling process:

- Excess precipitation is distributed uniformly and with constant intensity over the watershed.

- The watershed is divided into three separate processes: loss, transform, and baseflow. Part of the precipitation falling on the land surface is lost due to infiltration and is represented with a loss method. Rainfall that does not infiltrate becomes direct runoff and moves across the watershed surface or through the upper soil horizons and eventually reaches the watershed outlet. All runoff processes are represented as pure surface routing using a transform method. Groundwater contributions to channel flow are called baseflow and are not considered due to the brief duration of the hydrologic modeling simulation.

- The Espey "10-Minute Method" was used to estimate Snyder Parameters for watershed areas within the permit boundary and off-site areas with characteristics similar to watershed areas within the permit boundary.

2.3 Hydrologic Elements Naming Convention

The following naming convention was used in the current permitted and postdevelopment hydrologic evaluations:

CA – drainage area within the current permit boundary, current permitted condition

DA – drainage area within the proposed permit boundary, postdeveloped condition

OS – drainage area outside of the permit boundary

R – designates a reach that conveys runoff through a given drainage area (examples: R3 conveys runoff through drainage area CA3)

CP – comparison point where surface water runoff enters or exits the permit boundary

J – junction

POND – designates a pond (example: Pond 01 is within drainage area CA02 in the current permitted condition and within drainage area P1P in the postdeveloped condition.)

I – designates a drainage control structure (example: I-08 is a drainage control structure within drainage area I-08A in the postdeveloped condition.)

3 CURRENT PERMITTED CONDITIONS

The TASWA DRF is an existing 393-acre, Type I Municipal Solid Waste Disposal Facility operated by the Texoma Area Solid Waste Authority. The TASWA DRF is located in Grayson County, Texas, east of the City of Whitesboro.

The TASWA DRF is located along unnamed tributaries of Mustang Creek, which is part of the Red River Basin. The permit boundary of the TASWA DRF is generally located west of Mustang Creek. Appendix C1A includes Drawing C1A.1 which is a regional drainage area map depicting the location of the TASWA DRF and the regional drainage areas contributing stormwater runoff to Mustang Creek and its unnamed tributary.

The proposed permit boundary, as shown on Drawings C1A.1 and C1A.2, will be used to evaluate the current permitted and postdeveloped runoff conditions. The current permitted boundary analysis summary is shown on Drawing C1A.1. Refer to Appendix C1B for the current permitted hydrology calculations, as shown on Drawing C1A.1. These peak discharges were then used to design and evaluate the postdeveloped conditions.

Stormwater runoff does not enter the TASWA DRF permit boundary. The major portion of the stormwater runoff from the TASWA DRF entered unnamed tributaries of Mustang Creek at one location along the northern permit boundary. A minor portion of the stormwater runoff exits at four locations along the eastern permit boundary. The remaining portion of the stormwater runoff exits at four locations along the western permit boundary.

The locations where stormwater enters and exits the permit boundary are further discussed below in Table 1.

Table 1 – Current Permitted Boundary Analysis Summary

Boundary Comparison Point	25-Year Flow Rate (cfs)	25-Year Volume (ac-ft)	25-Year Velocity (fps)	Runon / Runoff	Drainage Areas	Comparison Point Description
Points Contributing to the North Boundary						
CP01	654.1	183.7	3.4	Runoff	CA1 contributes directly to CP01. CA2, CA3, CA4, CA5, CA6 are routed through Pond 1 to CP01.	Surface water from CA1 sheet flows into an unnamed tributary of Mustang Creek. Discharge from Pond 1 flows into an unnamed tributary of Mustang Creek via a defined natural channel.
CP10	92.5	15.5	3.5	Runoff	CA17 directly contributes to CP10.	Surface water from CA17 sheet flows into an unnamed tributary of Mustang Creek via a defined natural channel.
Points Contributing to the East Boundary						
CP02	132.2	22.2	2.3	Runoff	CA7 contributes directly to CP02.	Surface water sheet flows into an unnamed tributary of Mustang Creek.
CP03	81.3	14.8	1.4	Runoff	CA8 contributes directly to CP03.	Surface water sheet flows into an unnamed tributary of Mustang Creek.
CP04	111.7	19.3	1.5	Runoff	CA9 contributes directly to CP04.	Surface water sheet flows into an unnamed tributary of Mustang Creek.
CP05	47.3	7.3	1.7	Runoff	CA10 contributes directly to CP05.	Surface water sheet flows into an unnamed tributary of Mustang Creek.
Points Contributing to the West Boundary						
CP06	35.9	7.6	0.9	Runoff	CA11 contributes directly to CP06.	Surface water sheet flows into an unnamed tributary of Mustang Creek.
CP07	134.0	38.3	2.2	Runoff	CA12 contributes directly to CP07. CA13 routed through Pond 2 contributes to CP07.	Surface water from CA12 flows onto the property boundary as sheet flow, while flow from Pond 2 flows via defined natural channel.
CP08	59.2	12.6	2.4	Runoff	CA14 contributes directly to CP08. CA15 routed through Pond 3 contributes to CP08.	Surface water from CA14 flows onto the property boundary as sheet flow, while flow from Pond 3 flows via defined natural channel.
CP09	75.4	10.4	2.3	Runoff	CA16 directly contributes to CP09.	Surface water from CA16 sheet flows into an unnamed tributary of Mustang Creek via a defined natural channel.

4 POSTDEVELOPMENT CONDITIONS

Drawing C1A.2 of Appendix C1A delineates the postdevelopment drainage areas that contribute runoff to the proposed permit boundary. Peak discharges at the comparison points along the proposed permit boundary, as shown on Drawing C1A.2, were determined for the postdevelopment condition. Refer to Appendix C1C for postdevelopment hydrology calculations.

As in the current permitted condition:

Stormwater runoff does not enter the TASWA DRF permit boundary. The major portion of the stormwater runoff from the TASWA DRF enters unnamed tributaries of Mustang Creek at one location along the northern permit boundary. There is a second runoff location along the norther permit boundary just west of the primary runoff location. A minor portion of the stormwater runoff exits at four locations along the eastern permit boundary. The remaining portion of the stormwater runoff exits at four locations along the the western permit boundary.

The locations where stormwater enters and exits the permit boundary are further discussed below in Table 2.

Table 2 – Postdeveloped Boundary Analysis Summary

Boundary Comparison Point	25-Year Flow Rate (cfs)	25-Year Volume (ac-ft)	25-Year Velocity (fps)	Runon / Runoff	Drainage Areas	Comparison Point Description
Points Contributing to the North Boundary						
CP01	609.8	178.6	3.3	Runoff	DA01 contributes directly to CP01. DA02 through DA20 are routed through Pond 1 Post to CP01.	Surface water from DA01 sheet flows into an unnamed tributary of Mustang Creek. Discharge from Pond 1 flows into an unnamed tributary of Mustang Creek via a defined natural channel.
CP10	78.8	14.7	3.2	Runoff	DA35 contributes directly to CP10. DA26 and I-02A routing through Pond I-02 Post contributes to CP10.	Surface water from DA35 sheet flows and the discharge from Pond I-02 Post flow into an unnamed tributary of Mustang Creek via a defined natural channel.
Points Contributing to the East Boundary						
CP02	128.4	23.7	2.3	Runoff	DA27 contributes directly to CP02. Secondary Outlets from I-08 are routed to CP02.	Surface water sheet flows and Outlets from I-08 Post flow into an unnamed tributary of Mustang Creek.
CP03	80.1	13.7	1.4	Runoff	DA228 contributes directly to CP03. Secondary Outlets from I-10 are routed to CP03	Surface water sheet flows and Outlets from I-10 Post flow into an unnamed tributary of Mustang Creek.
CP04	110.3	18.7	1.4	Runoff	DA29 contributes directly to CP04. Secondary Outlets from I-12 are routed to CP04	Surface water sheet flows and Outlets from I-12 Post flow into an unnamed tributary of Mustang Creek.
CP05	30.1	5.8	1.4	Runoff	DA30 contributes directly to CP02.	Surface water sheet flows into an unnamed tributary of Mustang Creek.
Points Contributing to the West Boundary						
CP06	36.0	9.9	0.6	Runoff	DA31 contributes directly to CP06. Secondary Outlets from I-21 Pond are routed to CP06.	Surface water sheet flows and outlets from I-21 post flow into an unnamed tributary of Mustang Creek.
CP07	131.2	44.8	2.2	Runoff	DA32 contributes directly to CP07. DA22, DA23 and DA24 are routed through Pond 2.	Surface water sheet flows and Pond 2 Post flow into an unnamed tributary of Mustang Creek.
CP08	57.0	13.8	2.4	Runoff	DA33 contributes directly to CP08. DA25 is routed through Pond 3.	Surface water sheet flows and Pond 3 post flow into an unnamed tributary of Mustang Creek.
CP09	77.2	10.8	2.3	Runoff	DA34 contributes directly to CP09.	Surface water from into an unnamed tributary of Mustang Creek via a defined natural channel.

5 PROPOSED DRAINAGE SYSTEM DESIGN

30 TAC §330.63(c)(1), §330.303 and §330.305(a)–(f)

The proposed drainage system for the TASWA DRF will consist of drainage swales, downchutes, perimeter channels, detention ponds, and outlet structures.

The facility has been designed to prevent discharge of pollutants into waters in the state or waters of the United States, as defined by the Texas Water Code and the Federal Clean Water Act, respectively. TASWA has been authorized by the TCEQ to discharge stormwater runoff consistent with Texas Pollutant Discharge Elimination System (TPDES) Permit No. TXR05AH82, consistent with General Permit No. TXR050000 relating to stormwater discharges associated with industrial activity. Landfills are authorized under the General Permit.

5.1 Perimeter Drainage System Design

The perimeter drainage system is designed to convey the 25-year runoff from the developed landfill consistent with TCEQ regulations. The perimeter channel system design calculations are referenced in Appendix C1D. The perimeter drainage structure plans are included in Attachment C3.

The detention ponds are designed to provide the necessary storage and outlet control to mitigate impacts to the receiving channels downstream of the TASWA DRF. Detention pond design parameters are referenced in Appendix C1D, as included in the hydraulic modeling for postdeveloped conditions in Appendix C1C. The detention pond details are shown in Attachment C3. The detention pond outlet structures are designed as energy dissipators to reduce the velocity and turbulence of the flow leaving the detention ponds.

5.2 Final Cover Drainage Structure Design

Stormwater runoff will be collected in swales, located near the upper grade break on the landfill and on the 4:1 (horizontal to vertical) side slopes, leading to drainage letdown structures or chutes on the 4:1 side slopes and to the perimeter drainage system. The perimeter drainage system will be constructed as each sector is developed.

The final cover drainage system swales and chutes are designed to convey the 25-year peak flow rate. These swales, channels, and chutes will also reduce maintenance at the site after closure by minimizing erosion. The final cover erosion control design calculations are included in Appendix C1E. The final cover design, showing the locations of the drainage swales, downchutes, and final cover drainage structure details, is illustrated in Appendix C1E.

The chute/letdown structures are designed to convey the 25-year, 24-hour peak flow rate. The chutes are designed with 40-mil textured FML to minimize erosive conditions along the chute and at swale/chute confluences. There is a slope transition between the chute and perimeter road low water crossing. A hydraulic jump occurs at the chute/low water crossing transition that dissipates the energy and reduces the velocity across the perimeter road. Concrete is used at the chute/low water crossing transitions to minimize erosion. The letdown structures continue and convey stormwater into the perimeter channels or directly into the detention ponds. The letdown structures are designed using gabions or riprap to provide erosion protection after the perimeter road low-water crossing. The gabion elevations are staggered in order to remove excess energy created down the embankment slopes at the transition with the perimeter channel or detention ponds. The chute design calculations are included in Appendix C1E. Final cover drainage system details including the chute details are shown in Attachment C3. A typical detail of the low water crossing depicting where the chute crosses the perimeter road is also shown in Attachment C3.

5.3 Surface Water Runon Controls

There are no locations along the permit boundary where surface water enters the permit boundary in the postdeveloped condition. Surface water drainage in and around the facility will be controlled by the perimeter drainage system described in Section 5.1 and will be prevented from entering the landfill footprint and waste disposal area. The landfill perimeter road, berm, and perimeter drainage channels and detention ponds will be constructed as the landfill is developed as depicted in Attachment D1 and Attachment D3.

Temporary berms will be constructed around the active working face to divert uncontaminated surface water away from the active working face. Temporary containment berms will be constructed around the active working face to collect and contain surface water that has come in contact with the waste. These run-on and runoff controls around the active working face are designed to collect and control surface water generated from a 25-year, 24-hour storm event. Refer to Attachment D6 for these calculations.

6 EROSION AND SEDIMENTATION CONTROL

30 TAC §330.305

6.1 Final Cover Stormwater System Control Plan

Perimeter drainage channels and detention ponds will be constructed as the subsequent phased development of the landfill progresses. Erosion will be minimized in these structures by establishment of vegetation or with rock riprap, gabions, or other materials as provided for in the drainage design calculations for these permanent structures.

Swales and chutes will be constructed upon placement of the final cover. The final cover includes, among other things, an erosion layer that is a minimum of 24 inches of earthen material with the top 6 inches capable of sustaining native plant life and will be seeded with native and introduced grasses immediately following the application of final cover in order to minimize erosion. A soil loss demonstration for the erosion layer is included in Appendix C1E of this attachment. The swales and chutes include establishment of vegetation, rock riprap, gabions, and other materials as provided in the drainage calculations for these permanent structures.

6.2 Final Cover Stormwater System Maintenance Plan

The TASWA DRF will inspect, restore, and repair constructed permanent stormwater systems such as channels, drainage swales, chutes, and flood control structures in the event of wash-out or failure from extreme storm events. 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 48 hours of a rainfall event of 0.5 inches or more. Documentation of the inspection will be included in the site operating record.

The following items will be evaluated during the inspections:

- Erosion of final cover areas, perimeter ditches, chutes, swales, detention ponds, berms, and other drainage features
- Settlement of final cover areas, perimeter ditches, chutes, swales, and other drainage features
- Silt and sediment build-up in perimeter ditches, chutes, swales, and detention ponds
- Obstructions in drainage features
- Presence of erosion or sediment discharge at perimeter stormwater discharge locations

- Presence of sediment discharges along the site boundary in areas that 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 as soon as reasonably 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 will consist of the following, as needed:

- Placement of additional temporary or permanent vegetation
- Placement, grading, and stabilization of additional soils in eroded areas or in areas that have experienced settlement
- Replacement of riprap or other structural lining
- Placement of additional riprap in eroded areas or in areas that have experienced settlement
- Removal of obstructions from drainage features
- Removal of silt and sediment build-up in perimeter ditches, chutes, swales, detention ponds, retention ponds, and other surface water drainage structures.
- Repairs to erosion and sedimentation controls
- Installation of additional erosion and sedimentation controls

6.3 Intermediate Cover Erosion and Sedimentation Control Plan

Erosion and sediment controls have been designed for the intermediate cover phase of landfill development. The intermediate cover erosion and sedimentation control plan includes temporary structures and establishment of vegetation to minimize erosion of the intermediate cover and documentation requirements. Refer to Appendix C1F and Appendix C1G.

6.4 Daily Cover Erosion and Sedimentation Control Plan

Erosion and sediment controls for the daily cover phase of landfill development will be consistent with the requirements of Part IV. Daily cover will be placed over all solid waste at the end of each operating day as required by Part IV. The daily cover will be sloped to drain. Runoff from areas that have intact daily cover is considered uncontaminated stormwater runoff. Erosion and sediment controls for daily cover will include the following procedures:

- Areas with daily cover will be inspected daily for erosion that may cause contaminated runoff from the daily cover.

- After each rainfall event all daily cover areas will be inspected for erosion or other damage and repaired as necessary. Runoff from damaged or eroded areas will be handled as contaminated water until repairs are completed.

- Daily cover will be compacted and sloped to drain.

- Should erosion of daily cover be observed, the daily cover will be replaced so that no solid waste is exposed at the end of the operating day. In the event that additional soil stabilization or erosion control measures are deemed necessary, one or more of the following measures will be constructed: temporary sediment control fence, silt fence, swales, or filter berms.

7 CURRENT PERMITTED/POSTDEVELOPMENT COMPARISON

30 TAC §330.63(c)(1)(D)(iii) and §330.305(a)

Consistent with 30 TAC §330.63(c)(1)(D)(iii) and §330.305(a), the proposed landfill development will not adversely alter existing or permitted drainage patterns. A summary of the current permitted and postdevelopment drainage conditions analyzed is included as Drawing C1A.1 and Drawing C1A.2. Supporting calculations are presented in Appendix C1B and C1C. The current permitted boundary analysis to postdevelopment boundary analysis comparison is also summarized in tabular format in Appendix C1A. As required by the regulations, a summary of drainage patterns and flows produced by the 25-year storm event is presented on the following drawings.

- Drawing C1B.1: This drawing, included in Appendix C1B, depicts the current permitted stormwater runon and runoff locations along the permit boundary. Each location is identified with flows, velocities, and volume of runoff as appropriate in the summary table.

- Drawing C1C.1: This drawing, included in Appendix C1C, depicts the postdevelopment stormwater runon and runoff locations along the proposed permit boundary. Each postdevelopment discharge point is at the same location as the current permitted discharge point and is identified in the summary table.

For the postdevelopment site configuration shown on Drawing C1C.1, the stormwater outfall locations along the proposed permit boundary remain consistent with the current permitted outfall locations shown on Drawing C1B.1.

The current permitted and postdevelopment surface water runoff has been evaluated for the peak flow rate, volume of runoff, and velocity at each comparison point. A comparison table is included in Appendix C1A.

Conclusion

Given that: (1) drainage from the permit boundary or property boundary does not adversely alter the peak flow rate, velocity, or runoff volumes at the permit boundary and receiving channels, and (2) the stormwater discharge outfalls are consistent with the current permitted site configuration, except as noted, it is concluded that the proposed landfill development will not adversely alter existing or permitted drainage patterns consistent with §330.305(a).

8 CONCLUSIONS

The following conclusions summarize the results of the drainage analysis and design:

- The drainage design criteria and analyses used for these drainage calculations satisfy the requirements of 30 TAC Chapter 330.
- The final cover drainage structures (swales, chutes) are designed in accordance with the rules to convey peak flow rates from the 25-year rainfall event.
- Perimeter channels are designed in accordance with the rules for the 25-year rainfall event.
- Detention pond capacities and outlets are designed in accordance with the rules for the 25-year rainfall event.
- Erosion will be minimized by using Best Management Practices.
- The proposed landfill development will not adversely alter existing or current permitted drainage patterns.

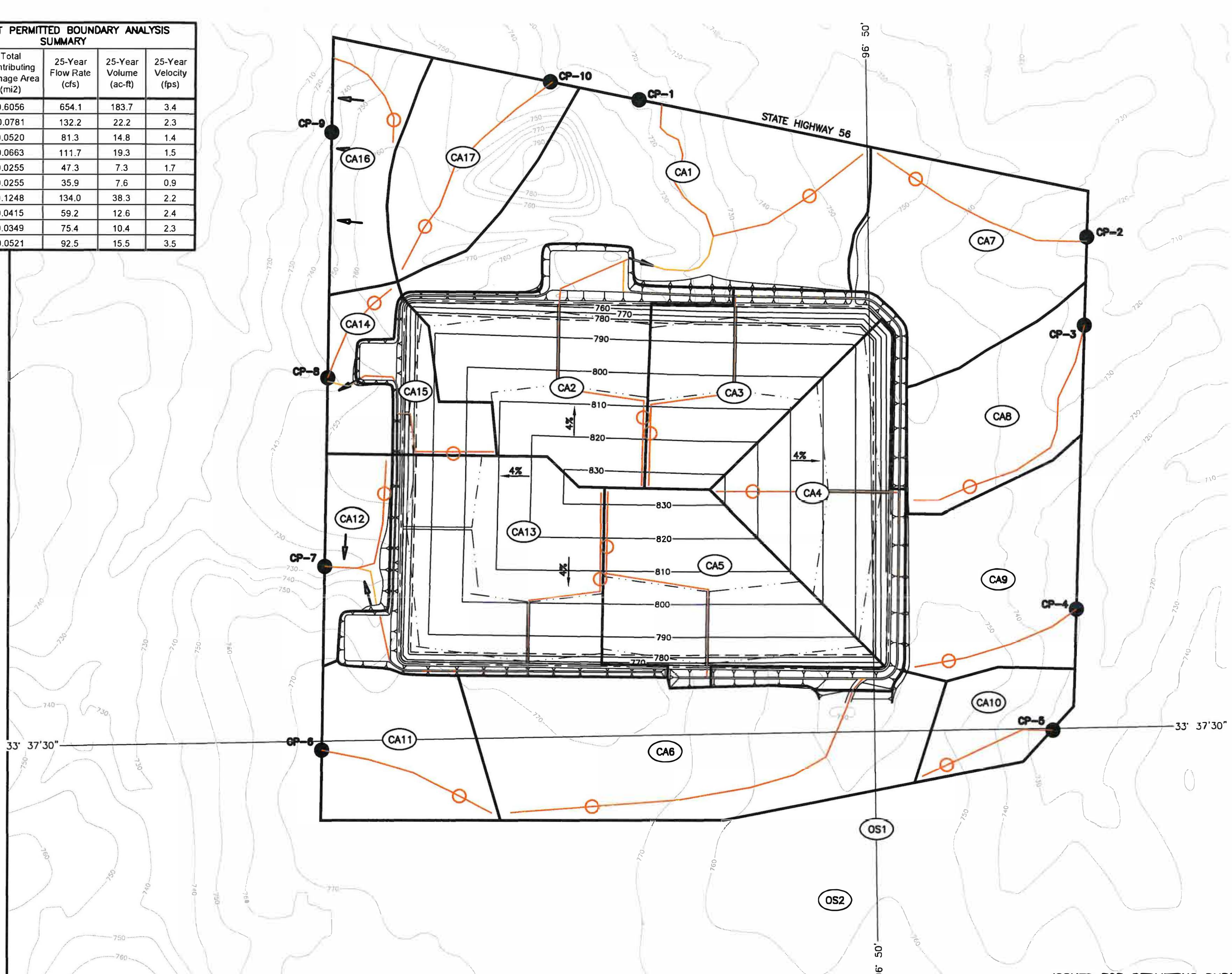
ATTACHMENT C1
APPENDIX C1A

CURRENT PERMITTED/POSTDEVELOPMENT COMPARISON

CONTENTS

CURRENT PERMITTED BOUNDARY ANALYSIS SUMMARY

Comparison Point	Total Contributing Drainage Area (mi2)	25-Year Flow Rate (cfs)	25-Year Volume (ac-ft)	25-Year Velocity (fps)
CP1	0.6056	654.1	183.7	3.4
CP2	0.0781	132.2	22.2	2.3
CP3	0.0520	81.3	14.8	1.4
CP4	0.0663	111.7	19.3	1.5
CP5	0.0255	47.3	7.3	1.7
CP6	0.0255	35.9	7.6	0.9
CP7	0.1248	134.0	38.3	2.2
CP8	0.0415	59.2	12.6	2.4
CP9	0.0349	75.4	10.4	2.3
CP10	0.0521	92.5	15.5	3.5



0 400 800
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290 LANDFILL FOOTPRINT
- 700 EXISTING 10' GROUND CONTOUR
- 800 LANDFILL 10' CONTOUR
- DRAINAGE AREA BOUNDARY
- CA01 DRAINAGE AREA DESIGNATION
- COMPARISON POINT-POINT DISCHARGE
- COMPARISON POINT-SHEET FLOW (NON-POINT DISCHARGE)

NOTE(S):

1. USGS CONTOURS DOWNLOADED FROM USGS WEBSITE ON MARCH 25, 2024.
2. CONTOURS WITHIN EXISTING LANDFILL FOOTPRINT DEPICT CURRENT PERMITTED FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.
4. DRAINAGE AREAS CONTRIBUTING TO EACH COMPARISON POINT ARE LISTED ON TABLE 1 – CURRENT PERMITTED BOUNDARY ANALYSIS SUMMARY IN SECTION 3 OF ATTACHMENT C1.

STATE OF TEXAS
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CURRENT PERMITTED BOUNDARY ANALYSIS SUMMARY

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1A.1

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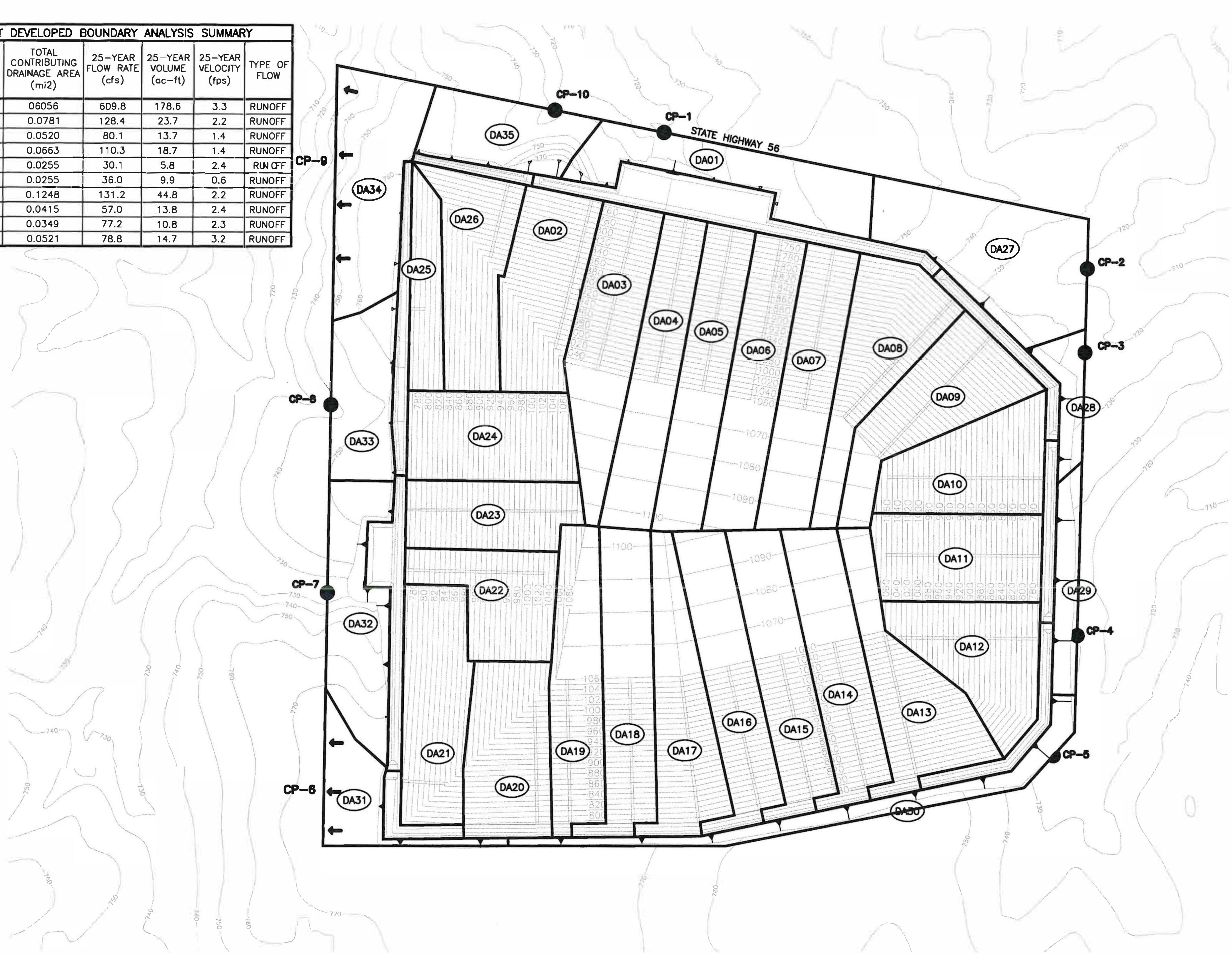
POST DEVELOPED BOUNDARY ANALYSIS SUMMARY					
BOUNDARY COMPARISON POINT	TOTAL CONTRIBUTING DRAINAGE AREA (mi2)	25-YEAR FLOW RATE (cfs)	25-YEAR VOLUME (ac-ft)	25-YEAR VELOCITY (fps)	TYPE OF FLOW
CP1	06056	609.8	178.6	3.3	RUNOFF
CP2	0.0781	128.4	23.7	2.2	RUNOFF
CP3	0.0520	80.1	13.7	1.4	RUNOFF
CP4	0.0663	110.3	18.7	1.4	RUNOFF
CP5	0.0255	30.1	5.8	2.4	RUN OFF
CP6	0.0255	36.0	9.9	0.6	RUNOFF
CP7	0.1248	131.2	44.8	2.2	RUNOFF
CP8	0.0415	57.0	13.8	2.4	RUNOFF
CP9	0.0349	77.2	10.8	2.3	RUNOFF
CP10	0.0521	78.8	14.7	3.2	RUNOFF



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SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LIMIT OF WASTE
- 700 EXISTING 10' GROUND CONTOUR
- 900 LANDFILL 10' CONTOUR
- DRAINAGE AREA BOUNDARY
- CA02 DRAINAGE AREA DESIGNATION
- COMPARISON POINT-POINT DISCHARGE
- ↓↓↓ COMPARISON POINT-SHEET FLOW (NON-POINT DISCHARGE)

NOTE(S):

1. USGS CONTOURS DOWNLOADED FROM USGS WEBSITE ON MARCH 25, 2024.
2. CONTOURS WITHIN EXISTING LANDFILL FOOTPRINT DEPICT CURRENT PERMITTED FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

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POST DEVELOPED BOUNDARY ANALYSIS SUMMARY

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

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TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1A.2

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CURRENT PERMITTED/POSTDEVELOPED BOUNDARY ANALYSIS SUMMARY TABLE

CURRENT PERMITTED/POSTDEVELOPED BOUNDARY ANALYSIS SUMMARY TABLE

Discharge Point	Total Contributing Drainage Area (mi²)				25-Year Flow Rate (cfs)				25-Year Volume (Ac-ft)				25-Year Velocity (fps)			
	Current Permitted	Post-Developed	Difference	Percent Difference	Current Permitted	Post-Developed	Difference	Percent Difference	Current Permitted	Post-Developed	Difference	Percent Difference	Current Permitted	Post-Developed	Difference	Percent Difference
CP1	0.6056	0.7141	0.1085	18%	654.1	609.8	-44.3	-7%	183.7	178.6	-5.1	-3%	3.4	3.3	-0.1	-3%
CP2	0.0781	0.0456	-0.0325	-42%	132.2	128.4	-3.8	-3%	22.2	23.7	1.5	7%	2.3	2.3	0.0	-1%
CP3	0.0520	0.0088	-0.0432	-83%	81.3	80.1	-1.2	-1%	14.8	13.7	-1.1	-7%	1.4	1.4	0.0	-1%
CP4	0.0663	0.0111	-0.0552	-83%	111.7	110.3	-1.4	-1%	19.3	18.7	-0.6	-3%	1.5	1.4	0.0	-1%
CP5	0.0255	0.0195	-0.0060	-24%	47.3	30.1	-17.2	-36%	7.3	5.8	-1.5	-21%	1.7	1.4	-0.3	-16%
CP6	0.0255	0.0161	-0.0094	-37%	35.9	36.0	0.1	0%	7.6	9.9	2.3	30%	0.9	0.6	-0.3	-37%
CP7	0.1248	0.1592	0.0344	28%	134.0	131.2	-2.8	-2%	38.3	44.8	6.5	17%	2.2	2.2	0.0	0%
CP8	0.0415	0.0449	0.0034	8%	59.2	57.0	-2.2	-4%	12.6	13.8	1.2	10%	2.4	2.4	0.0	-1%
CP9	0.0349	0.0363	0.0014	4%	75.4	77.2	1.8	2%	10.4	10.8	0.4	4%	2.3	2.3	0.0	1%
CP10	0.0521	0.0225	-0.0296	-57%	92.5	78.8	-13.7	-15%	15.5	14.7	-0.8	-5%	3.5	3.2	-0.2	-6%

ATTACHMENT C1
APPENDIX C1B

CURRENT PERMITTED HYDROLOGIC CALCULATIONS

CONTENTS

CURRENT PERMITTED NARRATIVE

30 TAC §330.305

This current permitted hydrologic analysis represents the hydrologic calculations as defined by the landfill completion plan for the TASWA Solid Waste Disposal and Recycling Facility (TASWA DRF) MSW Permit No. 2290 in accordance with §330.305.

CURRENT PERMITTED DRAINAGE AREA DRAWINGS

The current permitted drainage area summary (Drawing C1B.1) delineates the drainage areas that contribute stormwater runon or runoff to the proposed permit boundary. Drainage areas within the proposed permit boundary are designated by the prefix "CA". Refer to Drawing C1B.1 for the current permitted boundary drainage area summary.

Drawing C1B.2 is the soil map that depicts the TASWA DRF permit boundary and the existing soil types. The Soil Survey of Grayson County, Texas, published by the Soil Conservation Service, is the reference for the base map and soils information.

METHODS USED TO EVALUATE THE CURRENT PERMITTED CONDITION

The final closure configuration established by the 2005 permit application was used as the current permitted final closure configuration for the TASWA DRF.

The US Army Corps of Engineers Hydraulic Engineering Center's Hydraulic Modeling System (HEC-HMS) program was used to perform the hydrologic modeling of the TASWA DRF. HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic watershed systems.

Espey's "10-Minute" Method for estimating Snyder parameters was used to calculate peak discharge for each drainage area for the current permitted final closure configuration. The method is applicable for the steep terrain associated with final cover and for the increased imperviousness related to other landfill improvements.

Minor changes were made to the current permitted final closure configuration for existing ponds and existing drainage structures based on aerial topography, construction drawings, and field observations. The current permitted final closure configuration is defined as the landfill completion plan for the TASWA DRF MSW Permit No. 2290. The existing ponds and drainage structures within the 2290 permit boundary are constructed consistent with MSW Permit No. 2290 and any subsequent modifications and authorizations.

CURRENT PERMITTED WATERSHED CHARACTERISTICS

Watershed characteristics have been developed for the current permitted hydrologic evaluation. The watershed characteristics address drainage area runoff characteristics, unit hydrograph data, and reach characteristics. This information is included on pages C1B.9 and C1B.10.

The first table, titled Current Permitted Watershed Characteristics, page C1B.9, provides the summary of drainage areas, soil types, Curve Numbers (CN) values, initial loss, reach slope calculations, and determination of Manning's n value. The Soil Conservation Service (SCS) CN were derived from watershed characteristic tables from the SCS Technical Report 55 (TR-55), which included evaluation of soil and surface cover/condition characteristics. The second table, titled Unit Hydrograph Data – Snyder's Hydrograph Coefficients, page C1B.10, provides the determination of the Snyder's Unit Hydrograph parameters.

RAINFALL DATA

The hypothetical precipitation for the storm event for the facility was taken from the National Oceanic and Atmospheric Administration (NOAA) Point Precipitation Frequency Estimates (Atlas 14, Volume 11, Version 2). A return period of 25 years and a duration of 24 hours was used for the design storm. The rainfall data for the facility located in Grayson County, Texas is depicted in the table on page C1B.12.

CURRENT PERMITTED DRAINAGE STRUCTURE DESIGN PARAMETERS

Pages C1B.14 through C1B.16 include drainage structure data for the existing ponds, and culverts for the surface impoundments incorporated into the hydrologic model.

HYDROLOGIC ANALYSIS

For the hydrologic evaluation, HEC-HMS was used for the precipitation-runoff simulation for the current permitted condition. The following describes the various modeling components. The HEC-HMS hydrologic analysis results begin on page C1B.18.

Watershed Subareas and Schematization

The drainage areas that contribute flow to the TASWA DRF 2290A permit boundary were delineated into subareas to derive peak flows to determine current permitted runon and runoff flows. Hydrographs are developed for each subarea and appropriately combined and routed through existing surface drainage features. The subareas are shown on Drawing C1B.1, and pages C1B.18, 21 and 23 for the HEC-HMS schematic of the current permitted condition.

Time Step

The time step, or the program computation interval, is the duration of the unit hydrograph. The time step selected is 5 minutes, which results in 289 hydrograph ordinates in 24 hours.

Hypothetical Precipitation

A return period of 25 years and a duration of 24 hours was used for the design storm. The rainfall data used is shown in the rainfall data table on page C1B.12. The precipitation is assumed to be evenly distributed over the entire landfill for each time interval.

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. The CN values used for each drainage area are shown in the Watershed Characteristics tables on pages C1B.9 and C1B.10.

Synthetic Unit Hydrographs and Flow Routing

The rainfall/runoff transformation was performed with the Unit Hydrograph Method. The synthetic unit hydrographs for each watershed were derived by the Snyder Method and Espey, “10-Minute Method” for estimating Snyder Parameters for the landfill permit boundary. The parameters and input values for this model are included in the Watershed Characteristics tables on pages C1B.9 and C1B.10.

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

CURRENT PERMITTED VELOCITY SUMMARY

Surface water velocities were determined for each discharge point where the surface water exits the permit boundary. The 25-year, 24-hour peak flow rate was used to determine the velocity at the permit boundary. Manning’s Equation was used to evaluate the velocities at the discharge points. Refer to Drawing C1B.1 for the locations of the discharge points and peak flow rate. Refer to page C1B.30 for the current permitted velocity calculations.

CURRENT PERMITTED FLOW AND BOUNDARY ANALYSIS SUMMARY

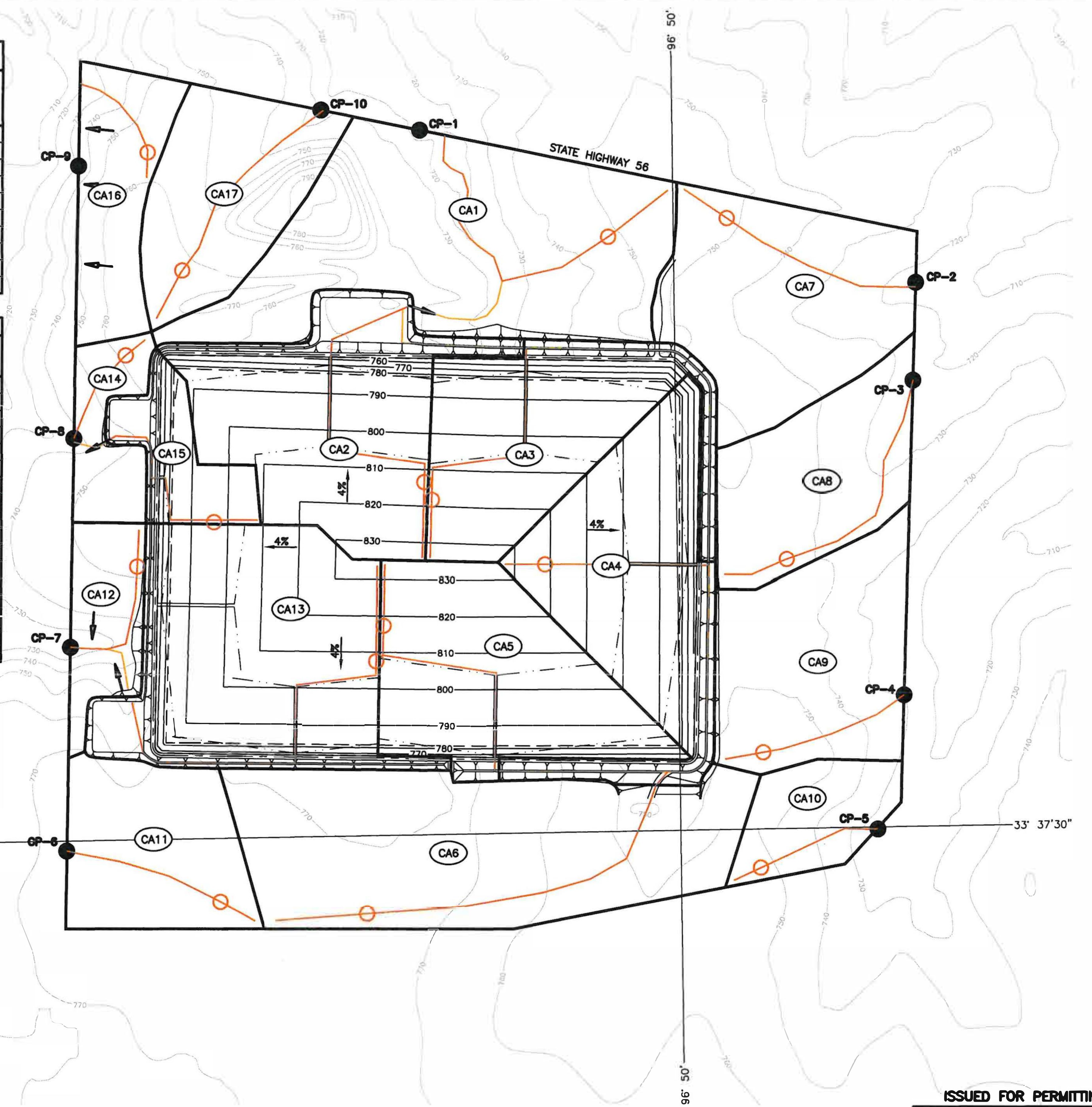
The current permitted flow summary table on page C1B.30 lists the peak flow rate for each drainage area for the 25-year rainfall event. This table summarizes the results of the hydrologic evaluation.

The boundary analysis summary for the current permitted conditions is provided on page C1B.30. The table provides for each comparison point (CP01 through CP10) the peak flow rate, velocity, and volume resulting from the HEC-HMS evaluation for the 25-year, 24 hour rainfall.

CURRENT PERMITTED DRAINAGE AREA DRAWINGS

CURRENT PERMITTED BOUNDARY ANALYSIS SUMMARY				
Comparis on Point	"Total Contributing Drainage Area (mi2)"	"25-Year Flow Rate (cfs)"	"25-Year Volume (ac-ft)"	"25-Year Velocity (fps)"
CP1	0.6056	654.1	183.7	3.4
CP2	0.0781	132.2	22.2	2.3
CP3	0.0520	81.3	14.8	1.4
CP4	0.0663	111.7	19.3	1.5
CP5	0.0255	47.3	7.3	1.7
CP6	0.0255	35.9	7.6	0.9
CP7	0.1248	134.0	38.3	2.2
CP8	0.0415	59.2	12.6	2.4
CP9	0.0349	75.4	10.4	2.3
CP10	0.0521	92.5	15.5	3.5

CURRENT PERMITTED DRAINAGE AREAS				
Watershed Name	Drainage Area (Ac)	Drainage Area (mi2)	25-Year Peak Flow (cfs)	25-Year Volume (Ac-ft)
CA1	78.6	0.1228	191.5	36.5
CA2	54.6	0.0853	160.2	26.9
CA3	44.3	0.0692	140.9	21.4
CA4	52.5	0.0821	186.3	25.4
CA5	46.8	0.0731	136.2	22.2
CA6	77.4	0.1210	164.9	35.9
CA7	50.0	0.0781	132.2	22.2
CA8	33.3	0.0521	81.3	14.8
CA9	42.4	0.0662	111.7	19.3
CA10	16.3	0.0255	47.3	7.3
CA11	31.2	0.0487	35.9	7.6
CA12	14.6	0.0228	41.7	6.8
CA13	65.3	0.1020	170.3	31.5
CA14	12.4	0.0193	38.2	5.5
CA15	14.2	0.0222	47.9	7.1
CA16	22.3	0.0349	75.4	10.4
CA17	33.3	0.0521	92.5	15.5



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SCALE IN FEET

LEGEND

2290A PERMIT BOUNDARY
2290A LANDFILL FOOTPRINT
EXISTING 10' GROUND CONTOUR
LANDFILL 10' CONTOUR
DRAINAGE AREA BOUNDARY
(CA01) DRAINAGE AREA DESIGNATION
COMPARISON POINT–POINT DISCHARGE
COMPARISON POINT–SHEET FLOW (NON–POINT DISCHARGE)

NOTE(S):

1. EXISTING GROUND CONTOURS DOWNLOADED FROM USGS TNM DOWNLOAD PROGRAM. IMAGERY DATE AUGUST 19, 2022.
2. CONTOURS WITHIN EXISTING LANDFILL FOOTPRINT DEPICT CURRENT PERMITTED FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

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CURRENT PERMITTED DRAINAGE AREA SUMMARY

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

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TBPG FIRM NO. 50222

C1B.1

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SCALE IN FEET

LEGEND

2290A PERMIT BOUNDARY

2290A LANDFILL FOOTPRINT

NOTES:

1. SOILS INFORMATION IS FROM THE SOIL SURVEY GEOGRAPHIC (SSURGO) DATABASE FOR GRAYSON COUNTY TEXAS COMPILED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE (USDA) AND THE NATIONAL RESOURCE CONSERVATION SERVICE (NRCS).

SOIL SYMBOL	SOIL NAME	HYDROLOGIC SOIL GROUP
16	Bunyan and Whitesboro soils, frequently flooded	B
30	Elbon soils, frequently flooded	C
39	Heiden clay, 1 to 3 percent slopes	D
40	Heiden clay, 3 to 5 percent slopes	D
52	Normangee clay loam, 1 to 3 percent slopes	D
53	Normangee clay loam, 4 to 8 percent slopes	D
71	Vertel clay, 3 to 5 percent slopes	D
72	Vertel clay, 5 to 12 percent slopes	D
80	Wilson silty clay loam, 1 to 3 percent slopes	D

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SOILS MAP

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

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C1B.2

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CURRENT PERMITTED WATERSHED CHARACTERISTICS

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
UNIT HYDROGRAPH DATA
Current Permitted Watershed Characteristics

			CN Determination					Main Reach Slope Calculation (for Espey Method)					Mannings "n" Determination			
Watershed Name	Watershed Area (ac)	Watershed Area (sq mi)	Final Cover Topslope Area (ac) CN = 85	Final Cover Sideslope Area (ac) CN = 87	Non-Final Cover Area (ac) CN = 84	Pond Area (ac) CN = 98	CN	Longest Reach (ft)	20% of Reach Length (ft)	Elevation @ 20% Reach Length from Upstream	Downstream Elevation	Slope (ft/ft)	Sheet Flow % of n = 0.070	Shallow Concentrated or Swale Flow % of n = 0.050	Channelized Flow % of n = 0.035	Composite n
CA1	78.6	0.1228			78.6		84	2530	506	748.0	720.0	0.0138	10	20	70	0.042
CA2	54.6	0.0853	38.3	9.5		6.8	87	2630	526	813.0	746.0	0.0318	10	20	70	0.042
CA3	44.3	0.0692	33.2	11.1		0.0	86	1990	398	818.0	732.0	0.0540	20	30	50	0.047
CA4	52.5	0.0821	35.7	16.8		0.0	86	1400	280	821.0	744.0	0.0688	20	40	40	0.048
CA5	46.8	0.0731	41.3	4.4		1.1	85	2080	416	818.0	768.0	0.0300	10	30	60	0.043
CA6	77.4	0.1210			77.4		84	3130	626	770.0	750.0	0.0080	10	20	70	0.042
CA7	50.0	0.0781			50.0		84	1780	356	750.0	717.0	0.0232	20	30	50	0.047
CA8	33.3	0.0521			33.3		84	2110	422	743.0	726.0	0.0101	10	30	60	0.043
CA9	42.4	0.0662			42.4		84	1320	264	750.0	729.0	0.0199	20	50	30	0.050
CA10	16.3	0.0255			16.3		84	1070	214	753.0	730.0	0.0269	30	60	10	0.055
CA11	31.2	0.0487			31.2		84	1390	278	775.0	770.0	0.0045	20	40	40	0.048
CA12	14.6	0.0228			14.6		84	1170	234	750.0	730.0	0.0214	30	50	20	0.053
CA13	65.3	0.1020	48.2	12.8		4.3	86	3260	652	808.0	749.0	0.0226	10	20	70	0.042
CA14	12.4	0.0193			12.4		84	850	170	761.0	738.0	0.0338	40	60	0	0.058
CA15	14.2	0.0222	7.4	4.2		2.6	88	1530	306	797.0	746.0	0.0417	20	40	40	0.048
CA16	22.3	0.0349			22.3		84	870	174	756.0	718.0	0.0546	30	70	0	0.056
CA17	33.3	0.0521			33.3		84	1870	374	763.0	726.0	0.0247	20	30	50	0.047

UNIT HYDROGRAPH DATA

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

Current Permitted Conditions

Watershed Name	Longest Reach (ft)	Slope (ft/ft)	Impervious Cover %	Manning's "n"	Eff. Coeff.	Tr (min)	Tlag (min)	Area (sq mi)	qp (cfs/sq mi)	Tlag (hr)	Cp
					(A)	(B)	(C)		(D)		(E)
CA1	2530	0.0138	2.0	0.042	0.88	39.2	36.7	0.1228	677.6	0.61	0.65
CA2	2630	0.0318	2.0	0.042	0.88	32.1	29.6	0.0853	851.1	0.49	0.66
CA3	1990	0.0540	2.0	0.047	0.90	27.5	25.0	0.0692	1013.7	0.42	0.66
CA4	1400	0.0688	2.0	0.048	0.90	23.9	21.4	0.0821	1171.0	0.36	0.65
CA5	2080	0.0300	2.0	0.043	0.88	30.9	28.4	0.0731	893.4	0.47	0.66
CA6	3130	0.0080	2.0	0.042	0.88	47.3	44.8	0.1210	555.5	0.75	0.65
CA7	1780	0.0232	2.0	0.047	0.90	33.1	30.6	0.0781	826.8	0.51	0.66
CA8	2110	0.0101	2.0	0.043	0.88	40.7	38.2	0.0521	673.6	0.64	0.67
CA9	1320	0.0199	2.0	0.050	0.90	32.1	29.6	0.0662	859.9	0.49	0.66
CA10	1070	0.0269	2.0	0.055	0.93	29.8	27.3	0.0255	966.6	0.46	0.69
CA11	1390	0.0045	2.0	0.048	0.90	47.2	44.7	0.0487	577.5	0.74	0.67
CA12	1170	0.0214	2.0	0.053	0.93	32.3	29.8	0.0228	893.3	0.50	0.69
CA13	3260	0.0226	2.0	0.042	0.88	36.8	34.3	0.1020	731.5	0.57	0.65
CA14	850	0.0338	2.0	0.058	0.94	27.3	24.8	0.0193	1074.6	0.41	0.69
CA15	1530	0.0417	2.0	0.048	0.90	27.6	25.1	0.0222	1055.8	0.42	0.69
CA16	870	0.0546	2.0	0.056	0.94	24.4	21.9	0.0349	1186.1	0.36	0.68
CA17	1870	0.0247	2.0	0.047	0.90	33.0	30.5	0.0521	844.8	0.51	0.67

(A) Conveyance efficiency from Dodson & Associates, Inc. Hands-On HEC-1, February 1999, pgs 6-19.

(B) $Tr=3.1(L^{0.23})(S^{-0.25})(I^{-0.18})(Effcoef^{1.57})$

(C) Tlag=Tr-(5/2)

(D) $qp=31600(A^{-0.04})(Tr^{-1.07})$

(E) $Cp=49.375(A^{-0.04})(Tr^{-1.07})(Tlag)$

Tr = surface runoff to unit hydrograph peak (min)
L = distance along main channel from study point to watershed boundary
S = main channel slope (ft/ft)
I = impervious cover within the watershed
Tlag = watershed lag time (min)
qp = Hydrograph peak discharge (cfs/sq. mi.)
Cp = Snyder's peaking coefficient

RAINFALL DATA

NOAA Atlas 14, Volume 11, Version 2
Location name: Whitesboro, Texas, USA*
Latitude: 33.636°, Longitude: -96.834°
Elevation: 743. 46ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

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

NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.423 (0.320-0.558)	0.489 (0.373-0.639)	0.595 (0.453-0.782)	0.685 (0.514-0.910)	0.808 (0.589-1.11)	0.905 (0.642-1.27)	1.00 (0.691-1.44)	1.10 (0.737-1.61)	1.22 (0.793-1.85)	1.31 (0.832-2.03)
10-min	0.878 (0.512-0.892)	0.782 (0.597-1.02)	0.954 (0.726-1.25)	1.10 (0.824-1.46)	1.30 (0.947-1.78)	1.48 (1.03-2.04)	1.61 (1.11-2.31)	1.76 (1.18-2.57)	1.94 (1.26-2.93)	2.07 (1.31-3.20)
15-min	0.844 (0.639-1.11)	0.974 (0.744-1.27)	1.19 (0.904-1.56)	1.36 (1.02-1.81)	1.61 (1.17-2.20)	1.80 (1.27-2.52)	1.98 (1.37-2.84)	2.17 (1.46-3.18)	2.41 (1.57-3.65)	2.59 (1.64-4.01)
30-min	1.18 (0.892-1.55)	1.36 (1.03-1.77)	1.65 (1.25-2.16)	1.89 (1.42-2.51)	2.22 (1.61-3.03)	2.47 (1.75-3.46)	2.73 (1.88-3.91)	2.99 (2.01-4.39)	3.34 (2.17-5.05)	3.61 (2.28-5.58)
60-min	1.53 (1.16-2.02)	1.77 (1.35-2.31)	2.15 (1.64-2.83)	2.48 (1.86-3.29)	2.93 (2.13-3.99)	3.27 (2.32-4.57)	3.62 (2.50-5.19)	4.00 (2.69-5.86)	4.50 (2.92-6.80)	4.89 (3.10-7.57)
2-hr	1.86 (1.42-2.43)	2.19 (1.67-2.81)	2.70 (2.07-3.50)	3.15 (2.38-4.14)	3.78 (2.77-5.11)	4.29 (3.06-5.93)	4.82 (3.35-6.82)	5.39 (3.65-7.81)	6.19 (4.05-9.24)	6.83 (4.35-10.4)
3-hr	2.05 (1.57-2.66)	2.44 (1.87-3.10)	3.04 (2.34-3.92)	3.57 (2.72-4.67)	4.34 (3.21-5.83)	4.97 (3.57-6.83)	5.64 (3.94-7.92)	6.36 (4.32-9.14)	7.38 (4.85-10.9)	8.21 (5.25-12.4)
6-hr	2.41 (1.87-3.09)	2.91 (2.25-3.65)	3.67 (2.85-4.67)	4.35 (3.34-5.62)	5.34 (3.98-7.09)	6.16 (4.46-8.37)	7.04 (4.95-9.77)	8.01 (5.48-11.3)	9.37 (6.19-13.7)	10.5 (6.75-15.6)
12-hr2	2.85 (2.23-3.62)	3.45 (2.69-4.29)	4.37 (3.43-5.51)	5.19 (4.01-6.63)	6.36 (4.77-8.35)	7.33 (5.34-9.83)	8.36 (5.93-11.5)	9.49 (6.55-13.3)	11.1 (7.39-16.0)	12.4 (8.05-18.3)
24-hr	3.36 (2.65-4.22)	4.06 (3.20-5.00)	5.14 (4.07-6.40)	6.09 (4.75-7.69)	7.45 (5.63-9.64)	8.54 (6.27-11.3)	9.72 (6.94-13.1)	11.0 (7.65-15.2)	12.8 (8.61-18.3)	14.3 (9.36-20.8)
2-day	3.91 (3.11-4.86)	4.71 (3.75-5.74)	5.94 (4.74-7.32)	7.02 (5.53-8.77)	8.56 (6.52-11.0)	9.80 (7.26-12.8)	11.1 (8.01-14.9)	12.6 (8.82-17.2)	14.7 (9.92-20.6)	16.4 (10.8-23.4)
3-day	4.28 (3.43-5.28)	5.14 (4.11-6.22)	6.46 (5.19-7.92)	7.62 (6.04-9.46)	9.28 (7.11-11.8)	10.6 (7.90-13.8)	12.0 (8.71-16.0)	13.6 (9.58-18.4)	15.9 (10.8-22.1)	17.7 (11.7-25.1)
4-day	4.56 (3.66-5.60)	5.46 (4.39-6.58)	6.86 (5.53-8.36)	8.08 (6.42-9.98)	9.83 (7.56-12.4)	11.2 (8.39-14.5)	12.7 (9.25-16.8)	14.4 (10.2-19.4)	16.8 (11.4-23.2)	18.7 (12.4-26.3)
7-day	5.17 (4.18-6.28)	6.16 (4.99-7.37)	7.71 (6.26-9.32)	9.07 (7.26-11.1)	11.0 (8.53-13.8)	12.6 (9.45-16.1)	14.3 (10.4-18.6)	16.1 (11.4-21.4)	18.7 (12.8-25.6)	20.9 (13.9-29.0)
10-day	5.69 (4.62-6.87)	6.76 (5.50-8.04)	8.44 (6.89-10.1)	9.89 (7.96-12.0)	12.0 (9.32-14.9)	13.7 (10.3-17.4)	15.5 (11.3-20.0)	17.4 (12.4-23.0)	20.2 (13.9-27.4)	22.5 (15.0-31.1)
20-day	7.41 (6.08-8.86)	8.70 (7.19-10.3)	10.8 (8.88-12.8)	12.5 (10.2-15.0)	15.0 (11.7-18.3)	16.9 (12.8-21.1)	18.9 (13.9-24.1)	21.0 (15.1-27.4)	24.1 (16.7-32.2)	26.5 (17.9-36.1)
30-day	8.85 (7.30-10.5)	10.3 (8.58-12.1)	12.7 (10.5-15.0)	14.7 (12.0-17.5)	17.4 (13.7-21.2)	19.5 (14.9-24.2)	21.7 (16.1-27.4)	24.0 (17.3-31.0)	27.3 (19.0-36.1)	29.8 (20.2-40.2)
45-day	10.8 (8.96-12.7)	12.5 (10.5-14.7)	15.3 (12.8-18.0)	17.7 (14.5-21.0)	20.9 (16.5-25.3)	23.3 (17.9-28.8)	25.8 (19.3-32.5)	28.5 (20.7-36.5)	32.2 (22.5-42.2)	35.1 (23.8-46.8)
60-day	12.5 (10.4-14.7)	14.5 (12.2-16.9)	17.7 (14.9-20.7)	20.4 (16.8-24.0)	24.0 (19.1-28.9)	28.8 (20.7-32.9)	29.7 (22.2-37.0)	32.8 (23.8-41.5)	36.7 (25.7-47.9)	39.9 (27.2-52.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical

CURRENT PERMITTED DRAINAGE STRUCTURE DESIGN PARAMETERS

Pond Data for HEC-HMS
Pond 1

Reservoir

Description:	
Downstream:	R1
Method:	Outflow Curve
Storage Method:	Elevation-Storage-Discharge
Stor-Dis Function:	Pond 1
Elev-Stor Function:	Pond 1
Primary:	Storage-Discharge
Initial Condition:	Inflow = Outflow

Spillway

Method:	Broad-Crested Spillway	
Direction:	Main	
Elevation:	741	ft
Length:	100	ft
Coefficient:	2.6	
Gates:	0	

Paired Data
Elevation-Storage Storage-Discharge
Pond 1

Elevation (ft)	Storage (ac-ft)	Discharge (cfs)
732.0	0.000	0
732.5	0.163	9
733.0	0.651	26
733.5	1.482	49
734.0	2.650	75
734.5	4.180	104
735.0	6.056	137
735.5	8.304	173
736.0	10.905	211
736.5	13.836	252
737.0	16.848	295
738.0	23.119	437.4
739.0	29.717	643
740.0	36.641	897.9
741.0	43.321	1205.3
742.0	50.164	1568.5

Pond Data for HEC-HMS
Pond 2

Reservoir

Description:	
Downstream:	R6
Method:	Outflow Curve
Storage Method:	Elevation-Storage-Discharge
Stor-Dis Function:	Pond 2
Elev-Stor Function:	Pond 2
Primary:	Storage-Discharge
Initial Condition:	Inflow = Outflow

Spillway

Method:	Broad-Crested Spillway	
Direction:	Main	
Elevation:	755	ft
Length:	100	ft
Coefficient:	2.6	
Gates:	0	

Paired Data
Elevation-Area Elevation-Discharge
Pond 2

Elevation (ft)	Area (ac)	Discharge (cfs)
750.0	0.000	0
750.5	0.547	3
751.0	1.093	9
751.5	1.670	16
752.0	2.247	25
752.5	2.329	35
753.0	2.411	46
754.0	2.528	93
755.0	2.646	162
756.0	2.767	255

Pond Data for HEC-HMS
Pond 3

Reservoir

Description:	
Downstream:	R7
Method:	Outflow Curve
Storage Method:	Elevation-Storage-Discharge
Stor-Dis Function:	Pond 3
Elev-Stor Function:	Pond 3
Primary:	Storage-Discharge
Initial Condition:	Inflow = Outflow

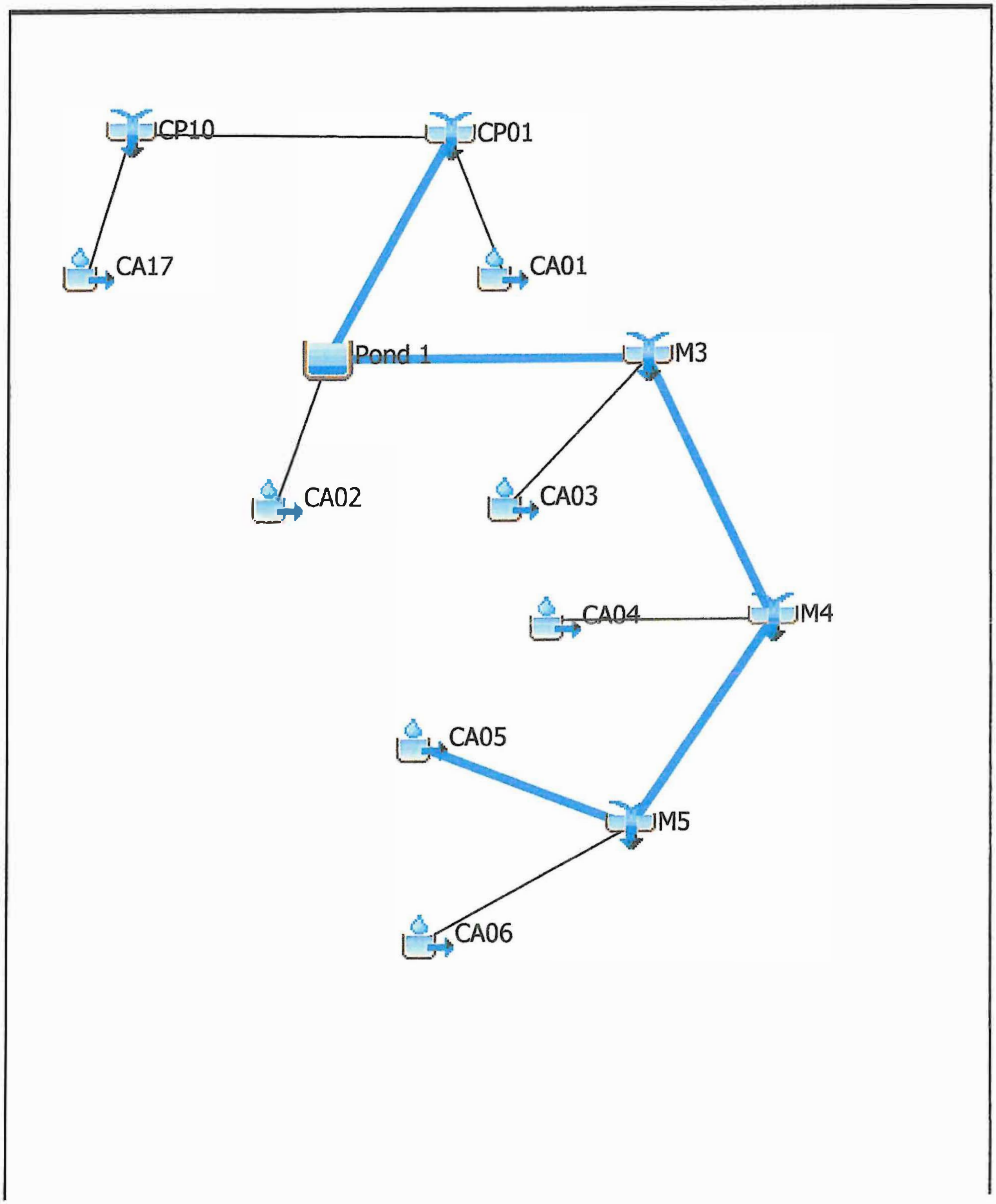
Spillway

Method:	Broad-Crested Spillway	
Direction:	Main	
Elevation:	755	ft
Length:	100	ft
Coefficient:	2.6	
Gates:	0	

Paired Data
Elevation-Area Elevation-Discharge
Pond 3

Elevation (ft)	Area (ac)	Discharge (cfs)
752.0	0.000	0
752.5	0.258	2
753.0	0.516	6
753.5	0.930	11
754.0	1.343	19
755.0	1.472	52
756.0	1.481	106

CURRENT PERMITTED HYDROLOGIC ANALYSIS
25-YEAR, 24-HOUR STORM EVENT


CP10
CP01
CA17
CA01
Pond 1
M3
CA02
CA03
CA04
M4
CA05
M5
CA06

Project:	2024 TASWA	Simulation Run:	North CP2
Start of Run:	01Jan2024, 00:00	Basin Model:	North CP2
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	04June2024, 13:21:14	Control Specifications	Control 1

Hydrologic Element	Drainage Area (MI^2)	Peak Discharge (CFS)	Time of Peak	Volume (ACRE-FT)
CA06	0.121	164.9	1 January 2024, 12:45	35.9
CA05	0.0731	136.2	1 January 2024, 12:30	22.2
R5	0.0731	135.6	1 January 2024, 12:35	22.2
M5	0.1941	291.3	1 January 2024, 12:40	58.1
R4	0.1941	291	1 January 2024, 12:45	58.1
CA04	0.0821	186.3	1 January 2024, 12:25	25.4
M4	0.2762	417.7	1 January 2024, 12:35	83.5
R3	0.2762	415.5	1 January 2024, 12:45	83.5
CA03	0.0692	140.9	1 January 2024, 12:30	21.4
M3	0.3454	531.8	1 January 2024, 12:40	104.9
R2	0.3454	530.9	1 January 2024, 12:40	104.8
CA02	0.0853	160.2	1 January 2024, 12:30	26.9
Pond 1	0.4307	481.8	1 January 2024, 13:10	131.7
R1	0.4307	481.5	1 January 2024, 13:15	131.7
CA01	0.1228	191.5	1 January 2024, 12:40	36.5
CA17	0.0521	92.5	1 January 2024, 12:35	15.5
CP10	0.0521	92.5	1 January 2024, 12:35	15.5
CP01	0.6056	654.1	1 January 2024, 13:05	183.7

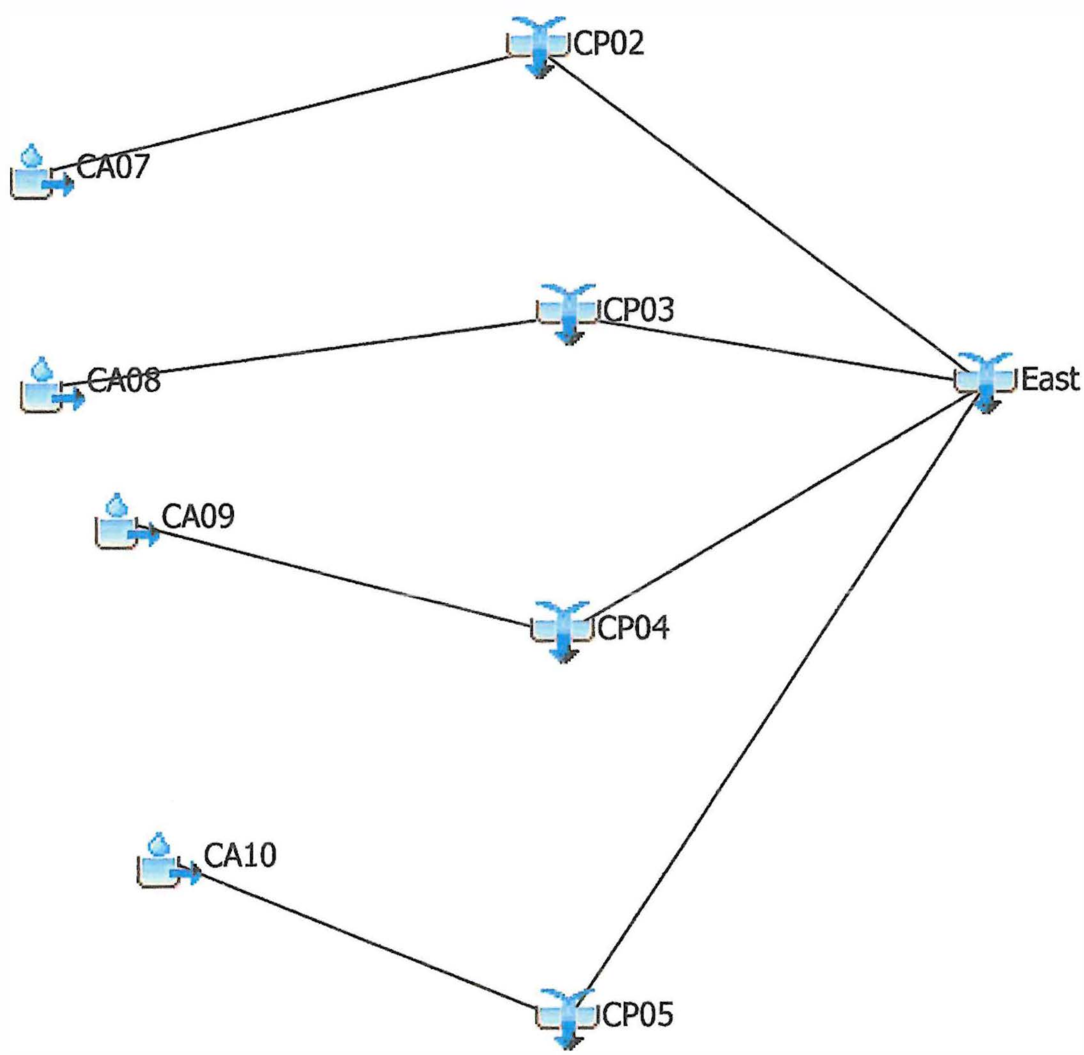
Project: 2024 TASWA Simulation Run: North CP2
Reservoir: Pond 1

Start of Run:	01Jan2024, 00:00	Basin Model:	North CP2
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	04Jun2024, 13:21:14	Control Specifications:	Control 1

Volume Units: ACRE-FT

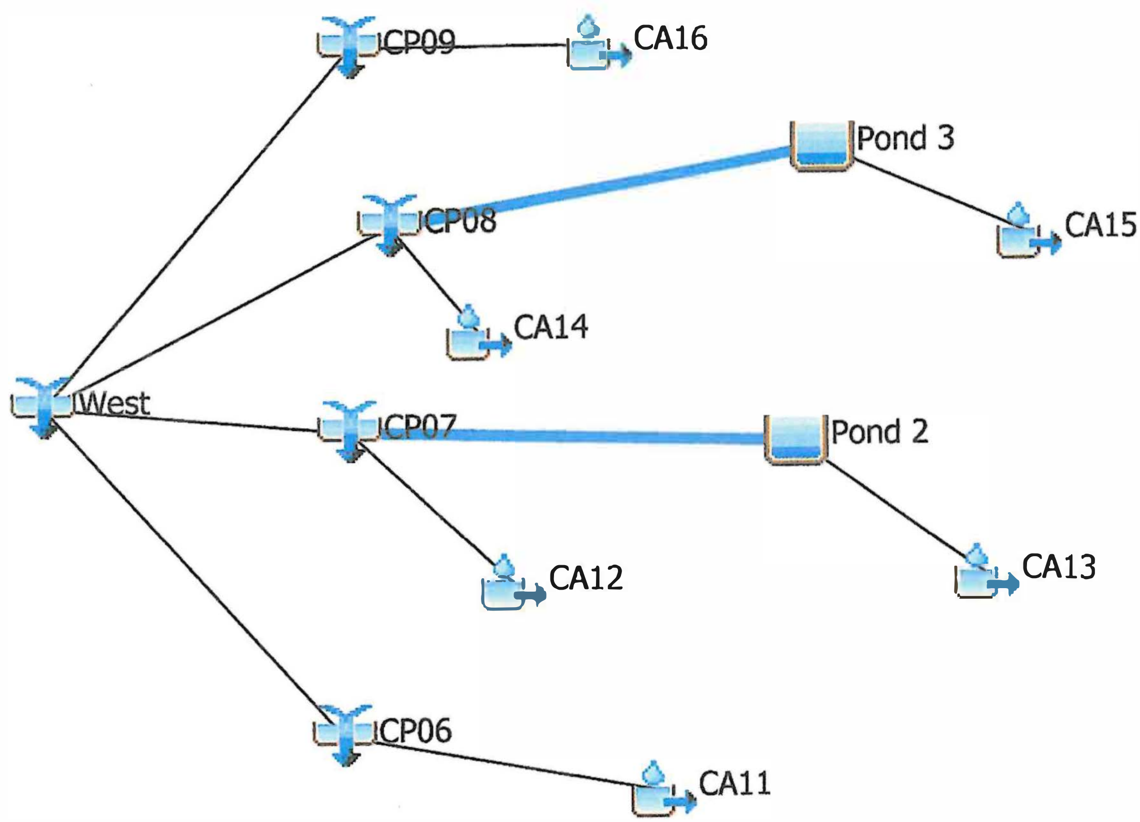
Computed Results

Peak Inflow:	679.1 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:40
Peak Discharge:	481.8 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 13:10
Inflow Volume:	131.7 (ACRE-FT)	Peak Storage:	24.5 (ACRE-FT)
Discharge Volume:	131.7 (ACRE-FT)	Peak Elevation:	738.2 (FT)


CP02
CA07
CP03
CA08
East
CA09
CP04
CA10
CP05

Project:	2024 TASWA	Simulation Run:	East CP 2
Start of Run:	01Jan2024, 00:00	Basin Model:	East CP 2
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	04 June 2024, 11:46:34	Control Specifications	Control 1

Hydrologic Element	Drainage Area (MI^2)	Peak Discharge (CFS)	Time of Peak	Volume (ACRE-FT)
CA07	0.0781	132.2	1 January 2022, 12:35	22.2
CP02	0.0781	132.2	1 January 2022, 12:35	22.2
CA08	0.052	81.3	1 January 2022, 12:40	14.8
CA09	0.0663	111.7	1 January 2022, 12:35	19.3
CP04	0.0663	111.7	1 January 2022, 12:35	19.3
CP03	0.052	81.3	1 January 2022, 12:40	14.8
CA10	0.0255	47.3	1 January 2022, 12:30	7.3
CP05	0.0255	47.3	1 January 2022, 12:30	7.3
East	0.2219	370.9	1 January 2022, 12:35	63.6


CP09
CA16
Pond 3
CP08
CA15
CA14
West
CP07
Pond 2
CA12
CA13
CP06
CA11

Project:	2024 TASWA	Simulation Run:	West CP 2
Start of Run:	01Jan2024, 00:00	Basin Model:	West CP 2
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	4June2024, 12:47:11	Control Specifications	Control 1

Hydrologic Element	Drainage Area (MI^2)	Peak Discharge (CFS)	Time of Peak	Volume (ACRE-FT)
CA13	0.1020	170.3	1 January 2024, 12:35	31.5
Pond 2	0.1020	111.5	1 January 2024, 13:05	31.5
R6	0.1020	111.2	1 January 2024, 13:10	31.5
CA12	0.0228	41.7	1 January 2024, 12:30	6.8
CP07	0.1248	134.0	1 January 2024, 13:00	38.3
CA11	0.0255	35.9	1 January 2024, 12:45	7.6
CA15	0.0222	47.9	1 January 2024, 12:30	7.1
Pond 3	0.0222	29.2	1 January 2024, 12:50	7.1
R7	0.0222	29.1	1 January 2024, 12:50	7.1
CA14	0.0193	38.2	1 January 2024, 12:25	5.5
CP08	0.0415	59.2	1 January 2024, 12:35	12.6
CA16	0.0349	75.4	1 January 2024, 12:25	10.4
CP09	0.0349	75.4	1 January 2024, 12:25	10.4
CP06	0.0255	35.9	1 January 2024, 12:45	7.6

Project: 2024 TASWA Simulation Run: West CP2

Reservoir: Pond 2

Start of Run:	01Jan2024, 00:00	Basin Model:	West CP2
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	04Jun2024, 12:47:11	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	170.3 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:35
Peak Discharge:	111.5 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 13:05
Inflow Volume:	31.5 (ACRE-FT)	Peak Storage:	7.6 (ACRE-FT)
Discharge Volume:	31.5 (ACRE-FT)	Peak Elevation:	754.3 (FT)

Project: 2024 TASWA Simulation Run: West CP2
Reservoir: Pond 3

Start of Run:	01Jan2024, 00:00	Basin Model:	West CP2
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	04Jun2024, 12:47:11	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	47.9 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:30
Peak Discharge:	29.2 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 12:50
Inflow Volume:	7.1 (ACRE-FT)	Peak Storage:	1.6 (ACRE-FT)
Discharge Volume:	7.1 (ACRE-FT)	Peak Elevation:	754.3 (FT)

CURRENT PERMITTED VELOCITY SUMMARY

Current Permitted 25-Year Velocity Calculations at Permit Boundary Comparison Points

Required: Determine the 25-year flow depths and velocities at the permit boundary.

Method: Calculate the flow depths and velocities using Manning's Equation.

Solution:

		Velocity Calculations						
Comparison Point	Q (cfs)	Width[1] (ft)	Bottom Slope[2] (%)	Side Slopes[3] (h:v)	Manning's n	Depth (ft)	Velocity (fps)	Shear Stress (psf)
CP01	654.1	200	0.6	15.0	0.030	**0.90**	**3.42**	**0.34**
CP02	132.2	250	1.6	25.0	0.030	**0.23**	**2.29**	**0.23**
CP03	81.3	450	1.2	0.0	0.030	**0.13**	**1.39**	**0.10**
CP04	111.7	1000	2.6	0.0	0.030	**0.08**	**1.45**	**0.13**
CP05	47.3	500	5.0	0.0	0.030	**0.06**	**1.65**	**0.18**
CP06	35.9	1100	3.0	0.0	0.030	**0.04**	**0.92**	**0.07**
CP07	134.0	200	1.0	8.0	0.030	**0.30**	**2.20**	**0.19**
CP08	59.2	200	4.0	25.0	0.030	**0.12**	**2.40**	**0.30**
CP09	75.4	500	8.0	0.0	0.030	**0.07**	**2.29**	**0.33**
CP10	92.5	100	3.0	10.0	0.030	**0.26**	**3.45**	**0.49**

Notes:

1. Comparison points where surface water runoff enters or exits the permit boundary in established natural or constructed channels; width refers to the bottom width of the channel.
   Comparison points where surface water runoff enters or exits the permit boundary as sheet flow or not well established channels; width refers to the sheet flow width.
2. For channels, bottom slope is the slope of the channel bottom where surface water enters or exits the permit boundary.
   For sheet flow, bottom slope is the slope of the ground where surface water enters or exits the permit boundary.
3. For channels, side slope is the average side slope of the channel where surface water enters or exits the permit boundary.
   For sheet flow, there are no side slopes and are represented by "0" in this table.

CURRENT PERMITTED FLOW AND BOUNDARY ANALYSIS SUMMARY

Current Permitted Flow Summary

Watershed Name	Drainage Area (Ac)	Drainage Area (mi^2)	25-Year Peak Flow (cfs)	25-Year Volume (Ac-ft)
CA1	78.6	0.1228	191.5	36.5
CA2	54.6	0.0853	160.2	26.9
CA3	44.3	0.0692	140.9	21.4
CA4	52.5	0.0821	186.3	25.4
CA5	46.8	0.0731	136.2	22.2
CA6	77.4	0.1210	164.9	35.9
CA7	50.0	0.0781	132.2	22.2
CA8	33.3	0.0521	81.3	14.8
CA9	42.4	0.0662	111.7	19.3
CA10	16.3	0.0255	47.3	7.3
CA11	31.2	0.0487	35.9	7.6
CA12	14.6	0.0228	41.7	6.8
CA13	65.3	0.1020	170.3	31.5
CA14	12.4	0.0193	38.2	5.5
CA15	14.2	0.0222	47.9	7.1
CA16	22.3	0.0349	75.4	10.4
CA17	33.3	0.0521	92.5	15.5

Current Permitted Boundary Analysis Summary

Comparison Point	Total Contributing Drainage Area (mi^2)	25-Year Flow Rate (cfs)	25-Year Volume (ac-ft)	25-Year Velocity (fps)
CP1	0.6056	654.1	183.7	3.4
CP2	0.0781	132.2	22.2	2.3
CP3	0.0520	81.3	14.8	1.4
CP4	0.0663	111.7	19.3	1.5
CP5	0.0255	47.3	7.3	1.7
CP6	0.0255	35.9	7.6	0.9
CP7	0.1248	134.0	38.3	2.2
CP8	0.0415	59.2	12.6	2.4
CP9	0.0349	75.4	10.4	2.3
CP10	0.0521	92.5	15.5	3.5

ATTACHMENT C1
APPENDIX C1C

POSTDEVELOPMENT HYDROLOGIC CALCULATIONS

CONTENTS

POSTDEVELOPMENT NARRATIVE

30 TAC §330.305(a)

The post development hydrologic analysis represents the hydrologic calculations as defined by the landfill completion plan for the TASWA Solid Waste Disposal and Recycling Facility (TASWA DRF) MSW Permit No. 2290A in accordance with §330.305(a)-(d).

POSTDEVELOPMENT DRAINAGE AREA DRAWINGS

The Postdevelopment Drainage Area Summary (Drawing C1C.1) delineates the drainage areas that contribute stormwater runon or runoff to the proposed permit boundary. Drainage areas within the permit boundary are designated by the prefix "DA". Refer to Drawing C1C.1 for the postdeveloped drainage area summary.

POSTDEVELOPMENT WATERSHED CHARACTERISTICS

Watershed characteristics have been developed for the postdevelopment hydrologic evaluation. The watershed characteristics address drainage area runoff characteristics, unit hydrograph data, reach characteristics, existing culverts, and the proposed final condition drainage system including the detention ponds. This information is included on pages C1C.7 and C1C.8.

The first table, titled Postdeveloped Watershed Characteristics, pages C1C.7 and C1C.8, provides the summary of drainage areas, soil types, Curve Numbers (CN) values, initial loss, reach slope calculations, and determination of Manning's n value. The Soil Conservation Service (SCS) CN were derived from watershed characteristic tables from the SCS Technical Report 55 (TR-55), which included evaluation of anticipated postdevelopment soil and surface cover/condition characteristics. The second table, titled Unit Hydrograph Data - Snyder's Hydrograph Coefficients, page C1C.9, provides the determination of the Snyder's Unit Hydrograph parameters. The runoff characteristics for the off-site drainage areas did not change from the current permitted condition.

POSTDEVELOPMENT DRAINAGE STRUCTURE DESIGN PARAMETERS

Pages C1C.10 through C1C.18 include drainage structure data for the existing and proposed ponds, and culverts for the surface impoundments incorporated into the hydrologic model. The postdevelopment hydrologic model is defined by the landfill completion plan for the TASWA DRF MSW Permit No. 2290A.

HYDROLOGIC ANALYSIS

For the hydrologic evaluation, HEC-HMS was used for the precipitation runoff simulation for the postdevelopment condition. The following describes the various modeling components. The HEC-HMS hydrologic analysis results begin on page C1C.19.

Watershed Subareas and Schematization

The drainage areas that contribute flow to the TASWA DRF 2290A permit boundary were delineated into subareas to derive peak flows to determine current permitted runon and runoff flows. Hydrographs are developed for each subarea and appropriately combined and routed through the swales and perimeter channels. The subareas are shown on Drawing C1C.1. For the HEC-HMS schematic of the postdevelopment condition, refer to Drawing C1C.5 and page C1C.29.

Time Step

The time step, or the program computation interval, is the duration of the unit hydrograph. The time step is selected as 5 minutes, which results in 289 hydrograph ordinates in 24 hours.

Hypothetical Precipitation

A return period of 25 years and a duration of 24 hours was used for the design storm. The rainfall data used is shown in the rainfall data table on page C1B.12. The precipitation is assumed to be evenly distributed over the entire landfill for each time interval.

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. The CN values used for each drainage area are shown in the Postdeveloped Watershed Characteristic table on pages C1C.7 and C1C.8.

Synthetic Unit Hydrographs and Flow Routing

The rainfall/runoff transformation was performed with the Unit Hydrograph Method. The synthetic unit hydrographs for each watershed were derived by the Snyder Method and Espey's "10-Minute Method" for estimating Snyder Parameters for the landfill permit boundary. The parameters and input values for this model are included in the Unit Hydrograph Data table on pages C1C.7 and C1C.8.

The Kinematic Wave 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, bottom width, and channel roughness.

Post Developed Velocity Summary

Surface water velocities were determined for each discharge point where the surface water enters or exits the permit boundary. The 25-year, 24-hour peak flow rate was analyzed to determine the velocity at the permit boundary. Manning's Equation was used to evaluate the velocities at the discharge points. Refer to Drawing C1C.1 for location of discharge points and peak flow rates. Refer to the postdevelopment velocity summary on pages C1C.35 for postdeveloped velocity calculations.

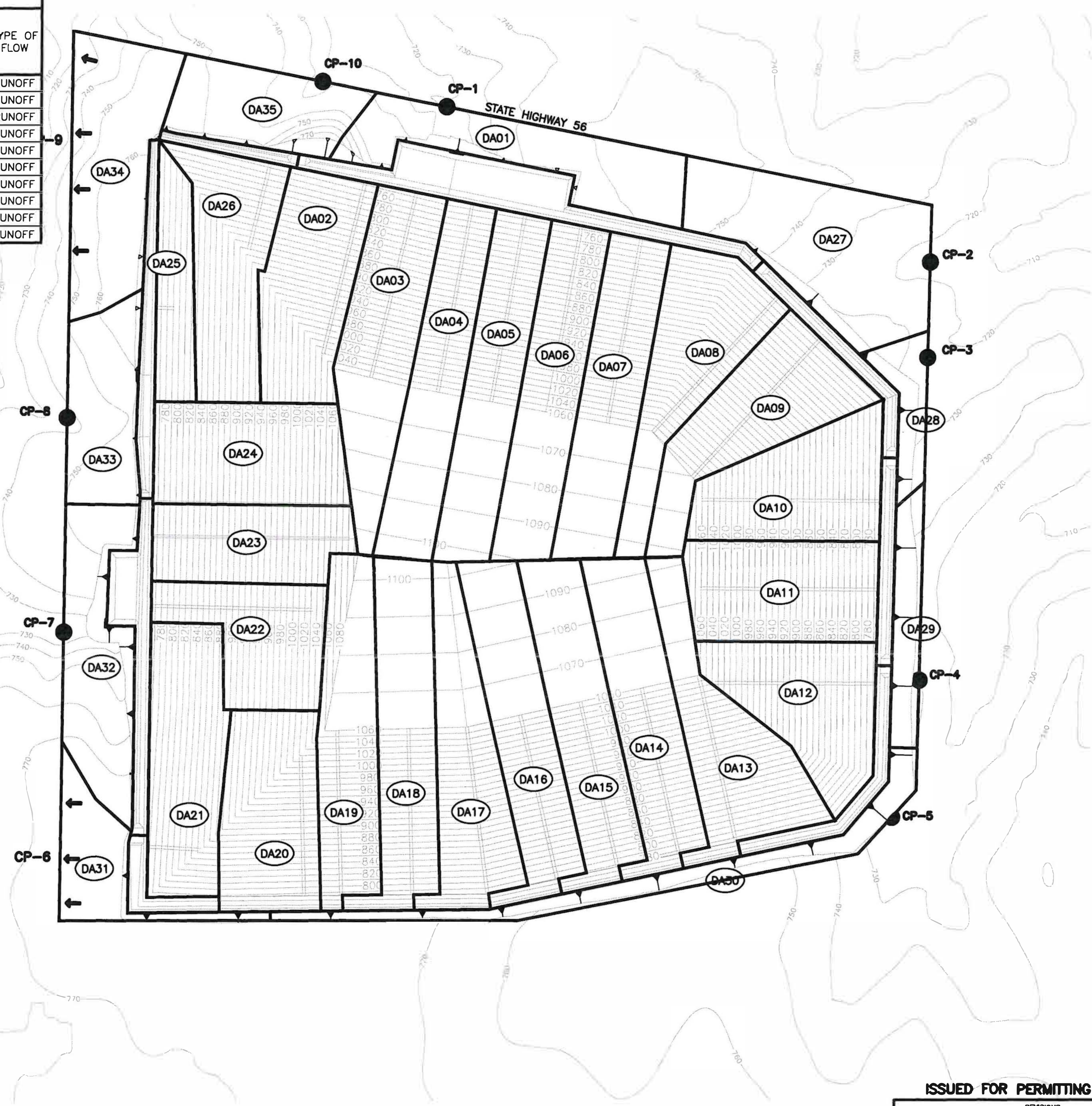
POSTDEVELOPMENT FLOW AND BOUNDARY ANALYSIS SUMMARY

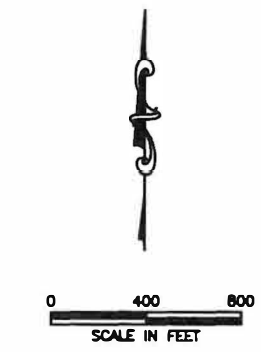
The postdevelopment flow summary table on page C1C.37 lists the postdevelopment runoff for each drainage area for the 25-year rainfall event. This table summarizes the results of the postdevelopment hydrologic evaluation. The boundary analysis summary for the postdevelopment condition is provided on page C1C.38. The table provides for each comparison point (CP01 through CP10) the peak flow rate, velocity, and volume resulting from the HEC-HMS evaluation for the 25-year, 24 hour rainfall.

POSTDEVELOPMENT DRAINAGE AREA DRAWING

POST DEVELOPED BOUNDARY ANALYSIS SUMMARY					
BOUNDARY COMPARISON POINT	TOTAL CONTRIBUTING DRAINAGE AREA (mi2)	25-YEAR FLOW RATE (cfs)	25-YEAR VOLUME (ac-ft)	25-YEAR VELOCITY (fps)	TYPE OF FLOW
CP1	06056	609.8	178.6	3.3	RUNOFF
CP2	0.0781	128.4	23.7	2.2	RUNOFF
CP3	0.0520	80.1	13.7	1.4	RUNOFF
CP4	0.0663	110.3	18.7	1.4	RUNOFF
CP5	0.0255	30.1	5.8	2.4	RUNOFF
CP6	0.0255	36.0	9.9	0.6	RUNOFF
CP7	0.1248	131.2	44.8	2.2	RUNOFF
CP8	0.0415	57.0	13.8	2.4	RUNOFF
CP9	0.0349	77.2	10.8	2.3	RUNOFF
CP10	0.0521	78.8	14.7	3.2	RUNOFF

POST DEVELOPED DRAINAGE AREAS			
WATERSHED NAME	AREA (ac)	25-YEAR FLOW RATE (cfs)	25-YEAR VOLUME (ac-ft)
DA1	19.7	59.0	9.7
POND 1	13.8	36.7	7.4
DA2	20.3	75.2	10.0
DA3	22.9	86.1	11.1
DA4	20.1	75.5	9.7
DA5	20.5	77.0	2.4
DA6	20.8	79.8	10.1
DA7	20.8	79.8	10.1
DA8	20.7	82.0	10.2
DA9	20.8	85.9	10.3
DA10	19.5	86.5	9.6
DA11	19.6	86.8	0
DA12	19.3	54.1	9.5
DA13	20.9	83.0	10.3
DA14	20.7	79.3	10.0
DA15	21.0	80.6	10.1
DA16	21.1	79.4	10.2
DA17	20.4	76.7	9.9
DA18	21.2	79.6	10.2
DA19	20.0	74.4	9.7
DA20	19.8	72.1	9.7
DA21	20.9	79.9	10.3
DA22	16.1	70.0	7.9
DA23	15.4	68.5	7.6
DA24	20.0	92.3	9.9
DA25	9.1	26.0	4.5
DA26	19.5	67.7	0
DA27	29.2	81.0	13.5
DA28	5.6	16.5	2.6
DA29	7.1	13.7	3.3
DA30	12.5	30.1	5.8
DA31	10.3	24.2	4.8
DA32	19.2	58.8	8.9
POND 2	7.5	22.1	35.9
DA33	14.5	48.5	6.7
POND 3	5.1	12.1	7.0
DA34	23.2	77.2	10.8
DA35	14.4	42.0	6.7





LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LIMIT OF WASTE
- 700 EXISTING 10' GROUND CONTOUR
- 900 LANDFILL 10' CONTOUR
- DRAINAGE AREA BOUNDARY
- CA01 DRAINAGE AREA DESIGNATION
- COMPARISON POINT-POINT DISCHARGE
- COMPARISON POINT-SHEET FLOW (NON-POINT DISCHARGE)

NOTE(S):

1. EXISTING GROUND CONTOURS DOWNLOADED FROM USGS WEBSITE ON MARCH 25, 2024.
2. CONTOURS WITHIN EXISTING LANDFILL FOOTPRINT DEPICT CURRENT PERMITTED FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED PROFESSIONAL ENGINEER
2/28/2025

ISSUED FOR PERMITTING PURPOSES

REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

POST DEVELOPED DRAINAGE AREA SUMMARY

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817-563-1144
TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1C.1

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POSTDEVELOPED WATERSHED CHARACTERISTICS

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
UNIT HYDROGRAPH DATA
Postdeveloped Watershed Characteristics

			CN Determination						Main Reach Slope Calculation (for Espey Method)					Mannings "n" Determination			
Watershed Name	Watershed Area (ac)	Watershed Area (sq mi)	Non-Final Cover Area (ac) CN = 84	Final Cover Topslope Area (ac) CN = 85	Final Cover Sideslope Area (ac) CN = 87	Channel Area (ac) CN=87	Pond Area (ac) CN = 98	CN	Longest Reach (ft)	20% of Reach Length (ft)	Elevation @ 20% Reach Length from Upstream	Downstream Elevation	Slope (ft/ft)	Sheet Flow % of n = 0.070	Shallow Concentrated or Swale Flow	Channelized Flow % of n = 0.035	Composite n
DA01	19.7	0.0308	0.0	0.0	19.7	0.0	0.0	87	1600	320	752.0	720.0	0.0250	20	40	40	0.048
DA02	20.3	0.0317	0.0	0.0	20.3	0.0	0.0	87	2220	444	936.2	745.8	0.1072	5	25	70	0.041
DA03	22.9	0.0358	0.0	8.3	14.6	0.0	0.0	86	2600	520	1085.0	742.0	0.1649	10	25	65	0.042
DA04	20.1	0.0314	0.0	9.9	10.2	0.0	0.0	86	2560	512	1085.0	740.8	0.1681	10	25	65	0.042
DA05	20.5	0.0320	0.0	9.5	11.0	0.0	0.0	86	2510	502	1084.0	742.6	0.1700	10	25	65	0.042
DA06	20.8	0.0325	0.0	9.5	11.3	0.0	0.0	86	2430	486	1081.0	744.6	0.1730	10	25	65	0.042
DA07	20.8	0.0325	0.0	8.8	12.0	0.0	0.0	86	2350	470	1079.0	746.6	0.1768	15	25	60	0.044
DA08	20.7	0.0323	0.0	4.0	16.7	0.0	0.0	87	2160	432	1077.0	752.0	0.1881	15	30	55	0.045
DA09	20.8	0.0325	0.0	3.6	17.2	0.0	0.0	87	1980	396	1077.0	754.0	0.2039	15	20	65	0.043
DA10	19.5	0.0305	0.0	0.0	19.5	0.0	0.0	87	1540	308	1060.0	760.0	0.2435	5	15	80	0.039
DA11	19.6	0.0306	0.0	0.0	19.6	0.0	0.0	87	1570	314	1063.0	762.6	0.2392	5	20	75	0.040
DA12	19.3	0.0302	0.0	0.0	19.3	0.0	0.0	87	1030	206	773.6	765.4	0.0100	10	60	30	0.048
DA13	20.9	0.0327	0.0	4.2	15.8	0.9	0.0	87	2170	434	1075.0	764.7	0.1787	15	30	55	0.045
DA14	20.7	0.0323	0.0	8.6	11.1	1.0	0.0	86	2270	454	1078.0	766.4	0.1716	15	25	60	0.044
DA15	21.0	0.0328	0.0	9.2	10.8	1.0	0.0	86	2350	470	1080.0	768.2	0.1659	15	25	60	0.044
DA16	21.1	0.0330	0.0	9.7	10.3	1.1	0.0	86	2410	482	1083.0	770.0	0.1623	10	25	65	0.042
DA17	20.4	0.0319	0.0	6.7	12.4	1.3	0.0	86	2440	488	1084.0	772.1	0.1598	10	25	65	0.042
DA18	21.2	0.0331	0.0	10.2	9.9	1.1	0.0	86	2460	492	1086.0	774.3	0.1584	10	25	65	0.042
DA19	20.0	0.0313	0.0	6.1	13.5	0.4	0.0	86	2510	502	1065.0	776.4	0.1437	10	25	65	0.042
DA20	19.8	0.0309	0.0	0.0	18.1	1.7	0.0	87	1840	368	900.0	786.0	0.0774	5	35	60	0.042
DA21	20.9	0.0327	0.0	0.0	20.9	0.0	0.0	87	1840	368	881.7	776.7	0.0713	5	35	60	0.042
DA22	16.1	0.0252	0.0	0.0	16.1	0.0	0.0	87	1730	346	1007.5	763.4	0.1764	5	35	60	0.042
DA23	15.4	0.0241	0.0	0.0	15.4	0.0	0.0	87	1360	272	1003.1	762.0	0.2216	5	20	75	0.040
DA24	20.0	0.0313	0.0	0.0	20.0	0.0	0.0	87	1850	370	1043.8	762.0	0.1904	5	30	65	0.041

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
UNIT HYDROGRAPH DATA

Postdeveloped Watershed Characteristics

			CN Determination						Main Reach Slope Calculation (for Espey Method)					Mannings "n" Determination			
Watershed Name	Watershed Area (ac)	Watershed Area (sq mi)	Non-Final Cover Area (ac) CN = 84	Final Cover Topslope Area (ac) CN = 85	Final Cover Sideslope Area (ac) CN = 87	Channel Area (ac) CN=87	Pond Area (ac) CN = 98	CN	Longest Reach (ft)	20% of Reach Length (ft)	Elevation @ 20% Reach Length from Upstream	Downstream Elevation	Slope (ft/ft)	Sheet Flow % of n = 0.070	Shallow Concentrated or Swale Flow	Channelized Flow % of n = 0.035	Composite n
DA25	9.1	0.0142	0.0	0.0	9.1	0.0	0.0	87	1010	202	769.5	761.7	0.0097	10	60	30	0.048
DA26	19.5	0.0305	0.0	0.0	19.5	0.0	0.0	87	2240	448	827.8	752.2	0.0422	5	25	70	0.041
DA27	29.2	0.0456	29.2	0.0	0.0	0.0	0.0	84	1950	390	751.0	717.0	0.0218	15	30	55	0.045
DA28	5.6	0.0088	5.6	0.0	0.0	0.0	0.0	84	950	190	732.0	725.0	0.0092	10	0	90	0.039
DA29	7.1	0.0111	7.1	0.0	0.0	0.0	0.0	84	1260	252	730.0	729.0	0.0010	10	0	90	0.039
DA30	12.5	0.0195	12.5	0.0	0.0	0.0	0.0	84	4270	854	772.0	728.0	0.0129	5	15	80	0.039
DA31	10.3	0.0161	10.3	0.0	0.0	0.0	0.0	84	440	88	773.0	772.0	0.0028	70	30	0	0.064
DA32	19.2	0.0300	19.2	0.0	0.0	0.0	0.0	84	1460	292	767.0	728.0	0.0334	20	40	40	0.048
DA33	14.5	0.0227	14.5	0.0	0.0	0.0	0.0	84	530	106	762.0	747.0	0.0354	55	45	0	0.061
DA34	23.2	0.0363	23.2	0.0	0.0	0.0	0.0	84	870	174	756.0	720.0	0.0517	35	70	-5	0.058
DA35	14.4	0.0225	14.4	0.0	0.0	0.0	0.0	84	1160	232	750.0	728.0	0.0237	25	70	5	0.054
I-02A	1.7	0.0027	0.0	0.0	0.0	1.7	0.0	87	840	168	753.5	744.0	0.0141	35	70	100	0.095
I-08A	4.0	0.0063	0.0	0.0	0.0	4.0	0.0	87	1520	304	749.2	743.2	0.0049	20	70	100	0.084
I-10A	3.3	0.0052	0.0	0.0	0.0	3.3	0.0	87	1230	246	755.4	751.2	0.0043	25	70	100	0.088
I-12A	4.5	0.0070	0.0	0.0	0.0	4.5	0.0	87	1820	364	763.2	757.1	0.0042	15	70	100	0.081
I-21A	2.7	0.0042	0.0	0.0	0.0	1.7	1.0	91	970	194	777.4	772.0	0.0070	30	70	100	0.091
P1P	13.8	0.0216	0.0	0.0	0.0	8.3	5.5	91	2110	422	739.8	728.0	0.0070	0	70	30	0.046
P2P	7.5	0.0117	0.0	0.0	0.0	4.5	3.0	91	1540	308	761.3	749.0	0.0100	0	70	30	0.046
P3P	5.1	0.0080	0.0	0.0	0.0	4.2	0.9	89	1960	392	755.1	750.0	0.0033	0	70	30	0.046

UNIT HYDROGRAPH DATA

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

Postdeveloped Conditions

Watershed Name	Longest Reach (ft)	Slope (ft/ft)	Impervious Cover %	Manning's "n"	Eff. Coeff.	Tr (min)	Tlag (min)	Area (sq mi)	qp (cfs/sq mi)	Tlag (hr)	Cp
					(A)	(B)	(C)		(D)		(E)
DA01	1600	0.0250	2.0	0.048	0.90	31.7	29.2	0.0308	899.0	0.49	0.68
DA02	2220	0.1072	2.0	0.041	0.88	22.8	20.3	0.0317	1277.4	0.34	0.68
DA03	2600	0.1649	2.0	0.042	0.88	21.2	18.7	0.0358	1372.0	0.31	0.67
DA04	2560	0.1681	2.0	0.042	0.88	21.1	18.6	0.0314	1391.5	0.31	0.67
DA05	2510	0.1700	2.0	0.042	0.88	20.9	18.4	0.0320	1401.5	0.31	0.67
DA06	2430	0.1730	2.0	0.042	0.88	20.7	18.2	0.0325	1418.6	0.30	0.67
DA07	2350	0.1768	2.0	0.044	0.88	20.4	17.9	0.0325	1438.6	0.30	0.67
DA08	2160	0.1881	2.0	0.045	0.88	19.7	17.2	0.0323	1493.5	0.29	0.67
DA09	1980	0.2039	2.0	0.043	0.88	18.9	16.4	0.0325	1558.9	0.27	0.67
DA10	1540	0.2435	2.0	0.039	0.85	16.4	13.9	0.0305	1819.7	0.23	0.66
DA11	1570	0.2392	2.0	0.040	0.85	16.6	14.1	0.0306	1802.0	0.23	0.66
DA12	1030	0.0100	2.0	0.048	0.90	36.1	33.6	0.0302	783.8	0.56	0.69
DA13	2170	0.1787	2.0	0.045	0.88	20.0	17.5	0.0327	1471.1	0.29	0.67
DA14	2270	0.1716	2.0	0.044	0.88	20.4	17.9	0.0323	1439.6	0.30	0.67
DA15	2350	0.1659	2.0	0.044	0.88	20.7	18.2	0.0328	1413.7	0.30	0.67
DA16	2410	0.1623	2.0	0.042	0.88	21.0	18.5	0.0330	1396.6	0.31	0.67
DA17	2440	0.1598	2.0	0.042	0.88	21.1	18.6	0.0319	1388.4	0.31	0.67
DA18	2460	0.1584	2.0	0.042	0.88	21.2	18.7	0.0331	1380.2	0.31	0.67
DA19	2510	0.1437	2.0	0.042	0.88	21.8	19.3	0.0313	1341.3	0.32	0.67
DA20	1840	0.0774	2.0	0.042	0.88	23.7	21.2	0.0309	1227.6	0.35	0.68
DA21	1840	0.0713	2.0	0.042	0.88	24.2	21.7	0.0327	1198.3	0.36	0.68
DA22	1730	0.1764	2.0	0.042	0.88	19.0	16.5	0.0252	1566.2	0.28	0.67
DA23	1360	0.2216	2.0	0.040	0.85	16.3	13.8	0.0241	1846.8	0.23	0.67
DA24	1850	0.1904	2.0	0.041	0.88	19.0	16.5	0.0313	1558.8	0.27	0.67
DA25	1010	0.0097	2.0	0.048	0.90	36.2	33.7	0.0142	805.1	0.56	0.71
DA26	2240	0.0422	2.0	0.041	0.88	28.9	26.4	0.0305	994.8	0.44	0.68
DA27	1950	0.0218	2.0	0.045	0.88	33.0	30.5	0.0456	848.8	0.51	0.67
DA28	950	0.0092	2.0	0.039	0.85	33.3	30.8	0.0088	897.1	0.51	0.72
DA29	1260	0.0010	2.0	0.039	0.85	62.0	59.5	0.0111	456.7	0.99	0.71
DA30	4270	0.0129	2.0	0.039	0.85	43.3	40.8	0.0195	656.5	0.68	0.70
DA31	440	0.0028	2.0	0.064	0.96	45.2	42.7	0.0161	631.2	0.71	0.70
DA32	1460	0.0334	2.0	0.048	0.90	28.9	26.4	0.0300	994.6	0.44	0.68
DA33	530	0.0354	2.0	0.061	0.96	25.1	22.6	0.0227	1167.6	0.38	0.69
DA34	870	0.0517	2.0	0.058	0.94	24.7	22.2	0.0363	1167.3	0.37	0.67
DA35	1160	0.0237	2.0	0.054	0.93	31.4	28.9	0.0225	921.0	0.48	0.69
I-02A	840	0.0141	2.0	0.095	1.09	42.6	40.1	0.0027	722.7	0.67	0.76
I-08A	1520	0.0049	2.0	0.084	1.04	59.6	57.1	0.0063	488.1	0.95	0.73
I-10A	1230	0.0043	2.0	0.088	1.06	60.4	57.9	0.0052	484.4	0.97	0.73
I-12A	1820	0.0042	2.0	0.081	1.04	64.7	62.2	0.0070	444.9	1.04	0.72
I-21A	970	0.0070	2.0	0.091	1.09	52.6	50.1	0.0042	566.5	0.84	0.74
P1P	2110	0.0070	2.0	0.046	0.90	46.5	44.0	0.0216	605.8	0.73	0.69
P2P	1540	0.0100	2.0	0.046	0.90	39.5	37.0	0.0117	737.9	0.62	0.71
P3P	1960	0.0033	2.0	0.046	0.90	55.3	52.8	0.0080	523.2	0.88	0.72

(A) Conveyance efficiency from Dodson & Associates, Inc. Hands-On HEC-1, February 1999, pgs 6-19.

(B) $Tr=3.1(L^{0.23})(S^{-0.25})(I^{-0.18})(Effcoef^{1.57})$

(C) $Tlag=Tr-(5/2)$

(D) $qp=31600(A^{-0.04})(Tr^{-1.07})$

(E) $Cp=49.375(A^{-0.04})(Tr^{-1.07})(Tlag)$

Tr = Surface runoff to unit hydrograph peak (min)

L = Distance along main channel from study point to watershed boundary

S = Main channel slope (ft/ft)

I = Impervious cover within the watershed

Tlag = Watershed lag time (min)

qp = Hydrograph peak discharge (cfs/sq. mi.)

Cp = Snyder's peaking coefficient

POSTDEVELOPMENT DRAINAGE STRUCTURE DESIGN PARAMETERS

Pond Data for HEC-HMS
Pond 1 Post

Reservoir

Description:	
Downstream:	R1
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	Pond 1 Post
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	None
Time Step Method:	Automatic Adaptation
Outlets:	1
Spillways:	1
Dam Tops:	1
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Outlet

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	2	
Solution Method:	Automatic	
Shape:	Box	
Chart:	8: Flared Wingwalls	
Scale:	1:Wingwalls flared 30 to 75 degrees	
Length:	150	ft
Rise:	4	ft
Span:	6	ft
Inlet Elevation:	728	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	727	
Exit Coefficient:	1	
Mannings n:	0.013	

Spillway

Method:	Broad-Crested Spillway	
Direction:	Main	
Elevation:	737.5	ft
Length:	100	ft
Coefficient:	2.6	
Gates:	0	

Dam Tops

Method:	Level Overflow
Direction:	Main
Elevation:	738
Length:	1190
Coefficient:	2.6

Paired Data

Elevation-Storage
Pond 1 Post

Elevation	Storage Cumulative		Incremental
(ft)	(ac-ft)	(cy)	(cy)
728.0	0.000	0.0	0.0
729.0	0.123	198.7	198.7
730.0	0.985	1,589.3	1,390.6
731.0	3.215	5,187.4	3,598.1
732.0	7.002	11,296.7	6,109.3
733.0	12.173	19,639.0	8,342.3
734.0	18.151	29,283.9	9,644.9
735.0	24.527	39,569.8	10,285.9
736.0	31.292	50,484.9	10,915.1
737.0	38.490	62,096.8	11,611.9
738.0	46.161	74,473.2	12,376.4
739.0	54.291	87,590.2	13,117.0
740.0	62.858	101,410.4	13,820.2

Pond Data for HEC-HMS
Pond 2 Post

Reservoir

Description:	
Downstream:	CP-7
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	Pond 2 Post
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	None
Time Step Method:	Automatic Adaptation
Outlets:	1
Spillways:	1
Dam Tops:	1
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Outlet

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Diameter:	3	ft
Inlet Elevation:	749	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	748.5	
Exit Coefficient:	1	
Mannings n:	0.013	

Spillway

Method:	Broad-Crested Spillway
Direction:	Main
Elevation:	760 ft
Length:	100 ft
Coefficient:	2.6
Gates:	0

Dam Tops

Method:	Level Overflow
Direction:	Main
Elevation:	761
Length:	250
Coefficient:	2.6

Paired Data
Elevation-Storage
Pond 2 Post

Elevation	Storage Cumulative		Incremental
(ft)	(ac-ft)	(cy)	(cy)
749.0	0.000	0.0	0.0
750.0	0.231	373.4	373.4
751.0	1.673	2,699.8	2,326.4
752.0	3.221	5,196.3	2,496.5
753.0	4.876	7,867.2	2,670.9
754.0	6.643	10,716.8	2,849.6
755.0	8.556	13,803.9	3,087.1
756.0	10.918	17,615.0	3,811.1
757.0	13.705	22,110.0	4,495.0
758.0	16.898	27,262.4	5,152.4
759.0	20.492	33,060.0	5,797.6
760.0	24.466	39,471.2	6,411.2
761.0	28.817	46,491.6	7,020.4
762.0	33.517	54,073.8	7,582.2

Pond Data for HEC-HMS
Pond 3 Post

Reservoir

Description:	
Downstream:	CP08
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	Pond 3 Post
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	None
Time Step Method:	Automatic Adaptation
Outlets:	1
Spillways:	1
Dam Tops:	1
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Spillway

Method:	Broad-Crested Spillway
Direction:	Main
Elevation:	755 ft
Length:	100 ft
Coefficient:	2.6
Gates:	0

Dam Tops

Method:	Level Overflow
Direction:	Main
Elevation:	756
Length:	250
Coefficient:	2.6

Paired Data

Elevation-Storage
Pond 3 Post

Elevation	Storage Cumulative		Incremental
(ft)	(ac-ft)	(cy)	(cy)
750.0	0.012	19.1	19.1
751.0	0.256	412.3	393.2
752.0	0.705	1,137.6	725.3
753.0	1.412	2,278.1	1,140.5
754.0	2.428	3,916.4	1,638.3
755.0	3.803	6,134.9	2,218.5
756.0	5.588	9,015.4	2,880.5
757.0	7.793	12,573.0	3,557.6

Outlet

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Diameter:	1.5	ft
Inlet Elevation:	750	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	749.5	
Exit Coefficient:	1	
Mannings n:	0.013	

Pond Data for HEC-HMS
I-02

Reservoir

Description:	
Downstream:	Pond 1 Post
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	I-02
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	R35
Time Step Method:	Automatic Adaptation
Outlets:	1
Spillways:	1
Dam Tops:	0
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Paired Data
Elevation-Storage
I-02

Elevation (ft)	Storage Cumulative (ac-ft)	Storage Cumulative (cy)	Storage Incremental (cy)
744.0	0.000	0.0	0.0
745.0	0.010	16.9	16.9
746.0	0.052	83.9	67.0
747.0	0.139	223.8	139.9
748.0	0.285	459.2	235.4
749.0	0.504	813.0	353.8
750.0	0.811	1,307.8	494.8
751.0	1.216	1,962.3	654.5

Outlet 1

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Diameter:	1	ft
Inlet Elevation:	744	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	743.5	
Exit Coefficient:	1	
Mannings n:	0.013	

Outlet 2

Method:	Culvert Outlet	
Direction:	Auxiliary	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culv	
Scale:	1: Square edge entrar	
Length:	150	ft
Diameter:	2.25	ft
Inlet Elevation:	744	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	743.5	
Exit Coefficient:	1	
Mannings n:	0.013	

Pond Data for HEC-HMS
I-08

Reservoir

Description:	
Downstream:	Pond 1 Post
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	I-08
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	R27
Time Step Method:	Automatic Adaptation
Outlets:	2
Spillways:	0
Dam Tops:	0
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Paired Data
Elevation-Storage
I-08

Elevation (ft)	Storage Cumulative (ac-ft)	Storage Cumulative (cy)	Storage Incremental (cy)
743.0	0.000	0.0	0.0
744.0	0.035	57.2	57.2
745.0	0.195	314.3	257.1
746.0	0.518	835.5	521.2
747.0	1.043	1,683.0	847.5
748.0	1.809	2,918.8	1,235.8
749.0	2.854	4,605.0	1,686.2
750.0	4.222	6,811.0	2,206.0
751.0	5.930	9,567.7	2,756.7
752.0	7.900	12,744.6	3,176.9

Outlet 1

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	2	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Rise:	6	ft
Span:	8	ft
Inlet Elevation:	743.2	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	742.4	
Exit Coefficient:	1	

Outlet 2

Method:	Culvert Outlet	
Direction:	Auxiliary	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culv	
Scale:	1: Square edge entrar	
Length:	150	ft
Diameter:	2.5	ft
Inlet Elevation:	743.2	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	742.4	
Exit Coefficient:	1	
Mannings n:	0.013	

Pond Data for HEC-HMS
I-10

Reservoir

Description:	
Downstream:	I-8
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	I-10
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	R28
Time Step Method:	Automatic Adaptation
Outlets:	2
Spillways:	0
Dam Tops:	0
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Paired Data
Elevation-Storage
I-10

Elevation (ft)	Storage Cumulative (ac-ft)	Storage Cumulative (cy)	Storage Incremental (cy)
751.0	0.000	0.0	0.0
752.0	0.042	67.5	67.5
753.0	0.228	368.0	300.5
754.0	0.605	975.8	607.8
755.0	1.217	1,962.8	987.0
756.0	2.108	3,401.0	1,438.2
757.0	3.305	5,332.2	1,931.2
758.0	4.747	7,659.2	2,327.0

Outlet 1

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	2	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Rise:	5	ft
Span:	8	ft
Inlet Elevation:	751.2	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	750.5	
Exit Coefficient:	1	

Outlet 2

Method:	Culvert Outlet	
Direction:	Auxiliary	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culv	
Scale:	1: Square edge entrar	
Length:	150	ft
Diameter:	3	ft
Inlet Elevation:	751.2	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	750.5	
Exit Coefficient:	1	
Mannings n:	0.013	

Pond Data for HEC-HMS
I-12

Reservoir

Description:	
Downstream:	I-10
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	I-12
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	CP-4
Time Step Method:	Automatic Adaptation
Outlets:	2
Spillways:	0
Dam Tops:	0
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Paired Data
Elevation-Storage
I-12

Elevation	Storage Cumulative		Incremental
(ft)	(ac-ft)	(cy)	(cy)
757.0	0.000	0.0	0.0
758.0	0.051	81.5	81.5
759.0	0.250	403.4	321.9
760.0	0.644	1,038.6	635.2
761.0	1.283	2,069.2	1,030.6
762.0	2.219	3,579.9	1,510.7
763.0	3.492	5,633.5	2,053.6
764.0	5.138	8,288.8	2,655.3

Outlet 1

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	2	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Rise:	4	ft
Span:	6	ft
Inlet Elevation:	757.1	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	756.4	
Exit Coefficient:	1	

Outlet 2

Method:	Culvert Outlet	
Direction:	Auxiliary	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culv	
Scale:	1: Square edge entrar	
Length:	150	ft
Diameter:	3.5	ft
Inlet Elevation:	757.1	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	756.4	
Exit Coefficient:	1	
Mannings n:	0.013	

Pond Data for HEC-HMS
I-21

Reservoir

Description:	
Downstream:	R31
Method:	Outflow Structures
Storage Method:	Elevation-Storage
Stor-Dis Function:	I-21
Initial Condition:	Inflow = Outflow
Main Tailwater:	Assume None
Auxiliary:	None
Time Step Method:	Automatic Adaptation
Outlets:	2
Spillways:	0
Dam Tops:	0
Pumps:	0
Dam Break:	No
Dam Seepage:	No
Release:	No
Evaporation:	No

Paired Data
Elevation-Storage
I-21

Elevation	Storage		
	Cumulative		Incremental
(ft)	(ac-ft)	(cy)	(cy)
772.0	0.000	0.0	0.0
773.0	0.031	49.9	49.9
774.0	0.694	1,119.5	1,069.6
775.0	1.469	2,369.4	1,249.9
776.0	2.375	3,831.6	1,462.2

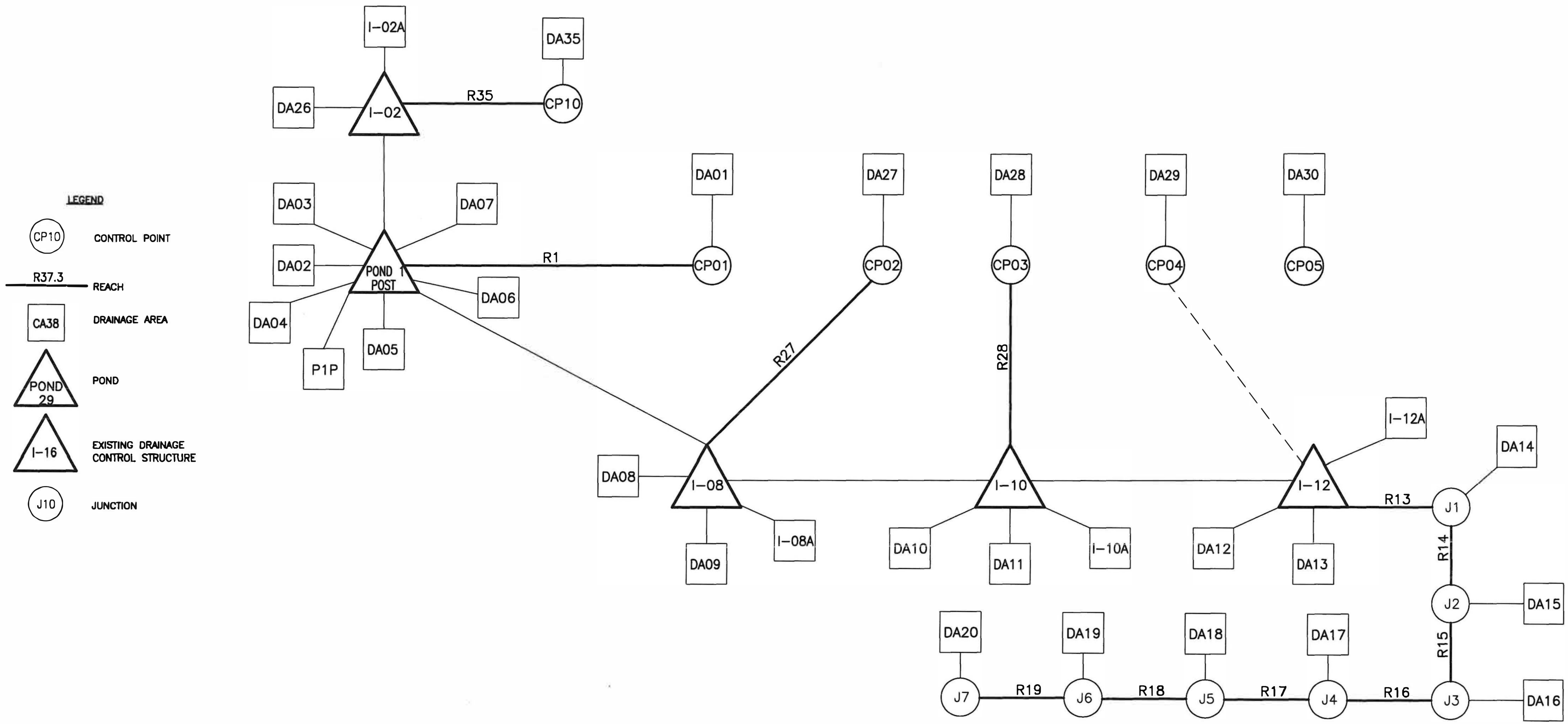
Outlet 1

Method:	Culvert Outlet	
Direction:	Main	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culvert	
Scale:	1: Square edge entrance with headwall	
Length:	150	ft
Diameter:	1	ft
Inlet Elevation:	772	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	771.5	
Exit Coefficient:	1	
Mannings n:	0.013	

Outlet 2

Method:	Culvert Outlet	
Direction:	Auxiliary	
Number Barrels:	1	
Solution Method:	Automatic	
Shape:	Circular	
Chart:	1: Concrete Pipe Culv	
Scale:	1: Square edge entrar	
Length:	150	ft
Diameter:	4	ft
Inlet Elevation:	772	ft
Entrance Coefficient:	0.5	
Outlet Elevation:	771.5	
Exit Coefficient:	1	
Mannings n:	0.013	

POSTDEVELOPED HYDROLOGIC ANALYSIS
25-YEAR, 24-HOUR STORM EVENT



STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED
PROFESSIONAL ENGINEER

2/28/2025

ISSUED FOR PERMITTING PURPOSES

REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

NORTH AND EAST SCHEMATIC
BOUNDARY ANALYSIS SUMMARY

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME

BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817–563–1144

TBPE FIRM NO. F–256
TBPG FIRM NO. 50222

C1C.2

O:\TASWA\P\Drawings\ATT C\C1–C–5_PostDrngGraph.dwg Layout: GraphDWG User: awhite

	Project:	2024 TASWA	Simulation Run:	North Post
	Start of Run:	01Jan2024, 00:00	Basin Model:	North Post
	End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
	Compute Time:	05June2024, 12:23:27	Control Specifications	Control 1

Hydrologic Element	Drainage Area (MI^2)	Peak Discharge (CFS)	Time of Peak	Volume (ACRE-FT)
DA20	0.0309	72.1	1 January 2024, 12:25	9.7
J7	0.0309	72.1	1 January 2024, 12:25	9.7
DA19	0.0313	74.4	1 January 2024, 12:20	9.7
R19	0.0309	71.2	1 January 2024, 12:25	9.7
J6	0.0622	144.3	1 January 2024, 12:25	19.4
R18	0.0622	143.1	1 January 2024, 12:25	19.4
DA18	0.0331	79.6	1 January 2024, 12:20	10.2
J5	0.0953	220	1 January 2024, 12:25	29.7
R17	0.0953	218.1	1 January 2024, 12:25	29.7
DA17	0.0319	76.7	1 January 2024, 12:20	9.9
J4	0.1272	292.2	1 January 2024, 12:25	39.5
R16	0.1272	289.3	1 January 2024, 12:25	39.6
DA16	0.033	79.4	1 January 2024, 12:20	10.2
J3	0.1602	365.9	1 January 2024, 12:25	49.8
R15	0.1602	362.4	1 January 2024, 12:25	49.8
DA15	0.0328	80.6	1 January 2024, 12:20	10.1
J2	0.193	439	1 January 2024, 12:25	59.9
R14	0.193	434.7	1 January 2024, 12:25	59.9
DA14	0.0323	79.3	1 January 2024, 12:20	10
J1	0.2253	510.1	1 January 2024, 12:25	69.9
R13	0.2253	505.3	1 January 2024, 12:25	69.9
DA13	0.0327	83	1 January 2024, 12:20	10.3
DA12	0.0302	54.1	1 January 2024, 12:35	9.5
I-12A	0.007	11.1	1 January 2024, 12:45	2.2
I-12	0.2952	461.2	1 January 2024, 12:35	76.4
DA11	0.0306	86.8	1 January 2024, 12:15	9.7
DA10	0.0305	86.5	1 January 2024, 12:15	9.6
I-10A	0.0052	8.9	1 January 2024, 12:40	1.6
I-10	0.3615	490.7	1 January 2024, 12:35	86.2
DA09	0.0325	85.9	1 January 2024, 12:20	10.3
DA08	0.0323	82	1 January 2024, 12:20	10.2
I-08A	0.0063	10.5	1 January 2024, 12:40	2
I-08	0.4326	557.1	1 January 2024, 12:35	98.4
DA03	0.0358	86.1	1 January 2024, 12:20	11.1
DA26	0.0305	62.7	1 January 2024, 12:30	9.6
I-02A	0.0027	5.9	1 January 2024, 12:30	0.9

I-02	0.0332	6.3	1 January 2024, 12:50	2.4
DA05	0.032	77	1 January 2024, 12:20	9.9
DA06	0.0325	79.8	1 January 2024, 12:20	10.1
DA07	0.0325	79.8	1 January 2024, 12:20	10.1
DA02	0.0317	75.2	1 January 2024, 12:25	10
DA04	0.0314	75.5	1 January 2024, 12:20	9.7
P1P	0.0216	36.7	1 January 2024, 12:40	7.4
Pond 1 Post	0.6833	575.4	1 January 2024, 13:05	168.9
R1	0.6833	575.4	1 January 2024, 13:05	168.9
DA01	0.0308	59	1 January 2024, 12:30	9.7
CP01	0.7141	609.8	1 January 2024, 13:00	178.6
DA35	0.0225	42	1 January 2024, 12:30	6.7
R35	0	40.5	1 January 2024, 12:50	8.1
CP10	0.0225	78.8	1 January 2024, 12:35	14.7
North	0.7366	676.6	1 January 2024, 12:55	193.4
DA27	0.0456	81	1 January 2024, 12:35	13.5
R27	0	47.9	1 January 2024, 12:40	10.1
CP02	0.0456	128.4	1 January 2024, 12:35	23.7
DA28	0.0088	16.5	1 January 2024, 12:35	2.6
R28	0	64	1 January 2024, 12:40	11.1
DA29	0.0111	13.7	1 January 2024, 13:00	3.3
DA30	0.0195	30.1	1 January 2024, 12:45	5.8
CP05	0.0195	30.1	1 January 2024, 12:45	5.8
CP04	0.0111	110.3	1 January 2024, 12:35	18.7
CP03	0.0088	80.1	1 January 2024, 12:35	13.7

Project:	2024 TASWA	Simulation Run:	North Post
	Reservoir:	Pond 1 Post	

Start of Run:	01Jan2024, 00:00	Basin Model:	North Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	05Jun2024, 12:23:27	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	1000.2 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:25
Peak Discharge:	575.4 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 13:05
Inflow Volume:	168.9 (ACRE-FT)	Peak Storage:	34.3 (ACRE-FT)
Discharge Volume:	168.9 (ACRE-FT)	Peak Elevation:	736.4 (FT)

Project: 2024 TASWA Simulation Run: North Post
Reservoir: I-02

Start of Run:	01Jan2024, 00:00	Basin Model:	North Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	05Jun2024, 12:23:27	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	68.6 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:30
Peak Discharge:	6.3 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 12:50
Inflow Volume:	10.5 (ACRE-FT)	Peak Storage:	1.1 (ACRE-FT)
Discharge Volume:	2.4 (ACRE-FT)	Peak Elevation:	750.7 (FT)

Project: 2024 TASWA Simulation Run: North Post
Reservoir: I-08

Start of Run:	01Jan2024, 00:00	Basin Model:	North Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	05Jun2024, 12:23:27	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	620.4 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:30
Peak Discharge:	557.1 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 12:35
Inflow Volume:	108.7 (ACRE-FT)	Peak Storage:	2.9 (ACRE-FT)
Discharge Volume:	98.4 (ACRE-FT)	Peak Elevation:	749.1 (FT)

Project: 2024 TASWA   Simulation Run: North Post

Reservoir: I-10

Start of Run:	01Jan2024, 00:00	Basin Model:	North Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	05Jun2024, 12:23:27	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	568.5 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:30
Peak Discharge:	490.7 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 12:35
Inflow Volume:	97.4 (ACRE-FT)	Peak Storage:	2.8 (ACRE-FT)
Discharge Volume:	86.2 (ACRE-FT)	Peak Elevation:	756.6 (FT)

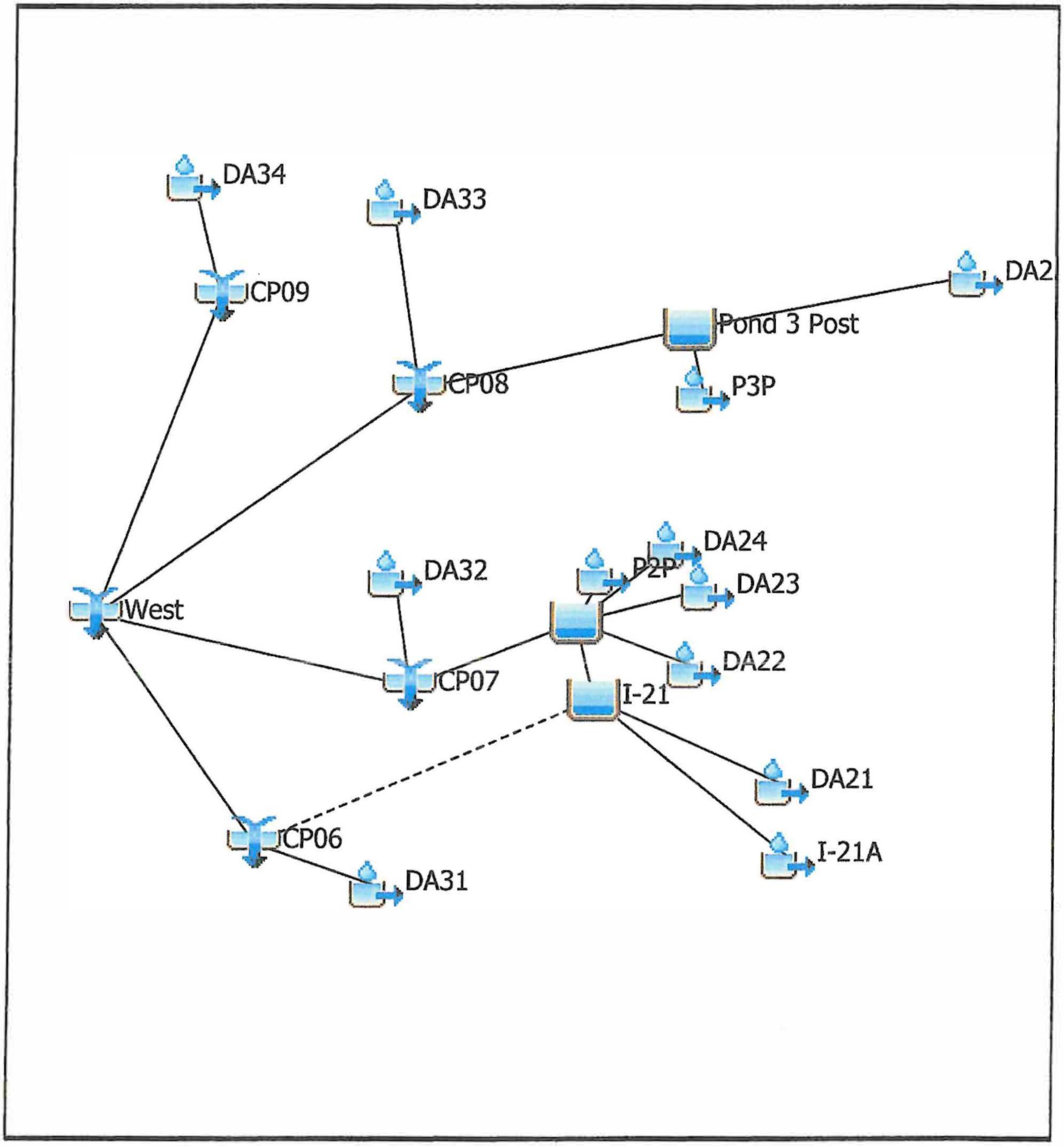
Project: 2024 TASWA Simulation Run: North Post
Reservoir: I-12

Start of Run:	01Jan2024, 00:00	Basin Model:	North Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	05Jun2024, 12:23:27	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	639.0 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:25
Peak Discharge:	461.2 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 12:35
Inflow Volume:	92.0 (ACRE-FT)	Peak Storage:	4.7 (ACRE-FT)
Discharge Volume:	76.4 (ACRE-FT)	Peak Elevation:	763.7 (FT)


DA34
DA33
DA2
CP09
Pond 3 Post
CP08
P3P
DA24
DA32
P2P
DA23
West
DA22
CP07
I-21
DA21
CP06
I-21A
DA31

Project:	2024 TASWA	Simulation Run:	West Post
Start of Run:	01Jan2024, 00:00	Basin Model:	West Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	10 June2024, 12:55:16	Control Specifications	Control 1

Hydrologic Element	Drainage Area (MI^2)	Peak Discharge (CFS)	Time of Peak	Volume (ACRE-FT)
DA25	0.0142	26	1 January 2024, 12:35	4.5
P3P	0.008	12.1	1 January 2024, 12:50	2.6
DA33	0.0227	48.5	1 January 2024, 12:25	6.7
Pond 3 Post	0.0222	12.2	1 January 2024, 13:50	7
DA21	0.0327	79.9	1 January 2024, 12:20	10.3
I-21A	0.0042	8	1 January 2024, 12:35	1.3
I-21	0.0369	40.5	1 January 2024, 12:45	6.5
DA24	0.0313	92.3	1 January 2024, 12:15	9.9
DA22	0.0252	70	1 January 2024, 12:20	7.9
DA23	0.0241	68.5	1 January 2024, 12:15	7.6
P2P	0.0117	22.1	1 January 2024, 12:35	3.9
Pond 2 Post	0.1292	80.8	1 January 2024, 13:10	35.9
DA32	0.03	58.8	1 January 2024, 12:30	8.9
CP07	0.1592	131.2	1 January 2024, 12:35	44.8
CP08	0.0449	57	1 January 2024, 12:25	13.8
DA34	0.0363	77.2	1 January 2024, 12:25	10.8
CP09	0.0363	77.2	1 January 2024, 12:25	10.8
DA31	0.0161	24.2	1 January 2024, 12:45	4.8
CP06	0.0161	36	1 January 2024, 12:45	9.9

Project: 2024 TASWA Simulation Run: West Post
Reservoir: Pond 2 Post

Start of Run:	01Jan2024, 00:00	Basin Model:	West Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	10Jun2024, 12:55:16	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	266.7 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:20
Peak Discharge:	80.8 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 13:10
Inflow Volume:	35.9 (ACRE-FT)	Peak Storage:	12.8 (ACRE-FT)
Discharge Volume:	35.9 (ACRE-FT)	Peak Elevation:	756.7 (FT)

Project: 2024 TASWA Simulation Run: West Post
Reservoir: Pond 3 Post

Start of Run:	01Jan2024, 00:00	Basin Model:	West Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	10Jun2024, 12:55:16	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	36.9 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:40
Peak Discharge:	12.2 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 13:50
Inflow Volume:	7.1 (ACRE-FT)	Peak Storage:	2.6 (ACRE-FT)
Discharge Volume:	7.0 (ACRE-FT)	Peak Elevation:	754.1 (FT)

Project: 2024 TASWA   Simulation Run: West Post

Reservoir: I-21

Start of Run:	01Jan2024, 00:00	Basin Model:	West Post
End of Run:	03Jan2024, 00:00	Meteorologic Model:	25-Year
Compute Time:	10Jun2024, 12:55:16	Control Specifications:	Control 1

Volume Units: ACRE-FT

Computed Results

Peak Inflow:	85.9 (CFS)	Date/Time of Peak Inflow:	01Jan2024, 12:20
Peak Discharge:	40.5 (CFS)	Date/Time of Peak Discharge:	01Jan2024, 12:45
Inflow Volume:	11.6 (ACRE-FT)	Peak Storage:	2.3 (ACRE-FT)
Discharge Volume:	6.5 (ACRE-FT)	Peak Elevation:	775.9 (FT)

POSTDEVELOPED VELOCITY SUMMARY

Postdeveloped 25-Year Velocity Calculations at Permit Boundary Comparison Points

Required: Determine the 25-year flow depths and velocities at the permit boundary.

Method: Calculate the flow depths and velocities using Manning's Equation.

Solution:

		Velocity Calculations						
Comparison Point	Q (cfs)	Width[1] (ft)	Bottom Slope[2] (%)	Side Slopes[3] (h:v)	Manning's n	Depth (ft)	Velocity (fps)	Shear Stress (psf)
CP01	609.8	200	0.6	15.0	0.030	**0.86**	**3.33**	**0.32**
CP02	128.4	250	1.6	25.0	0.030	**0.22**	**2.26**	**0.22**
CP03	80.1	450	1.2	0.0	0.030	**0.13**	**1.38**	**0.10**
CP04	110.3	1000	2.6	0.0	0.030	**0.08**	**1.44**	**0.12**
CP05	30.1	500	5.0	0.0	0.030	**0.04**	**1.38**	**0.14**
CP06	36.0	1100	3.0	0.0	0.030	**0.06**	**0.58**	**0.11**
CP07	131.2	200	1.0	8.0	0.030	**0.29**	**2.21**	**0.18**
CP08	57.0	200	4.0	25.0	0.030	**0.12**	**2.37**	**0.30**
CP09	77.2	500	8.0	0.0	0.030	**0.07**	**2.31**	**0.33**
CP10	78.8	100	3.0	10.0	0.030	**0.24**	**3.24**	**0.44**

Notes:

1. Comparison points where surface water runoff enters or exits the permit boundary in established natural or constructed channels; width refers to the bottom width of the channel.
   Comparison points where surface water runoff enters or exits the permit boundary as sheet flow or not well established channels; width refers to the sheet flow width.
2. For channels, bottom slope is the slope of the channel bottom where surface water enters or exits the permit boundary.
   For sheet flow, bottom slope is the slope of the ground where surface water enters or exits the permit boundary.
3. For channels, side slope is the average side slope of the channel where surface water enters or exits the permit boundary.
   For sheet flow, there are no side slopes and are represented by "0" in this table.

POSTDEVELOPED FLOW AND BOUNDARY ANALYSIS SUMMARY

Postdeveloped Flow Summary

Watershed Name	Drainage Area (Ac)	Drainage Area (mi^2)	25-Year Peak Flow (cfs)	25-Year Volume (Ac-ft)
DA01	19.7	0.0308	59.0	9.7
DA02	20.3	0.0317	75.2	10.0
DA03	22.9	0.0358	86.1	11.1
DA04	20.1	0.0314	75.5	9.7
DA05	20.5	0.0320	77.0	9.9
DA06	20.8	0.0325	79.8	10.1
DA07	20.8	0.0325	79.8	10.1
DA08	20.7	0.0323	82.0	10.2
DA09	20.8	0.0325	85.9	10.3
DA10	19.5	0.0305	86.5	9.6
DA11	19.6	0.0306	86.8	9.7
DA12	19.3	0.0302	54.1	9.5
DA13	20.9	0.0327	83.0	10.3
DA14	20.7	0.0323	79.3	10.0
DA15	21.0	0.0328	80.6	10.1
DA16	21.1	0.0330	79.4	10.2
DA17	20.4	0.0319	76.7	9.9
DA18	21.2	0.0331	79.6	10.2
DA19	20.0	0.0313	74.4	9.7
DA20	19.8	0.0309	72.1	9.7
DA21	20.9	0.0327	79.9	10.3
DA22	16.1	0.0252	70.0	7.9
DA23	15.4	0.0241	68.5	7.6
DA24	20.0	0.0313	92.3	9.9
DA25	9.1	0.0142	26.0	4.5
DA26	19.5	0.0305	62.7	9.6
DA27	29.2	0.0456	81.0	13.5
DA28	5.6	0.0088	16.5	2.6
DA29	7.1	0.0111	13.7	3.3
DA30	12.5	0.0195	30.1	5.8
DA31	10.3	0.0161	24.2	4.8
DA32	19.2	0.0300	58.8	8.9
DA33	14.5	0.0227	48.5	6.7
DA34	23.2	0.0363	77.2	10.8
DA35	14.4	0.0225	42.0	6.7
I-02A	1.7	0.0027	6.3	2.4
I-08A	4.0	0.0063	10.5	2.0
I-10A	3.3	0.0052	8.9	1.6
I-12A	4.5	0.0070	11.1	2.2
I-21A	2.7	0.0042	8.0	1.3
P1P	13.8	0.0216	36.7	7.4
P2P	7.5	0.0117	22.1	3.9
P3P	5.1	0.0080	12.1	2.6

Postdeveloped Boundary Analysis Summary

Comparison Point	Total Contributing Drainage Area (mi^2)	25-Year Flow Rate (cfs)	25-Year Volume (ac-ft)	25-Year Velocity (fps)
CP1	0.7141	609.8	178.6	3.33
CP2	0.0456	128.4	23.7	2.26
CP3	0.0088	80.1	13.7	1.38
CP4	0.0111	110.3	18.7	1.44
CP5	0.0195	30.1	5.8	1.38
CP6	0.0161	36.0	9.9	0.58
CP7	0.1592	131.2	44.8	2.21
CP8	0.0449	57.0	13.8	2.37
CP9	0.0363	77.2	10.8	2.31
CP10	0.0225	78.8	14.7	3.24

ATTACHMENT C1
APPENDIX C1D

PERIMETER DRAINAGE SYSTEM DESIGN

CONTENTS

NARRATIVE

30 TAC §§330.303 and 330.305

This appendix presents the design of the TASWA DRF perimeter drainage channels and detention ponds in accordance with §330.305(a)-(d).

PERIMETER DRAINAGE PLAN

Drawing C1D.1 depicts the perimeter drainage channels (ditches), detention ponds, and surface water impoundments at the TASWA DRF. The plan reflects the perimeter channel design and stationing. The perimeter channel hydraulic analysis is included for the 25-year rainfall event.

PERIMETER CHANNEL DESIGN SUMMARY

The perimeter channels are designed for peak discharge resulting from the 25-year storm event. The perimeter channel depths and calculated normal depths are summarized in the table below. In several locations along the perimeter channel, the depths are much greater than necessary to convey the predicted stormwater flow rates; however, minimum channel slopes were maintained to help prevent excessive velocity and erosion. The perimeter channel design calculations are shown on page C1D.7. Perimeter channel profiles are included in Attachment C3.

Perimeter Channel Summary

Station (feet)	Station (feet)	Flow Depth (feet)	Depth Description	Interior Berm/Road		Exterior Berm	
				Minimum Channel Depth (feet)	Minimum Freeboard	Minimum Channel Depth (feet)	Minimum Freeboard (feet)
East Ditch							
0+00	1+36	3.17	Normal	8.0	4.83	6.0	2.83
1+36	2+98	2.99	Normal	8.0	5.01	6.0	3.01
2+98	13+12	2.78	Normal	8.0	5.22	6.0	3.22
13+12	16+25	3.29	Normal	8.0	4.71	6.0	2.71
16+25	20+26	3.08	Normal	8.0	4.92	6.0	2.92
20+26	26+46	2.83	Normal	8.0	5.17	6.0	3.17
26+46	29+86	2.91	Normal	8.0	5.09	6.0	3.09
29+86	33+51	3.35	Normal	8.0	4.65	6.0	2.65
33+51	39+40	3.11	Normal	8.0	4.89	6.0	2.89
39+40	43+72	2.82	Normal	8.0	5.18	6.0	3.18
43+72	45+70	3.38	Normal	8.0	4.62	6.0	2.62
45+70	52+11	3.31	Normal	8.0	4.69	6.0	2.69
52+11	56+52	3.23	Normal	8.0	4.77	6.0	2.77
56+52	63+54	3.23	Normal	8.0	4.77	6.0	2.77
63+54	67+48	2.96	Normal	8.0	5.04	6.0	3.04
67+48	71+68	2.74	Normal	8.0	5.26	6.0	3.26
71+68	75+80	2.48	Normal	8.0	5.52	6.0	3.52
75+80	80+65	2.20	Normal	8.0	5.8	6.0	3.8
80+65	85+74	1.89	Normal	8.0	6.11	6.0	4.11
85+74	90+50	1.49	Normal	8.0	6.51	6.0	4.51
90+50	98+66	1.00	Normal	8.0	7	6.0	5
West Ditch 1							
0+00	7+85	0.75	Normal	8.0	7.25	6.0	5.25
7+85	13+39	0.52	Normal	8.0	7.48	6.0	5.48
13+39	14+92	0.82	Normal	8.0	7.18	6.0	5.18
14+92	19+06	0.21	Normal	8.0	7.79	6.0	5.79
14+92	19+06	0.33	Normal	8.0	7.67	6.0	5.67
19+06	24+75	0.21	Normal	8.0	7.79	6.0	5.79
West Ditch 2							
0+00	1+24	1.72	Normal	8.0	6.28	6.0	4.28
1+24	3+55	1.32	Normal	8.0	6.68	6.0	4.68
West Ditch 3							
0+00	3+55	0.24	Normal	8.0	7.26	6.0	3.26
West Ditch 4							
0+00	15+52	0.56	Normal	8	7.44	6.0	5.44
North Ditch							
0+00	5+76	0.17	Normal	8.0	7.83	6.0	5.83
5+76	8+36	0.70	Normal	8.0	7.3	6.0	5.3
8+36	15+77	0.17	Normal	8.0	7.83	6.0	5.83

Notes:

1. Minimum freeboard based on the pool depth of the drainage control structure as shown on drawings in Attachment C3.

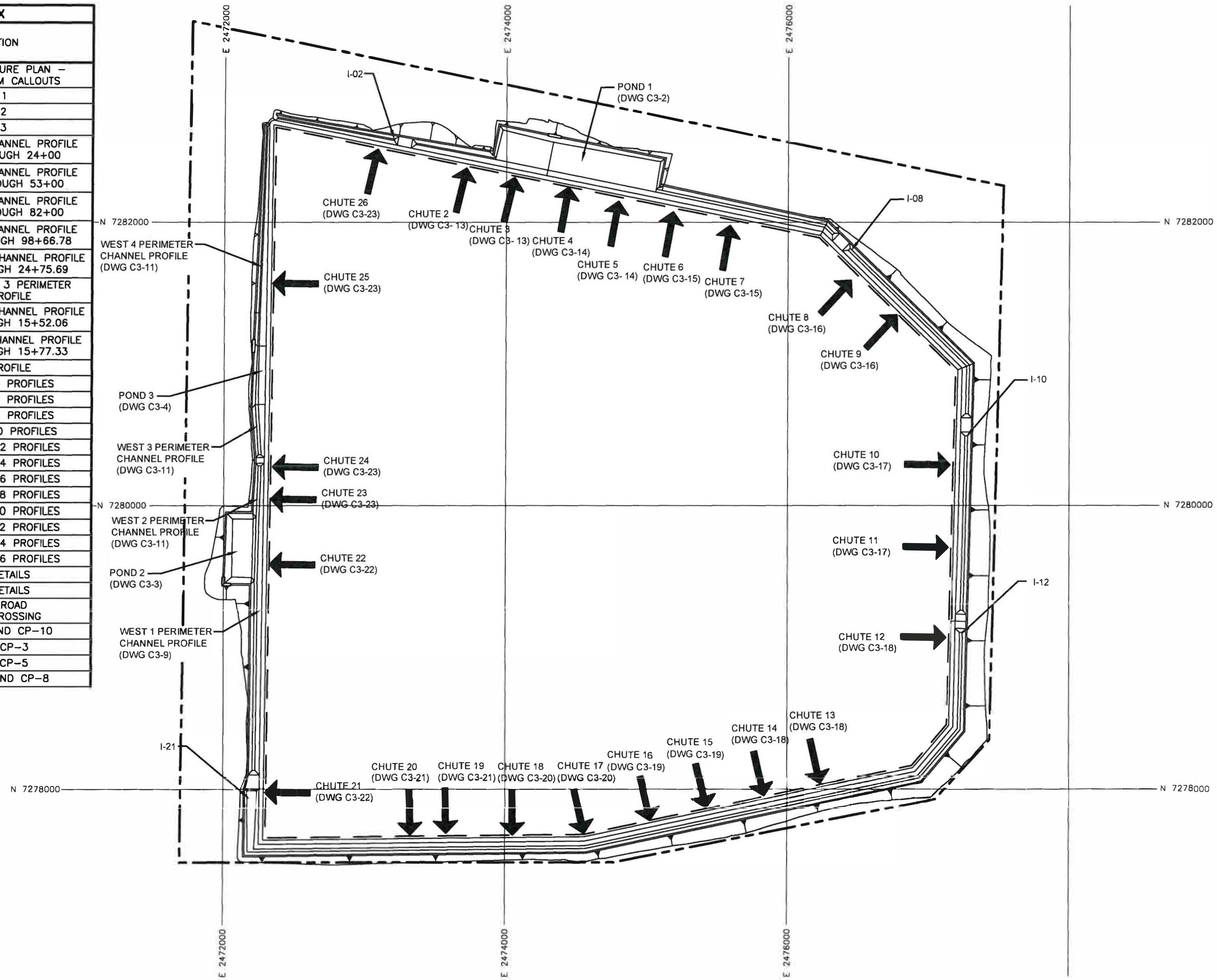
DETENTION POND ANALYSIS

The detention pond was designed to provide the necessary storage and outlet control to mitigate impacts to the receiving channels downstream of the TASWA DRF. The hydraulic design parameter for the detention pond are provided on pages C1C.11 through C1C.13. Detention pond design information is included in Attachment C3. The following table provides storage volume and surface elevation for the 25-year storm event.

Detention Pond	25-Year Water Surface Elevation (feet-msl)	Exterior Berm		Interior Berm/Road	
		Perimeter Pond Berm Elevation (feet-msl)	Freeboard (feet)	Access Road Elevation (feet-msl)	Freeboard (feet)
Pond 1 Post	**736.4**	**738**	**1.6**	**740.0**	**3.6**
Pond 2 Post	**756.7**	**762.0**	**5.3**	**763.5**	**6.8**
Pond 3 Post	**754.1**	**756.0**	**1.9**	**762.0**	**7.9**

PERIMETER DRAINAGE PLAN

DRAWING INDEX	
DRAWING	DESCRIPTION
C3-1	DRAINAGE STRUCTURE PLAN – DRAINAGE SYSTEM CALLOUTS
C3-2	POND 1
C3-3	POND 2
C3-4	POND 3
C3-5	EAST PERIMETER CHANNEL PROFILE STA. 0+00 THROUGH 24+00
C3-6	EAST PERIMETER CHANNEL PROFILE STA. 24+00 THROUGH 53+00
C3-7	EAST PERIMETER CHANNEL PROFILE STA. 53+00 THROUGH 82+00
C3-8	EAST PERIMETER CHANNEL PROFILE STA. 82+00 THROUGH 98+66.78
C3-9	WEST 1 PERIMETER CHANNEL PROFILE STA. 0+00 THROUGH 24+75.69
C3-10	WEST 2 AND WEST 3 PERIMETER CHANNEL PROFILE
C3-11	WEST 4 PERIMETER CHANNEL PROFILE STA. 0+00 THROUGH 15+52.06
C3-12	NORTH PERIMETER CHANNEL PROFILE STA. 0+00 THROUGH 15+77.33
C3-13	CHUTE 2 PROFILE
C3-14	CHUTE 3 AND 4 PROFILES
C3-15	CHUTE 5 AND 6 PROFILES
C3-16	CHUTE 7 AND 8 PROFILES
C3-17	CHUTE 9 AND 10 PROFILES
C3-18	CHUTE 11 AND 12 PROFILES
C3-19	CHUTE 13 AND 14 PROFILES
C3-20	CHUTE 15 AND 16 PROFILES
C3-21	CHUTE 17 AND 18 PROFILES
C3-22	CHUTE 19 AND 20 PROFILES
C3-23	CHUTE 21 AND 22 PROFILES
C3-24	CHUTE 23 AND 24 PROFILES
C3-25	CHUTE 25 AND 26 PROFILES
C3-26	DRAINAGE DETAILS
C3-27	DRAINAGE DETAILS
C3-28	PERIMETER ROAD LOW WATER CROSSING
C3-29	CP-1, CP-9, AND CP-10
C3-30	CP-2 AND CP-3
C3-31	CP-4 AND CP-5
C3-32	CP-6, CP-7, AND CP-8



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SCALE IN FEET

LEGEND

2290A PERMIT BOUNDARY
2290A LANDFILL FOOTPRINT

NOTE(S):

1. REFER TO DRAINAGE SYSTEM CALLOUTS FOR PONDS, CHANNELS, CHUTES, AND CULVERT DETAILS.

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED PROFESSIONAL ENGINEER
2/28/2025

ISSUED FOR PERMITTING PURPOSES

REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

PERIMETER DRAINAGE PLAN

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1D.1

O:\TASWA\P\Drawings\AIT C\C3-1_DrngStructures.dwg Layout: C1-D-1 User: awhite

PERIMETER CHANNEL DESIGN CALCULATIONS

Depth and Velocity Calculations for the Perimeter Channels for the 25-Year Peak Runoff

Required: Determine the velocity and depth for the perimeter channels and compare to the permissible non-erodible flow velocity.

Method: Manning's Equation for flow velocity.

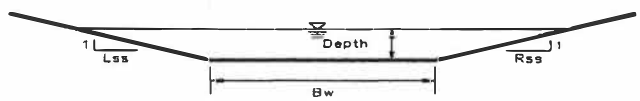
References:

1. Texas Department of Transportation, *Hydraulic Design Manual,* March 2004.

Solution:

Manning's Equation V = (k/n)(R^2/3)(S^1/2)

V = Velocity (fps)
k = Conversion Factor = 1.486
n = Manning's Roughness Coefficient = 0.03 Grass lined channel
R = Hydraulic Radius = A/Pw
A = Cross-Sectional Area (ft^2)
Pw = Wetted Perimeter (ft)
S = Channel Slope (ft/ft)
Bw = Bottom Width (ft)



Channel	Channel Station		Q (cfs)	S (ft/ft)	BW (ft)	Rss (H:V)	Lss (H:V)	D (ft)	R (ft)	A (sf)	PW (ft)	V (fps)	Shear Stress (psf)
East Ditch													
E1	0+00	1+36	716.7	0.0066	20	4.0	4.0	3.17	2.25	103.79	46.18	6.91	1.31
E2	1+36	2+98	636.9	0.0066	20	4.0	4.0	2.99	2.14	95.38	44.62	6.68	1.23
E3	2+98	13+12	557.1	0.0066	20	4.0	4.0	2.78	2.02	86.69	42.96	6.43	1.15
E4	13+12	16+25	669.1	0.0050	20	4.0	4.0	3.29	2.32	109.15	47.14	6.13	1.03
E5	16+25	20+26	587.1	0.0050	20	4.0	4.0	3.08	2.19	99.38	45.37	5.91	0.96
E6	20+26	26+46	501.2	0.0050	20	4.0	4.0	2.83	2.05	88.76	43.36	5.65	0.88
E7	26+46	29+86	490.7	0.0043	20	4.0	4.0	2.91	2.10	92.26	44.03	5.32	0.78
E8	29+86	33+51	643.4	0.0043	20	4.0	4.0	3.35	2.35	112.03	47.65	5.74	0.90
E9	33+51	39+40	556.9	0.0043	20	4.0	4.0	3.11	2.21	101.00	45.67	5.51	0.84
E10	39+40	43+72	461.2	0.0043	20	4.0	4.0	2.82	2.04	88.27	43.27	5.22	0.76
E11	43+72	45+70	653.2	0.0043	20	4.0	4.0	3.38	2.37	113.25	47.86	5.77	0.91
E12	45+70	52+11	599.1	0.0039	20	4.0	4.0	3.31	2.33	110.23	47.33	5.43	0.81
E13	52+11	56+52	599.1	0.0043	20	4.0	4.0	3.23	2.28	106.43	46.65	5.63	0.87
E14	56+52	63+54	599.1	0.0043	20	4.0	4.0	3.23	2.28	106.43	46.65	5.63	0.87
R13	63+54	67+48	505.3	0.0043	20	4.0	4.0	2.96	2.12	94.21	44.40	5.36	0.79
R14	67+48	71+68	434.7	0.0043	20	4.0	4.0	2.74	1.99	84.63	42.55	5.14	0.73
R15	71+68	75+80	362.4	0.0043	20	4.0	4.0	2.48	1.84	74.38	40.49	4.87	0.67
R16	75+80	80+65	289.3	0.0043	20	4.0	4.0	2.20	1.66	63.46	38.16	4.56	0.59
R17	80+65	85+74	218.1	0.0043	20	4.0	4.0	1.89	1.46	52.09	35.58	4.19	0.51
R18	85+74	90+50	143.1	0.0044	20	4.0	4.0	1.49	1.20	38.63	32.27	3.70	0.41
R19	90+50	98+66	71.2	0.0044	20	4.0	4.0	1.00	0.85	24.10	28.28	2.95	0.28
West Ditch 1													
W1-1	0+00	7+85	40.5	0.0040	20	4.0	4.0	0.75	0.66	17.14	26.15	2.36	0.19
W1-2	7+85	13+39	40.0	0.0134	20	4.0	4.0	0.52	0.47	11.49	24.29	3.48	0.44
W1-3	13+39	14+92	87.9	0.0134	20	4.0	4.0	0.82	0.72	19.16	26.78	4.59	0.69
W1-4	14+92	19+06	8.0	0.0125	20	4.0	4.0	0.21	0.20	4.27	21.69	1.87	0.16
W1-5	14+92	19+06	8.0	0.0024	20	4.0	4.0	0.33	0.31	7.14	22.76	1.12	0.05
W1-6	19+06	24+75	8.0	0.0125	20	4.0	4.0	0.21	0.20	4.27	21.69	1.87	0.16
West Ditch 2													
W2-1	0+00	1+24	182.9	0.0043	20	4.0	4.0	1.72	1.35	46.10	34.15	3.97	0.46
W2-2	1+24	3+55	114.4	0.004	20	4.0	4.0	1.32	1.08	33.42	30.90	3.42	0.35
West Ditch 3													
W3	0+00	3+55	12.1	0.018	20	4.0	4.0	0.24	0.22	4.93	21.94	2.46	0.26
West Ditch4													
W4	0+00	15+52	26.0	0.005	20	4.0	4.0	0.56	0.50	12.37	24.59	2.10	0.16
North Ditch													
N1	0+00	5+76	6.2	0.014	20	4.0	4.0	0.17	0.16	3.52	21.40	1.76	0.15
N1-2	5+76	8+36	68.6	0.014	20	4.0	4.0	0.70	0.62	16.06	25.80	4.27	0.61
N1-3	8+36	15+77	5.9	0.014	20	4.0	4.0	0.17	0.16	3.42	21.36	1.73	0.14

ATTACHMENT C1
APPENDIX C1E

FINAL COVER DRAINAGE STRUCTURE DESIGN

CONTENTS

NARRATIVE

30 TAC §§330.303 and 330.305

This appendix presents the supporting documentation for evaluation of the final cover erosion layer and drainage structures. Appendix C1E addresses the requirements of 30 TAC §330.305(d) and (e) related to the final condition of final cover areas. The requirements of 30 TAC §330.305(d) and (e) related to intermediate phases are addressed in Appendix C1G.

FINAL COVER PLAN

The final cover plans depict the final cover drainage system consisting of a series of swales and chutes. The drainage area for the largest area contributing to a side slope swale is shown on Drawing C1E.1. Drainage areas for each downchute are shown on Drawing C1E.2. Final cover details are included in Attachment C3.

EROSION LAYER EVALUATION

The erosion layer evaluation is based on the Universal Soil Loss Equation (USLE) following Soil Conservation Service (SCS) procedures. The evaluation is based on a 25-year event. The 24-inch-thick Subtitle D layer is sufficient. Calculations are included beginning on page C1E.6.

SHEET FLOW VELOCITY

The sheet flow velocity calculations are presented for the 4 percent top slope and the 25 percent side slope configurations. The procedures outlined in the TxDOT *Hydraulic Design Manual*, May 2014, were used to determine velocities. Maximum lengths of runoff for both final cover conditions were evaluated. Calculations are shown on page C1E.15.

DRAINAGE SWALE DESIGN

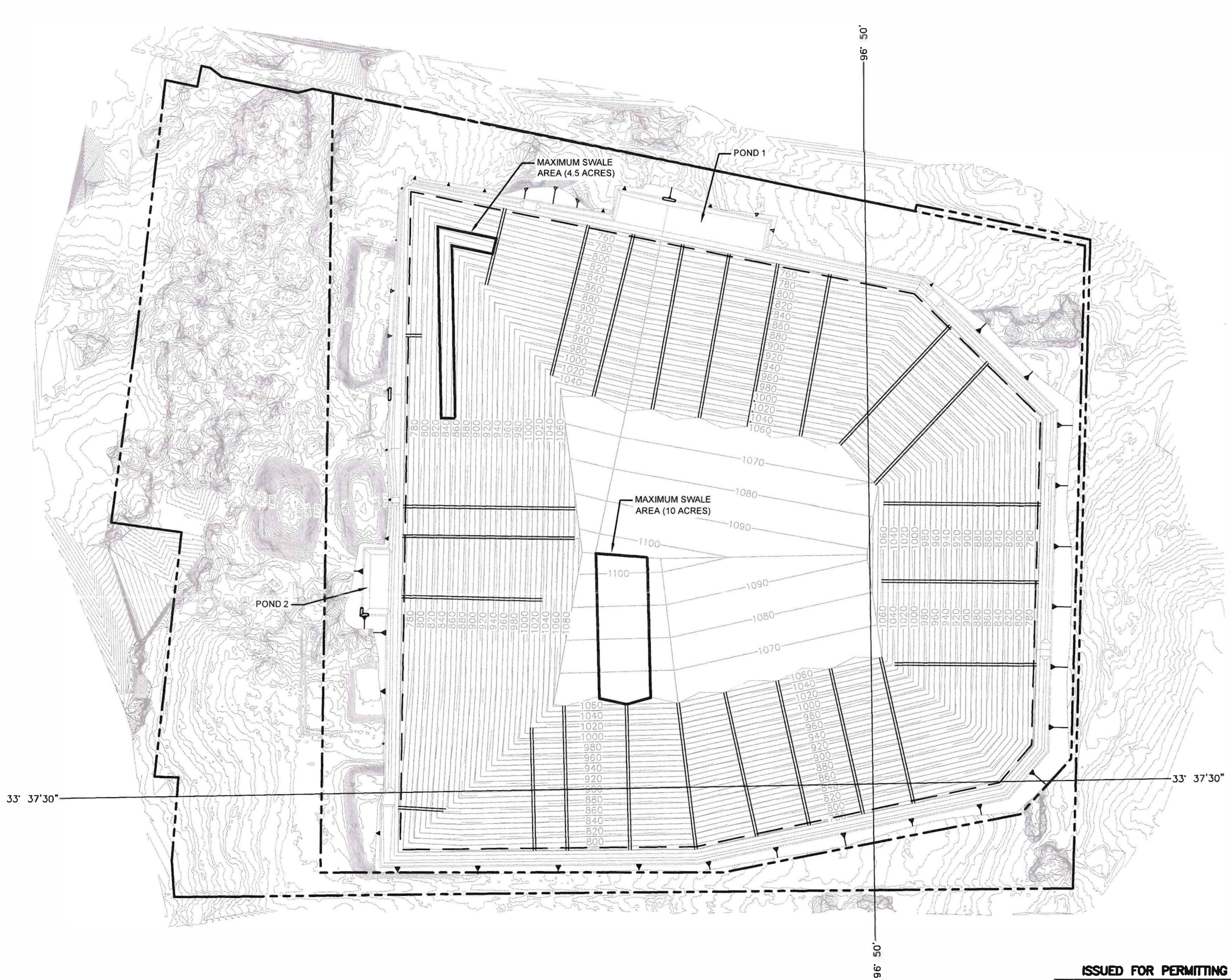
The drainage swale design calculations are presented for the typical swale flowline slope of 0.5 percent. The procedures in the TxDOT *Hydraulic Design Manual*, May 2014, were used to determine the flow depth, swale capacity, and contributing drainage area. Calculations are shown beginning on page C1E.16.

CHUTE DESIGN

The drainage letdown or chutes have been evaluated to determine critical velocities, flow depths in the chute, and receiving perimeter channel. Calculations are shown beginning on page C1E.19. Erosion protection within each chute is provided by 40-mil textured FML. Erosion protection at low-water crossings will be 12-inch-thick concrete. The erosion protection after the low-water crossings will be 40-mil thick flexible membrane liner (FML). Profiles of each drainage chute are included in Attachment C3.

Chutes and low-water crossings are designed to provide sufficient flow depth for the peak flow rate from the design storm. The design storm for chutes and low-water crossing is the 25-year, 24-hour rainfall event. Chutes are designed to provide 2 feet of flow depth. The maximum calculated flow depth for any chute is 0.26 feet; therefore, the chutes provide a minimum of 1.74 feet of freeboard. Low-water crossings are designed to provide 1 foot of flow depth. The maximum calculated flow depth for any low-water crossing is 0.63 feet; therefore, the low-water crossings provide a minimum of 0.37 feet of freeboard. After the low-water crossing, the flow width is initially 20-feet with 1 foot of flow depth provided and gradually transitions to a 30-foot flow width and ties into the channel sideslope. The maximum calculated flow depth after the low-water crossing is 0.20 feet which provides 0.80 feet of freeboard. Refer to Drawing C1E.2, page C1E.5, for a depiction of the depth of flow for a typical drainage letdown or chutes. The drawing depicts Chute 26 which is the chute with the maximum flow depth within the chute.

FINAL COVER PLANS



0 400 800
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- 700 EXISTING 10' GROUND CONTOUR
- 900 LANDFILL 10' CONTOUR
- SWALE AREA BOUNDARY
- SWALE

NOTE(S):

1. EXISTING GROUND CONTOURS PROVIDED BY BIGGS & MATHEWS ENVIRONMENTAL, FROM DRONE SURVEY FLOWN JUNE 1, 2022.
2. CONTOURS WITHIN EXISTING LANDFILL FOOTPRINT DEPICT CURRENT PERMITTED FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED PROFESSIONAL ENGINEER
2/28/2025

ISSUED FOR PERMITTING PURPOSES

REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

MAXIMUM SWALE AREA

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1E.1

O:\TASWA\P\Drawings\ATT C\C1-E-1.dwg Layout: C1-E-1 User: owhi...

Chute Drainage Area	Chute Area (acre)
DA2	20.3
DA3	22.9
DA3	20.1
DA4	20.5
DA5	20.8
DA6	20.8
DA7	20.7
DA8	20.8
DA9	19.5
DA10	19.6
DA11	19.3
DA12	20.9
DA13	20.7
DA14	21.0
DA15	21.1
DA16	20.4
DA17	21.2
DA18	20.0
DA19	19.8
DA20	20.9
DA21	16.1
DA22	15.4
DA23	20.0
DA24	9.1
DA25	19.5
DA26	23.7

0 400 800
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- EXISTING 10' GROUND CONTOUR
- LANDFILL 10' CONTOUR
- SWALE AREA BOUNDARY
- SWALE

NOTE(S):

1. EXISTING GROUND CONTOURS PROVIDED BY BIGGS & MATHEWS ENVIRONMENTAL, FROM DRONE SURVEY FLOWN JUNE 1, 2022.
2. CONTOURS WITHIN EXISTING LANDFILL FOOTPRINT DEPICT CURRENT PERMITTED FINAL CONTOURS.
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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CHUTE AREA

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
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TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1E.2

EROSION LAYER EVALUATION

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 TASWA DRF. 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. The minimum thickness of the erosion layer is based on the depth of frost penetration, or 6 inches, whichever is greater. For Grayson County, the approximate depth of frost penetration is less than 6 inches.

2. Soil loss is calculated using the Universal Soil Loss Equation (USLE) by following SCS procedures. In accordance with regulatory guidance, the calculated soil loss from final cover will not exceed 3 tons per acre per year. Soil loss thickness is calculated by multiplying the soil loss by the postclosure year period (30 years), multiplying by a safety factor of 2, and then converting the soil loss to a thickness. The USLE, with a safety factor of 2, calculates the soil loss of the 4 percent top slopes to be 6.03 inches and the side slopes to be 6.70 inches. These thicknesses are then compared to the actual soil thickness of the erosion layer, which is 24 inches. These calculations begin on page C1E.8.

3. Sheet flow velocities for a 25-year storm event are calculated to be less than permissible nonerodible velocities. The supporting calculations are presented on page C1E.15.

4. Vegetation for the site will be native and introduced grasses with root depths of 6 inches to 8 inches.

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 may 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.

6. Slope stability information is included in Attachment D5.

Erosion Loss Evaluation

Required: Determine the required soil thickness and compare to the actual soil thickness.

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 thickness of soil loss.

References:

1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution:

Annual Soil Loss in tons/acre/year (A) = RKLSCP

Design Parameters	Top Slope (4%)	Perimeter Slope (25%)	
Rainfall Factor (R) =	275	275	Grayson County
Soil Erodibility Factor (K) =	0.25	0.25	(Loam)
Longest Run =	1100	120	ft
Slope =	4.0	25	%
Topographic Factor (LS) =	0.79	6.45	
Crop Management Factor (C) =	0.006	0.006	(tall grass with 85% cover)
Erosion Control Practice Factor (P) =	0.50	1.00	(Contouring)
Soil Loss (A) =	0.16	2.66	tons/acre/yr.

Erosion Layer Thickness Evaluation:

Required Thickness (T) = 6 inches* + AYF/w
* - Includes required 6 inch minimum

	Top Slope (4%)	Perimeter Slope (25%)	
Soil Loss (A) =	0.16	2.66	tons/acre/yr.
Postclosure Period =	30	30	years
Factor of Safety (F) =	2	2	
Specific Weight of Soil (w) =	125	125	pcf
Required Soil Thickness (T)	**6.04**	**6.70**	**inches**
Actual Soil Thickness	24.00	24.00	inches

Summary: As noted in the permit drawings, the erosion layer will be a minimum of 24 inches thick. As shown above, this is a conservative design considering the maximum expected soil loss for a 30 year period is 6.70 inches.

LS Factor Calculations

Required: Determine the length slope factor based on slope length and slope gradient.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution:

$$\text{Length/Slope Factor (LS)} = ((L/72.6)^{m})*((65.41*\sin^{2}(S))+(4.56*\sin(S))+0.065)$$

LS = Length Slope Factor
L = Slope Length (ft)
S = Slope (%)
m = exponent dependent on the slope gradient

m =		
	0.2	for S <= 1.0%
	0.3	for 1.0% < S <= 3.5%
	0.4	for 3.5% < S < 5.0%
	0.5	for S => 5.0%

L (ft)	S (%)	S (ft/ft)	S (radians)	S (degrees)	m	LS
1100	4.0	25.00	0.040	2.291	0.3	0.795
120	25	4.00	0.245	14.036	0.5	6.452

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

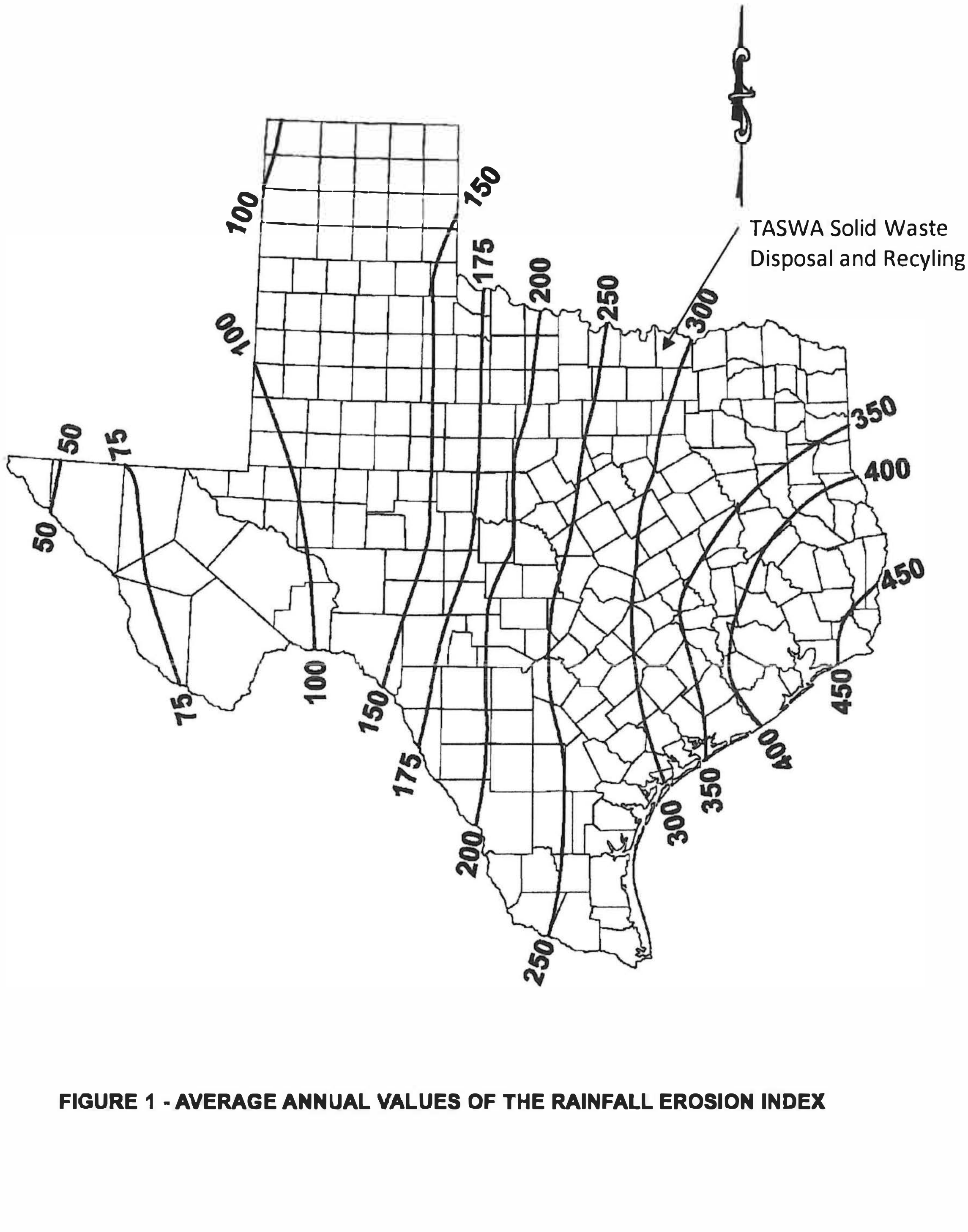


FIGURE 1 - AVERAGE ANNUAL VALUES OF THE RAINFALL EROSION INDEX

Table 1: Approximate Values of Factor K for USDA Textural Classes

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

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		

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.

Table 2: Factor C for Permanent Pasture, Range, and Idle Land[1]

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Vegetative Canopy		Cover that Contacts the Soil Surface					
Type and Height[2]	Percent Cover[3]	Percent Ground Cover					
		0	20	40	60	80	95+
No Appreciable Canopy		0.45	0.20	0.10	0.042	0.013	0.003
Tall weeds or short brush with average drop fall height of 20 in.	25	0.36	0.17	0.09	0.038	0.013	0.011
	50	0.26	0.13	0.07	0.035	0.012	0.003
	75	0.17	0.10	0.06	0.032	0.011	0.003

Extracted from: United States Department of Agriculture, AGRICULTURE HANDBOOK NUMBER 537

[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 feet.

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

Table 3: P Factors for Contouring, Contour Stripcropping and Terracing

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Land Slope	P Values		
%	Contouring†	Contour Stripcropping	Terracing†
2.0 to 7	0.50	0.25	0.50
8.0 to 12	0.60	0.30	0.60
13.0 to 18	0.80	0.40	0.80
19.0 to 24	0.90	0.45	0.90

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

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

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

Rooting Depth	Soil Loss Tolerance Values Annual Soil Loss (Tons/Acre)	
Inches	Renewable Soil a/	Renewable Soil b/
0 - 10	1	1
10 - 20	2	1
20 - 40	3	2
40 - 60	4	3
60	5	4

(This table appeared in SCS (6), p.4)

a/ Soil with favorable substrata that can be renewed by tillage, fertilizer, organic matter, and other management practices. This column does not represent MSWLF final covers under normal conditions.

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

SHEET FLOW

Sheet Flow Velocity

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

Method:
1. Determine the 25-year peak flow rate using the Rational Method.
2. Calculate flow depth using Manning's Equation.
3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised May 2014. (Note: The Hydraulic Design Manual, Revised September 2019, uses a different equation to calculate rainfall intensity which is not consistent with Reference 2.)
2. NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 11 Version 2.0: Texas, 2018.

Solution:

1. Determine the 25-year peak flow rate (Q) using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.30	in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10.0	min	(conservative minimum value)
Rainfall Intensity (I) =	7.8	in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70		(typical value for final cover systems)
25-Year Peak Flow Rate (Q) =	CIA	cfs	

	Top Slope (4%)	Perimeter Slope (25%)		
Longest Run =	1100	120	ft	(longest sheet flow distance to swale)
Width =	1.00	1.00	ft/ft	(unit width of flow)
Area =	0.0253	0.0028	acre	
Q	0.138	0.015	cfs	

2. Calculate the flow depth using Manning's Equation.
   - Rearrange Manning's Equation for wide and shallow flow to calculate flow depth:

$$y = (Qn/1.49S^{0.5})^{0.6}$$

Manning's Roughness (n) =		0.03		(typical value for vegetated final cover)
Slope =	0.025	0.250	ft/ft	(final cover design slopes)
Depth (y) =	0.0886	0.0118	ft	

3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.
   - A permissible non-erodible velocity of 5 ft/sec is typical for vegetated final covers.
   - Refer to page C3-A-8 for soil loss calculations.

$$V = Q / (y * \text{width})$$

Sheet flow velocity	**1.56**	**1.28**	**ft/sec**

Summary: Permissable non-erodible velocity is 5.0 ft/sec with vegetated final cover. Therefore, the expected sheet flow velocity is acceptable on the final cover system top and side slopes with vegetation provided.

DRAINAGE SWALE DESIGN

Drainage Swale Analysis - Topslopes

Required: Determine the topslope drainage swale capacity.

Method:

1. Calculate the topslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable topslope drainage area using the Rational Method.
3. Provide the maximum proposed topslope drainage area for comparison.

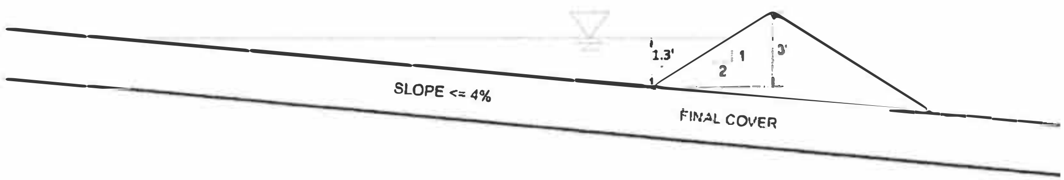
References:

1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised May 2014. (Note: The Hydraulic Design Manual, Revised September 2019, uses a different equation to calculate rainfall intensity which is not consistent with Reference 2.)
2. NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 11 Version 2.0: Texas, 2018.

Solution:

1. Calculate flow capacity using Manning's Equation.

- Swale Characteristics:



Max swale flow depth (D) =	1.30	ft	
Running swale slope (S) =	0.5	%	
Manning's Roughness (n) =	0.03		(typical value for vegetated final cover)
Left slope (LS) =	25.00	:1	
Right slope (RS) =	2	:1	
Flow Area (A) =	((LS+RS)*D^2)/2		
Wetted Perimeter (WP) =	((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)		
Hydraulic Radius (R) =	A / WP		
Flow Area (A) =	22.815	sf	
Wetted Perimeter (WP) =	35.433	ft	
Hydraulic Radius (R) =	0.644	ft	

- Use Manning's Equation to determine the flow velocity in the swale.

Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n

Velocity (V) = 2.619 ft/sec

- Calculate the swale's flow capacity.

Swale capacity (Q) = V * A

Q = 59.7 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.30	in	(ref 2)
Time of Concentration (tc) =	10	min	(conservative minimum value)
Rainfall Intensity (I) =	7.8	in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70		(typical value for final cover systems)
25-Year Peak Flow Rate (Q) =	CIA	cfs	

- Rearrange the Rational Formula to calculate allowable drainage area:

Drainage Area = Q / (CI)

Maximum Allowable Swale Drainage Area = 10.94 acres

3. Provide the maximum proposed topslope drainage area for comparison.

Maximum Proposed Swale Drainage Area = 10.00 acres

Summary: The maximum proposed topslope swale drainage area is 10 acres. This is less than the maximum allowable drainage area of 10.94 acres for the proposed swale configuration.

Drainage Swale Analysis - Sideslopes

Required: Determine the sideslope drainage swale capacity.

Method:

1. Calculate the sideslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable sideslope drainage area using the Rational Method.
3. Provide the maximum proposed sideslope drainage area for comparison.

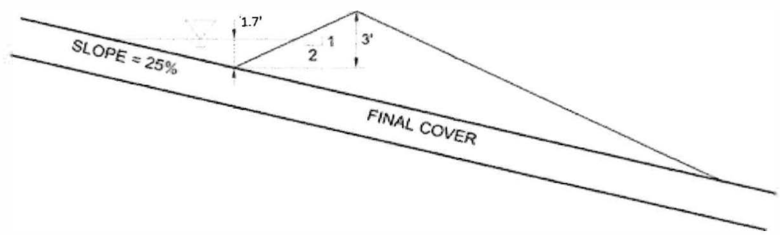
References:

1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised May 2014. (Note: The Hydraulic Design Manual, Revised September 2019, uses a different equation to calculate rainfall intensity which is not consistent with Reference 2.)
2. NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 11 Version 2.0: Texas, 2018.

Solution:

1. Calculate flow capacity using Manning's Equation.

- Swale Characteristics:



Max swale flow depth (D) =	1.70 ft	
Running swale slope (S) =	0.5 %	
Manning's Roughness (n) =	0.03	(typical value for vegetated final cover)
Left slope (LS) =	4.00 :1	
Right slope (RS) =	2 :1	
Flow Area (A) =	((LS+RS)*D^2)/2	
Wetted Perimeter (WP) =	((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)	
Hydraulic Radius (R) =	A / WP	

Flow Area (A) =	8.670 sf
Wetted Perimeter (WP) =	10.811 ft
Hydraulic Radius (R) =	0.802 ft

- Use Manning's Equation to determine the flow velocity in the swale.

Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n

Velocity (V) = 3.032 ft/sec

- Calculate the swale's flow capacity.

Swale capacity (Q) = V * A

Q = 26.3 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.30 in	(ref 2)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	7.8 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for final cover systems)
25-Year Peak Flow Rate (Q) =	CIA cfs	

- Rearrange the Rational Formula to calculate allowable drainage area:

Drainage Area = Q / (CI)

Maximum Allowable Swale Drainage Area = 4.81 acres

3. Provide the maximum proposed sideslope drainage area for comparison.

Maximum Proposed Swale Drainage Area = 4.50 acres

Summary: The maximum proposed sideslope swale drainage area is 4.5 acres. This is less than the maximum allowable drainage area of 4.81 acres for the proposed swale configuration.

DRAINAGE LETDOWN (OR CHUTE) DESIGN

Down Chute Design

Required: Determine final cover collection channel and down chute flowrates.

Method:
1. Determine the flow from each chute drainage area using the Rational Method

Reference
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised May 2014.
(Note: The Hydraulic Design Manual, Revised September 2019, uses a different equation to calculate rainfall intensity which is not consistent with Reference 2.)
2. NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 11 Version 2.0: Texas, 2018.

Solution:
1. Determine the 25-Year Peak Flow Rate using the Rational Method.

25-Year Rainfall Depth (Pd) = 1.30 in (ref 2)
Time of Concentration (tc) = 10 min (conservative minimum value)
Rainfall Intensity (I) = 7.8 in/hr (ref 1, I = Pd/tc)
Runoff Coefficient (C) = 0.70 (typical value for final cover systems)
25-Year Peak Flow Rate (Q) = CIA cfs

Chute Drainage Area	Chute Area (acre)	25-Year Peak Flow Rate (cfs)
DA2	20.3	110.8
DA3	22.9	125.0
DA4	20.1	109.7
DA5	20.5	111.9
DA6	20.8	113.6
DA7	20.8	113.6
DA8	20.7	113.0
DA9	20.8	113.6
DA10	19.5	106.5
DA11	19.6	107.0
DA12	19.3	105.4
DA13	20.9	114.1
DA14	20.7	113.0
DA15	21.0	114.7
DA16	21.1	115.2
DA17	20.4	111.4
DA18	21.2	115.8
DA19	20.0	109.2
DA20	19.8	108.1
DA21	20.9	114.1
DA22	16.1	87.9
DA23	15.4	84.1
DA24	20.0	109.2
DA25	9.1	49.7
DA26	19.5	106.5

Downchute Calculations

Required: Determine the flow depth and velocity in the downchutes and low-water crossings.

Method: Calculate the flow depth and velocity using Manning's Equation.

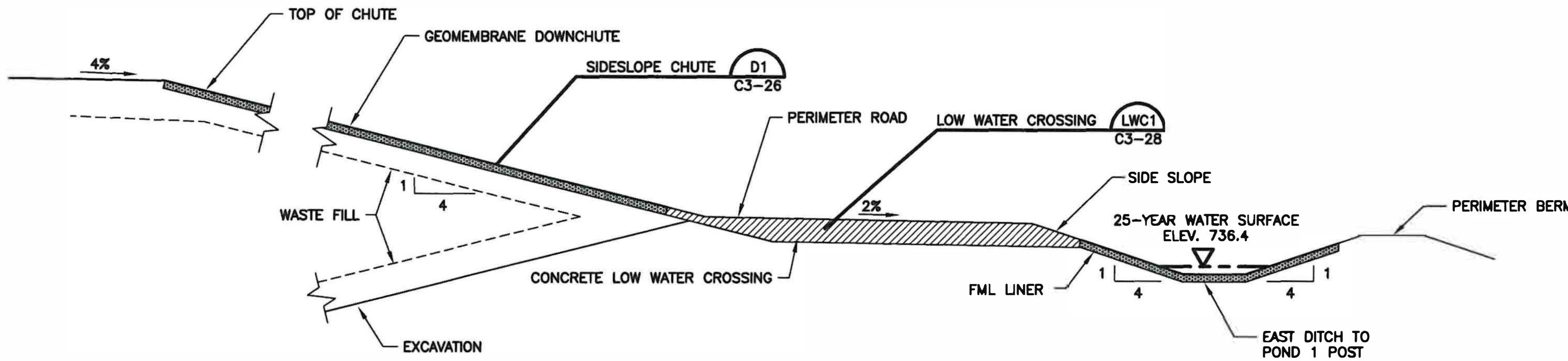
Solution:

		Chute						Low-Water Crossing						Erosion Protection after Low-Water Crossing					
Chute	Q (cfs)	Width (ft)	Slope (%)	Side Slopes (h:v)	Manning's n	Depth (ft)	Velocity (fps)	Width (ft)	Slope (%)	Side Slopes (h:v)	Manning's n	Depth (ft)	Velocity (fps)	Width (ft)	Slope (%)	Side Slopes (h:v)	Manning's n	Depth (ft)	Velocity (fps)
DA2	110.8	20	25	4	0.013	**0.24**	**21.63**	20	2	12	0.020	**0.62**	**6.51**	30	25	12	0.013	**0.19**	**18.05**
DA3	125.0	20	25	4	0.013	**0.26**	**22.63**	20	2	12	0.020	**0.66**	**6.75**	30	25	12	0.013	**0.20**	**18.87**
DA4	109.7	20	25	4	0.013	**0.24**	**21.55**	20	2	12	0.020	**0.62**	**6.49**	30	25	12	0.013	**0.19**	**17.99**
DA5	111.9	20	25	4	0.013	**0.25**	**21.71**	20	2	12	0.020	**0.62**	**6.53**	30	25	12	0.013	**0.19**	**18.12**
DA6	113.6	20	25	4	0.013	**0.25**	**21.83**	20	2	12	0.020	**0.63**	**6.56**	30	25	12	0.013	**0.19**	**18.22**
DA7	113.6	20	25	4	0.013	**0.25**	**21.83**	20	2	12	0.020	**0.63**	**6.56**	30	25	12	0.013	**0.19**	**18.22**
DA8	113.0	20	25	4	0.013	**0.25**	**21.79**	20	2	12	0.020	**0.63**	**6.55**	30	25	12	0.013	**0.19**	**18.18**
DA9	113.6	20	25	4	0.013	**0.25**	**21.83**	20	2	12	0.020	**0.63**	**6.56**	30	25	12	0.013	**0.19**	**18.22**
DA10	106.5	20	25	4	0.013	**0.24**	**21.30**	20	2	12	0.020	**0.61**	**6.43**	30	25	12	0.013	**0.19**	**17.79**
DA11	107.0	20	25	4	0.013	**0.24**	**21.34**	20	2	12	0.020	**0.61**	**6.44**	30	25	12	0.013	**0.19**	**17.82**
DA12	105.4	20	25	4	0.013	**0.24**	**21.22**	20	2	12	0.020	**0.60**	**6.41**	30	25	12	0.013	**0.18**	**17.72**
DA13	114.1	20	25	4	0.013	**0.25**	**21.87**	20	2	12	0.020	**0.63**	**6.57**	30	25	12	0.013	**0.19**	**18.25**
DA14	113.0	20	25	4	0.013	**0.25**	**21.79**	20	2	12	0.020	**0.63**	**6.55**	30	25	12	0.013	**0.19**	**18.18**
DA15	114.7	20	25	4	0.013	**0.25**	**21.91**	20	2	12	0.020	**0.63**	**6.58**	30	25	12	0.013	**0.19**	**18.28**
DA16	115.2	20	25	4	0.013	**0.25**	**21.95**	20	2	12	0.020	**0.63**	**6.59**	30	25	12	0.013	**0.19**	**18.31**
DA17	111.4	20	25	4	0.013	**0.25**	**21.67**	20	2	12	0.020	**0.62**	**6.52**	30	25	12	0.013	**0.19**	**18.09**
DA18	115.8	20	25	4	0.013	**0.25**	**21.99**	20	2	12	0.020	**0.64**	**6.59**	30	25	12	0.013	**0.20**	**18.34**
DA19	109.2	20	25	4	0.013	**0.24**	**21.51**	20	2	12	0.020	**0.62**	**6.48**	30	25	12	0.013	**0.19**	**17.96**
DA20	108.1	20	25	4	0.013	**0.24**	**21.42**	20	2	12	0.020	**0.61**	**6.46**	30	25	12	0.013	**0.19**	**17.89**
DA21	114.1	20	25	4	0.013	**0.25**	**21.87**	20	2	12	0.020	**0.63**	**6.57**	30	25	12	0.013	**0.19**	**18.25**
DA22	87.9	20	25	4	0.013	**0.21**	**19.81**	20	2	12	0.020	**0.55**	**6.06**	30	25	12	0.013	**0.17**	**16.57**
DA23	84.1	20	25	4	0.013	**0.21**	**19.47**	20	2	12	0.020	**0.53**	**5.97**	30	25	12	0.013	**0.16**	**16.30**
DA24	109.2	20	25	4	0.013	**0.24**	**21.51**	20	2	12	0.020	**0.62**	**6.48**	30	25	12	0.013	**0.19**	**17.96**
DA25	49.7	20	25	4	0.013	**0.15**	**15.91**	20	2	12	0.020	**0.40**	**5.05**	30	25	12	0.013	**0.12**	**13.37**
DA26	106.5	20	25	4	0.013	**0.24**	**21.30**	20	2	12	0.020	**0.61**	**6.43**	30	25	12	0.013	**0.19**	**17.79**

Notes:

1. Flow rates were calculated using the Rational Method for the 25-year rainfall event.
2. The energy dissipation at the chute and low-water crossing confluence is accomplished via a hydraulic jump and was designed in accordance with *Hydraulic Design of Stilling Basins and Energy Dissipators*, A. J. Peterka, United States Department of the Interior, Bureau of Reclamation, 1978.
   The length of the hydraulic jump is approximately five times the flow depth in the low-water crossing.
3. Erosion protection on downchute will be 40-mil textured flexible membrane liner (FML).
   Erosion protection at low-water crossing will be 12-inch-thick concrete.
   Erosion protection after low-water crossing will be 40-mil textured flexible membrane liner (FML).

CHUTE PROFILE

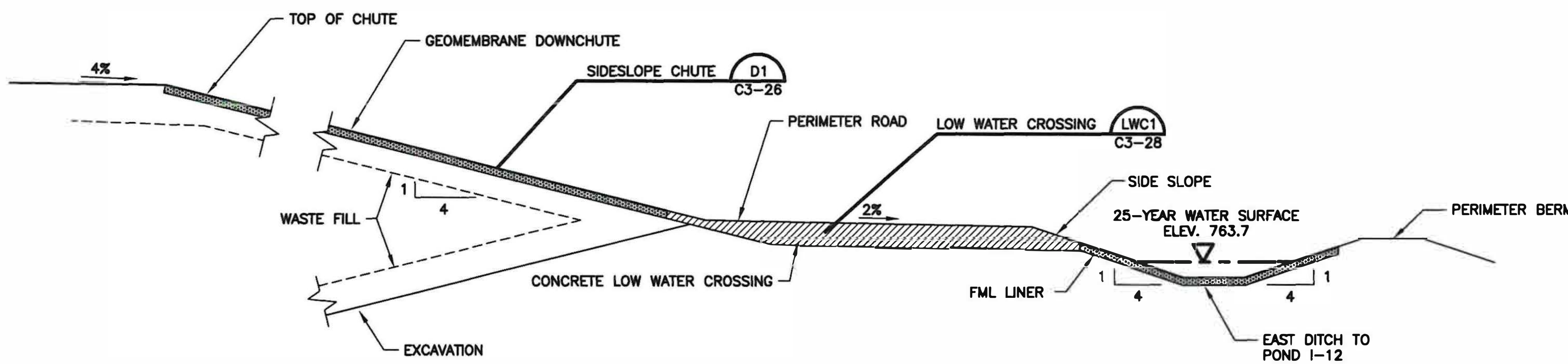


CHUTE 3 PROFILE (CP3 / C3-14)

0 10 20
SCALE IN FEET

CHUTE 3 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.26
	FLOW VELOCITY (FPS)	22.63
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.66
	FLOW VELOCITY (FPS)	6.75
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.87

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 26 PROFILE (CP26 / C3-25)

0 10 20
SCALE IN FEET

CHUTE 18 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.99
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.64
	FLOW VELOCITY (FPS)	6.59
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.20
	FLOW VELOCITY (FPS)	18.34

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED
PROFESSIONAL ENGINEER

2/28/2025

ISSUED FOR PERMITTING PURPOSES

REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CHUTE 3 AND 18 PROFILES

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DISPOSAL AND RECYCLING FACILITY
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C1.E.3

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ATTACHMENT C1
APPENDIX C1F

INTERMEDIATE COVER
EROSION AND SEDIMENTATION CONTROL PLAN

CONTENTS

NARRATIVE

This appendix presents temporary erosion and sediment control structures for the intermediate cover phase of landfill development. Temporary means the time between the construction of intermediate cover and the construction of final cover or the placement of additional waste, as the case may be. Appendix C1F addresses the requirements of 30 TAC §330.305(d) and (e) related to the intermediate cover phase of the landfill.

As defined in the guidance document issued by TCEQ titled "Surface Water Drainage and Erosional Stability Guidelines for a Municipal Solid Waste Landfill" dated May 2018; intermediate topslope surfaces and external sideslopes.

> "For the purposes of compliance with 30 TAC §330.305(d), 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 stormwater directly flows to a perimeter channel or detention pond designed in accordance with 30 TAC 330.63(c), 330.303, and 330.305).
> - Have received intermediate or final cover.
> - Have either reached their permitted elevation, or will subsequently remain inactive for longer than 180 days."

Slopes that drain to ongoing waste placement, pre-excavated areas, areas that have received only daily cover, or areas under construction that have not received waste are not covered under this appendix. Areas that have received final cover are not covered in this appendix. This appendix addresses only intermediate cover slopes.

INTERMEDIATE COVER

Drawing C1-F-1 shows the areas that have been constructed and have received final, daily or intermediate cover. Cell 26 is currently being developed. Fill operations are ongoing in Cell 25. Areas where fill operations are currently ongoing will receive daily cover. Areas that have been inactive for longer than 180 days have received intermediate cover. Temporary erosion control measures may need to be installed on existing intermediate cover areas to control erosion and minimize soil loss if these areas have less than 60 percent vegetative cover. Intermediate cover areas that have existing well established vegetation (at least 60 percent coverage) will not be disturbed to construct temporary erosion control features.

Areas that reach their permitted elevation or plan to remain inactive for longer than 180 days will receive intermediate cover. As areas receive intermediate cover, temporary erosion control measures will be constructed. Temporary erosion and sediment control features will be placed within 180 days from construction of intermediate cover. All intermediate cover areas will be managed to control erosion and achieve predicted soil loss of less than 50 tons per acre per year. Temporary and permanent drainage structures will be constructed as the landfill develops intermediate and final cover slopes. These structures provide erosion and sediment control.

The TASWA DRF has an active stormwater pollution prevention plan (SWPPP), Permit No. TXR05AH82, prepared consistent with the TPDES general permit. The SWPPP is up to date and maintained in the Site Operating Record. The SWPPP provides detailed Best Management Practices (BMPs) including training and implementation strategies to reduce the potential of pollutants in stormwater discharge. The plan also includes detailed stormwater and erosion control measures for current landfill construction activities.

EROSION AND SEDIMENT CONTROL LANDFILL COVER PHASES

The purpose of this section is to define the landfill cover phases and where they are addressed throughout the TASWA DRF permit:

Daily Cover – Daily cover is defined in §330.165(a). Daily cover consists of 6 inches of well compacted earthen material not previously mixed with garbage, rubbish, or other solid waste applied at the end of each operating day. The placement and erosion control practices for daily cover areas are defined in Part IV and in the Best Management Practices Section of this appendix.

Intermediate Cover – Intermediate cover is defined in §330.165(c). Intermediate cover consists of at least 12 inches of suitable earthen material and is graded and maintained to prevent erosion and ponding of water. The placement requirements and erosion control practices for intermediate cover areas are defined in this appendix.

Final Cover – Final cover is defined in Subchapter K. The placement and erosion control practices for final cover areas are defined in Appendix C1E. Final cover at the TASWA DRF will be managed as provided for in the closure and postclosure plan required by 30 TAC 330 Subchapter K, Closure and Post-Closure.

BEST MANAGEMENT PRACTICES

Vegetation and temporary erosion control structures provide the most effective means to reduce the amount of soil loss during operation of the landfill. Best management practices utilized for erosion and sediment control may be broadly categorized as nonstructural and structural controls. Nonstructural controls addressing erosion include the following:

- Minimization of the disruption of the natural features, drainage, topography, or 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
- Plans to confine sediment to the construction area during the construction phase
- Scheduling of construction activities during the time of year with the least erosion potential, when applicable
- Specific plans for the stabilization of exposed surfaces in a timely manner

Structural controls are preventative and also mitigative since they control erosion and sediment movement. Structural controls addressing erosion include the following:

- Vegetative and Non-Vegetative Stabilization. A soil stabilization and vegetation schedule is provided in this appendix.
- Check Dams. Check dams may be constructed using gravel, rock, gabions, compost socks, or sandbags to reduce flow velocity and therefore erosion in a perimeter channel or detention pond.
- Filter Berms. Filter berms may be constructed of mulch, woodchips, brush, compost, shredded woodwaste, or synthetic filter materials. Mesh socks may be filled with compost, mulch, wood chips, brush, or shredded woodwaste. Filter berms or filled mesh socks may be installed at the bottom of slopes, throughout the perimeter drainage system, and on sideslopes. The maximum drainage area to the filter berm or filled mesh sock will not exceed 2 acres. Specifications for the filter berms are provided on Drawing C1-F-3, Detail TD11.
- Baled Hay. Hay bales, straw bales, or baled hay shall be approximately 30 inches in length and be composed entirely of vegetable matter. Hay bales shall be embedded in the soil a minimum of 4 inches and where possible one-half the height of the hay bale.
- Sediment Traps. Sediment traps are small, excavated areas that function as a sediment basin. Sediment traps allow for the settling of suspended sediment in stormwater runoff. Sediment traps may be constructed in perimeter channels, temporary internal channels, and at entrances to detention ponds. The maximum drainage area contributing to a sediment trap will not exceed 10 acres.

- Temporary Sediment Control Fence or Silt Fence. Silt fences or fabric filter fences may be used where there is sheet flow. The maximum drainage area to the silt fence will not exceed the manufacturer's specification, but in no case be greater than 0.5 acre per 100 feet of fence. To ensure sheet flow, a gravel collar or level spreader may be used upslope of the silt fence.

- Swales. These structures will be constructed of a material with the top 6 inches capable of sustaining native plant growth. Rolled erosion control mats or blankets made from natural materials or synthetic fiber, grass, or compost/mulch/straw may be used as erosion protection along the flowline. These structures direct the flow to the drainage system. These structures decrease downslope velocities of runoff that could cause erosion on the intermediate cover slopes.

- Letdown Chutes. Letdown chutes are bermed conveyance structures constructed on the intermediate cover slopes. Flow will be directed to the letdown chutes via swales, then conveyed to the perimeter drainage system. The letdown chutes will be lined with an FML geomembrane, turf reinforcement mats, riprap, concrete, gabions, crushed concrete, or stone.

Erosion will be controlled by vegetation on topslopes, sideslopes, swales, and in drainage conveyance structures with flow velocities less than or equal to 5 fps. For drainage conveyance structures with flow velocities greater than 5 fps, turf reinforcement, rock riprap, concrete, gabions, or other appropriate materials will be used for surface reinforcement.

Intermediate cover erosion and sediment control structures are shown on Drawings C1F.2 through C1F.4. During site development, both structural and non-structural BMPs will be employed to control erosion.

The potential for wind erosion of the intermediate cover surface will be mitigated through the placement of temporary intermediate cover erosion control measures and establishment of vegetative cover. Temporary erosion control measures include surface roughening, surface wetting, application of tackifiers, or hydromulching the intermediate cover surface.

SOIL STABILIZATION AND VEGETATION SCHEDULE

The soil stabilization and vegetation schedule is as follows:

- Areas that will remain inactive for periods greater than 180 days will receive intermediate cover.

- Intermediate cover on slopes will be stabilized by tracking into the slope. Soil stabilization can be enhanced by mulching, the addition of soil tackifiers, soil treatment, or any combination of these measures. The intermediate cover will be graded to provide positive drainage.

- Temporary erosion control structures will be installed within 180 days from when intermediate cover is constructed.

- The intermediate cover area will be seeded or sodded as soon as practical, following placement of intermediate cover and will be documented in the site operating record. All intermediate cover areas will be managed to control erosion and achieve a predicted soil loss of less than 50 tons per acre per year. A 60 percent vegetative cover will be established over the intermediate cover areas within 180 days from intermediate cover construction unless prevented by climatic events (e.g., drought, rainfall, etc.). Additional temporary erosion control measures will be implemented during these events to facilitate the establishment of vegetative cover.

- Mulch, woodchips, or compost may 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, wood chips, or compost will be used to stabilize recently graded or seeded areas. The mulch, wood chips, or compost will be spread evenly over a recently seeded area and tracked into the surface to protect the soil from erosion and moisture loss, if required to promote the establishment of vegetation. These materials are not required for the establishment of vegetation on the intermediate cover; however, they may be used if the TASWA DRF determines they are needed to promote vegetative growth or to provide additional erosional stability to the intermediate cover surface. These materials will vary in thickness but will not be placed to a thickness to inhibit vegetative growth.

- The intermediate cover and temporary erosion control structures will be maintained as detailed in the Stormwater System Maintenance Plan.

- Final cover will be constructed as the site develops. Temporary erosion control features will be removed as permanent erosion control structures are constructed.

STORMWATER SYSTEM MAINTENANCE PLAN

The TASWA DRF will restore and repair temporary stormwater systems such as channels, drainage swales, chutes, and flood control structures in the event of wash-out or failure. In addition, the BMPs discussed in this appendix will also be replaced or repaired in the event of failure. Excessive sediment will be removed, as needed, so that the drainage structures function as designed. Site inspections by landfill personnel will be performed weekly or within 48 hours of a rainfall event of 0.5 inches or more.

The following items will be evaluated during the inspections:

- Erosion of intermediate cover areas, perimeter ditches, temporary 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

- Presence of ponded water on intermediate cover or behind temporary erosion control structures

- Obstructions in drainage features
- Presence of erosion or sediment discharge at offsite stormwater discharge locations
- Temporary erosion and sediment control features

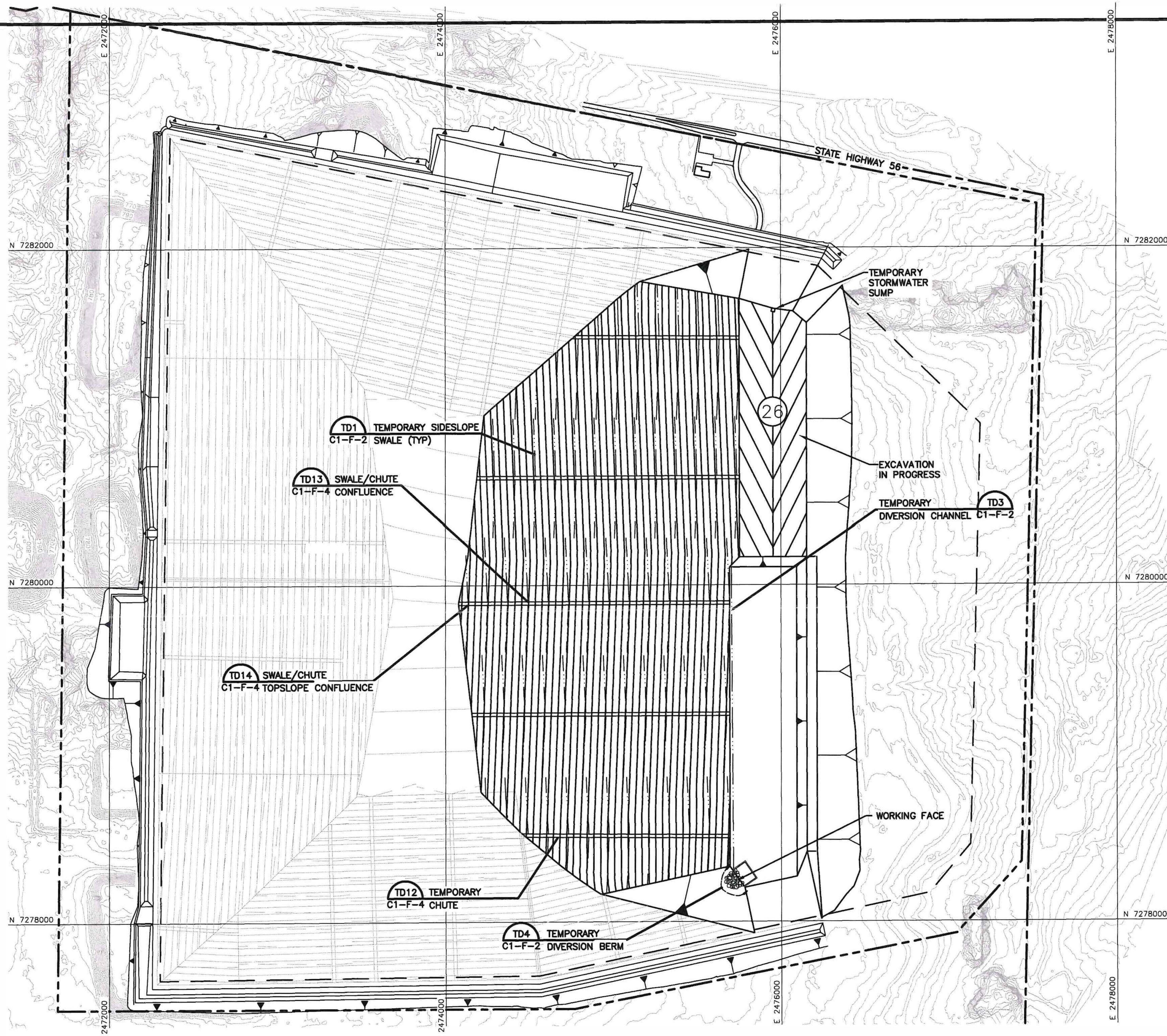
Maintenance activities will be performed to correct damaged or deficient items noted during the site inspections. These activities will be performed as soon as possible after the inspection. The time frame for correction of damaged or deficient items will vary based on weather, ground conditions, and other site-specific conditions.

Maintenance activities will consist of the following, as needed:

- Placement of additional temporary or permanent vegetation
- Placement, grading, and stabilization of additional soils in eroded areas or in areas which have settled
- Replacement of riprap or other structural lining
- Removal of obstructions from drainage features
- Removal of silt and sediment build-up from the temporary erosion control structures
- Removal of ponded water on the intermediate cover or behind temporary erosion control structures
- Repairs to erosion and sedimentation controls
- Installation of additional erosion and sedimentation controls

Documentation and training requirements are discussed below:

- Site inspections by landfill personnel will be performed weekly or within 48 hours of a rainfall event of 0.5 inches or more.
- Documentation of the inspection will be included in the site operating record.
- Documentation of maintenance activities that were performed to correct damaged or deficient items noted during the site inspections will be included in the site operating record.
- Landfill personnel will be trained to perform inspections, install and maintain temporary erosion control structures.



0 300 600
SCALE IN FEET

LEGEND

— · —	2290A PERMIT BOUNDARY
— —	2290A LANDFILL FOOTPRINT
N 7279000	STATE PLANE COORDINATES
750	EXISTING 10' GROUND CONTOUR
700	EXCAVATION CONTOUR

NOTES:

1. EXISTING GROUND CONTOURS PROVIDED BY BIGGS AND MATHEWS ENVIRONMENTAL FROM DRONE SURVEY FLOWN ON JUNE 1, 2022.

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED PROFESSIONAL ENGINEER
2/28/2025

INTERMEDIATE COVER EROSION CONTROL FEATURES

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

BME
BIGGS & MATHEWS ENVIRONMENTAL
1700 ROBERT ROAD, STE. 100
MANSFIELD, TEXAS 76063
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
C1F.1

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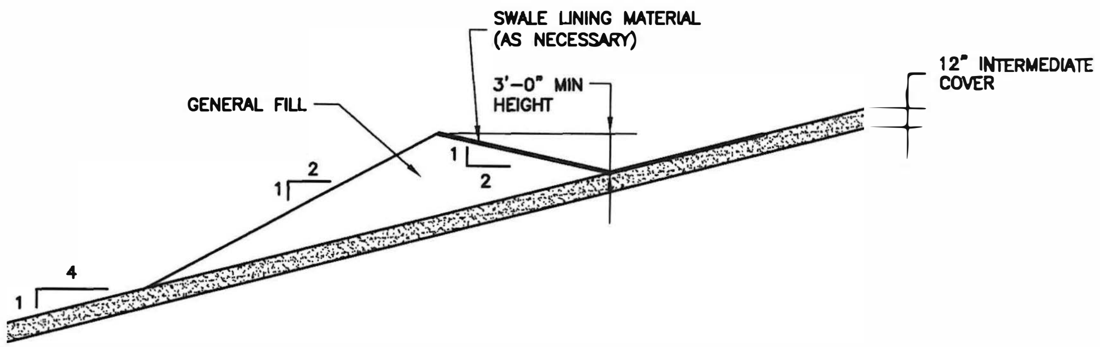
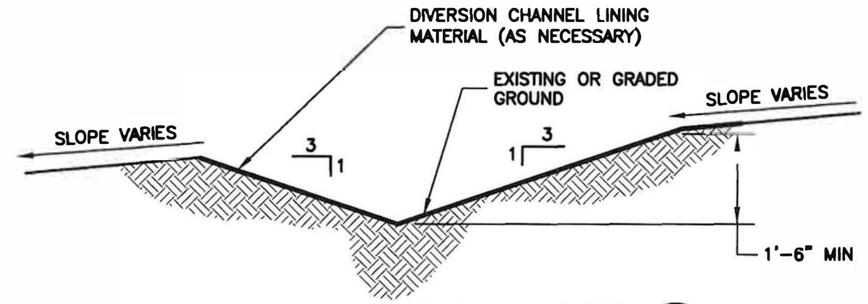


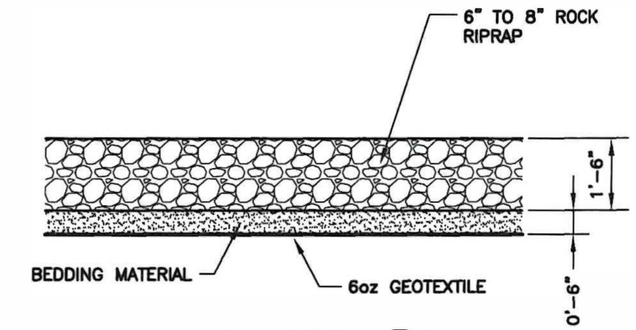
TEMPORARY SIDESLOPE SWALE TD1 C1-F-2

NTS



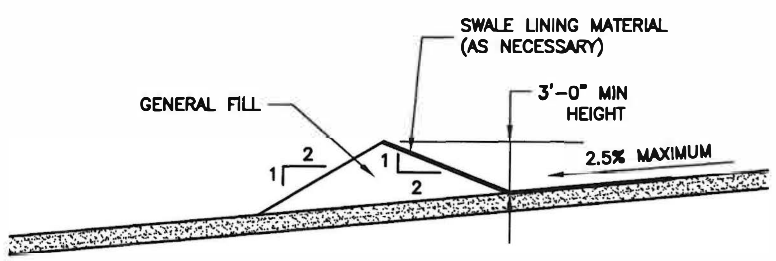
TEMPORARY DIVERSION CHANNEL TD3 C1-F-2

NTS



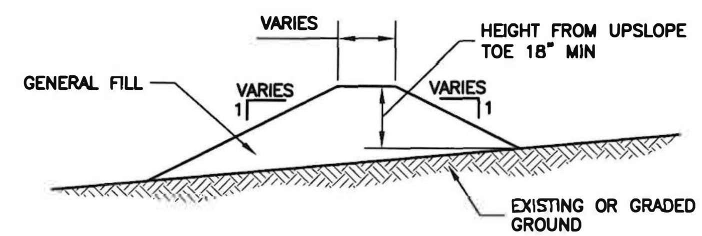
ROCK RIPRAP TD5 C1-F-2

NTS



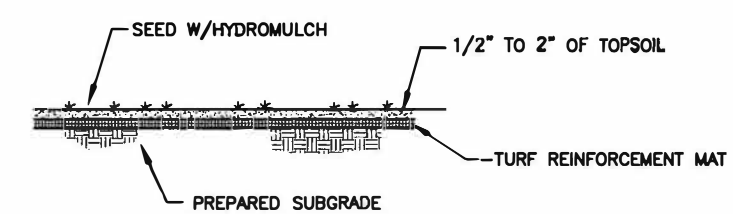
TEMPORARY TOPSLOPE SWALE TD2 C1-F-2

NTS



TEMPORARY DIVERSION BERM TD4 C1-F-2

NTS



TEMPORARY TURF REINFORCEMENT MATTING TD6 C1-F-2

NTS

NOTE:

1. LINING MATERIAL, IF NECESSARY, FOR THE TEMPORARY DRAINAGE SWALES WILL BE TURF REINFORCEMENT MATTING OR OTHER SUITABLE MATERIALS.

TEMPORARY EROSION CONTROL STRUCTURES

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4. ACTUAL DIMENSIONS OF TEMPORARY EROSION CONTROL STRUCTURES MAY VARY BASED ON SITE CONDITIONS.

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TEMPORARY EROSION CONTROL STRUCTURES

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C1F.2

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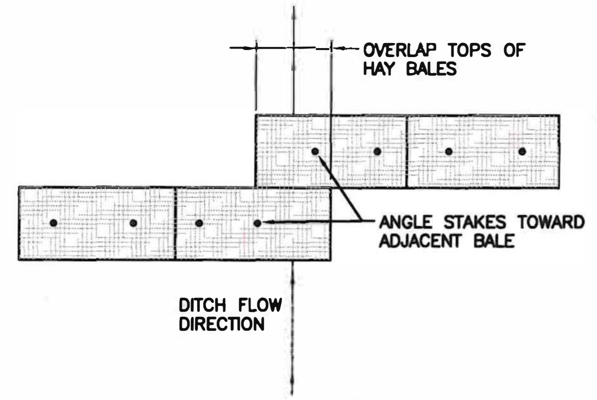
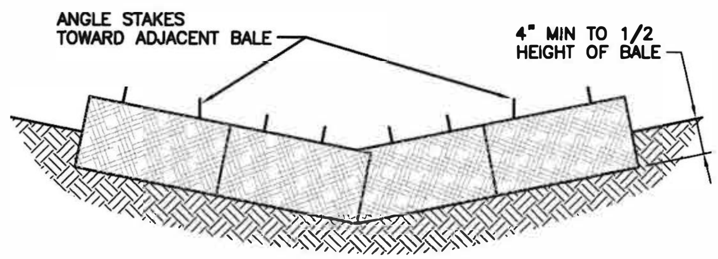


PLAN VIEW



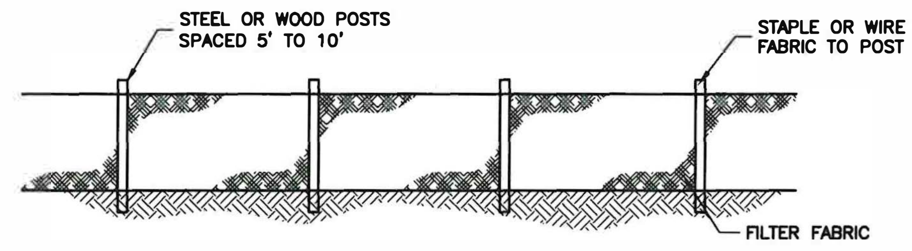
PROFILE VIEW

BALED HAY FOR EROSION CONTROL (TD7)

NTS C1-F-3

HAY BALE NOTE:

1. HAY BALES SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF 4" AND WHERE POSSIBLE 1/2 THE HEIGHT OF THE BALE.

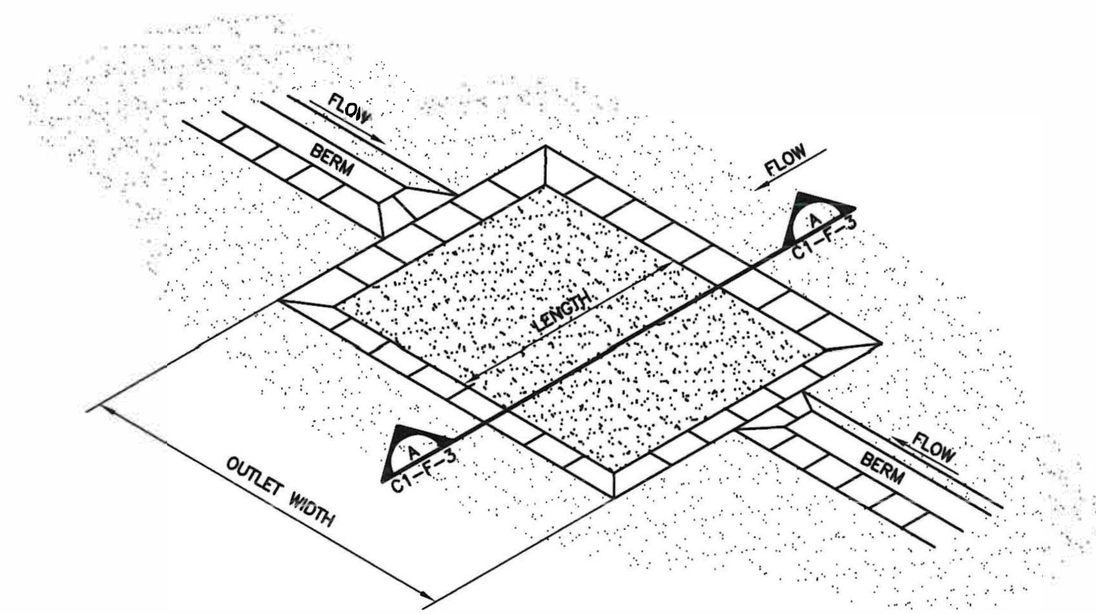


TEMPORARY SEDIMENT CONTROL (SILT) FENCE (TD9)

NTS C1-F-3

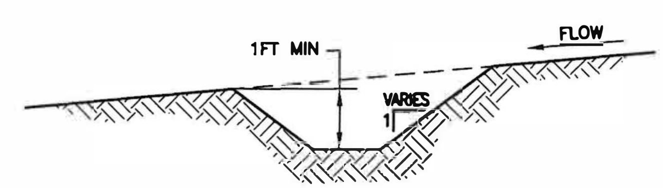
SILT FENCE NOTES:

1. MAXIMUM DRAINAGE AREA TO THE FENCE SHOULD NOT EXCEED THE MANUFACTURER'S SPECIFICATION BUT IN NO CASE BE GREATER THAN 0.5 ACRE PER 100 FEET OF FENCE.
2. TO ENSURE SHEET FLOW, A GRAVEL COLLAR OR LEVEL SPREADER MAY BE USED UPSLOPE OF THE SILT FENCE.



SEDIMENT TRAP PLAN

NTS



SEDIMENT TRAP SECTION (A-A)

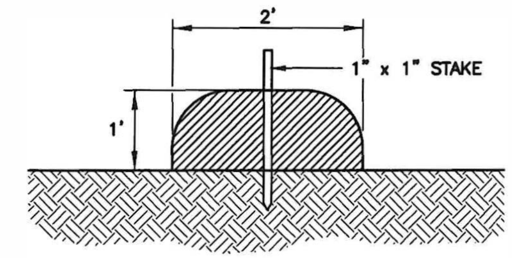
NTS C1-F-3

SEDIMENT TRAP (TD10)

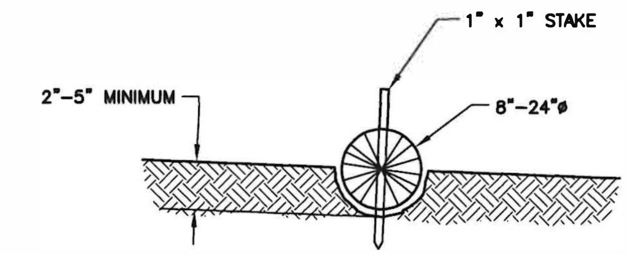
NTS C1-F-3

NOTE:

1. OUTLET INTO STABILIZED AREA (VEGETATION, ROCK, ETC.)
2. THE MAXIMUM AREA CONTRIBUTING TO A SEDIMENT TRAP SHOULD BE LESS THAN 10 ACRES.



OPTION 1



OPTION 2

FILTER BERM (TD11)

NTS C1-F-3

FILTER BERM NOTES:

1. FILTER BERMS MAY BE CONSTRUCTED OF MULCH, WOODCHIPS, BRUSH, COMPOST, SHREDDED WOODWASTE, OR SIMILAR MATERIALS.
2. FILTER BERMS MAY ALSO CONSIST OF MESH SOCKS FILLED WITH MULCH, WOOHCHIPS, BRUSH, COMPOST, SHREDDED WOODWASTE, OR SIMILAR MATERIALS.
3. RUNOFF MUST NOT BE ALLOWED TO RUN UNDER OR AROUND THE COMPOST FILTER BERM.
4. STAKES WILL BE PLACED 2-5" DEEP.
5. MAXIMUM DRAINAGE AREA TO THE FILTER BERM SHOULD NOT EXCEED 2 ACRES.

TEMPORARY EROSION CONTROL STRUCTURES
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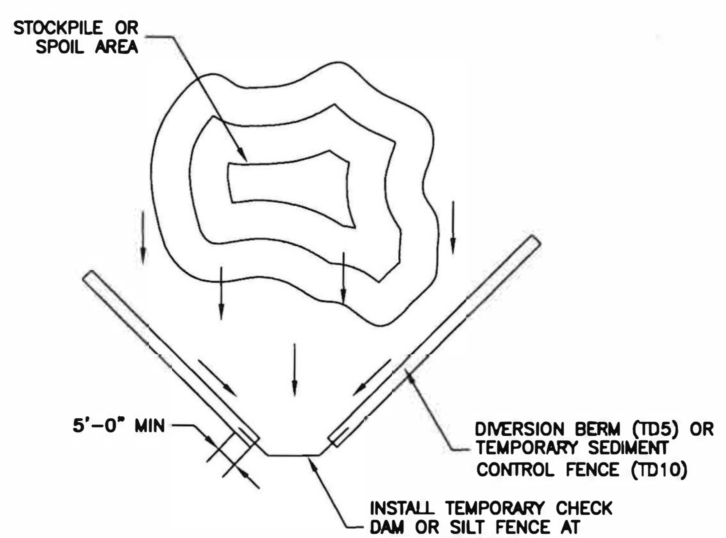

STOCKPILE EROSION CONTROL (TD8)

NTS C1-F-3

NOTE:

1. CONSTRUCT DIVERSION DIKE TO DIVERT STORMWATER RUN-OFF FROM STOCKPILE OR SPOIL AREA THROUGH CHECK DAM, HAY BALES, OR SILT FENCE.

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TEMPORARY EROSION CONTROL STRUCTURES

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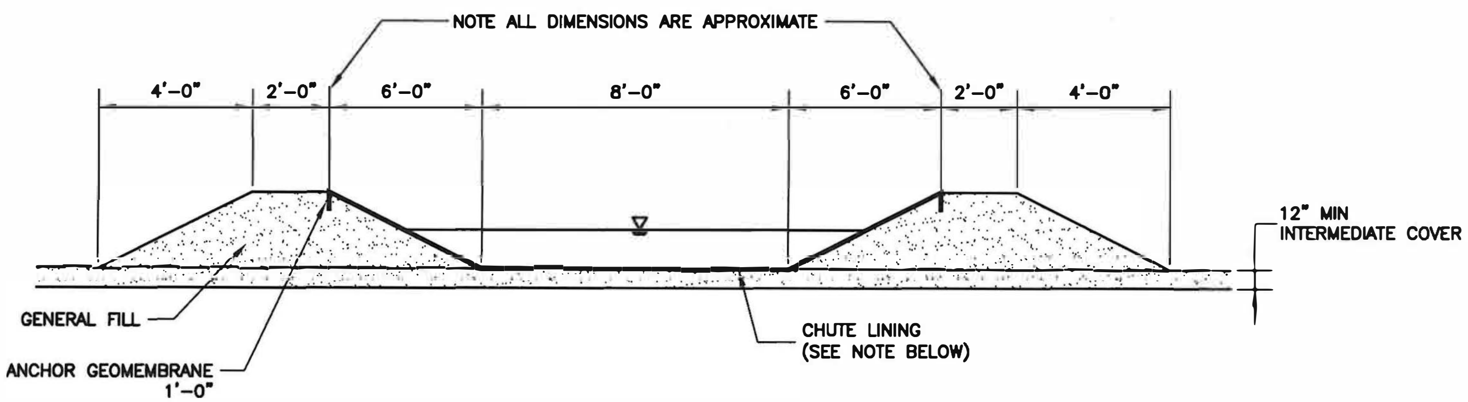
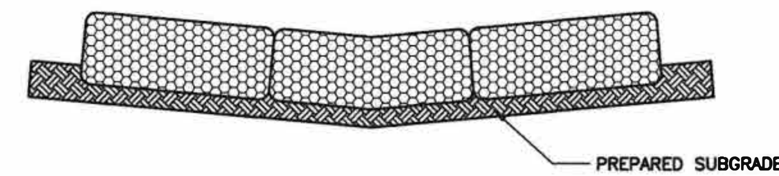


TEMPORARY CHUTE LETDOWN TD12 C1-F-4

NTS

NOTE: CHUTE LINING WILL CONSIST OF ONE OF THE FOLLOWING: TURF REINFORCEMENT, SACRIFICIAL GEOMEMBRANE, GABIONS, ROCK RIPRAP, CONCRETE, CRUSHED CONCRETE, OR STONE.



CHECK DAM TD15 C1-F-4

NTS

CHECK DAM NOTES:

1. MAY BE CONSTRUCTED USING GRAVEL, ROCK, GABIONS, COMPOST SOCKS, OR SAND BAGS.
2. PLACED ON PREPARED SUBGRADE OR BEDDING MATERIAL ALONG THE CONTOUR AT 0% GRADE OR AS NEAR AS POSSIBLE.
3. TOP WIDTH OF TWO FEET MINIMUM.
4. SIDESLOPES 2H:1V OR FLATTER.
5. MAY BE USED WHEN CONTRIBUTING DRAINAGE AREAS ARE LESS THAN 10 ACRES. MULTIPLE CHECK DAMS MAY BE INSTALLED IF DRAINAGE AREAS ARE GREATER THAN 10 ACRES.
6. CHECK DAMS SHOULD BE USED WHEN THE VOLUME OF RUNOFF IS TOO GREAT FOR OTHER EROSION CONTROL FEATURES (i.e. SILT FENCES, HAY BALES).

TEMPORARY EROSION CONTROL STRUCTURES

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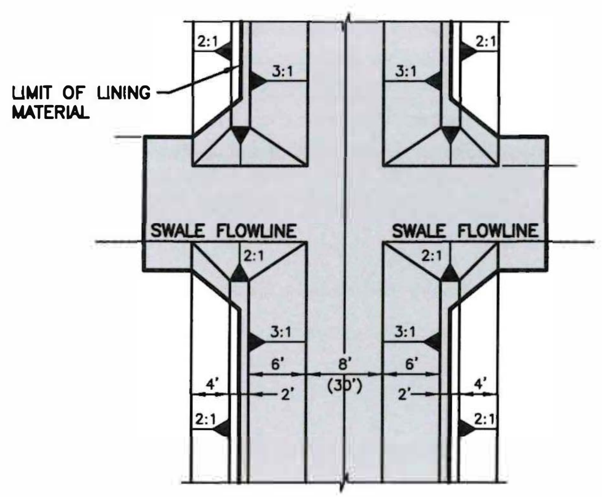
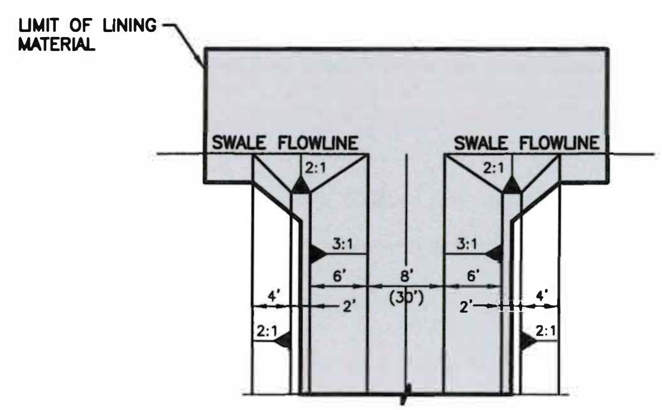


SWALE/CHUTE CONFLUENCE TD13 C1-F-4

NTS



SWALE/CHUTE TOPSLOPE CONFLUENCE TD14 C1-F-4

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TEMPORARY EROSION CONTROL STRUCTURES

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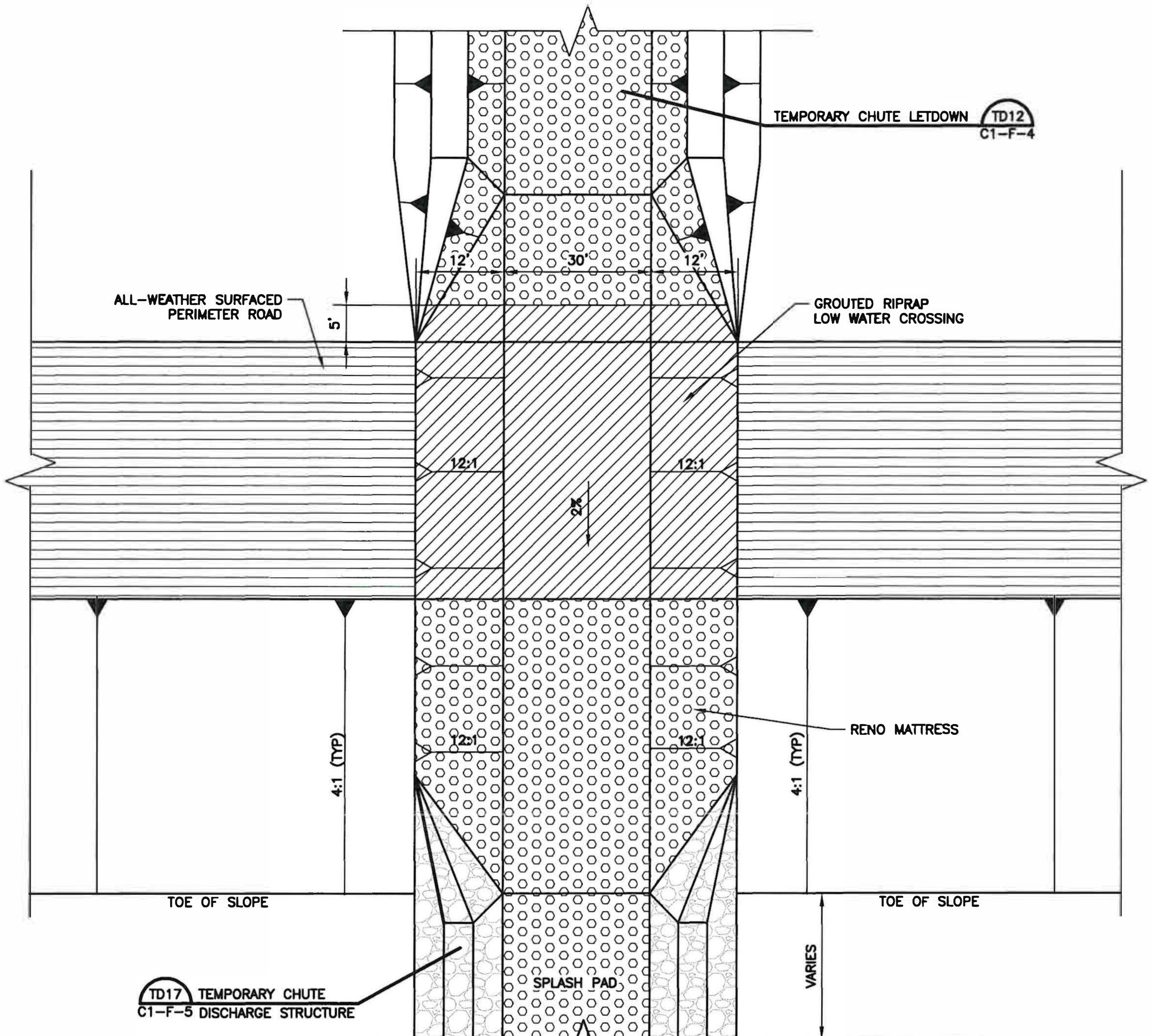
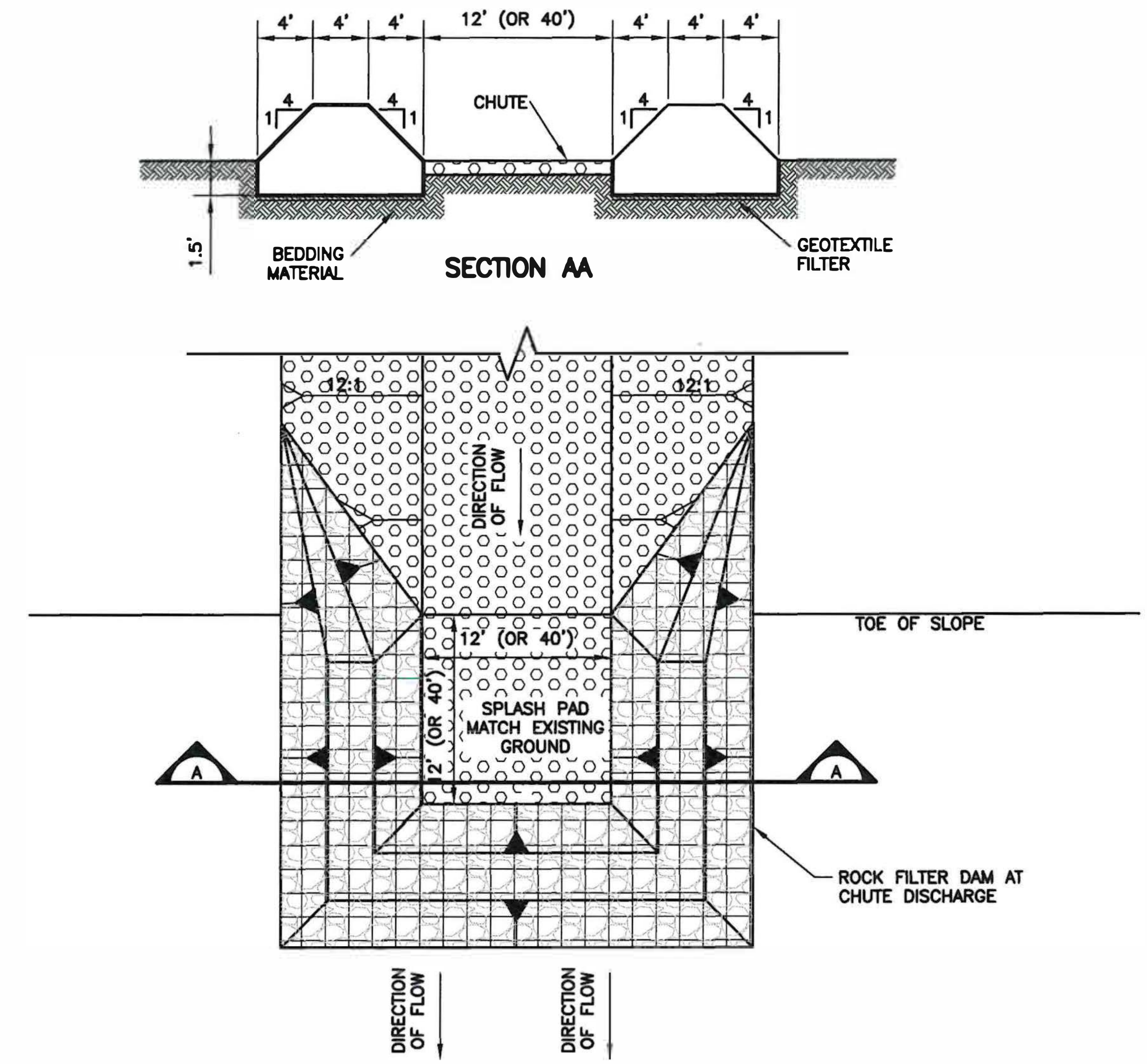


TEMPORARY LOW WATER CROSSING TD16 C1-F-5

NTS



TEMPORARY CHUTE DISCHARGE STRUCTURE TD17 C1-F-5

NTS

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LOW WATER CROSSING

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ATTACHMENT C1
APPENDIX C1G

INTERMEDIATE COVER
EROSION CONTROL STRUCTURE DESIGN

CONTENTS

NARRATIVE

This appendix presents the supporting documentation to evaluate and design temporary erosion and sediment control structures for the intermediate cover phase of landfill development. Appendix C1G addresses the requirements of 30 TAC §330.305(d) and (e) and provides the evaluation and design of temporary erosion and sediment control structures for intermediate cover slopes.

INTERMEDIATE COVER PLAN

As intermediate cover is constructed, temporary chutes and swales will be constructed to prevent erosion and sedimentation. Erosion control features (i.e., filter berms, rock check dams, hay bales, or equivalent) may be constructed at the toe of filled areas to minimize erosion and prevent disturbance of the existing grassed slopes. Otherwise, temporary erosion and sediment control features will be installed within 180 days from when the intermediate cover is constructed. An existing conditions summary and Best Management Practices are included in Appendix C1F. Example intermediate cover drainage calculations are included in this appendix for use in site operations.

INTERMEDIATE COVER EVALUATION

The intermediate cover evaluation is based on the Universal Soil Loss Equation (USLE) following Soil Conservation Service (SCS) procedures. The evaluation is based on a 12-inch thick intermediate cover layer with 60 percent vegetated cover. Calculations for the soil loss for intermediate cover on external 4 percent and 25 percent slopes have been provided on pages C1G.4 through C1G.11.

SHEET FLOW DESIGN

The sheet flow calculations are presented for external 4 percent and 25 percent slope configurations. The permissible non-erodible velocities should be less than 5 ft/sec (clayey soil) or 4 ft/sec (sandy soil) on vegetated intermediate cover. The Manning's Equation and Rational Method were used to calculate sheet flow velocity.

TEMPORARY DRAINAGE SWALE DESIGN

The temporary drainage swales are designed for typical drainage areas and flowline slopes. The procedures in the TxDOT Hydraulic Design Manual, September 2019, were used to determine peak flow, flow depth, flow velocity, and swale capacity. The Rational Method and the Manning's Equation were used to calculate the design parameters.

TEMPORARY DIVERSION CHANNEL DESIGN

The temporary diversion channels are designed for typical drainage areas and flowline slopes. The procedures in the TxDOT Hydraulic Design Manual, September 2019, were used to determine peak flow, flow depth, flow velocity, and diversion channel capacity. The Rational Method and the Manning's Equation were used to calculate the design parameters.

TEMPORARY DRAINAGE LETDOWN DESIGN

The temporary drainage letdowns are designed for typical drainage areas on a 25 percent external side slope. The procedures in the TxDOT Hydraulic Design Manual, September 2019, were used to determine peak flow, flow depth, flow velocity, and letdown capacity. The Rational Method and the Manning's Equation were used to calculate the design parameters.

INTERMEDIATE COVER EVALUATION

INTERMEDIATE COVER EVALUATION

SOIL LOSS

This section presents the supporting documentation for evaluation of the potential for intermediate cover soil erosion loss at the TASWA DRF. 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 intermediate cover is evaluated based on the maximum soil loss of 50 tons per acre per year.

	4% slope	**25% slope**
Maximum Sheet Flow Length	1100 ft	120 ft
Soil Loss	1.15 tons/acre/year	16.77tons/acre/year

2. Soil loss is calculated using the Universal Soil Loss Equation (USLE) by following SCS procedures. The soil loss is based on 60 percent vegetative cover as recommended in the TNRCC, "Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook" (October 1993). These calculations are provided on pages C1G.16 and C1G.17.

3. Sheet flow velocities for a 25-year storm event are calculated to be less than permissible non-erodible velocities. The supporting calculations are presented on page C1G.13.

4. Temporary vegetation for the intermediate cover areas will be native and introduced grasses with root depths of 6 inches to 8 inches.

5. Native and introduced grasses will be hydroseeded, drill seeded, or broadcast seeded with fertilizer on the disked (parallel to contours) intermediate cover layer as soon as practical following placement of intermediate cover and will be documented in the site operating record. All intermediate cover areas will be managed to control erosion and achieve a predicted soil loss of less than 50 tons per acre per year. Temporary erosion and sediment control features (including at least 60 percent vegetative cover) will be installed within 180 days from when the intermediate cover is constructed. Areas that experience erosion or do not readily vegetate will be reseeded until vegetation is established or the soil will be replaced with soil that will support the grasses.

SOIL LOSS FOR EXISTING INTERMEDIATE COVER AREAS

This section presents the supporting documentation for evaluation of the potential for intermediate cover soil erosion loss on the existing intermediate cover slopes at the TASWA DRF. These areas have existing well established vegetation (at least 60 percent coverage) and will not be disturbed to construct temporary erosion control features.

	4% slope	25% slope
Maximum Sheet Flow Length	1100 ft	120 ft
Soil Loss	1.15 tons/acre/year	16.77 tons/acre/year

SHEET FLOW VELOCITY

The sheet flow velocity calculations are presented for external 4 percent and 25 percent slope configurations. The procedures outlined in the TxDOT Hydraulic Manual were used to determine velocities. Maximum sheet flow lengths for all three conditions were evaluated. Calculations are provided on page C1G.13.

Intermediate Cover Erosion Loss Evaluation

Required: 1. Determine the erosion loss for the intermediate cover design based on a maximum soil loss of 50 tons/acre/year.

Method: Expected soil loss is calculated using the Universal Soil Loss Equation.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution: Annual Soil Loss in tons/acre/year (A) = RKLSCP

Design Parameters	External Top Slope (4%)	External Side Slope (25%)	
Rainfall Factor (R) =	275	275	Grayson County
Soil Erodibility Factor (K) =	0.25	0.25	(Loam)
Longest Run =	1,100	120	ft
Slope =	4.0	25	%
Topographic Factor (LS) =	0.79	6.45	
Crop Management Factor (C) =	0.042	0.042	(60% vegetative cover)
Erosion Control Practice Factor (P) =	0.50	0.90	
Soil Loss (A) =	1.15	16.77	tons/acre/year

Summary: As noted in the permit drawings, the intermediate cover will be a minimum of 12 inches thick. As shown above, the maximum soil loss is 16.77 tons/acre/year, which is less than the maximum allowable soil loss of 50 tons/acre/year.

Intermediate Cover LS Factor Calculations

Required: 1. Determine the Length/Slope Factor based on slope length and slope gradient.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution: Length/Slope Factor (LS) = ((L/72.6)m)*((65.41*sin2(S))+(4.56*sin(S))+0.065)

LS = Length/Slope Factor
L = Slope Length (ft)
S = radians
m = exponent dependent on the slope gradient

m = 0.2 for S <= 1.0%
0.3 for 1.0% < S <= 3.5%
0.4 for 3.5% < S < 5.0%
0.5 for S => 5.0%

Length, L (ft)	Slope, S %	Slope, S (ft/ft)	θ (radians)	θ (degrees)	m	LS
1,100	4.0	25.00	0.040	2.291	0.3	0.79
120	25	4	0.245	14.036	0.5	6.45

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

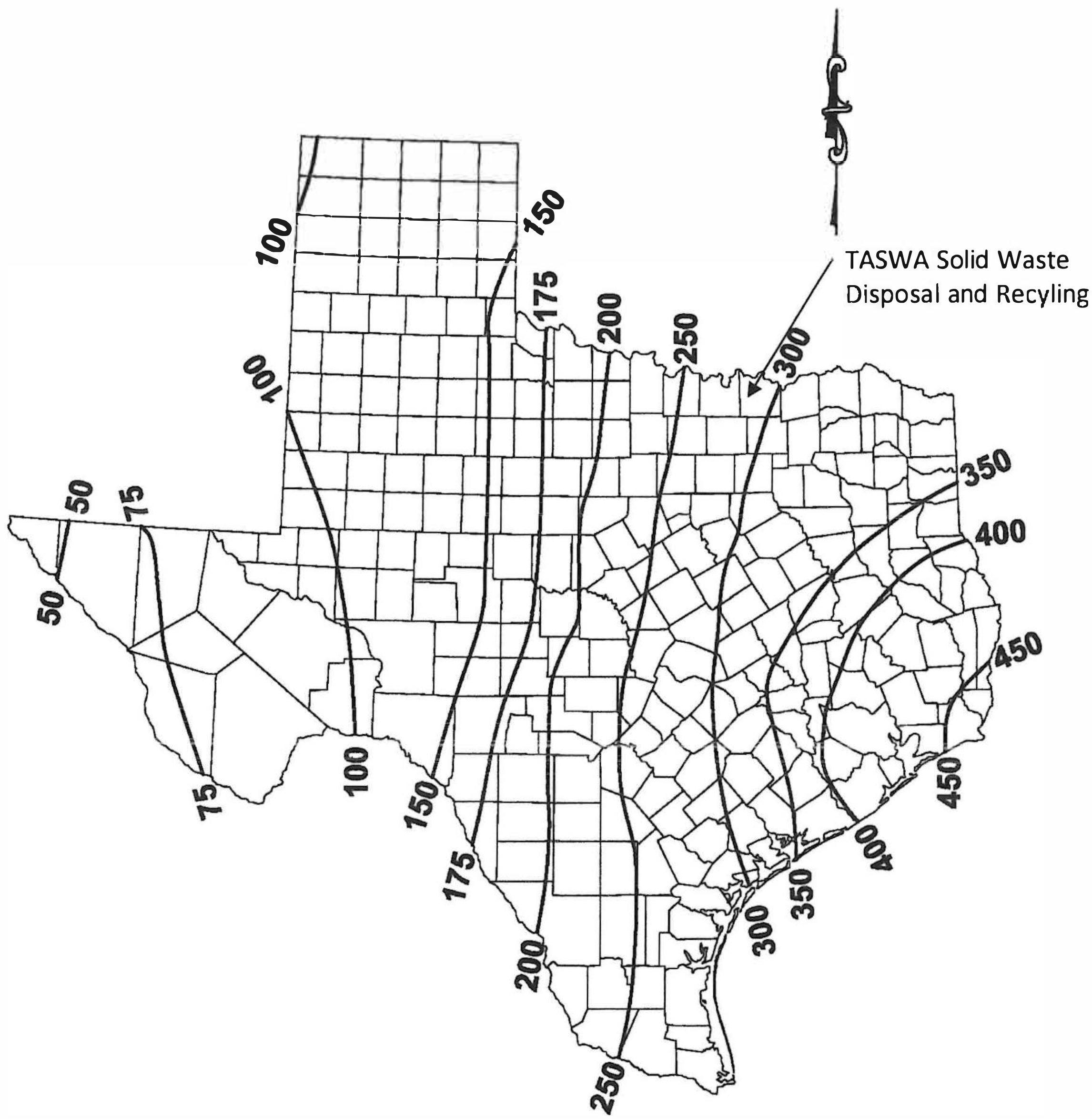


FIGURE 1 - AVERAGE ANNUAL VALUES OF THE RAINFALL EROSION INDEX

Table 1: Approximate Values of Factor K for USDA Textural Classes

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

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		

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.

Table 2: Factor C for Permanent Pasture, Range, and Idle Land[1]

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Vegetative Canopy		Cover that Contacts the Soil Surface					
Type and Height[2]	Percent Cover[3]	Percent Ground Cover					
		0	20	40	60	80	95+
No Appreciable Canopy		0.45	0.20	0.10	0.042	0.013	0.003
Tall weeds or short brush with average drop fall height of 20 in.	25	0.36	0.17	0.09	0.038	0.013	0.011
	50	0.26	0.13	0.07	0.035	0.012	0.003
	75	0.17	0.10	0.06	0.032	0.011	0.003

Extracted from: United States Department of Agriculture, AGRICULTURE HANDBOOK NUMBER 537

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 feet.

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

Table 3: P Factors for Contouring, Contour Stripcropping and Terracing

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Land Slope	P Values		
%	Contouring†	Contour Stripcropping	Terracing†
2.0 to 7	0.50	0.25	0.50
8.0 to 12	0.60	0.30	0.60
13.0 to 18	0.80	0.40	0.80
19.0 to 24	0.90	0.45	0.90

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

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

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

Rooting Depth	Soil Loss Tolerance Values Annual Soil Loss (Tons/Acre)	
Inches	Renewable Soil a/	Renewable Soil b/
0 - 10	1	1
10 - 20	2	1
20 - 40	3	2
40 - 60	4	3
60	5	4

(This table appeared in SCS (6), p.4)

a/ Soil with favorable substrata that can be renewed by tillage, fertilizer, organic matter, and other management practices. This column does not represent MSWLF final covers under normal conditions.

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

SHEET FLOW

Intermediate Cover Sheet Flow Velocity

Required: Determine the sheet flow velocity for the intermediate cover design and compare to the permissable non-erodible flow velocity.

Method:
1. Determine the 25-year peak flow rate using the Rational Method.
2. Calculate flow depth using Manning's Equation.
3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:

1. Determine the 25-year peak flow rate (Q) using the Rational Method

25-Year Rainfall Depth (Pd) =	1.30	in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10.0	min	(conservative minimum value)
Rainfall Intensity (I) =	7.8	in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70		(typical value for intermediate cover)
25-Year Peak Flow Rate (Q) =	CIA	cfs	

	External Top Slope (4%)	External Side Slope (25%)		
Longest Run =	1100	120	ft	(longest sheet flow distance to swale)
Width =	1.00	1.00	ft/ft	(unit width of flow)
Area =	0.0253	0.0028	acre	
Q	0.138	0.015	cfs	

2. Calculate the flow depth using Manning's Equation.
- Rearrange Manning's Equation for wide and shallow flow to calculate flow depth:

$$y = (Qn/1.49S^{0.5})^{0.6}$$

Manning's Roughness (n) = 0.03 (typical value for vegetated intermediate cover)

Slope =	0.025	0.250	ft/ft
Depth (y) =	0.089	0.012	ft

3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.
- A permissible non-erodible velocity of 5 ft/sec (clayey soil) or 4 ft/sec (sandy soil) is typical for vegetated intermediate covers. Refer to page C1-G-6 for soil loss calculations.

$$V = Q / (y * \text{width})$$

Sheet flow velocity	**1.56**	**1.28**	**ft/sec**

Summary: The permissable non-erodible velocity should be less than 5.0 ft/sec (clayey soil) or 4.0 ft/sec (sandy soil) on vegetted intermediate cover. Therefore, the expected sheet flow velocity is acceptable on the external intermediate cover slopes with 60% vegetative cover.

TEMPORARY DRAINAGE SWALE DESIGN

TEMPORARY DRAINAGE SWALE DESIGN

The temporary drainage swale design for intermediate cover areas is presented for the typical swale flowline of 0.5 percent. The procedures in the TxDOT Hydraulic Design Manual were used to determine peak flow, flow depth, flow velocity, and swale capacity. The temporary swales will be located on the intermediate cover to prevent erosion as follows:

Slope (%)	Maximum Sheet Flow Length (ft)	Maximum Drainage Area (acres)	Maximum Swale Length (ft)
4	1100	34.4	1363
25	120	7.4	2688

All temporary swales shall be designed to minimize erosion and provide a maximum flow depth of 2 feet. The total height of the swales at the flowline is a minimum of 3 feet, as depicted in Appendix C1F on page C1F.8. As noted in the calculations, the velocities in the swales are less than permissible non-erodible velocities. If sustained erosion is observed, facility management will evaluate and construct additional temporary drainage swales. Example drainage swale calculations for a grassed intermediate cover are provided on pages C1G.16 and C1G.17.

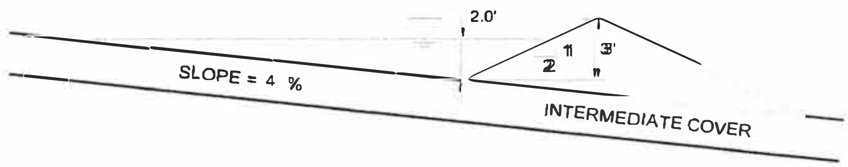
Drainage Swale Analysis - External Intermediate Cover Topslopes

Required: Determine the inermediate cover topslope drainage swale capacity.

Method:
1. Calculate the intermediate cover topslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable topslope drainage area using the Rational Method.
3. Determine the maximum swale length based on the maximum sheet flow length.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:
1. Calculate flow capacity using Manning's Equation.
 - Swale Characteristics:



Max swale flow depth (D) =	2.00 ft
Running swale slope (S) =	0.5 %
Manning's Roughness (n) =	0.03 (typical value for vegetated intermediate cover)
Left slope (LS) =	25.00 :1
Right slope (RS) =	2 :1
Flow Area (A) =	((LS+RS)*D^2)/2
Wetted Perimeter (WP) =	((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)
Hydraulic Radius (R) =	A / WP

Flow Area (A) =	54.000 sf
Wetted Perimeter (WP) =	54.512 ft
Hydraulic Radius (R) =	0.991 ft

- Use Manning's Equation to determine the flow velocity in the swale.

Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n

Velocity (V) = 3.481 ft/sec

- Calculate the swale's flow capacity.

Swale capacity (Q) = V * A

Q = 188.0 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.30 in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	7.8 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for intermediate cover)
25-Year Peak Flow Rate (Q) =	CIA cfs	

- Rearrange the Rational Formula to calculate allowable drainage area:

Drainage Area = Q / (CI)

Maximum Allowable Swale Drainage Area = 34.4 acres

3. Determine the maximum swale length based on the maximum sheet flow length.

Maximum Sheet Flow Length = 1100 ft

$$\text{Maximum Swale Length} = \frac{\text{Maximum Swale Drainage Area} * 43560}{\text{Maximum Sheet Flow Length}}$$

Maximum Swale Length = 1363

Summary: The maximum sheet flow length will be 1100 feet and maximum drainage area is 34.4 acres. The calculated velocity is less than the permissible non-erodible velocity.

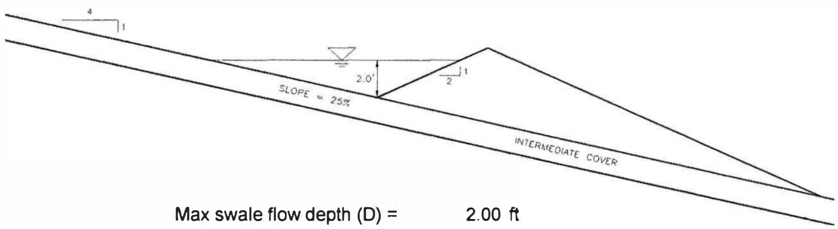
Drainage Swale Analysis - External Intermediate Cover Sideslopes

Required: Determine the inermediate cover sideslope drainage swale capacity.

Method:
1. Calculate the intermediate cover sideslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable sideslope drainage area using the Rational Method.
3. Determine the maximum swale length based on the maximum sheet flow length.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:
1. Calculate flow capacity using Manning's Equation.
 - Swale Characteristics:



Max swale flow depth (D) =	2.00 ft	
Running swale slope (S) =	0.5 %	
Manning's Roughness (n) =	0.03	(typical value for vegetated intermediate cover)
Left slope (LS) =	4.00 :1	
Right slope (RS) =	2 :1	
Flow Area (A) =	((LS+RS)*D^2)/2	
Wetted Perimeter (WP) =	((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)	
Hydraulic Radius (R) =	A / WP	

Flow Area (A) =	12.000 sf
Wetted Perimeter (WP) =	12.718 ft
Hydraulic Radius (R) =	0.944 ft

 - Use Manning's Equation to determine the flow velocity in the swale.

Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n

Velocity (V) = 3.378 ft/sec

 - Calculate the swale's flow capacity.

Swale capacity (Q) = V * A

Q = 40.5 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.30 in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	7.8 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for intermediate cover)
25-Year Peak Flow Rate (Q) =	CIA cfs	

 - Rearrange the Rational Formula to calculate allowable drainage area:

Drainage Area = Q / (CI)

Maximum Allowable Swale Drainage Area = 7.4 acres

3. Determine the maximum swale length based on the maximum sheet flow length.

Maximum Sheet Flow Length = 120 ft

$$\text{Maximum Swale Length} = \frac{\text{Maximum Swale Drainage Area} * 43560}{\text{Maximum Sheet Flow Length}}$$

Maximum Swale Length = 2688 ft

Summary: The maximum sheet flow length will be 120 feet and maximum drainage area is 7.4 acres. The calculated velocity is less than the permissible non-erodible velocity.

TEMPORARY DIVERSION CHANNEL DESIGN

TEMPORARY DIVERSION CHANNEL DESIGN

The temporary diversion channel design for preventing surface water from entering excavated areas is presented for three typical slopes of 0.5 percent and three typical drainage areas of 10, 30, and 50 acres. The procedures in the TxDOT Hydraulic Design Manual were used to determine peak flow, flow depth, flow velocity, and diversion channel capacity. Temporary diversion channels will be designed to minimize erosion and sedimentation. Temporary diversion channels will be excavated only in areas of in-situ soil or soil stockpile areas. They will not be used over lined areas or areas that have received waste.

Temporary Diversion Channel

Diversion channel drainage areas were based on the typical size that may occur during the development of the site.
The diversion channels are intended to prevent surface water from entering the excavated areas.
10-30-, and 50-acre drainage areas were considered:

Diversion Channel Slope	Diversion Channel Area (Acres)	Flow (cfs)	Bottom Width (ft)	Side Slopes (H:V)	Manning's number (n)	Normal Depth (ft)	Flow Area (ft^2)	Velocity (ft/s)	Energy Head (ft)
0.5	10	54.6	0	3	0.03	2.235	14.99	3.64	2.44
0.5	30	163.8	10	3	0.03	2.161	35.62	4.60	2.49
0.5	50	273.0	20	3	0.03	2.108	55.49	4.92	2.48

Notes:

1. The calculations shown in the table above are normal depths from the 25-year rainfall event.
2. The required diversion channel depth will have 0.5 foot of freeboard.
3. Diversion channels shall be grassed. Erosion control features will be provided for velocities exceeding 5 fps.
4. During operation of the site different configurations of diversion channels may be used to prevent surface water from entering excavated areas. The landfill operator will determine the sizing of diversion channels if different lining materials is used.
5. The shading represents sample calculation presented on pages C1-G-20 and C1-G-21.

Temporary Diversion Channel
Example Calculations

Required: Determine the necessary dimensions of the temporary diversion channel for routing surface water around excvations.

Methods:
1. Calculate the 25-year peak flow rate (Q) for a 1-acre drainage area using the Rational Method.
2. Calculate the normal depth for the temporary diversion channel for a drainage area of 1 acre with a slope of 2%.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:
1. Calculate the 25-year peak flow rate (Q) for a 1-acre drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.30 in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10.0 min	(conservative minimum value)
Rainfall Intensity (I) =	7.8 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(ref 1, Table 4-11)
Area (A) =	50 acre	
25-Year Peak Flow Rate (Q) =	CIA cfs	
Q =	(0.7)(7.8)(50)	
Q =	273.0 cfs	

2. Calculate the normal depth for the temporary diversion channel for a drainage area of 1 acre with a slope of 0.5%.

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 sideslope of diversion channel
z_l = z-ratio (ratio of run to rise for channel sideslope) for left sideslope of diversion channel
A_f = flow area, sf
g = gravitational acceleration = 32.2 ft/s^2
T = top width of flow, ft
d = normal depth of diversion channel, ft

Design Inputs:

Q_d =	273.0	cfs (from page C1-G-20)
S =	0.005	ft/ft
b =	20	ft
z_r =	3	(H) : 1 (V)
z_l =	3	(H) : 1 (V)
n =	0.03	

Temporary Diversion Channel
Example Calculations

Step A - 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 = 2.1080

R = 1.665 ft

A_f = 55.49 sf

Solve for Q: Q = 273.0

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

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

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

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

Q = VA => V = Q/A

V = 4.92 ft/s

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

T = 32.65 ft

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

F_r = 0.67

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

Velocity Head = 0.38 ft

Energy Head = depth + velocity head

Energy Head = 2.48 ft

TEMPORARY DRAINAGE LETDOWN DESIGN

TEMPORARY DRAINAGE LETDOWN DESIGN

Temporary sideslope swales will collect and route surface water runoff from intermediate cover sideslope areas to temporary drainage letdowns on the intermediate cover sideslopes. Temporary topslope swales will collect and route surface water runoff from intermediate cover top dome areas to temporary drainage letdowns on the intermediate cover sideslopes. Temporary topslope chutes are not required as topslope areas will not exceed the limit of sheet flow of 1100 feet.

The temporary letdowns design is applicable for external sideslopes of the landfill with intermediate cover. Temporary letdown chutes will typically consist of channels lined with erosion control material. The temporary flow depth provided is 2-feet. The design flow depth for geomembrane lined letdowns is 0.25 feet which provides a freeboard of 1.75 feet. Refer to Drawing C1F.1, for a depiction of the depth of flow for a typical temporary chute/letdown structure.

The flow capacity of the letdown structures was determined based on the Manning's Equation. The maximum flow calculated from the Manning's Equation is used to determine the maximum drainage area based on the Rational Method. The design calculations presented on pages C1G.24 and C1G.25 represent typical calculations for letdown chutes lined with different materials on a 25 percent slope. If sustained erosion is observed, facility management will evaluate the use and construction of temporary letdowns.

Temporary Letdown/Chute Flow Evaluation

Required: 1. Determine the capacity of a variety of letdown chutes with different lining materials.

Method:
1. Use Manning's Equation to calculate the temporary chute capacity for a variety of lining materia
2. Use the Rational Method to determine the maximum drainage area for a variety of temporary chute lining materials and temporary chute bottom widths.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution: 1. Chutes will be designed to function during the 25-year storm event.

Where: Q = Chute capacity (cfs)
n = Manning's Coefficient (unitless)[(1)]
A = Cross sectional area (ft^2)
WP = Wetted Perimeter (ft)
R = Hydraulic Radius (ft)
S = Letdown slope (ft/ft)
d = Normal Depth (ft)
b = Bottom Width of Chute (ft)
z = Chute Side Slope (ft/ft)

$$A = bd + zd^2$$

$$WP = b + 2\,[(zd)^2 + d^2]^{0.5}$$

$$R = A / WP$$

$$Q = \frac{1.486 (A)(R^{2/3})(S^{1/2})}{n}$$

[(1)] The Manning's Coefficient was selected from the references for the applicable lining material.

Temporary Letdown/Chute Flow Evaluation

HDPE Geomembrane Lined Chute

Depth d (ft)	Bottom Width b (ft)	Letdown Slope S (ft/ft)	Chute Side Slope z (ft/ft)	Manning's Coefficient* n	Area A (sf)	Wetted Perimeter WP (ft)	Hydraulic Radius R (ft)	Velocity V (fps)	Flow Rate Q (cfs)
0.25	8	0.25	3	0.013	2.19	9.58	0.228	21.35	46.7
0.25	30	0.25	3	0.013	7.69	31.58	0.243	22.28	171.3

* Manning's coefficient selected for a temporary HDPE geomembrane lined chute.

2. Use the Rational Method to determine the maximum drainage area for a variety of temporary chute lining materials and temporary chute bottom widths.

25-Year Rainfall Depth (Pd) =	1.30 in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10.0 min	(conservative minimum value)
Rainfall Intensity (I) =	7.8 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(ref 1, Table 4-11)

- Rearranging the rational formula, the maximum drainage area is determined as follows:

Q = Flow Rate
A = Maximum Drainage Area
A = Q/(CI)
A = 46.7/(0.7*7.8)
A = 8.6 acres

HDPE Geomembrane Lined Chute

Bottom Width (ft)	Flow Rate (cfs)	Maximum Drainage Area (acres)
8	46.7	8.6
30	171.3	31.4

DESIGN SUMMARY

The TASWA DRF will implement the erosion and sediment control features on the intermediate cover as the landfill develops. The following items will be implemented as filling operations are ongoing:

- Intermediate cover will be established on all areas that have received waste but will remain inactive for periods greater than 180 days.
- Sufficient permanent and temporary erosion and sediment control features shall be constructed to redirect surface water and prevent erosion.
- Temporary erosion and sediment control features shall be constructed within 180 days of placement of intermediate cover.
- Temporary erosion control structures (e.g., rock check dams, filter berms) may be established along the toe of existing vegetated intermediate cover areas with approximately 70-90 percent coverage.
- Final cover will be constructed as the site develops. Temporary erosion control features will be removed as permanent erosion controls are constructed.
- The erosion and sediment control plan and temporary erosion and sediment control details for the intermediate cover are included in Appendix C1F.

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT C2
FLOOD CONTROL ANALYSIS

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED
PROFESSIONAL ENGINEER
2/28/2025
Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

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TEXAS BOARD OF PROFESSIONAL GEOSCIENTISTS
FIRM REGISTRATION NO. 50222

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2/28/2025
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CONTENTS

1 FLOOD CONTROL AND ANALYSIS

30 TAC §330.63(c)(2), §330.307, and §330.547

The flood control and analysis includes the demonstrations consistent with the requirements of §§330.63(c)(2), 330.307, and 330.547. Drawing C2A.1 shows that the facility is not located within the 100-Year Special Flood Hazard Area. The TASWA DRF current and proposed waste disposal operations will be conducted outside the 100-year floodplain.

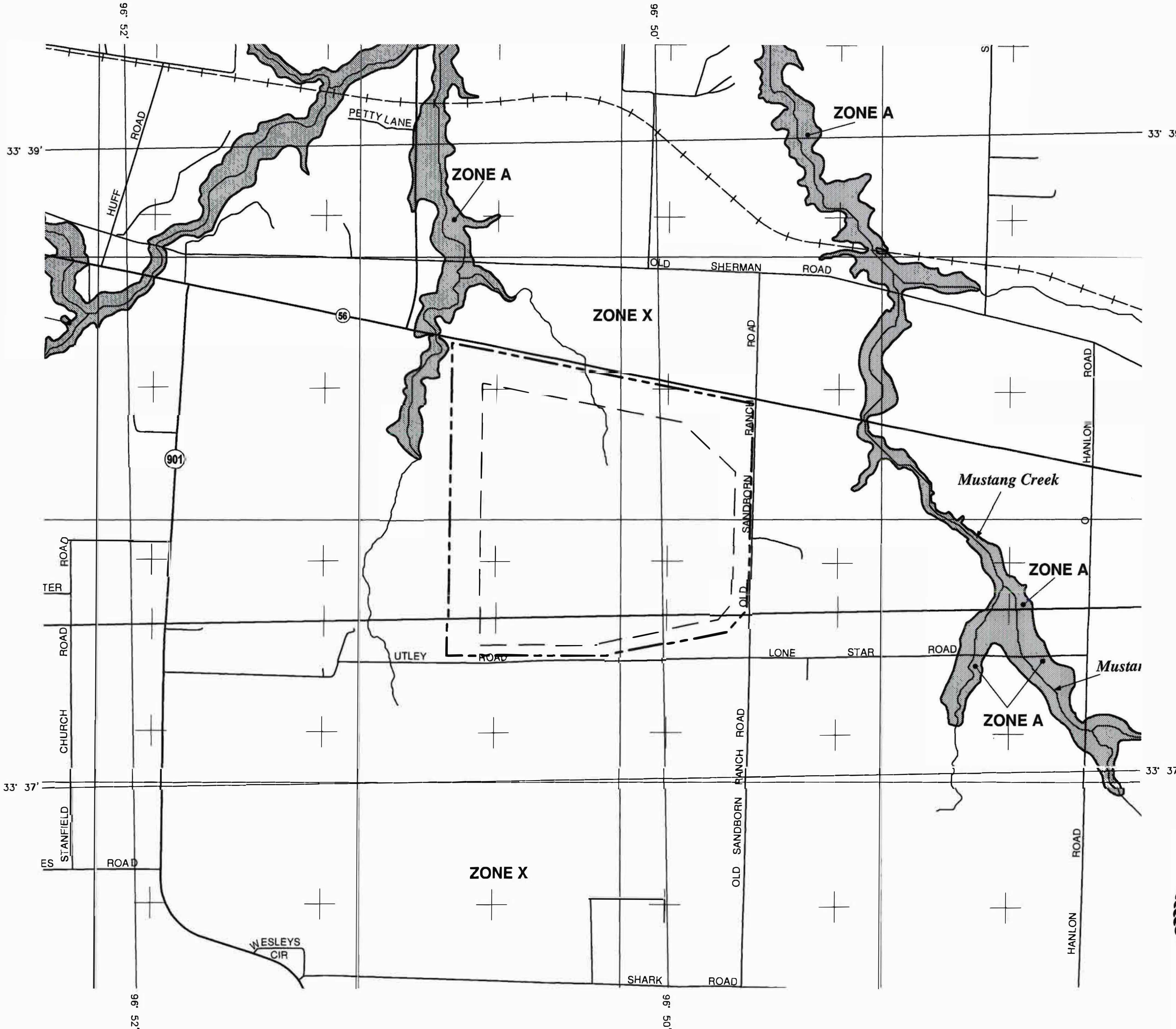
In accordance with §330.63(c)(2), the TASWA DRF is not located within a 100-year floodplain. FEMA has defined the limits of the 100-year floodplain (1% annual chance) in the vicinity of the landfill and published the Flood Insurance Rate Map (FIRM) for the area as the FIRM Community Panel Numbers 48181C0250F and 48181C0375F with an effective date of September 29, 2010. The FIRM identifies areas within the facility permit boundary as Zone X - areas determined to be outside the 0.2% annual chance floodplain; Zone AE - base flood elevations determined; and as floodway areas in Zone AE. A copy of the FIRM is included in Appendix IIJ.

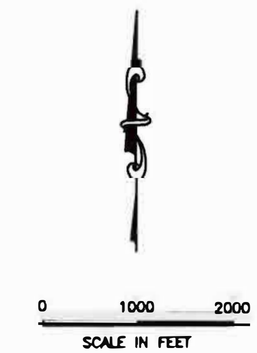
Since the TASWA DRF is not located within a 100-year floodplain, flood protection levees are not required and §330.307 is not applicable.

In accordance with §330.547(a), the TASWA DRF's waste disposal operations will not be located in the 100-year floodway. In accordance with §330.547(b), the TASWA DRF's new and existing municipal solid waste disposal units are not located in the 100-year floodplain, will not restrict the flow of the 100-year flood, will not reduce the temporary water storage capacity of the floodplain, and will not result in the washout of solid waste. Further, in accordance with §330.547(c), the TASWA DRF's processing and/or storage units are not located within the 100-year floodplain.

ATTACHMENT C2
APPENDIX C2A

100-YEAR FLOODPLAIN MAP





LEGEND

2290A PERMIT BOUNDARY

2290A LANDFILL FOOTPRINT

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.

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.

Floodplain boundary

Floodway boundary

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 ticks, zone 14

6000000 FT 5000-foot grid values: Texas State Plane coordinate system, north central zone (FIPSZONE 4202), Lambert Conformal Conic

NOTE(S):

1. THIS MAP HAS BEEN COMPILED FROM FEMA FLOOD INSURANCE RATE MAP (FIRM) OF GRAYSON COUNTY, TEXAS AND INCORPORATED AREAS COMMUNITY PANEL NUMBERS 48181C0250F AND 48181C0375F REVISED SEPTEMBER 29, 2010.

STATE OF TEXAS
FELIPE ANTONIO WESCOUP
103826
LICENSED
PROFESSIONAL ENGINEER

2/28/2025

ISSUED FOR PERMITTING PURPOSES ONLY

FLOOD INSURANCE RATE MAP (FIRM)

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

BME

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TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
C2A.1

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

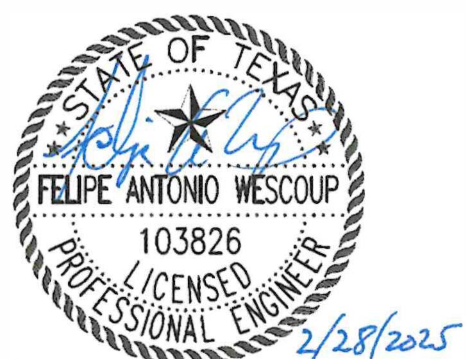
PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT C3
DRAINAGE SYSTEM PLANS AND DETAILS

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025



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TEXAS BOARD OF PROFESSIONAL GEOSCIENTISTS
FIRM REGISTRATION NO. 50222

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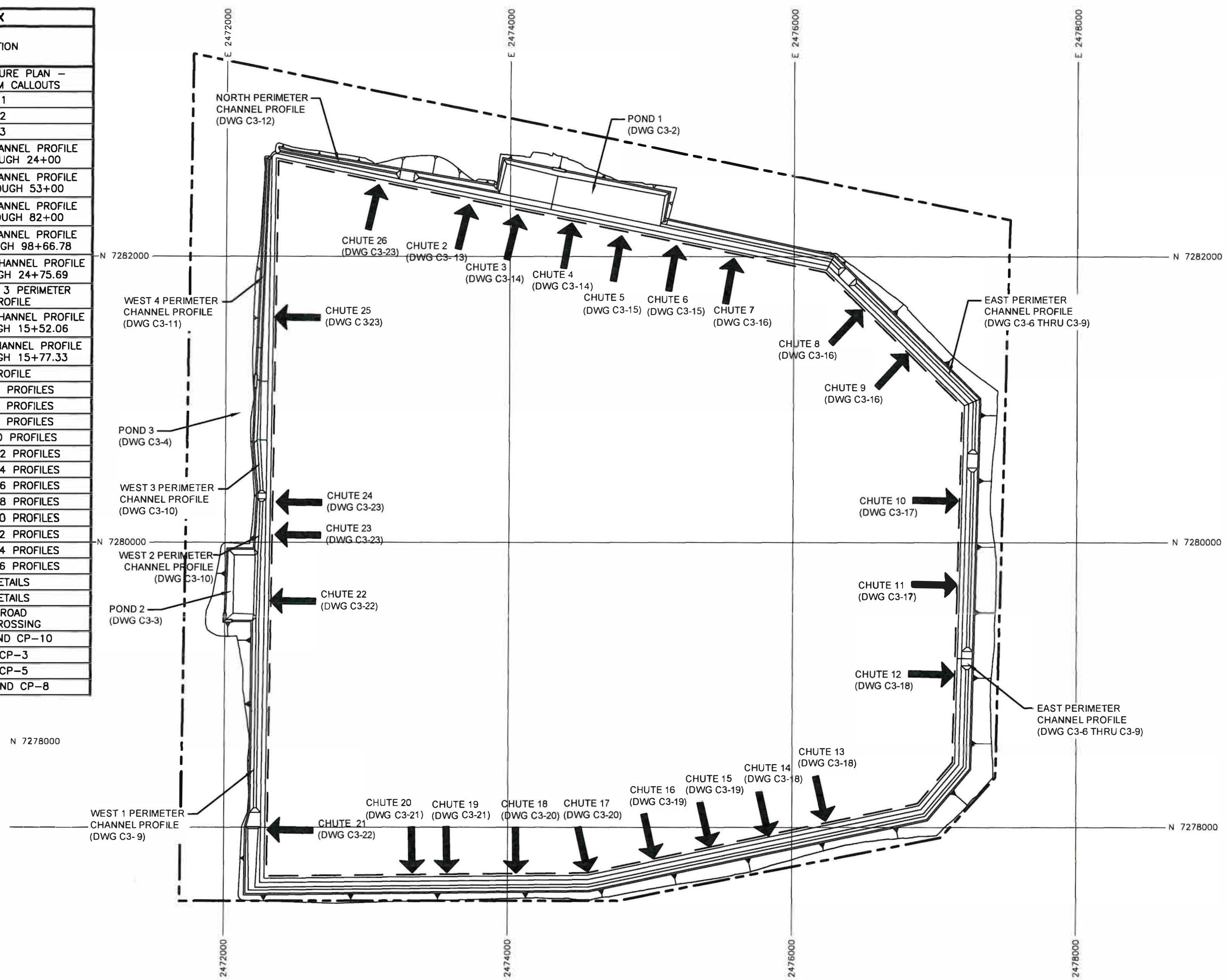
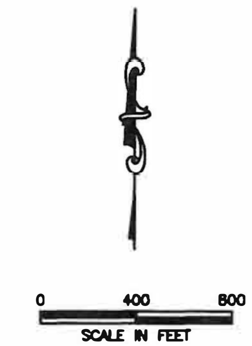
C3-18	CHUTE 11 AND 12 PROFILES
C3-19	CHUTE 13 AND 14 PROFILES
C3-20	CHUTE 15 AND 16 PROFILES
C3-21	CHUTE 17 AND 18 PROFILES
C3-22	CHUTE 19 AND 20 PROFILES
C3-23	CHUTE 21 AND 22 PROFILES
C3-24	CHUTE 23 AND 24 PROFILES
C3-25	CHUTE 25 AND 26 PROFILES
C3-26	DRAINAGE DETAILS
C3-27	DRAINAGE DETAILS
C3-28	PERIMETER ROAD LOW WATER CROSSING
C3-29	CP-1, CP-9, AND CP-10
C3-30	CP-2 AND CP-3
C3-31	CP-4 AND CP-5
C3-32	CP-6, CP-7, AND CP-8





LEGEND

2290A PERMIT BOUNDARY

2290A LANDFILL FOOTPRINT

NOTE(S):

1. REFER TO DRAINAGE SYSTEM CALLOUTS FOR PONDS, CHANNELS, CHUTES, AND CULVERT DETAILS.

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DRAINAGE STRUCTURE PLAN (DRAINAGE SYTEM CALLOUTS)

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TBPG FIRM NO. 50222

C3.1

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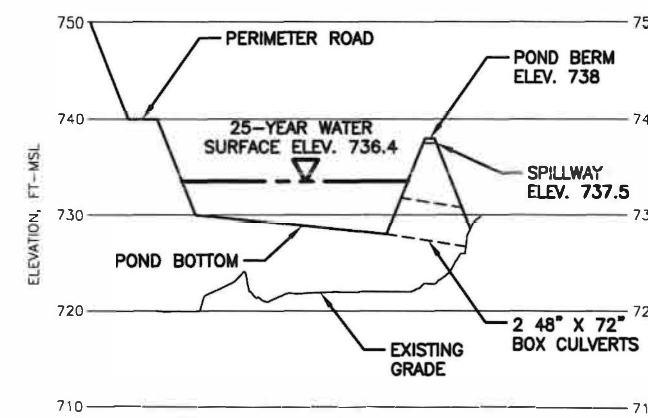
0 100 200
SCALE IN FEET

LEGEND

— - - —	2290A PERMIT BOUNDARY
— — —	2290A LANDFILL FOOTPRINT
—— 500 ——	10' FINAL COVER CONTOUR
→	DRAINAGE FLOW DIRECTION

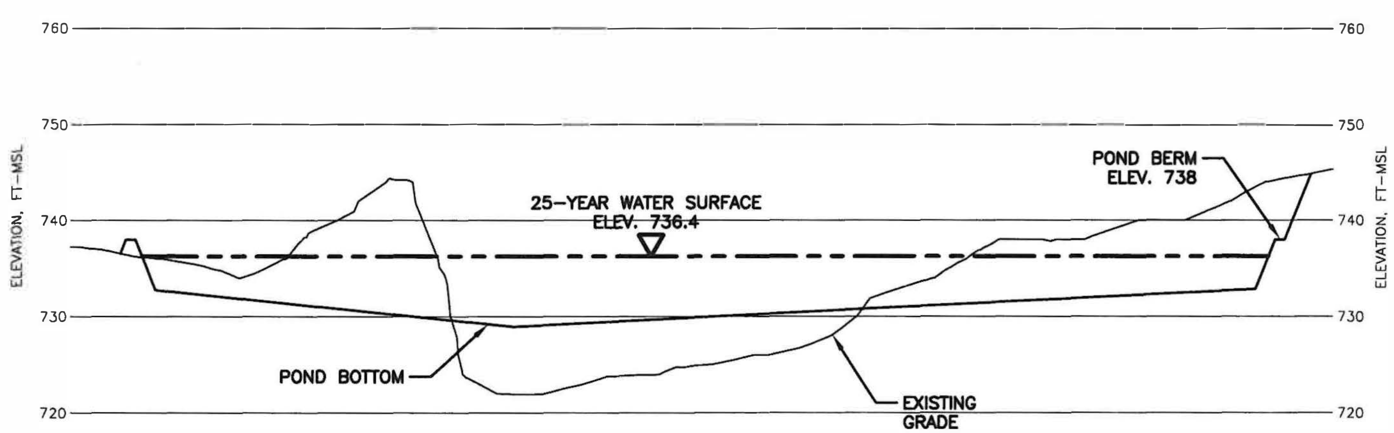
NOTE(S):

1. EXISTING GROUND CONTOURS PROVIDED BY BIGGS & MATHEWS ENVIRONMENTAL, FROM DRONE SURVEY FLOWN JUNE 1, 2022.
2. REFER TO DRAINAGE SYSTEM CALLOUTS FOR PONDS, CHANNELS, CHUTES, AND CULVERT DETAILS.



POND 1 – SECTION B (B)

0 100 200 HORIZONTAL SCALE IN FEET; 0 10 20 VERTICAL SCALE IN FEET



POND 1 – SECTION A (A)

0 100 200 HORIZONTAL SCALE IN FEET; 0 10 20 VERTICAL SCALE IN FEET

POND 1 ELEVATION–STORAGE RELATIONSHIP

ELEVATION (FT)	VOLUME AT ELEVATION (AC–FT)
728	0.00
729	0.12
730	0.99
731	3.22
732	7.00
733	12.17
734	18.15
735	24.53
736	31.29
737	38.49
738	46.16
739	54.29
740	62.86

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POND 1

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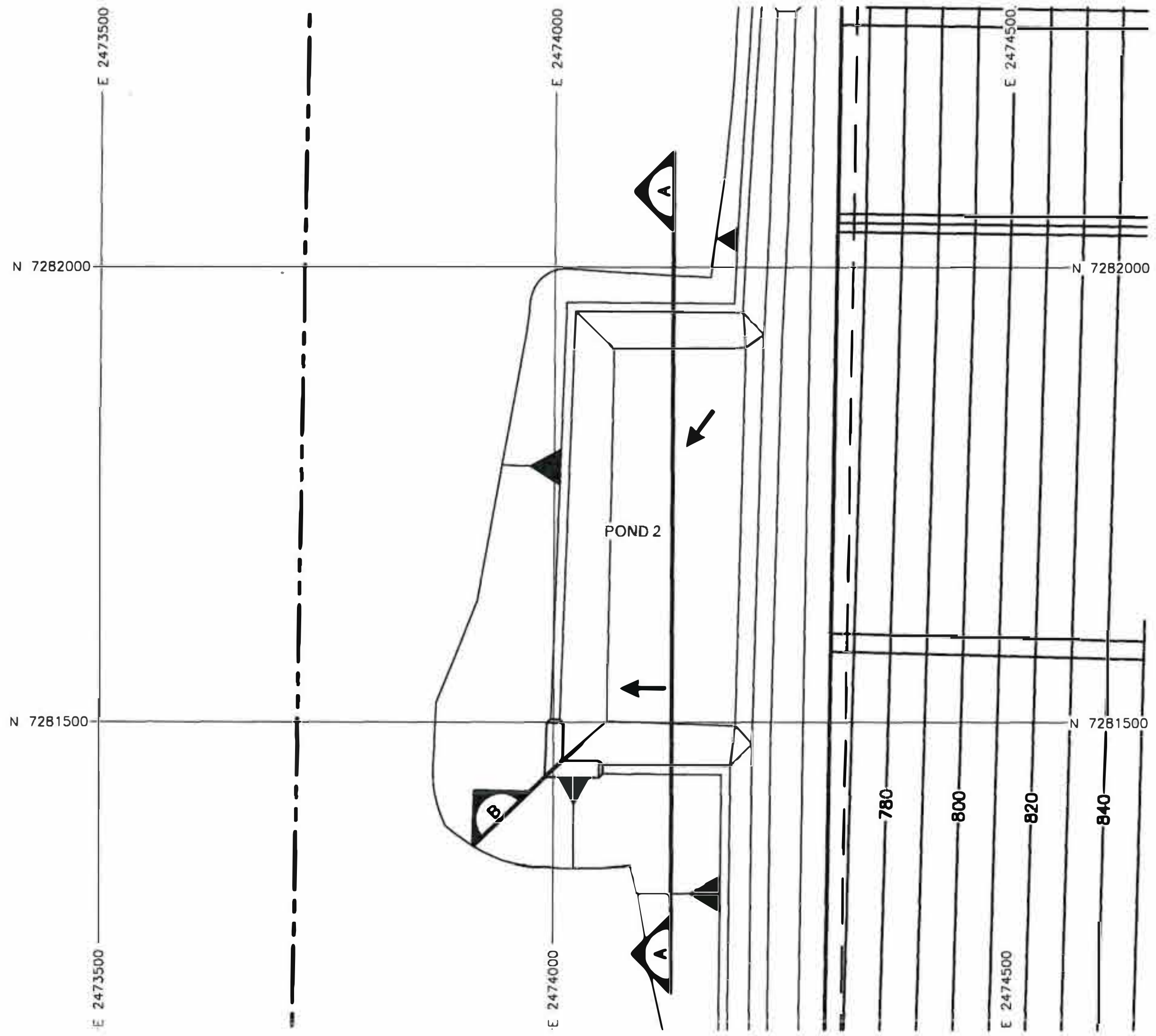
TBPG FIRM NO. 50222

C3.2



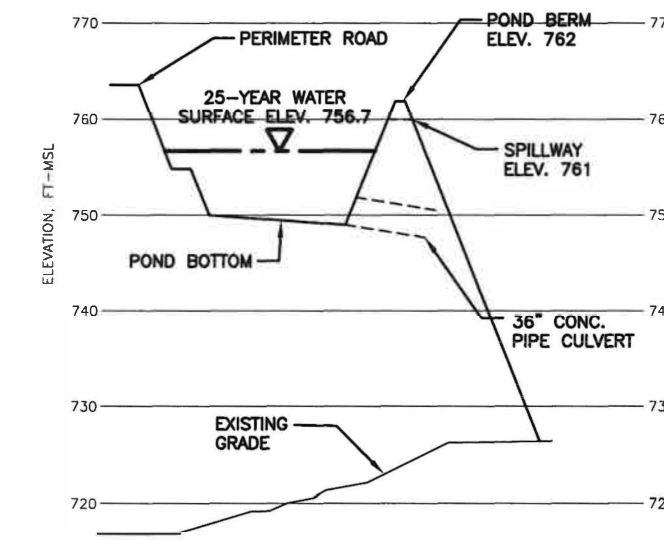
0 100 200
SCALE IN FEET

LEGEND

2290A PERMIT BOUNDARY
2290A LANDFILL FOOTPRINT
500 10' FINAL COVER CONTOUR
DRAINAGE FLOW DIRECTION

NOTE(S):

1. REFER TO DRAINAGE SYSTEM CALLOUTS FOR PONDS, CHANNELS, CHUTES, AND CULVERT DETAILS.



POND 2 - SECTION B (B)

0 100 200 HORIZONTAL SCALE IN FEET
0 10 20 VERTICAL SCALE IN FEET

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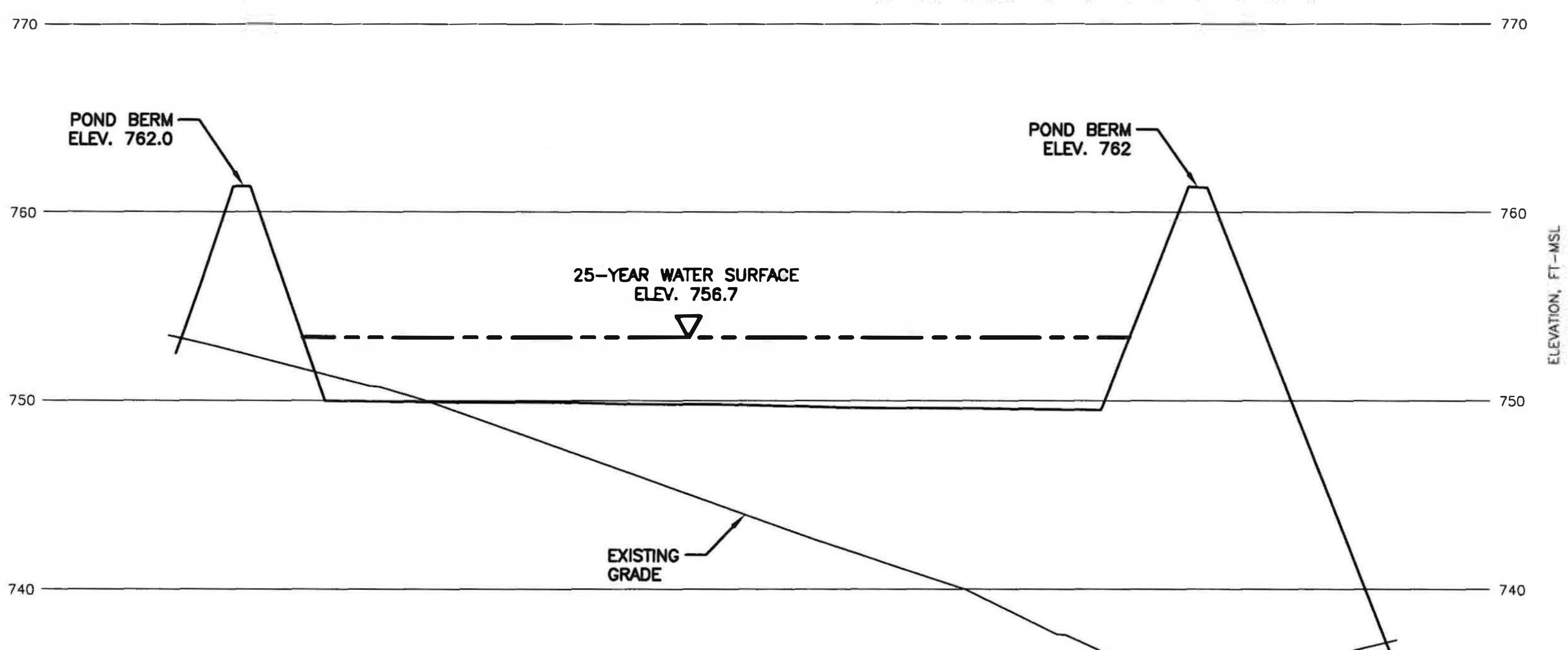

POND 2 - SECTION A (A)

0 50 100 HORIZONTAL SCALE IN FEET
0 10 20 VERTICAL SCALE IN FEET

POND 2 ELEVATION-STORAGE RELATIONSHIP

ELEVATION (FT)	VOLUME AT ELEVATION (AC-FT)
749	0.00
750	0.231
751	1.67
752	3.22
753	4.88
754	6.64
755	8.56
756	10.92
757	13.71
758	16.90
759	20.49
760	24.47
761	28.82
762	33.52

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POND 2

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TBPG FIRM NO. 50222

C3.3

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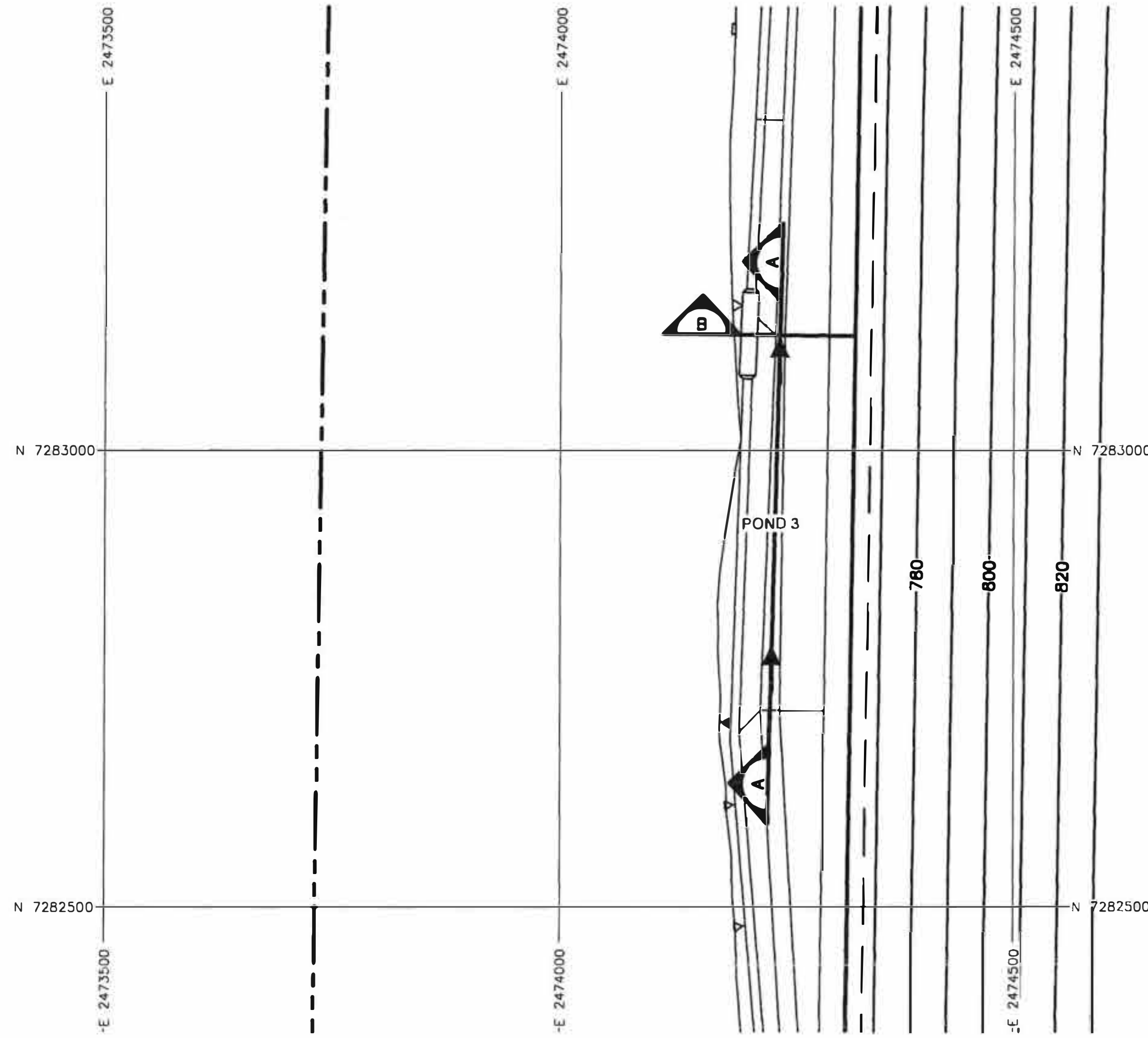
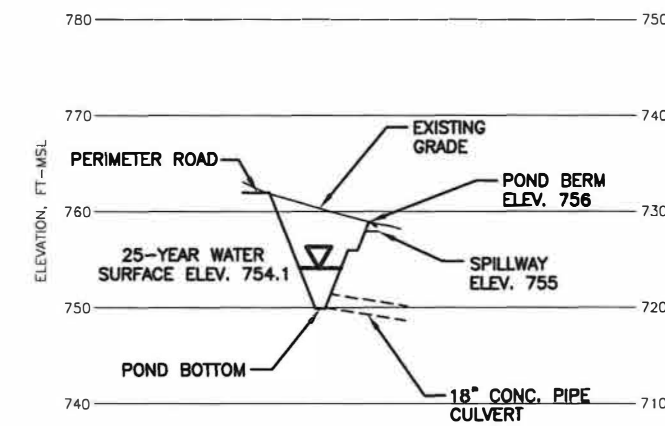


LEGEND

—— - - ——	2290A PERMIT BOUNDARY
— — — —	2290A LANDFILL FOOTPRINT
——500——	10' FINAL COVER CONTOUR
→	DRAINAGE FLOW DIRECTION

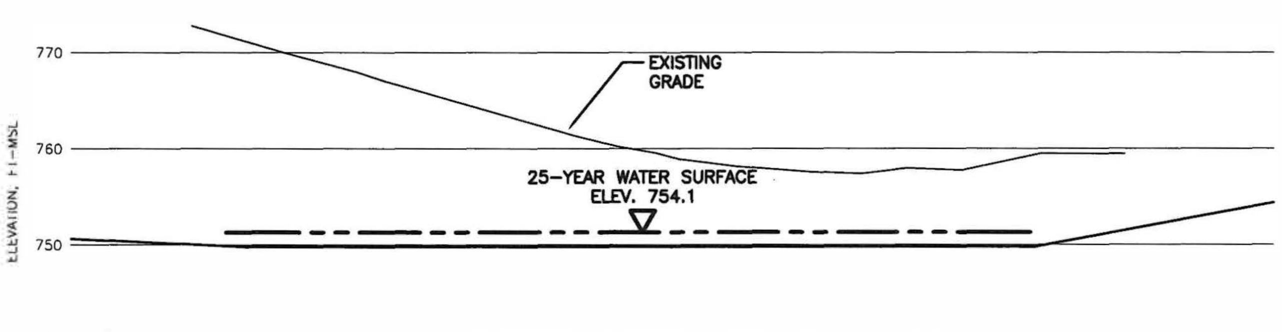
NOTE(S):

1. REFER TO DRAINAGE SYSTEM CALLOUTS FOR PONDS, CHANNELS, CHUTES, AND CULVERT DETAILS.



POND 3 – SECTION B (B)

0 100 200 HORIZONTAL SCALE IN FEET — 0 10 20 VERTICAL SCALE IN FEET



POND 3 – SECTION A (A)

0 50 100 HORIZONTAL SCALE IN FEET — 0 10 20 VERTICAL SCALE IN FEET

POND 3 ELEVATION–STORAGE RELATIONSHIP	
ELEVATION (FT)	VOLUME AT ELEVATION (AC–FT)
750	0.01
751	0.26
752	0.71
753	1.41
754	2.43
755	3.80
756	5.59
757	7.79

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POND 3

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TBPG FIRM NO. 50222

C3.4

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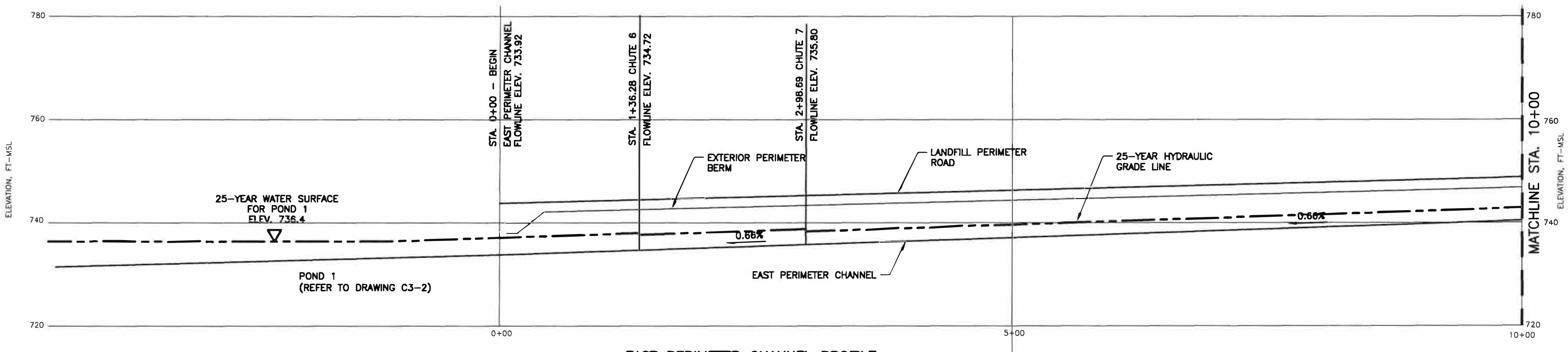
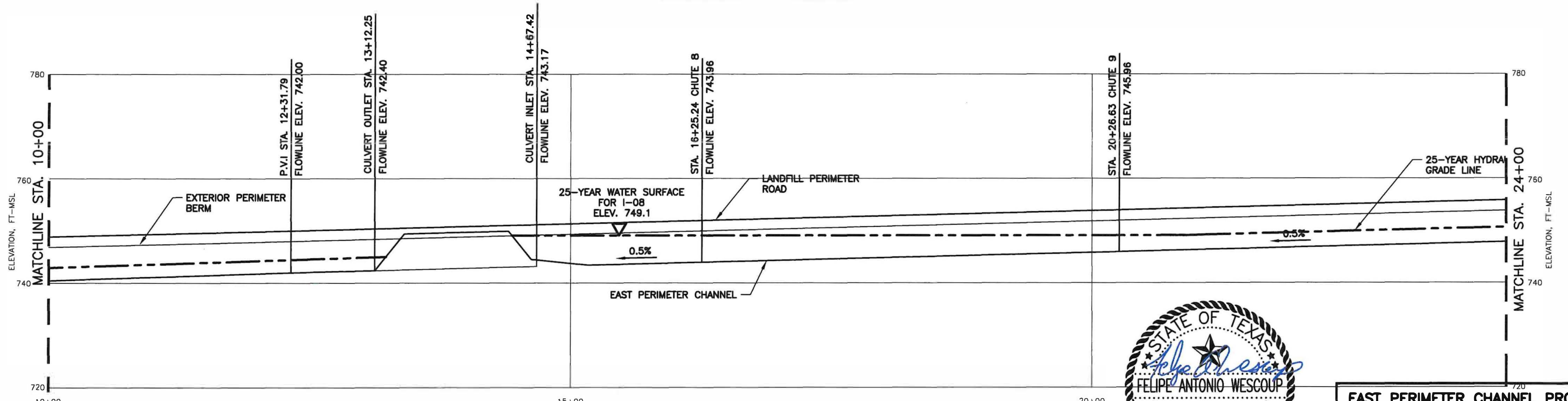


EAST PERIMETER CHANNEL PROFILE

STA. 0+00 TO 10+00

0 50 100 HORIZONTAL SCALE

0 10 20 VERTICAL SCALE



EAST PERIMETER CHANNEL PROFILE

STA. 10+00 TO 24+00

0 50 100 HORIZONTAL SCALE

0 10 20 VERTICAL SCALE

25–YEAR HYDRAULIC ANALYSIS

STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE–BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	1+36	0.0066	20	6	3.17	2.83	716.7	6.91	TURF MAT
1+36	2+98	0.0066	20	6	2.99	3.01	636.9	6.68	TURF MAT
2+98	13+12	0.0066	20	6	2.78	3.22	557.1	6.43	TURF MAT
13+12	16+25	0.0050	20	6	3.29	2.71	669.1	6.13	TURF MAT
16+25	20+26	0.0050	20	6	3.08	2.92	587.1	5.91	TURF MAT
20+26	24+00	0.0050	20	6	2.83	3.17	501.2	5.65	TURF MAT

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REV	DATE	DESCRIPTION	DWN BY

EAST PERIMETER CHANNEL PROFILE 0+00 THROUGH 24+00

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C3.5

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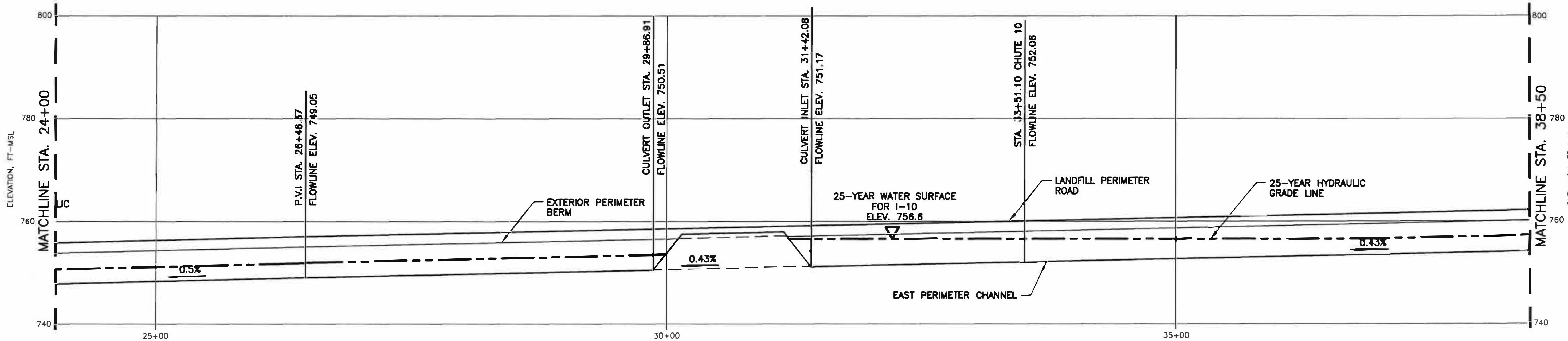
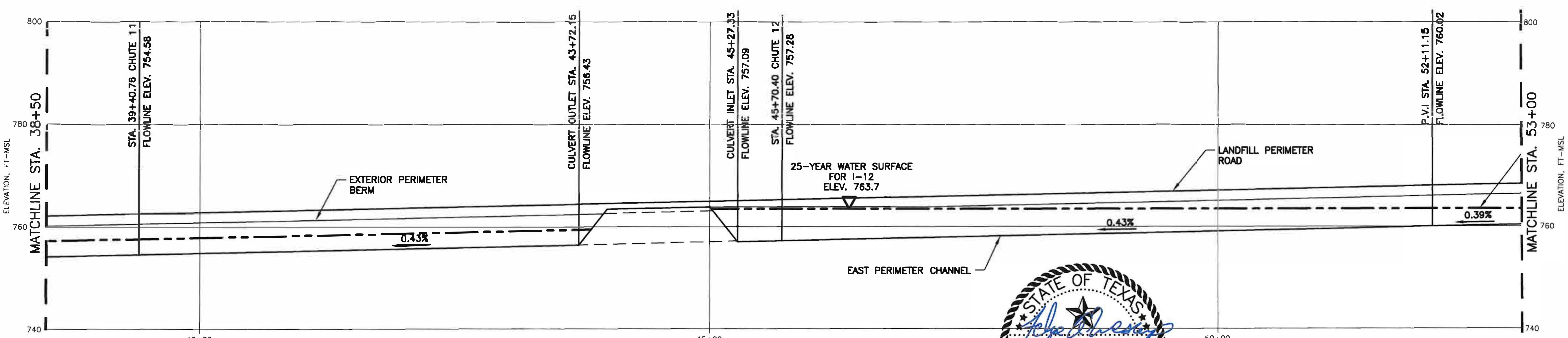


EAST PERIMETER CHANNEL PROFILE

STA. 24+00 TO 38+50

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE



EAST PERIMETER CHANNEL PROFILE

STA 38+50 TO 53+00

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE

25-YEAR HYDRAULIC ANALYSIS

STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
24+00	26+46	0.0050	20	6	2.83	3.17	501.2	5.65	TURF MAT
26+46	29+86	0.0043	20	6	2.91	3.09	490.7	5.32	TURF MAT
29+86	33+51	0.0043	20	6	3.35	2.65	643.4	5.74	TURF MAT
33+51	39+40	0.0043	20	6	3.11	2.89	556.9	5.51	TURF MAT
39+40	43+72	0.0043	20	6	2.82	3.18	461.2	5.22	TURF MAT
43+72	45+70	0.0043	20	6	3.38	2.62	653.2	5.77	TURF MAT
45+70	52+11	0.0039	20	6	3.31	2.69	599.1	5.43	TURF MAT
52+11	53+00	0.0043	20	6	3.23	2.77	599.1	5.63	TURF MAT

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EAST PERIMETER CHANNEL PROFILE 24+00 THROUGH 53+00

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C3.6

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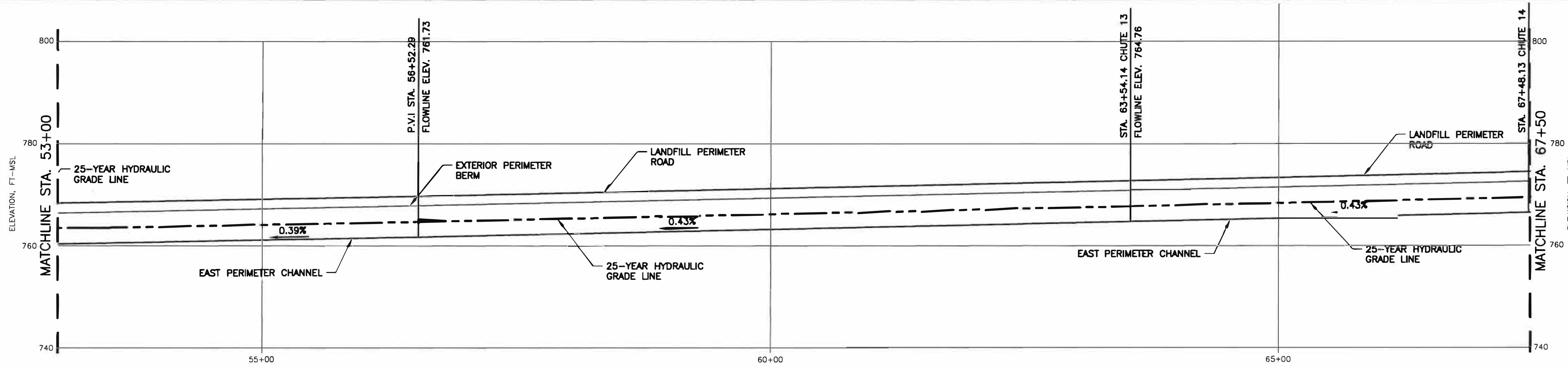
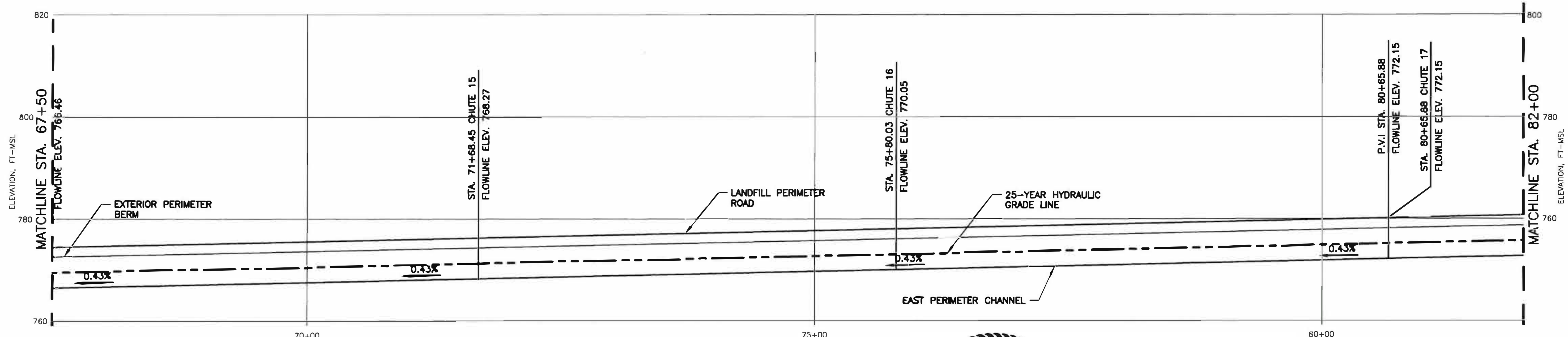


EAST PERIMETER DITCH PROFILE

STA. 53+00 TO 67+50

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE



EAST PERIMETER DITCH PROFILE

STA 67+50 TO 82+00

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE

25-YEAR HYDRAULIC ANALYSIS

STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
53+00	56+52	0.0043	20	6	3.23	2.77	599.1	5.63	TURF MAT
56+52	63+54	0.0043	20	6	3.23	2.77	599.1	5.63	TURF MAT
63+54	67+48	0.0043	20	6	2.96	3.04	505.3	5.36	TURF MAT
67+48	71+68	0.0043	20	6	2.74	3.26	434.7	5.14	VEGETATION
71+68	75+80	0.0043	20	6	2.48	3.52	362.4	4.87	VEGETATION
75+80	80+65	0.0043	20	6	2.20	3.8	289.3	4.56	VEGETATION
80+65	82+00	0.0043	20	6	1.89	4.11	218.1	4.19	VEGETATION

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EAST PERIMETER DITCH PROFILE 53+00 THROUGH 82+00

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C3.7

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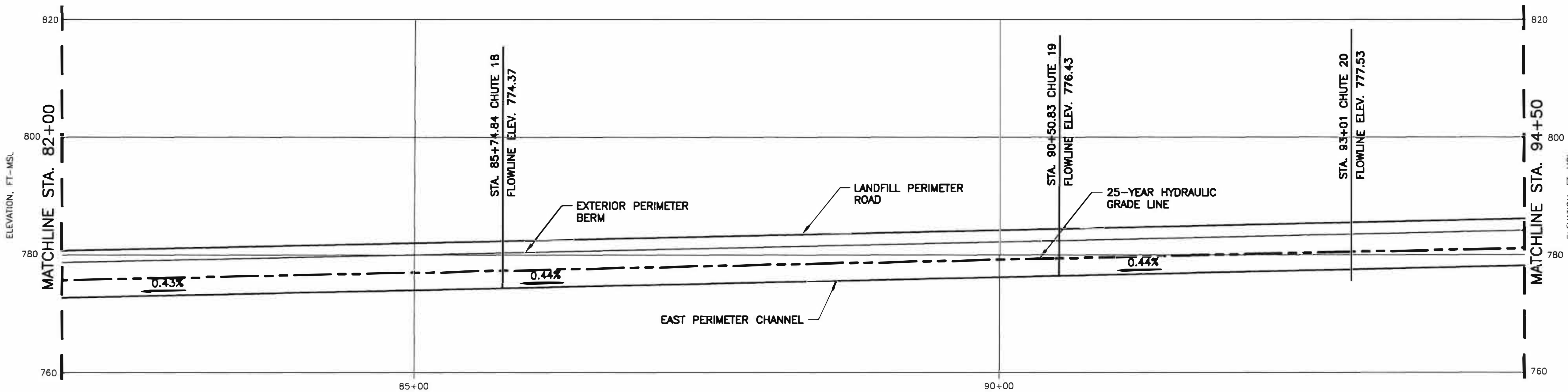
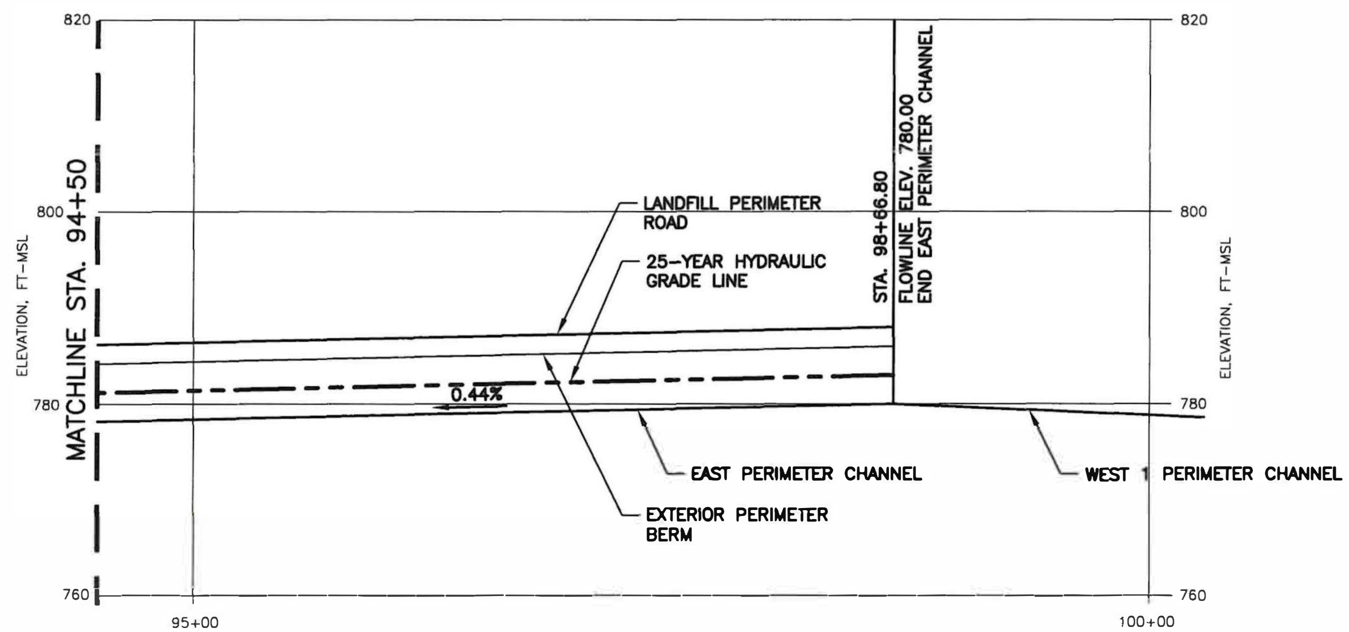


EAST PERIMETER DITCH PROFILE

STA. 82+00 TO 96+50

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE



EAST PERIMETER DITCH PROFILE

STA 94+00 TO 100+00

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE

25-YEAR HYDRAULIC ANALYSIS

STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
82+00	85+74	0.0043	20	6	1.89	4.11	218.1	4.19	VEGETATION
85+74	90+50	0.0044	20	6	1.49	4.51	143.1	3.70	VEGETATION
90+50	98+66	0.0044	20	6	1.00	5	71.2	2.95	VEGETATION

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EAST PERIMETER DITCH PROFILE 82+00 THOUGH 98+66.80

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C3.8

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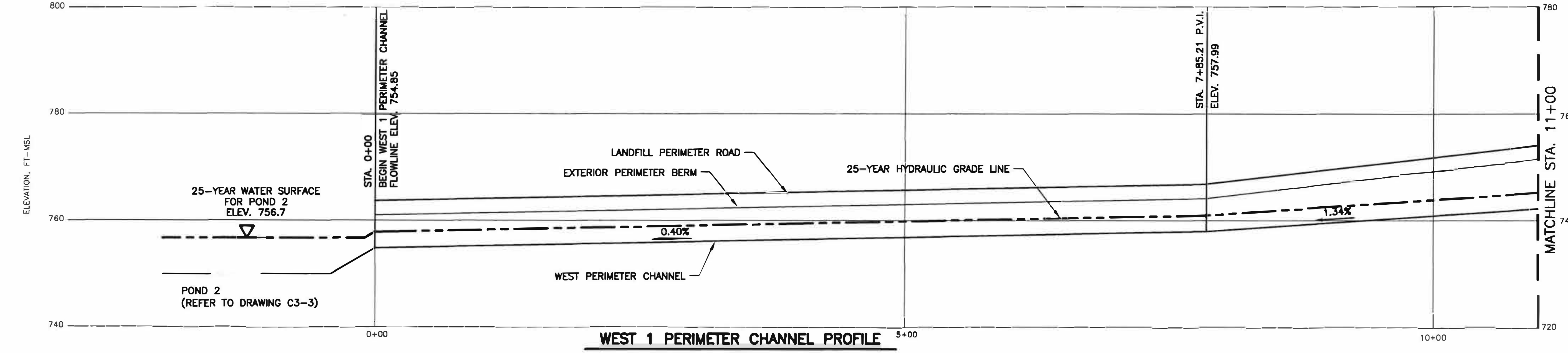
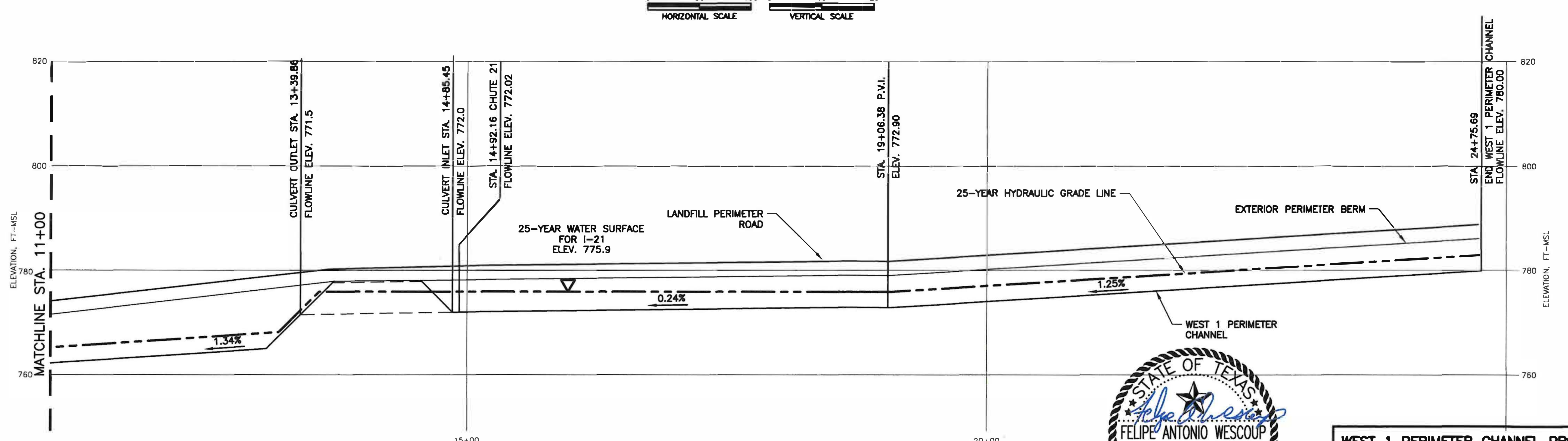


WEST 1 PERIMETER CHANNEL PROFILE

STA. 0+00 TO 11+00

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE



WEST 1 PERIMETER CHANNEL PROFILE

STA. 11+00 TO 24+62.72

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE

25-YEAR HYDRAULIC ANALYSIS									
STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	7+85	0.0040	20	6	0.75	5.25	40.5	2.36	VEGETATION
7+85	13+39	0.0134	20	6	0.52	5.48	40.0	3.48	VEGETATION
13+39	14+92	0.0134	20	6	0.82	5.18	87.9	4.59	VEGETATION
14+92	19+06	0.0125	20	6	0.21	5.79	8.0	1.87	VEGETATION
14+92	19+06	0.0024	20	6	0.33	5.67	8.0	1.12	VEGETATION
19+06	24+75	0.0125	20	6	0.21	5.79	8.0	1.87	VEGETATION

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WEST 1 PERIMETER CHANNEL PROFILE
0+00 THROUGH 24+75

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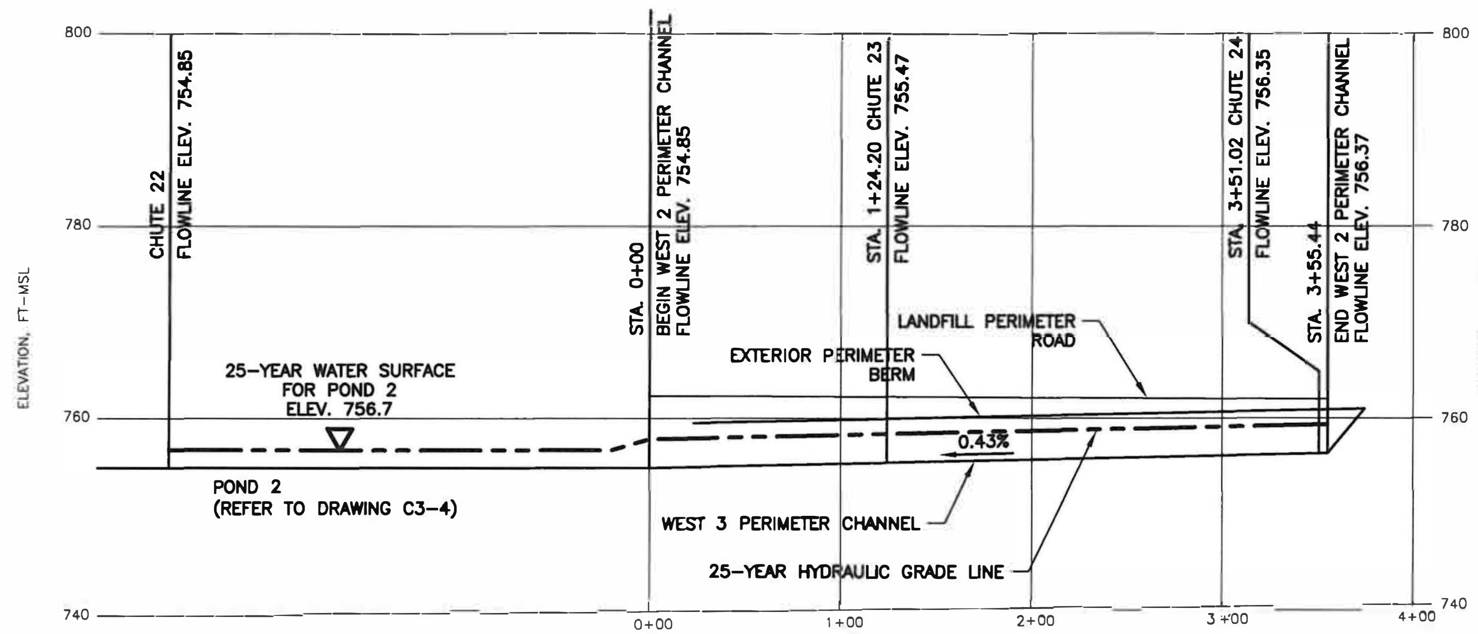
C3.9

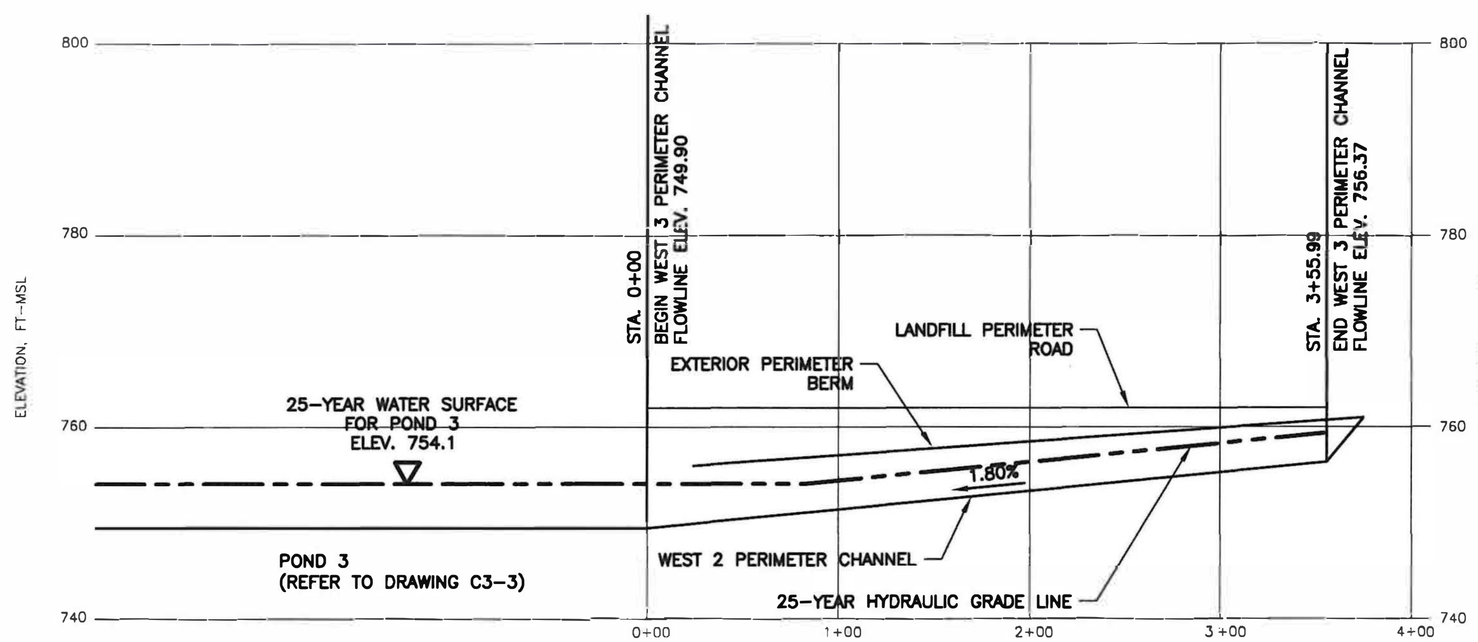


WEST 2 PERIMETER CHANNEL PROFILE

STA. 0+00 TO 3+55.96

0 50 100 HORIZONTAL SCALE
0 10 20 VERTICAL SCALE

25-YEAR HYDRAULIC ANALYSIS										
STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	1+24	0.0043	20	6	1.72	4.28	182.9	3.97	VEGETATION
1+24	3+55	0.004	20	6	1.32	4.68	114.4	3.42	VEGETATION



WEST 3 PERIMETER CHANNEL PROFILE

STA. 0+00 TO 3+55.45

0 50 100 HORIZONTAL SCALE
0 10 20 VERTICAL SCALE

25-YEAR HYDRAULIC ANALYSIS										
STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	3+55	0.18	20.0	6.0	0.24	5.76	12.1	0.26	VEGETATION

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WEST 2 AND WEST 3 PERIMETER CHANNEL PROFILE

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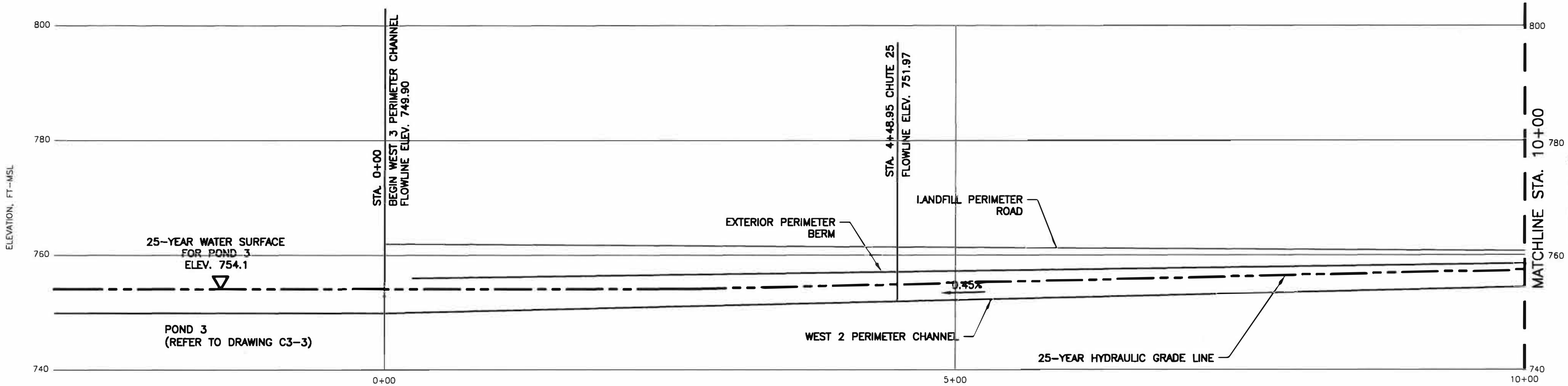
TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C3.10

O:\TASWA\P\Drawings\ATT C\C3-9thru11_WestChan.dwg Layout: West 2 & 3 Perimeter Channel User: awhite

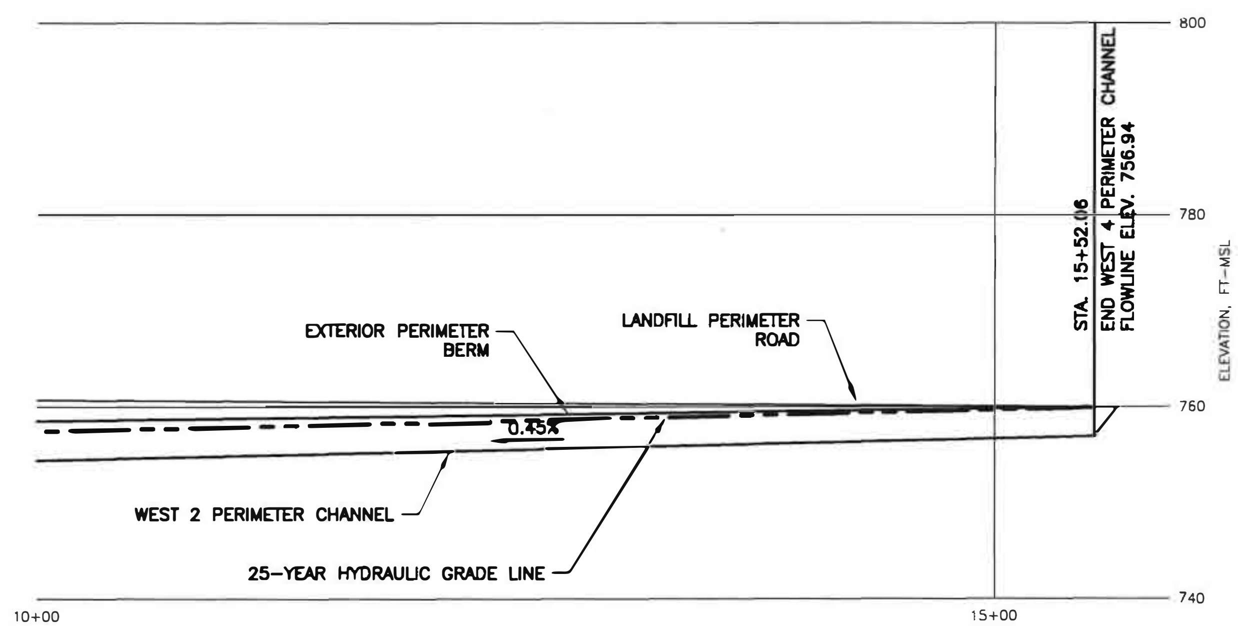


25-YEAR HYDRAULIC ANALYSIS										
STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	15+52.06	0.45	20.0	6.0	0.56	5.44	26.0	2.10	VEGETATION

WEST 4 PERIMETER CHANNEL PROFILE

STA. 0+00 TO 10+00

HORIZONTAL SCALE: 0, 50, 100 — VERTICAL SCALE: 0, 10, 20



25-YEAR HYDRAULIC ANALYSIS										
STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	15+52.06	0.45	20.0	6.0	0.56	5.44	26.0	2.10	VEGETATION

WEST 4 PERIMETER CHANNEL PROFILE

STA. 10+00 TO 15+52.06

HORIZONTAL SCALE: 0, 50, 100 — VERTICAL SCALE: 0, 10, 20

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WEST 4 PERIMETER CHANNEL PROFILE
STA. 0+00 THROUGH 15+52.06

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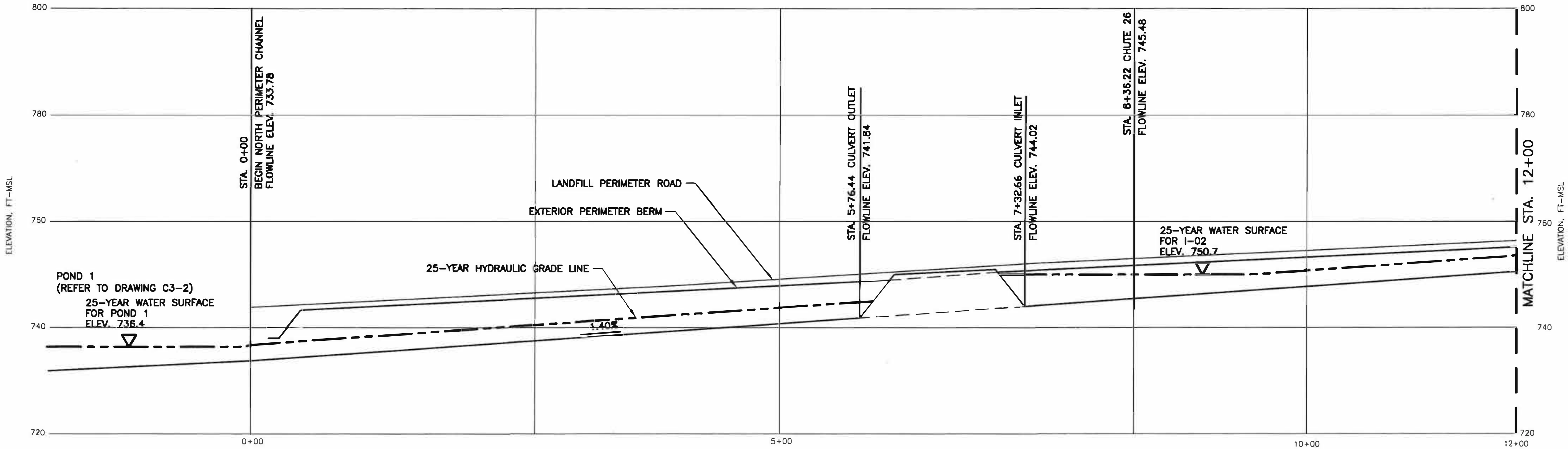
C3.11

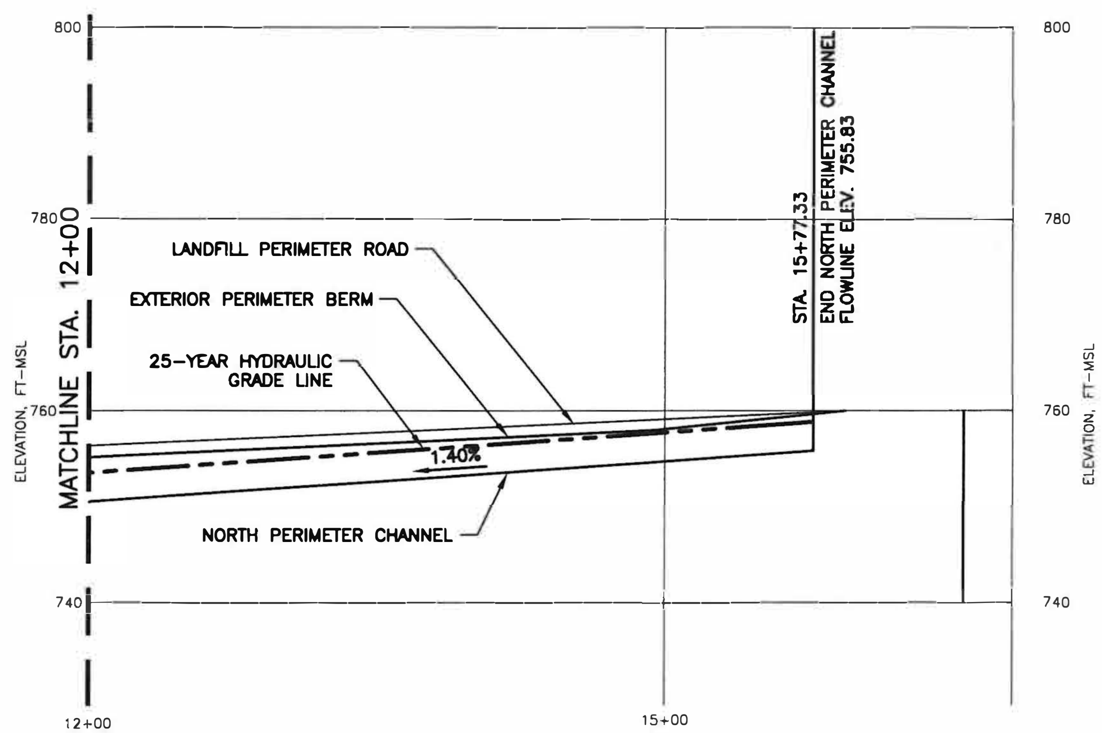
O:\TASWA\P\Drawings\ATT C\C3-9thru11_WestChan.dwg Layout: West 4 Perimeter Channel User: owhite



NORTH PERIMETER CHANNEL PROFILE

STA. 0+00 TO 12+00

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE



NORTH PERIMETER CHANNEL PROFILE

STA. 12+00 TO 15+77.33

0 50 100 HORIZONTAL SCALE — 0 10 20 VERTICAL SCALE

STATION		BOTTOM SLOPE (%)	BOTTOM WIDTH (ft)	CHANNEL DEPTH (ft)	FLOW DEPTH (ft)	FREE-BOARD (ft)	FLOW RATE (cfs)	FLOW VELOCITY (fps)	EROSION PROTECTION
0+00	5+76	0.014	20	6	0.17	5.83	6.20	1.76	VEGETATION
5+76	8+36	0.014	20	6	0.70	5.3	68.60	4.27	VEGETATION
8+36	15+77	0.014	20	6	0.17	5.83	5.90	1.73	VEGETATION

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NORTH PERIMETER CHANNEL PROFILE
0+00 THROUGH 15+77.33

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C3.12

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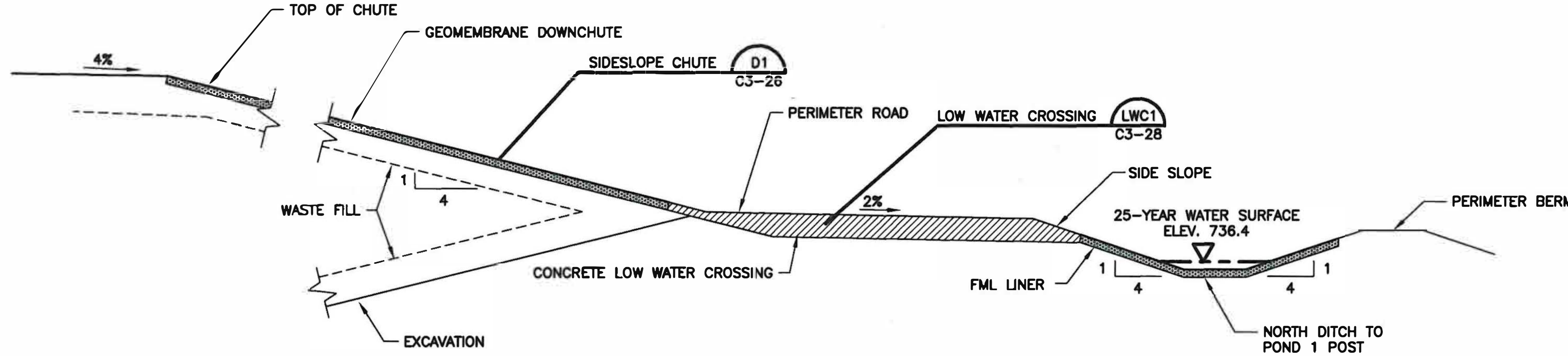

CHUTE 2 PROFILE (CP2 / C3-13)

0 10 20
SCALE IN FEET

CHUTE 2 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.63
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.62
	FLOW VELOCITY (FPS)	6.51
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.05

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTE 2 PROFILE

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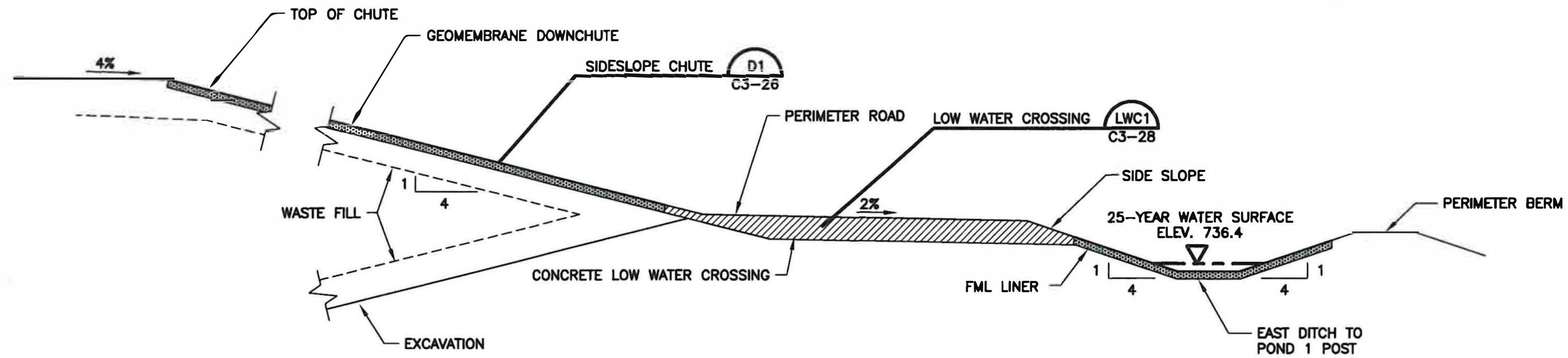
C3.13

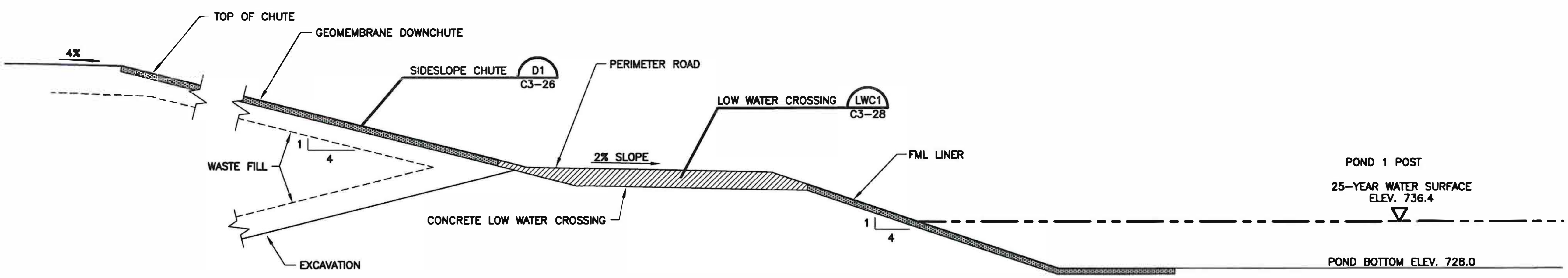


CHUTE 3 PROFILE (CP3, C3-14)

0 10 20 SCALE IN FEET

CHUTE 3 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.26
	FLOW VELOCITY (FPS)	22.63
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.66
	FLOW VELOCITY (FPS)	6.75
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.87

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 4 PROFILE (CP4, C3-14)

0 10 20 SCALE IN FEET

CHUTE 4 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.55
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.62
	FLOW VELOCITY (FPS)	6.49
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	17.99

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTE 3 AND 4 PROFILES

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C3.14

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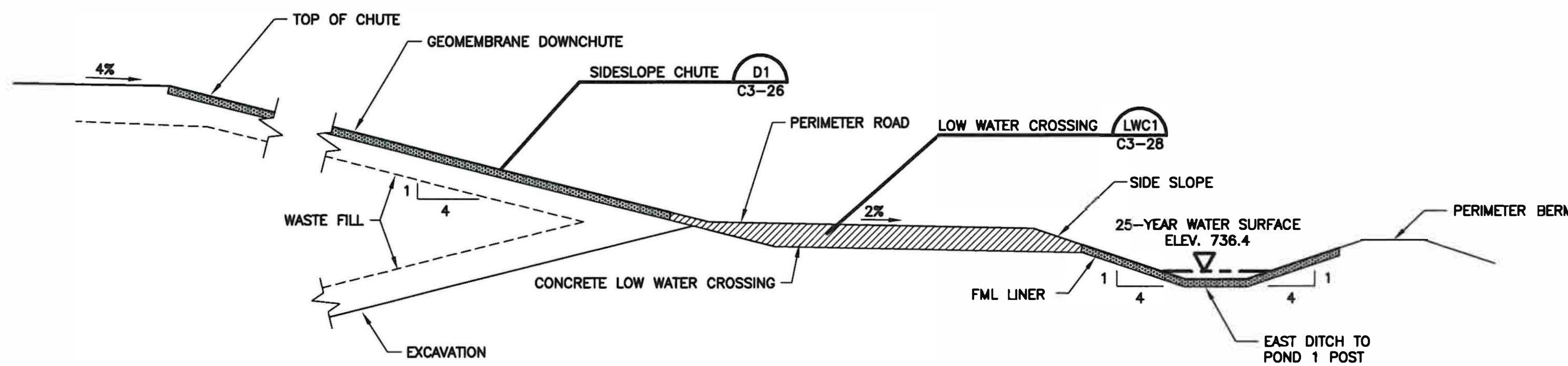
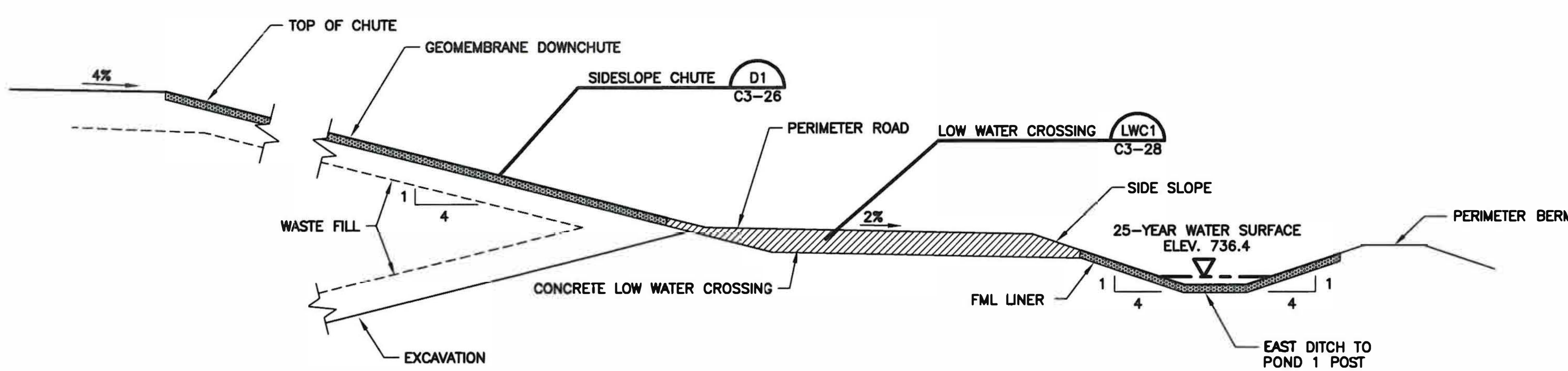


CHUTE 5 PROFILE (CP5 / C3-15)

0 10 20
SCALE IN FEET

CHUTE 5 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.71
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.62
	FLOW VELOCITY (FPS)	6.53
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.12

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 6 PROFILE (CP6 / C3-15)

0 10 20
SCALE IN FEET

CHUTE 6 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.83
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.56
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.22

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTE 5 AND 6 PROFILES

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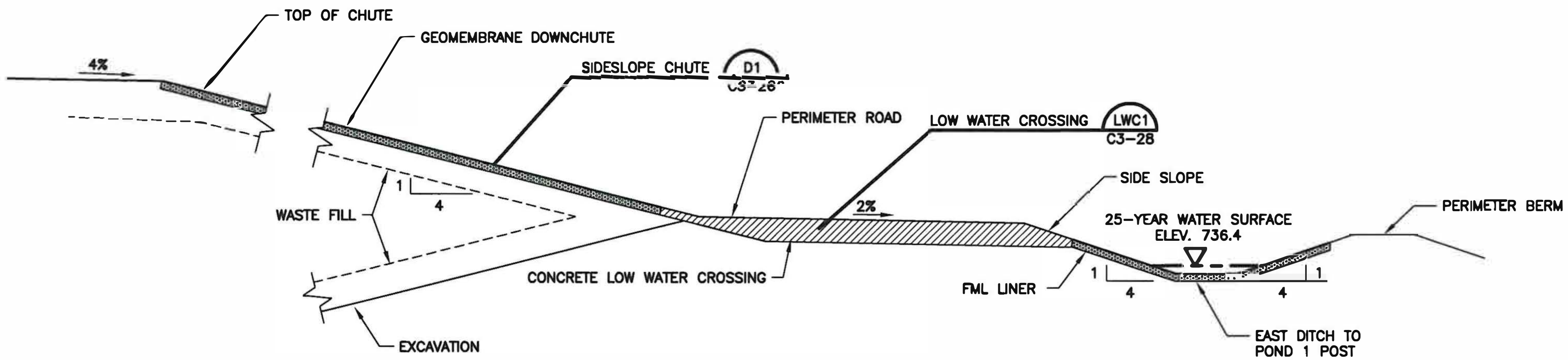
C3.15

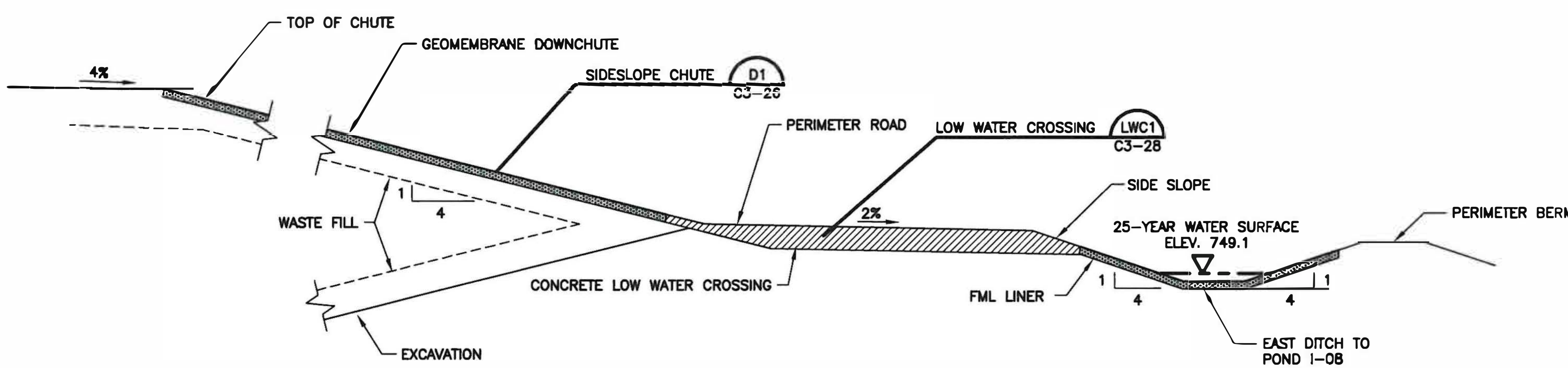


CHUTE 7 PROFILE (CP7 C3-16)

0 10 20
SCALE IN FEET

CHUTE 7 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.83
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.56
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.22

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 8 PROFILE (CP8 C3-16)

0 10 20
SCALE IN FEET

CHUTE 8 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.79
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.55
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.18

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTE 7 AND 8 PROFILES

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C3.16

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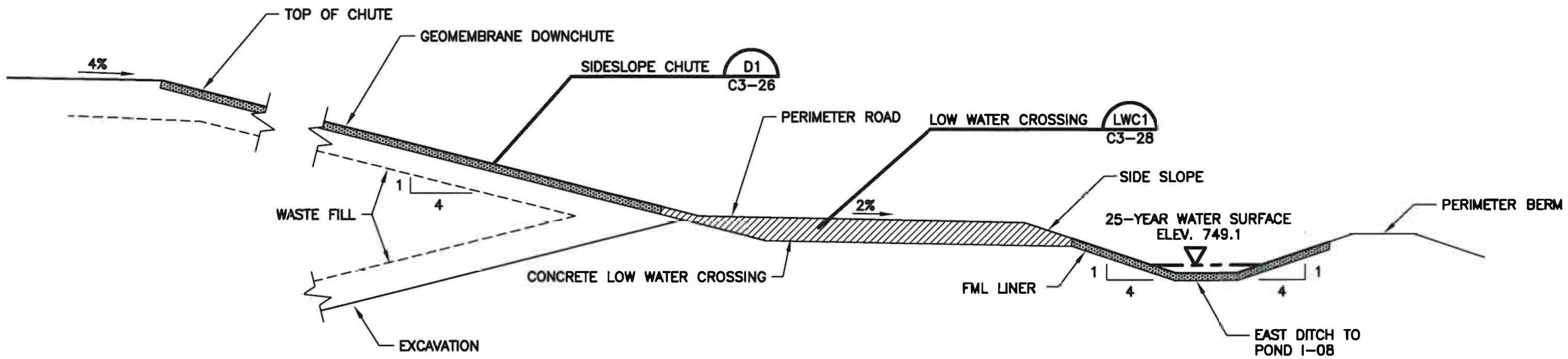
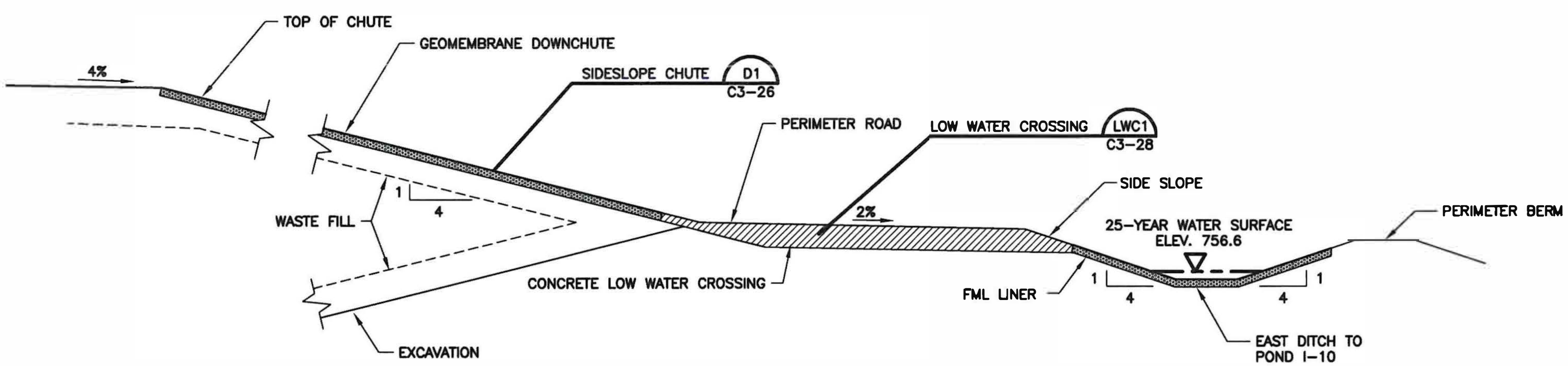


CHUTE 9 PROFILE CP9 C3-17

0 10 20 SCALE IN FEET

CHUTE 9 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.83
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.56
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.22

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 10 PROFILE CP10 C3-17

0 10 20 SCALE IN FEET

CHUTE 10 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.30
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.61
	FLOW VELOCITY (FPS)	6.63
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	17.79

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTES 9 AND 10 PROFILES

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C3.17

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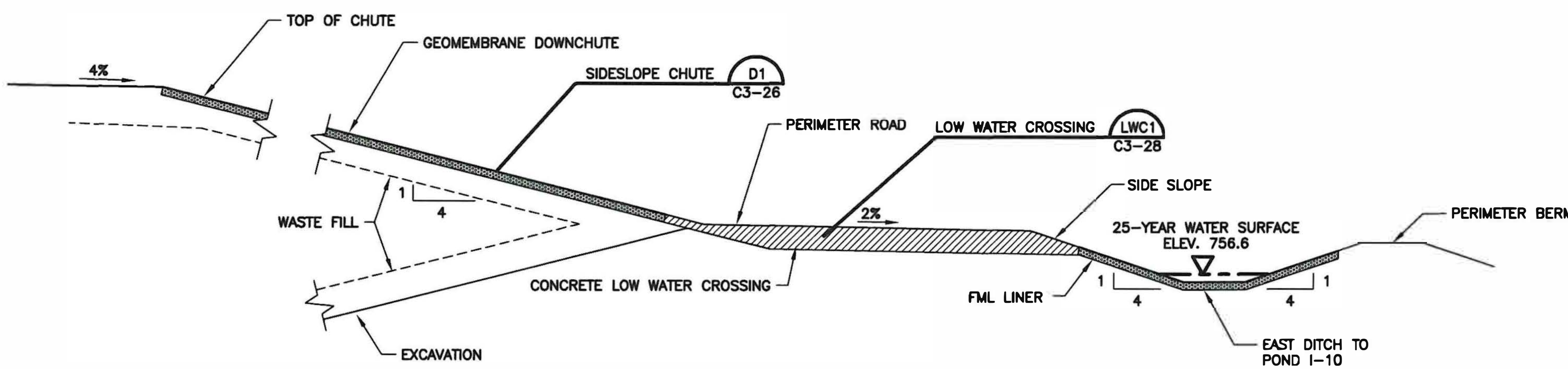
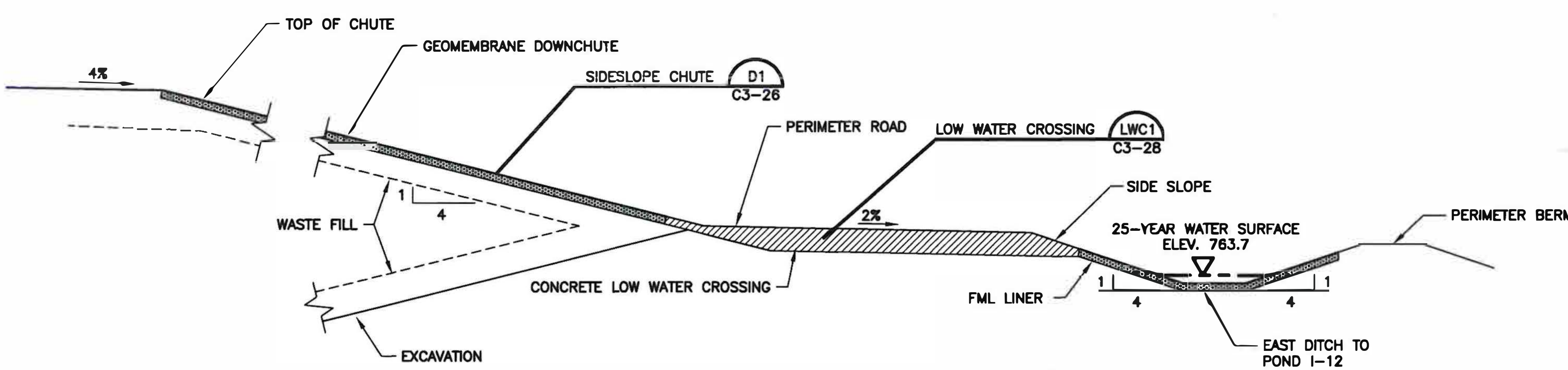


CHUTE 11 PROFILE (CP11 C3-18)

0 10 20
SCALE IN FEET

CHUTE 11 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.34
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.61
	FLOW VELOCITY (FPS)	6.44
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	17.82

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 12 PROFILE (CP12 C3-18)

0 10 20
SCALE IN FEET

CHUTE 12 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.22
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.60
	FLOW VELOCITY (FPS)	6.41
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.18
	FLOW VELOCITY (FPS)	17.72

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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REV	DATE	DESCRIPTION	DWN BY

CHUTE 11 AND 12 PROFILES

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C3.18

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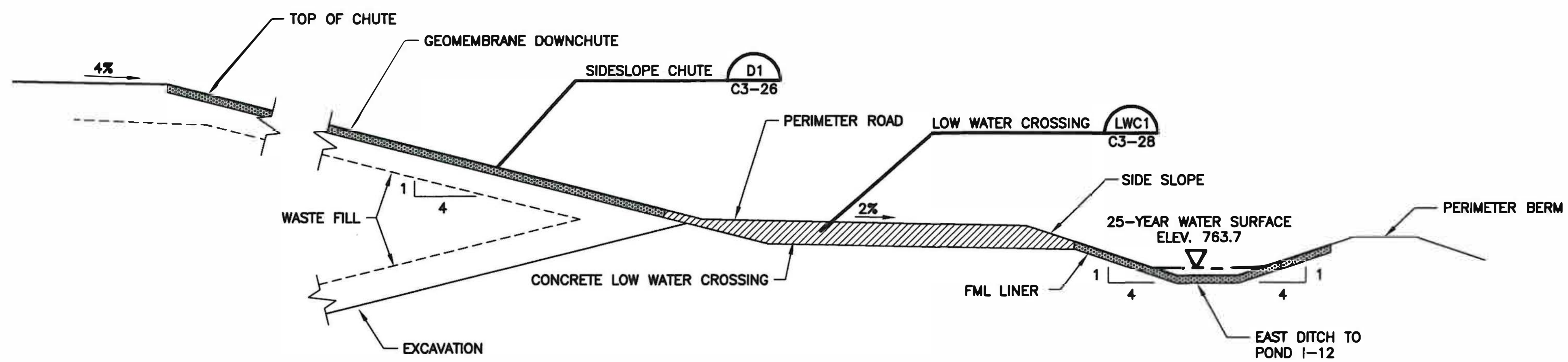
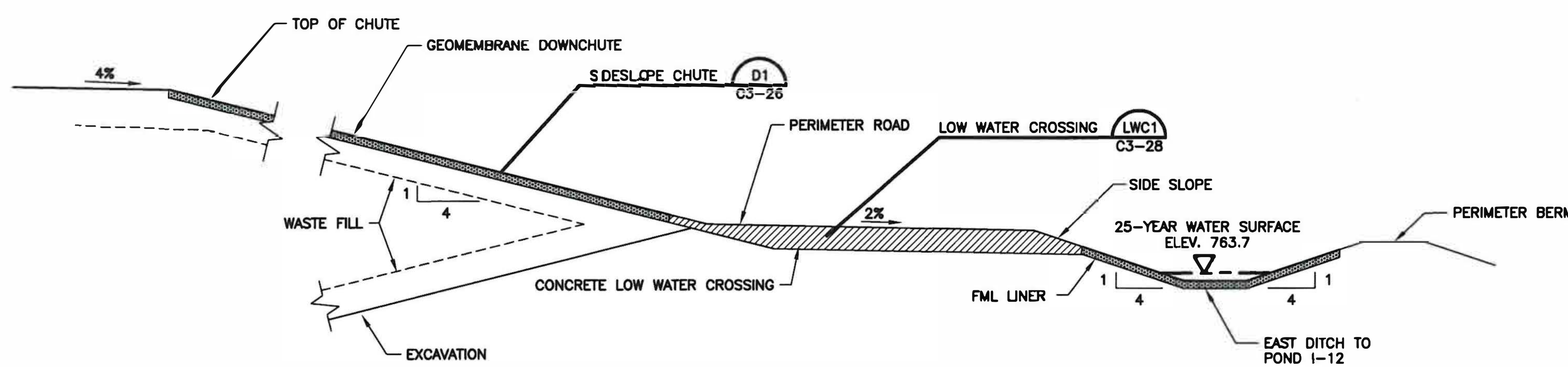


CHUTE 13 PROFILE (CP13 / C3-19)

0 10 20
SCALE IN FEET

CHUTE 13 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.87
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.57
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.25

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 14 PROFILE (CP14 / C3-19)

0 10 20
SCALE IN FEET

CHUTE 14 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.79
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.55
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.18

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTE 13 AND 14 PROFILES

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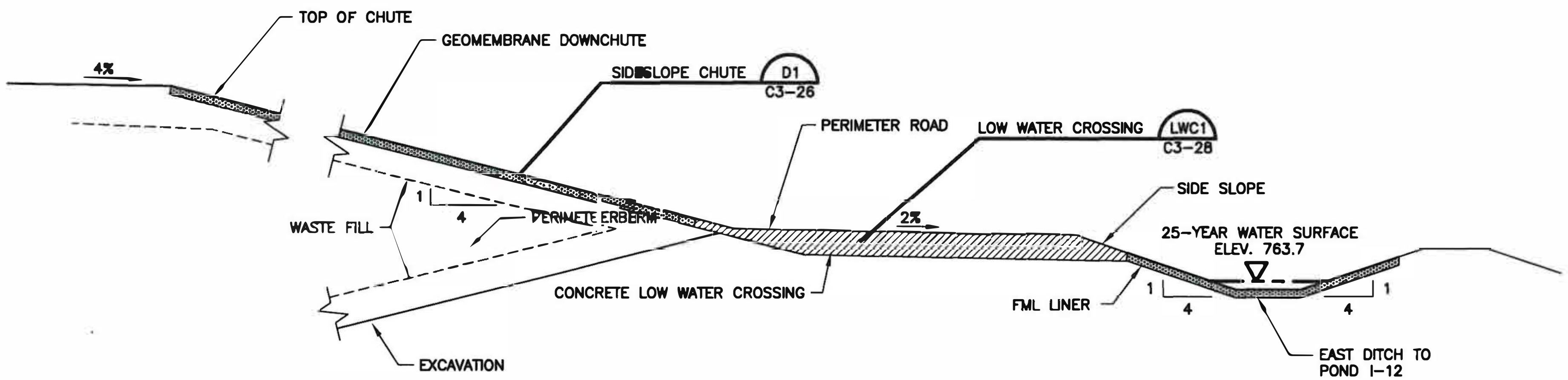
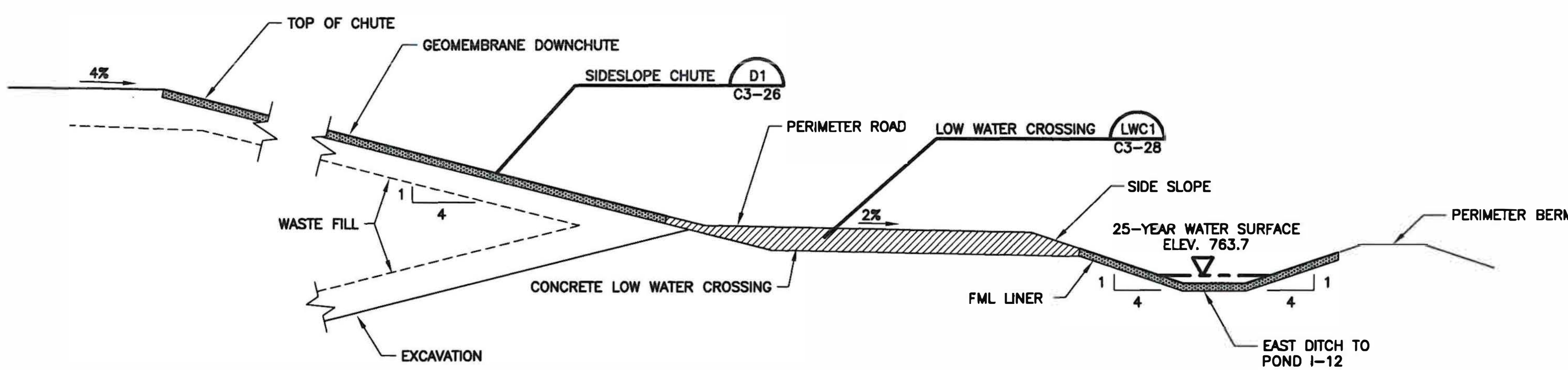


CHUTE 15 PROFILE CP15 C3-20

0 10 20 SCALE IN FEET

CHUTE 15 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.91
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.58
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.28

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 16 PROFILE CP16 C3-20

0 10 20 SCALE IN FEET

CHUTE 16 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.95
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.59
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.31

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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CHUTE 15 AND 16 PROFILES

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C3.20

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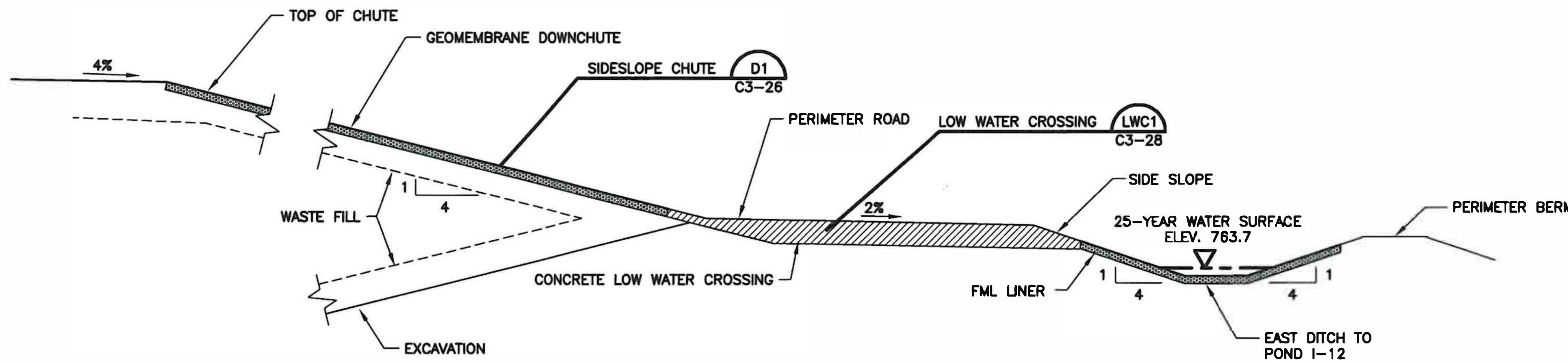
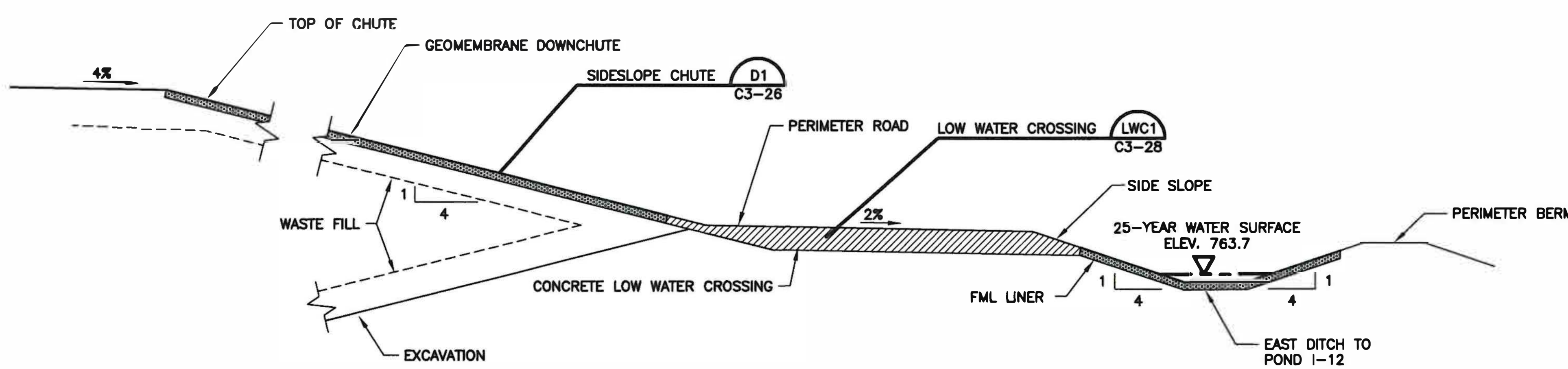


CHUTE 17 PROFILE (CP17 / C3-21)

0 10 20
SCALE IN FEET

CHUTE 17 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.67
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.62
	FLOW VELOCITY (FPS)	6.52
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.09

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 18 PROFILE (CP18 / C3-21)

0 10 20
SCALE IN FEET

CHUTE 18 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.99
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.64
	FLOW VELOCITY (FPS)	6.59
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.20
	FLOW VELOCITY (FPS)	18.34

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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REVISIONS

REV	DATE	DESCRIPTION	DWN BY

CHUTE 17 AND 18 PROFILES

TEXOMA AREA SOLID WASTE AUTHORITY
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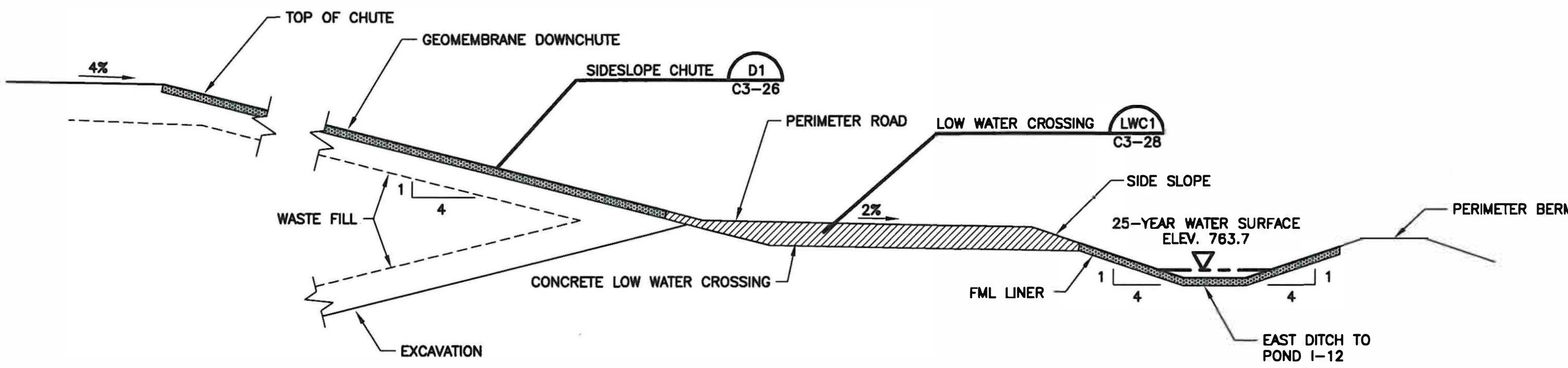
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C3.21

O:\TASWA\P\Drawings\ATT C\C3-13thru25.dwg Layout: C3-21 User:

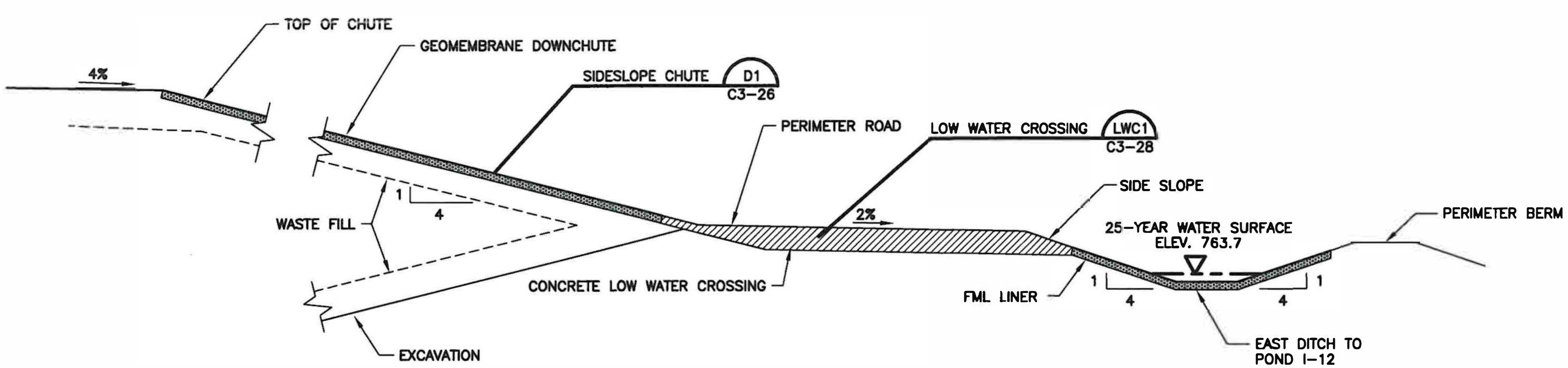


CHUTE 19 PROFILE (CP19 / C3-22)

0 10 20
SCALE IN FEET

CHUTE 19 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.51
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.62
	FLOW VELOCITY (FPS)	6.48
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	17.96

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 20 PROFILE (CP20 / C3-22)

0 10 20
SCALE IN FEET

CHUTE 20 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.42
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.61
	FLOW VELOCITY (FPS)	6.46
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	17.89

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CHUTE 19 AND 20 PROFILES

TEXOMA AREA SOLID WASTE AUTHORITY
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TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C3.22

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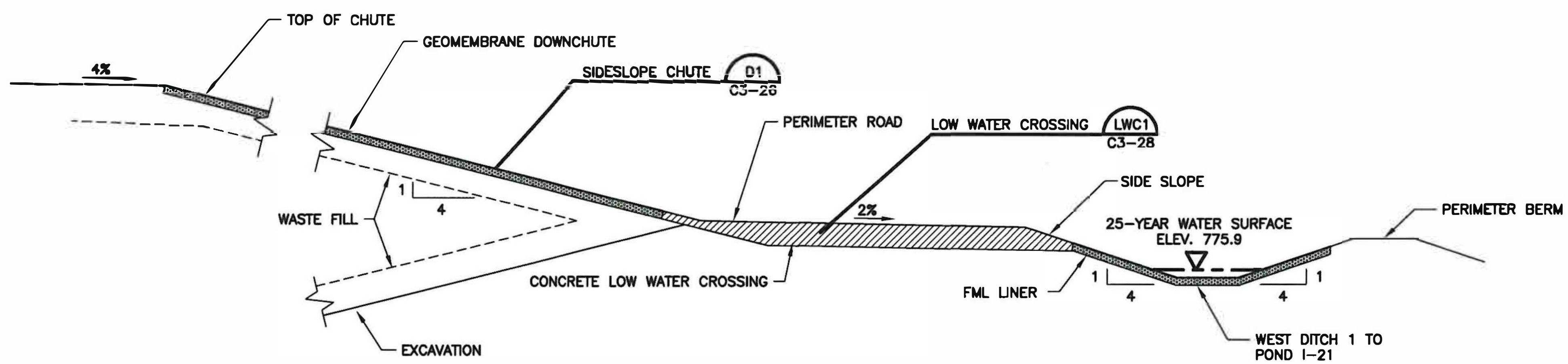
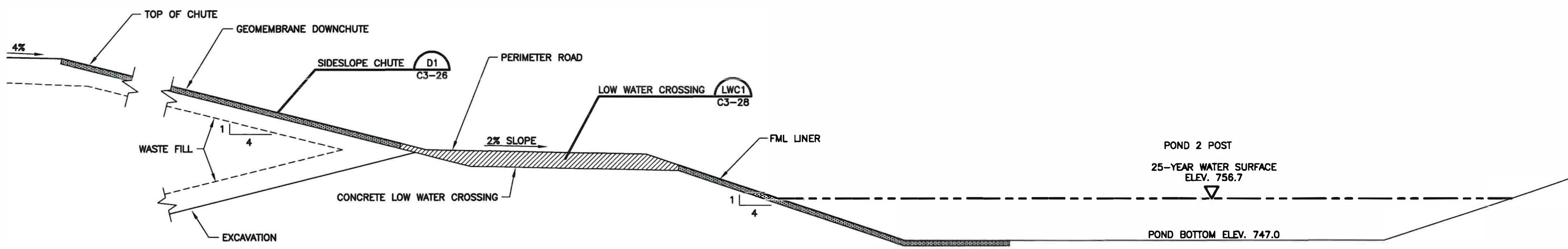


CHUTE 21 PROFILE (CP21 C3-23)

0 10 20
SCALE IN FEET

CHUTE 21 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.87
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.63
	FLOW VELOCITY (FPS)	6.57
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	18.25

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 22 PROFILE (CP22 C3-23)

0 10 20
SCALE IN FEET

CHUTE 22 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.21
	FLOW VELOCITY (FPS)	19.81
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.55
	FLOW VELOCITY (FPS)	6.06
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.17
	FLOW VELOCITY (FPS)	16.57

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CHUTE 20 AND 21 PROFILES

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TBPG FIRM NO. 50222

C3.23

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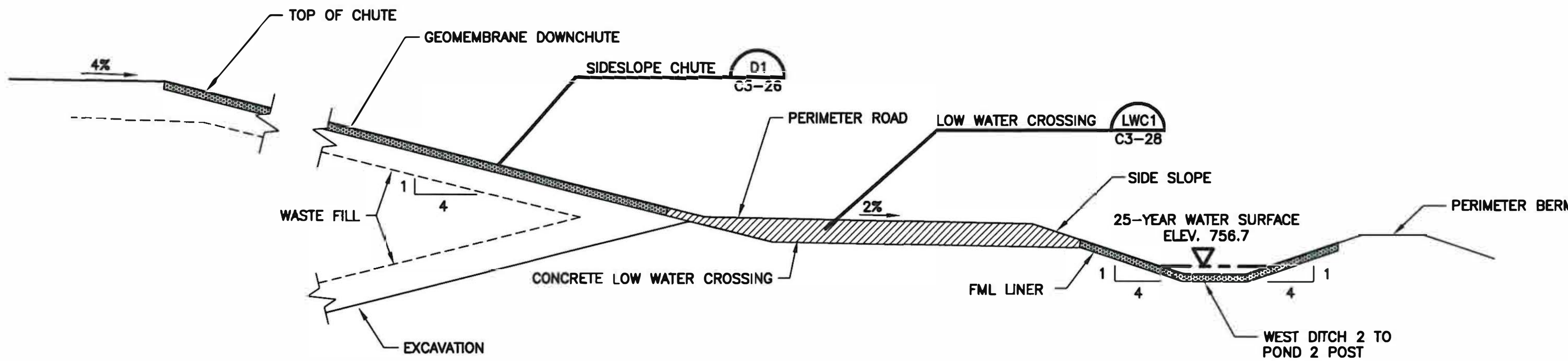
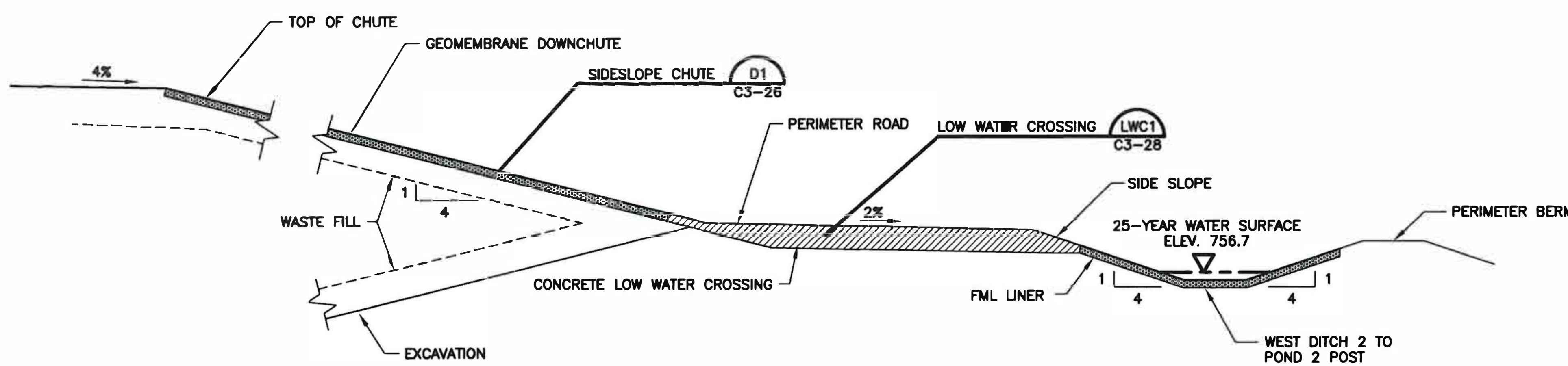


CHUTE 23 PROFILE (CP23 C3-24)

0 10 20
SCALE IN FEET

CHUTE 23 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.21
	FLOW VELOCITY (FPS)	19.47
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.53
	FLOW VELOCITY (FPS)	5.97
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.16
	FLOW VELOCITY (FPS)	16.30

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 24 PROFILE (CP24 C3-24)

0 10 20
SCALE IN FEET

CHUTE 24 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.24
	FLOW VELOCITY (FPS)	21.51
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.62
	FLOW VELOCITY (FPS)	6.48
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.19
	FLOW VELOCITY (FPS)	17.96

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CHUTE 23 AND 24 PROFILES

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TBPG FIRM NO. 50222

C3.24

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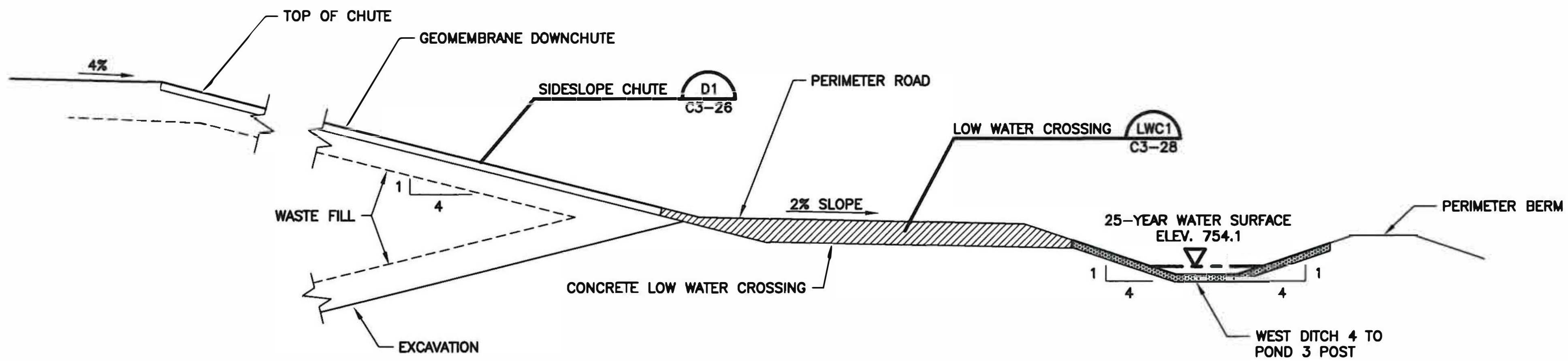
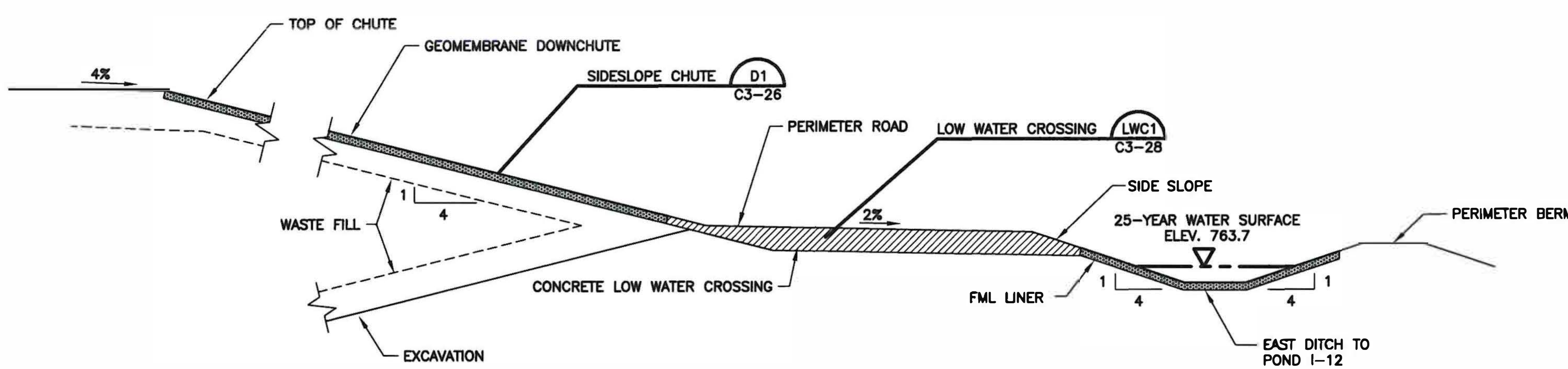


CHUTE 25 PROFILE (CP25 / C3-25)

0 10 20
SCALE IN FEET

CHUTE 25 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.15
	FLOW VELOCITY (FPS)	15.91
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.40
	FLOW VELOCITY (FPS)	5.05
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.12
	FLOW VELOCITY (FPS)	13.37

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.



CHUTE 26 PROFILE (CP26 / C3-25)

0 10 20
SCALE IN FEET

CHUTE 18 INFORMATION		
CHUTE	FLOW DEPTH (FT)	0.25
	FLOW VELOCITY (FPS)	21.99
	BERM HEIGHT (FT)	2.0
LOW-WATER CROSSING	FLOW DEPTH (FT)	0.64
	FLOW VELOCITY (FPS)	6.59
AFTER LOW-WATER CROSSING	FLOW DEPTH (FT)	0.20
	FLOW VELOCITY (FPS)	18.34

NOTE: SEE ATTACHMENT C1, APPENDIX C1-E, PAGE C1-E-21 FOR DOWNCHUTE CALCULATIONS.

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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CHUTE 25 AND 26 PROFILES

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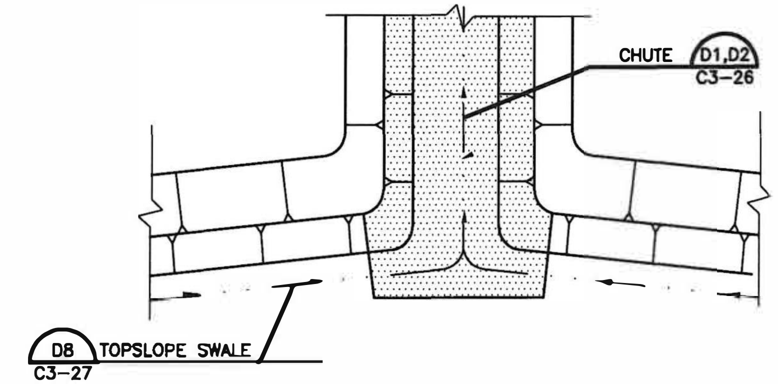
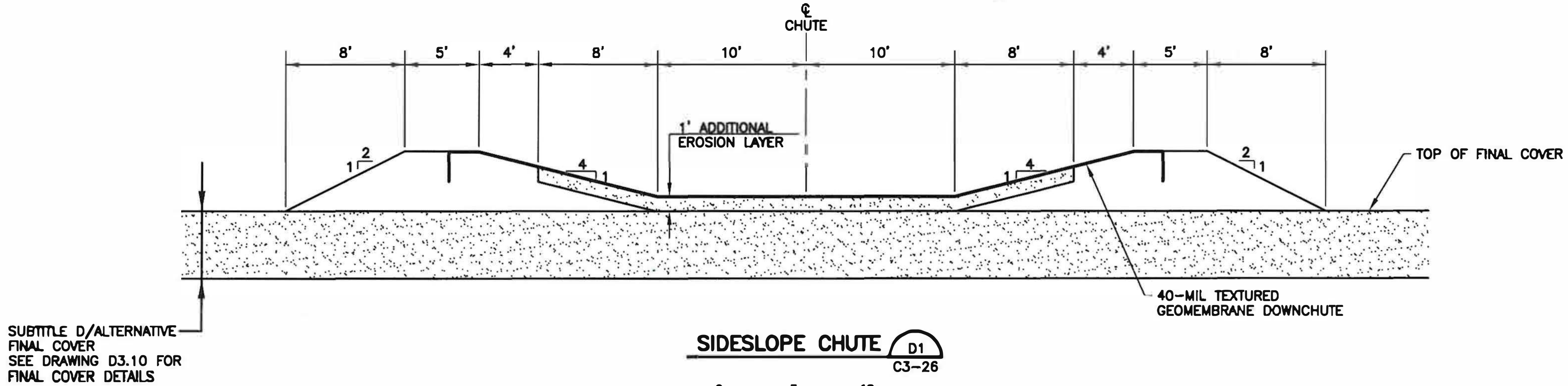
C3.25



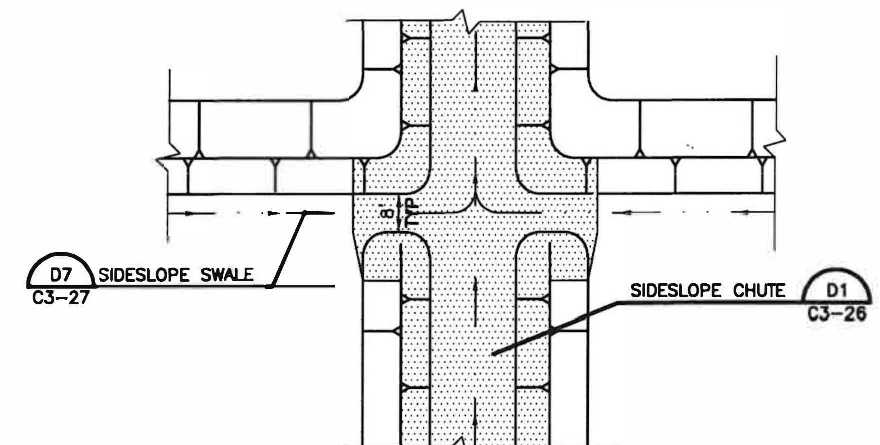
SWALE/CHUTE TOPSLOPE CONFLUENCE (D4, C3-26)

0 5 10
SCALE IN FEET



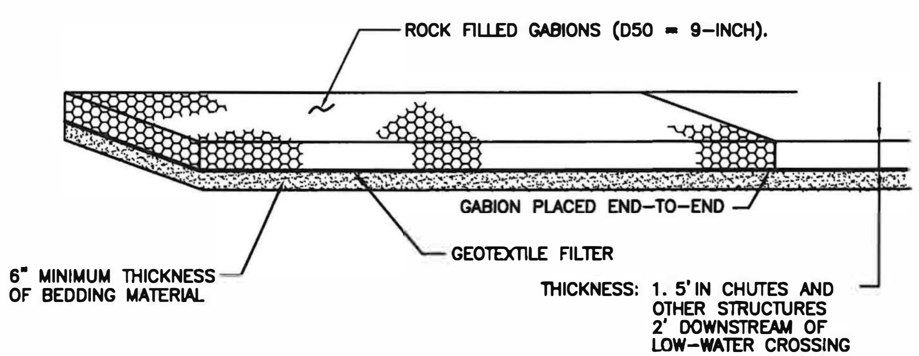
SIDESLOPE CHUTE (D1, C3-26)

0 5 10
SCALE IN FEET



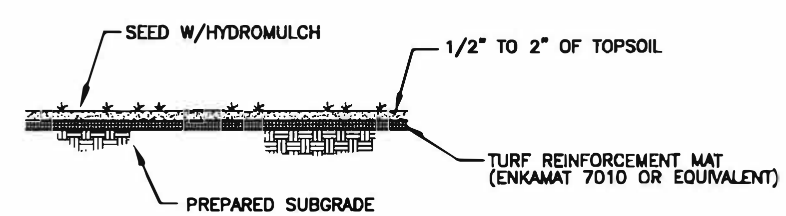
SWALE/CHUTE SIDESLOPE CONFLUENCE (D5, C3-26)

0 5 10
SCALE IN FEET



GABIONS (RENO MATTRESS) (D3, C3-26)

0 2 4
SCALE IN FEET



TURF REINFORCEMENT MATTING (TYP) (D6, C3-26)

NTS

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REV	DATE	DESCRIPTION	DWN BY

DRAINAGE DETAILS

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TBPG FIRM NO. 50222

C3.26

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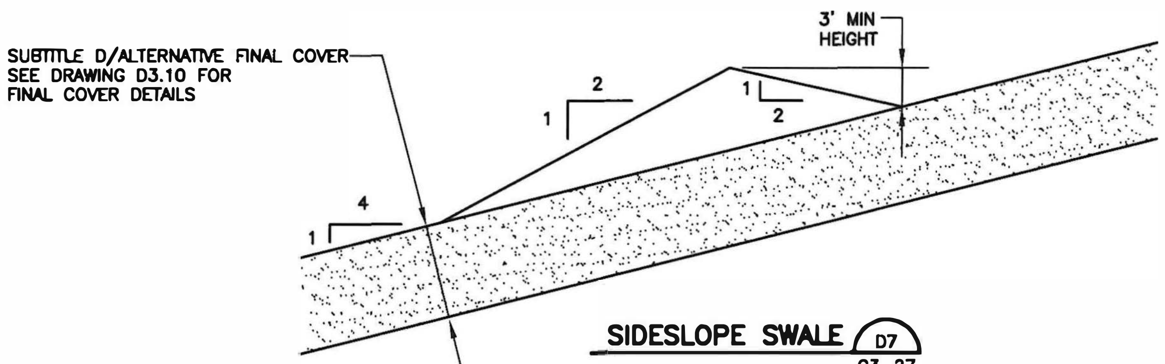
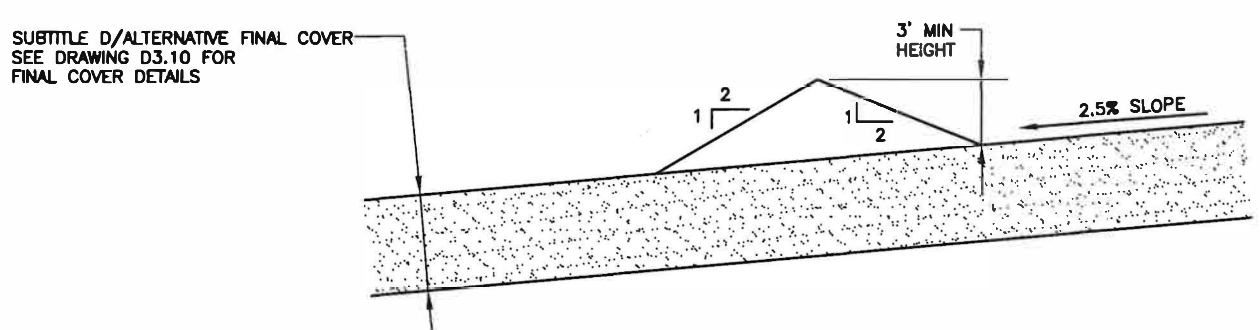
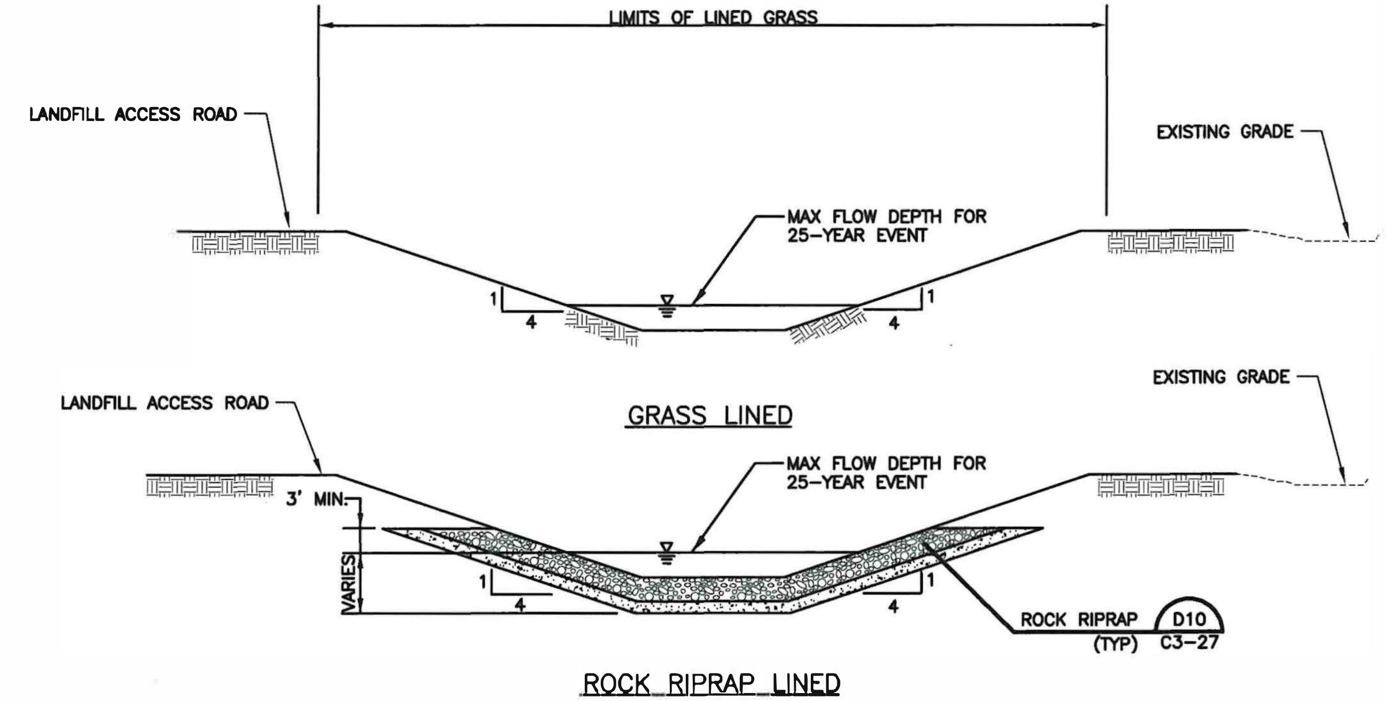


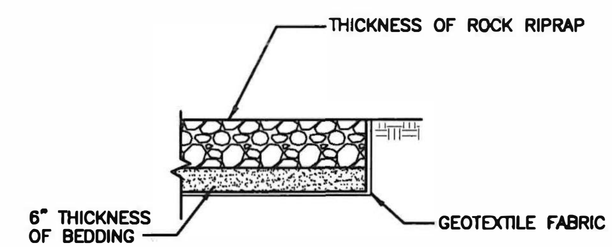
SIDESLOPE SWALE D7 C3-27
NTS



TOPSLOPE SWALE D8 C3-27
NTS



TRAPEZOIDAL DITCH D9 C3-27
NTS



ROCK RIPRAP (TYP) D10 C3-27

0 2 4
SCALE IN FEET

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REV	DATE	DESCRIPTION	DWN BY

DRAINAGE DETAILS

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TBPG FIRM NO. 50222

C3.27

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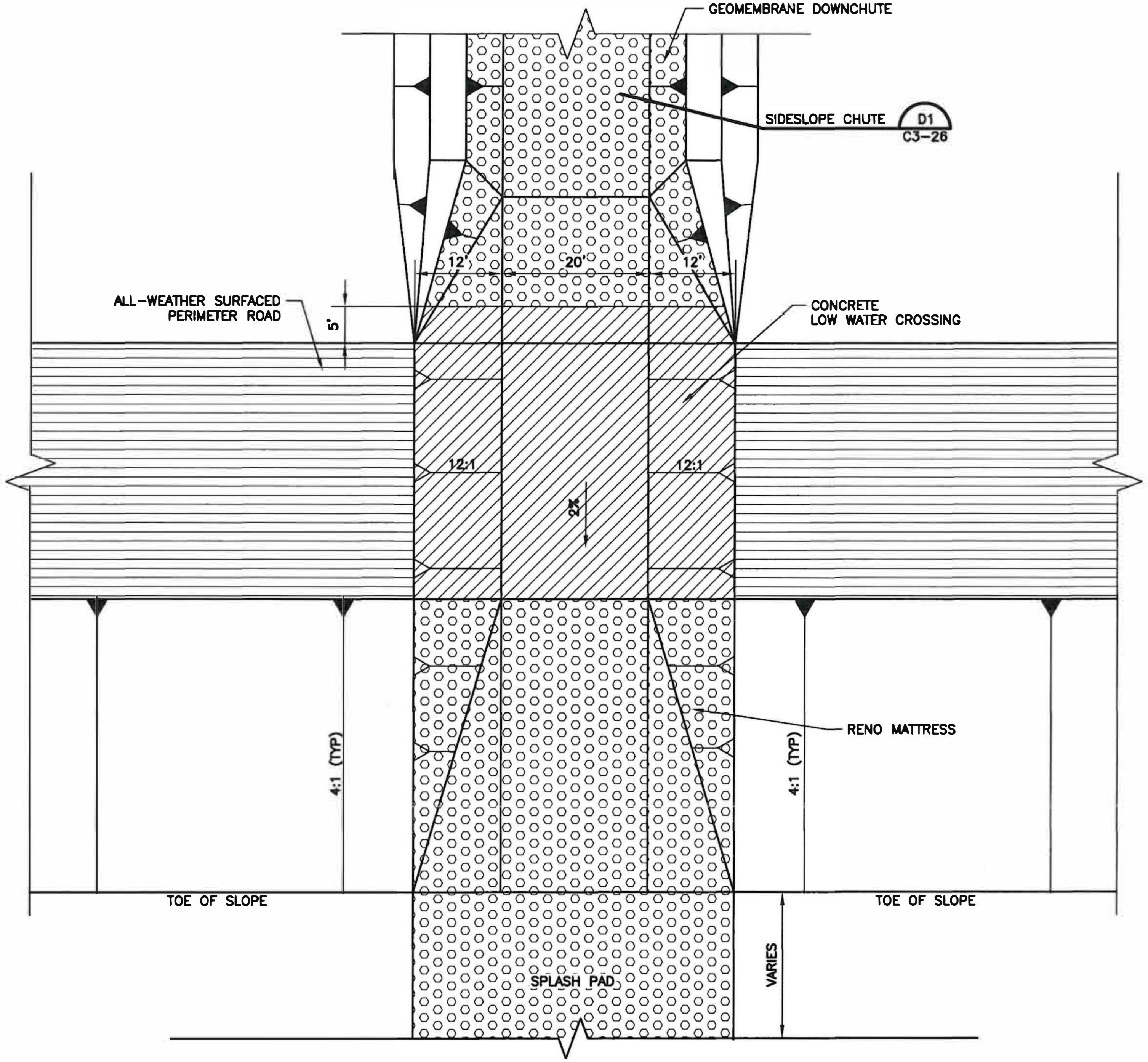
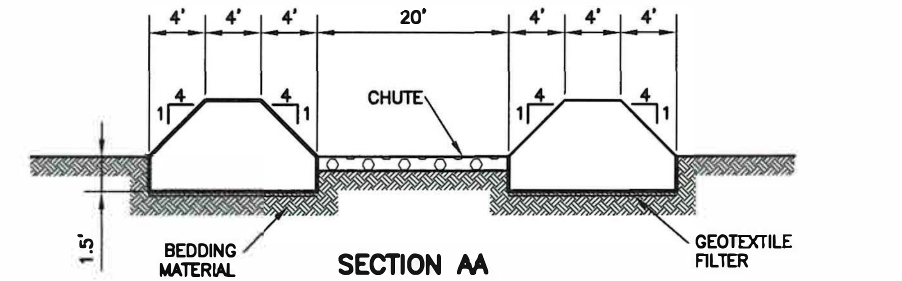
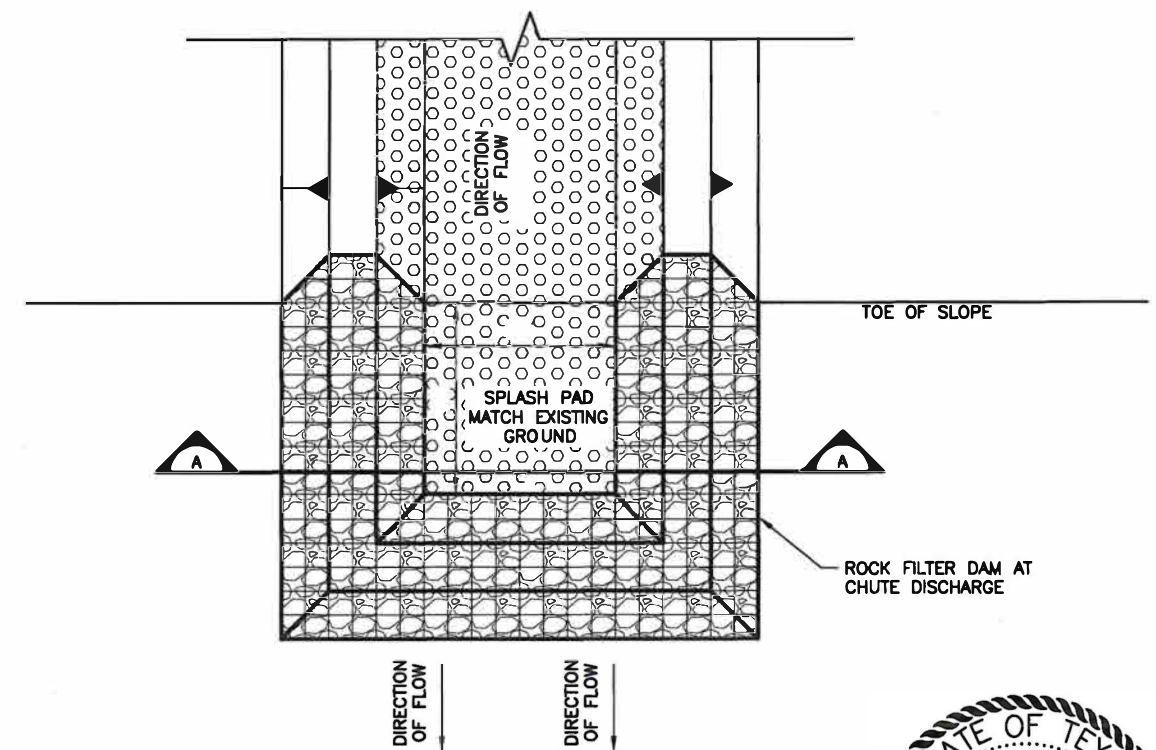


LOW WATER CROSSING LWC1 C3-28

NTS



SECTION AA



CHUTE DISCHARGE STRUCTURE CDS1 C3-28

NTS

NOTE: CHUTE 13 WILL INCLUDE A LOW WATER CROSSING DISCHARGE.

2/28/2025

PERIMETER ROAD
LOW WATER CROSSING

TEXOMA AREA SOLID WASTE AUTHORITY
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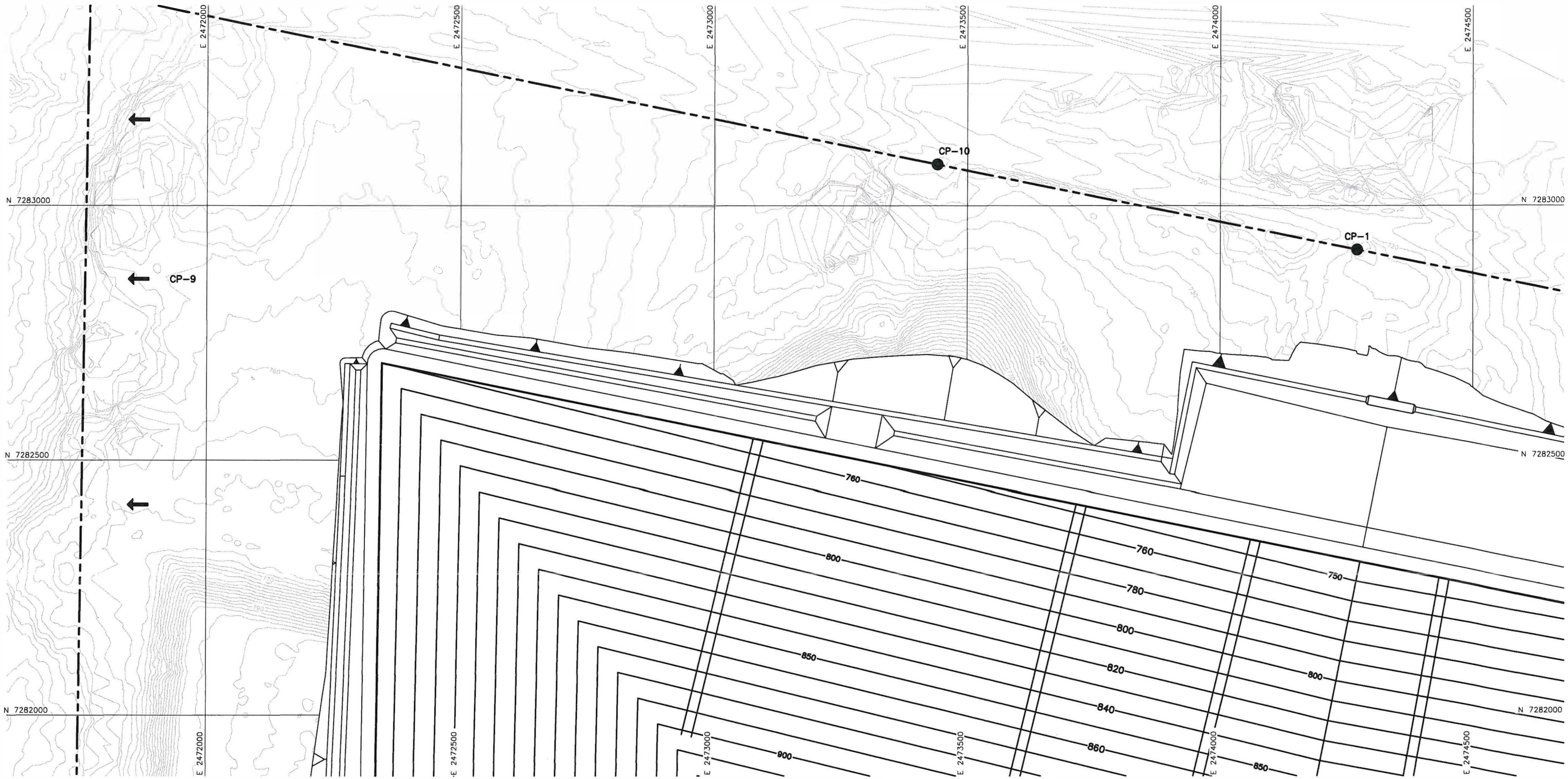
C3.28

O:\TASWA\P\Drawings\ATT C\C3-26thru28.dwg Layout: C3-28 User: owhite



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0 100 200
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- 700 EXISTING 10' GROUND CONTOUR
- 900 LANDFILL 10' CONTOUR
- DRAINAGE AREA BOUNDARY
- (DA01) DRAINAGE AREA DESIGNATION
- ● COMPARISON POINT-POINT DISCHARGE
- → FLOW DIRECTION

NOTE(S):

1. 7.5 MINUTE TOPOGRAPHIC BASE MAPS SADLER, TEX AND ETHEL, TEX DOWNLOADED FROM USGS WEBSITE ON FEBRUARY 10, 2022.
2. CONTOURS WITHIN LANDFILL FOOTPRINT DEPICT FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CP-1, CP-9 AND CP-10

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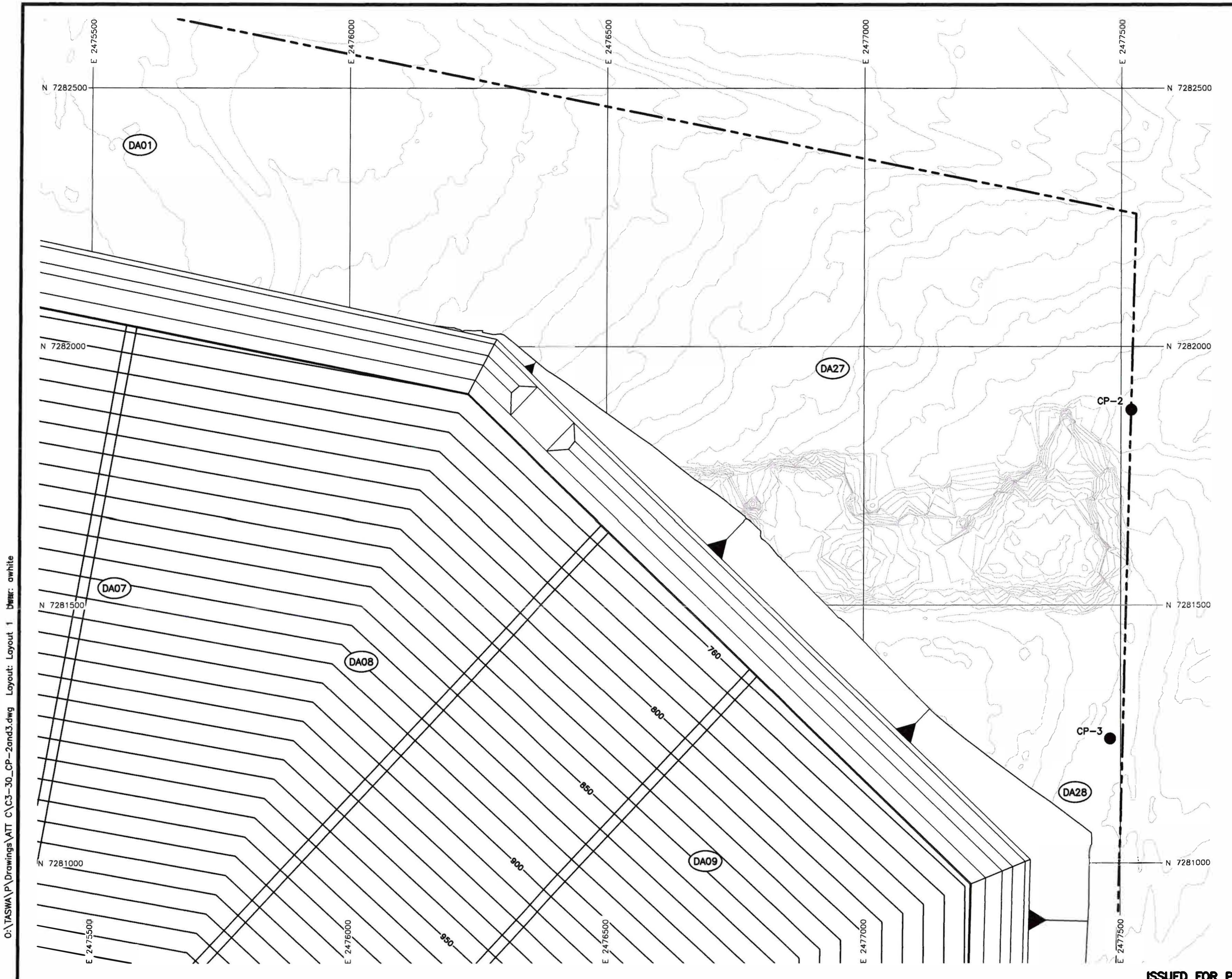
TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C3.29



LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- EXISTING 10' GROUND CONTOUR
- LANDFILL 10' CONTOUR
- DRAINAGE AREA BOUNDARY
- DA01 DRAINAGE AREA DESIGNATION
- COMPARISON POINT–POINT DISCHARGE
- FLOW DIRECTION

NOTE(S):

1. 7.5 MINUTE TOPOGRAPHIC BASE MAPS SADLER, TEX AND ETHEL, TEX DOWNLOADED FROM USGS WEBSITE ON FEBRUARY 10, 2022.
2. CONTOURS WITHIN LANDFILL FOOTPRINT DEPICT FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

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REVISIONS			
REV	DATE	DESCRIPTION	DWN BY

CP-2 AND CP-3

TEXOMA AREA SOLID WASTE AUTHORITY
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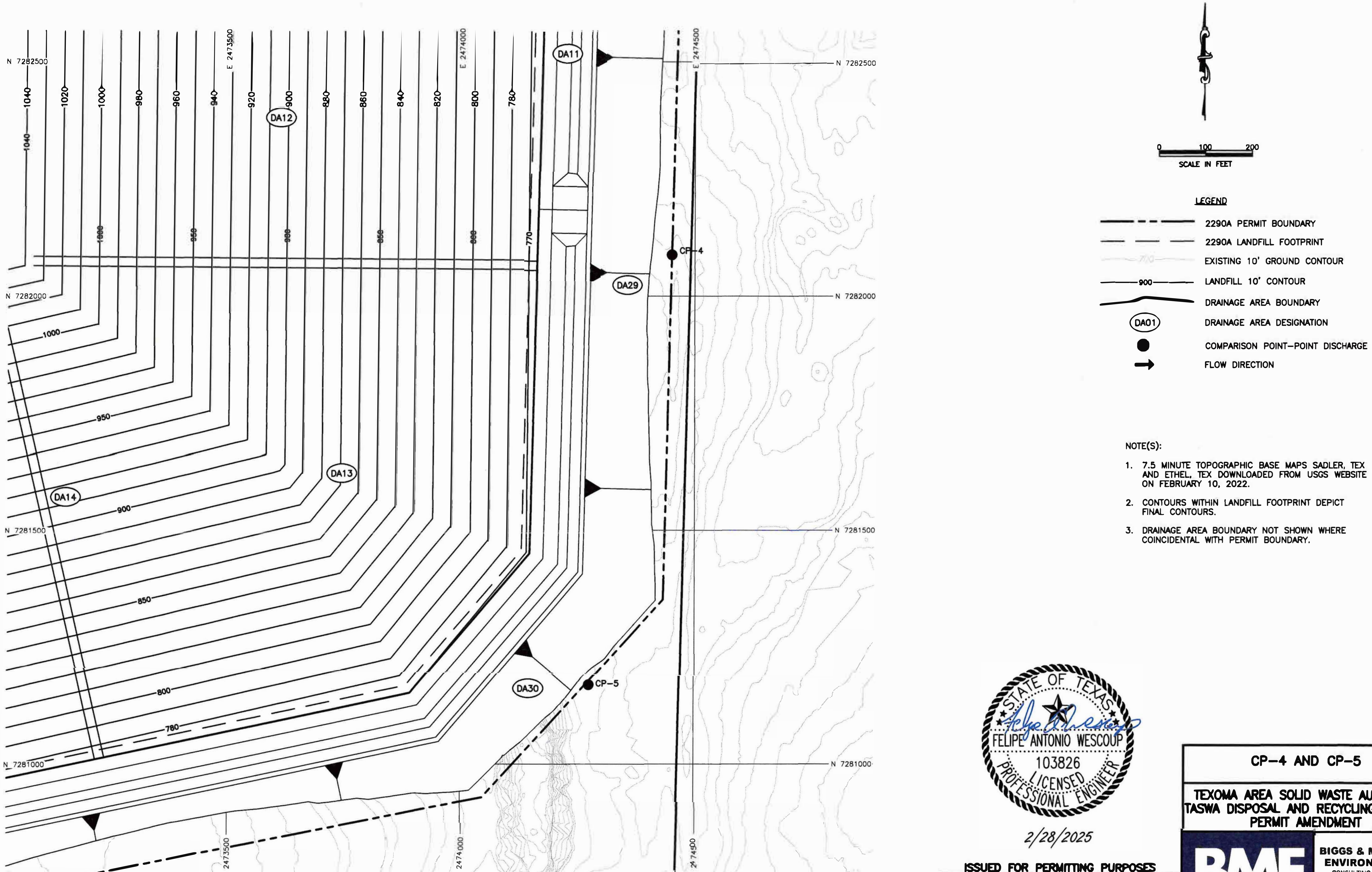
TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C3.30



NOTE(S):

1. 7.5 MINUTE TOPOGRAPHIC BASE MAPS SADLER, TEX AND ETHEL, TEX DOWNLOADED FROM USGS WEBSITE ON FEBRUARY 10, 2022.
2. CONTOURS WITHIN LANDFILL FOOTPRINT DEPICT FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

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REV	DATE	DESCRIPTION	DWN BY

CP-4 AND CP-5

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TBPG FIRM NO. 50222

C3.31

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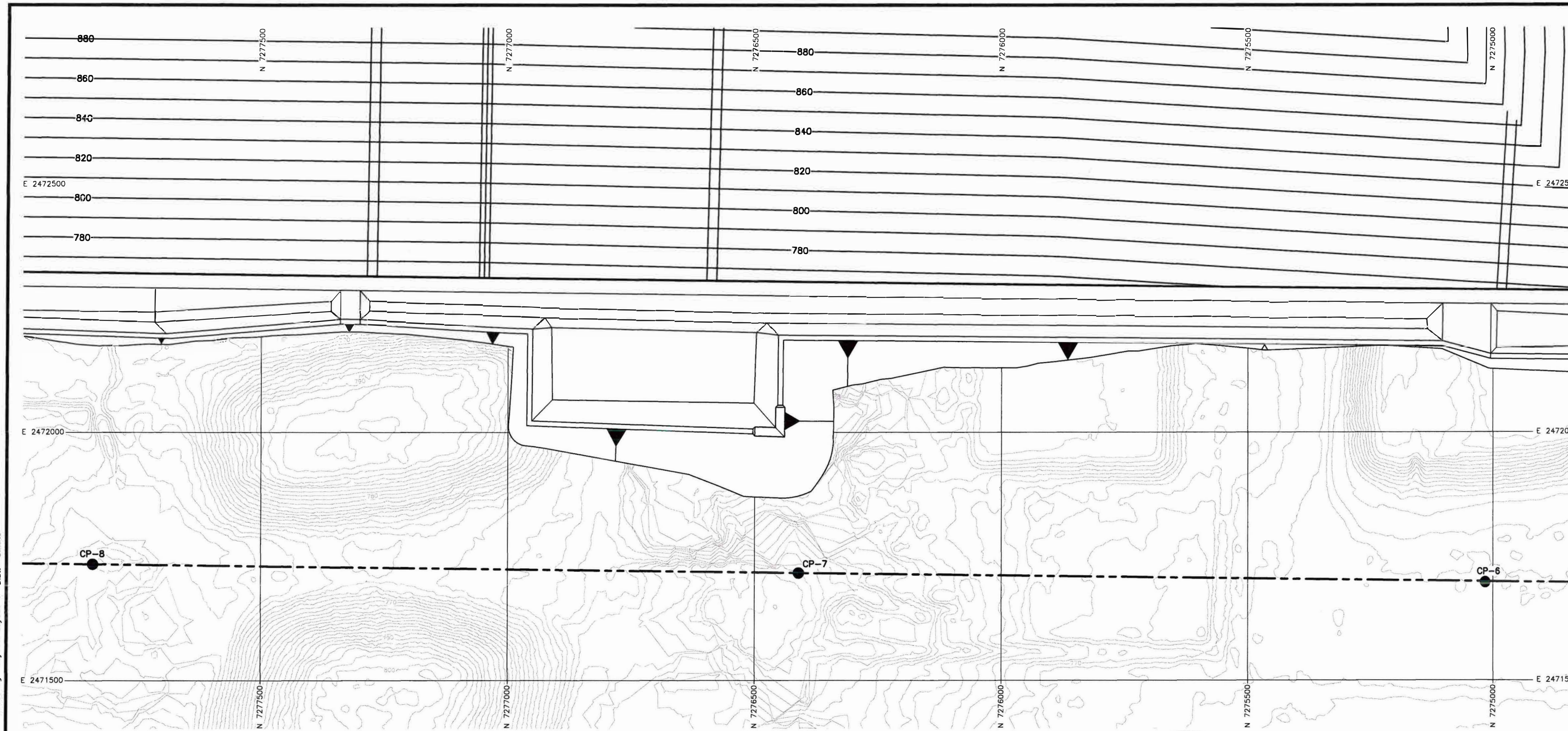

0 100 200
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- EXISTING 10' GROUND CONTOUR
- 900 LANDFILL 10' CONTOUR
- DRAINAGE AREA BOUNDARY
- DA01 DRAINAGE AREA DESIGNATION
- COMPARISON POINT-POINT DISCHARGE
- FLOW DIRECTION

NOTE(S):

1. 7.5 MINUTE TOPOGRAPHIC BASE MAPS SADLER, TEX AND ETHEL, TEX DOWNLOADED FROM USGS WEBSITE ON FEBRUARY 10, 2022.
2. CONTOURS WITHIN LANDFILL FOOTPRINT DEPICT FINAL CONTOURS.
3. DRAINAGE AREA BOUNDARY NOT SHOWN WHERE COINCIDENTAL WITH PERMIT BOUNDARY.

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REVISIONS

REV	DATE	DESCRIPTION	DWN BY

CP-6, CP-7, AND CP-8

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TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

C3.32

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TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT D
WASTE MANAGEMENT UNIT DESIGN

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

STATE OF TEXAS
DAVID L. CLARK
81905
LICENSED
PROFESSIONAL ENGINEER
2-28-25

Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

BIGGS & MATHEWS ENVIRONMENTAL
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CONTENTS

30 TAC §330.63(d)

1 WASTE MANAGEMENT UNIT DESIGN

30 TAC §330.63(d)(3)

The TASWA Disposal and Recycling Facility (TASWA DRF) is a Type I solid waste disposal and recycling facility.

Site Layout Plans are provided in Attachment D1.

Cross sections are provided in Attachment D2.

Construction Details are provided in Attachment D3.

Site Life calculations are provided in Attachment D4.

Geotechnical design calculations are provided in Attachment D5.

Leachate and Contaminated Water Management Plan is provided in Attachment D6.

Liner Quality Control Plan is provided in Attachment D7.

Final Cover Quality Control Plan is provided in Attachment D8.

2 MATERIAL STAGING AREAS

30 TAC §330.63(d)(4)(B)

The material staging areas have been designed for the rapid processing and minimum detention of solid waste at the facility. Solid waste capable of creating public health hazards or nuisances will be transferred promptly and will not be allowed to result in nuisances or public health hazards. The material staging areas have been designed to control and contain a worst-case spill or release from the units and the unenclosed areas associated with the staging areas, and account for precipitation from the 25-year, 24-hour rainfall event. The material staging areas may include the large item staging area, reusable materials staging area, citizen's convenience area, and clean wood staging area as noted on Attachment D1, Drawing D1.1.

2.1 Large Item Staging Area

A staging area for large items and white goods may be provided near the active working face or may be provided at the citizen's convenience center. Large items and white goods include ovens, dishwashers, freezers, air conditioners, scrap metal and other large items. Typically, large items and white goods are received in source-separated loads. Should large items or white goods be received in mixed loads, they will be removed from the active face and staged on the ground near the active working face, or citizen's convenience center. The large items and white goods are unloaded and then transferred into steel roll-off containers or designated areas at the citizen's convenience center for storing until transport to an off-site recycler. The roll-off containers, if used for storage, will be covered with tarps to prevent rainfall from accumulating inside the containers and to prevent generation of contaminated water. The elimination of contaminated water within the roll-off containers will limit the potential for generating odors within the area. These items may be recycled to prevent a nuisance and to preclude discharge, but will not be stored in excess of 180 days. Large items that are not recycled will be disposed of at the working face.

The large item staging area, when located within the waste disposal footprint will be placed only over areas that have received intermediate cover. Surface water runoff will be diverted around the storage area. Surface water from the large item staging area will be contained by containment and diversion berms consistent with Attachment D6.

2.2 Reusable Materials Staging Area

Inert materials such as brick, concrete, etc., and non-inert materials such as asphalt may be stockpiled for use on facility access roads and staging areas or for erosion control in drainage structures. Asphalt will not be used for erosion control in drainage structures. The reusable materials staging area will be located within the waste disposal footprint and will be relocated periodically as the active working face moves. The size of the stockpiles may vary depending on the amount of materials received at any given time. Since the brick and concrete materials are inert, run-on and runoff from rainfall will not be controlled in a special manner and odor control measures are not required for these materials. Since asphalt is not an inert material, it will be managed in a manner that will prevent runoff of contaminated water, discharge of waste, or the creation of nuisance conditions. These inert and non-inert materials will continuously be reused for site operations, and there is no time limit on the storage of these materials.

2.3 Citizen's Convenience Center

A citizen's convenience center for waste drop-off will be located within the site entrance facilities. General construction details of the Citizen's Convenience Center are provided in Attachment B, Drawing B.3. Roll-off containers, as well as containers for recycled goods, may be provided. Containers with waste will be emptied at the active working face at the end of each day minimizing the potential for odors. Recycle containers will periodically be transported to an appropriate recycling facility. Large items and white goods may be stored at the citizen's convenience center and will be periodically transported to an appropriate recycling facility.

2.4 Woodwaste/Brush Mulching Area

The woodwaste/brush mulching area, if utilized, will be located within the landfill footprint and will process incoming yard trimmings, clean wood materials and vegetative materials, including trees and brush, into wood chips and mulch. The wood chips and mulch will be stored in small piles and will be managed to prevent fire, safety, or health hazards in accordance with 30 TAC §330.209(a).

3 LANDFILL UNITS

30 TAC §§330.63(d)(4) and 330.457

The landfill unit's design includes all weather operation, landfilling methods, landfill design parameters, site life projection, landfill cross sections, and the liner and final cover quality control plans.

3.1 All Weather Operation

The landfill perimeter roads, haul road, and access roads will be constructed of crushed stone, gravel, or other suitable materials to provide access to the disposal areas during all weather conditions. To enhance operating efficiency, a disposal area close to the all-weather roads may be reserved for wet weather operations. The wet weather area will move as operations progress.

The perimeter road will be constructed outside the landfill footprint in the buffer zone. The construction and maintenance of the perimeter road will not disturb the integrity and function of the final cover, liner, or any monitoring system.

Site personnel will maintain the landfill access roads for all weather access. Stockpiles of crushed stone, gravel, or other similar material will be available for use in maintaining access roads. Grading equipment or other appropriate equipment will be used as necessary to control or remove mud accumulations on the landfill access roads around the landfill and the landfill entrance road.

Tracking of mud onto public access roads will be minimized by the all-weather surfaces of the interior access roads and the landfill entrance road.

3.2 Landfilling Methods

The development method for the landfill is a combination of area-excavation fill followed by aerial fill to the proposed landfill completion grades. Final cover placement will generally follow the sequence of development as shown on Drawing D1.1 and will be ongoing as the site is developed. The landfill will be closed according to the closure plan provided in Attachment H.

3.3 Landfill Design Parameters

The deepest excavations, maximum waste, and final cover heights are summarized below.

Landfill Design Parameters

	2290A Condition
Maximum Elevation of Final Cover (msl)	1106.7 ft
Maximum Waste Elevation (ft-msl)	1102.2 ft
Elevation of Deepest Excavation (msl)	663.9 ft

Excavation side slopes and waste side slopes will not exceed 4H:1V. Waste top slopes will not exceed 4 percent. Excavation and final completion plans are presented in Attachment D1.

3.4 Site Life Projection

The total disposal capacity will be approximately 183.5 million cubic yards (waste and daily cover), which will provide an estimated 92 years of site life. Calculations and assumptions for the remaining disposal capacity and site life estimate are included in Attachment D4.

3.5 Landfill Cross Sections

Cross sections of the landfill unit are provided in Attachment D2. These sections show the top of the proposed fill (top of the final cover), maximum elevation of the proposed fill, top of the wastes, existing ground, bottom of the excavations, side slopes of excavations, groundwater monitoring wells, and the initial and static levels of any water encountered. Soil borings, monitoring wells, and gas monitoring probes near the sections have been projected onto the sections. The section locations were selected to represent typical conditions across the site.

3.6 Liner Quality Control Plan

Quality control plans for liner systems prepared in accordance with §330.339 are provided in Attachment D7. Details of the liner systems are provided in Attachment D3.

3.7 Final Cover Quality Control Plan

Quality control plans for the final cover systems are provided in Attachment D8. Details of the final cover systems are provided in Attachment D3.

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN

ATTACHMENT D1
SITE LAYOUT PLANS

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

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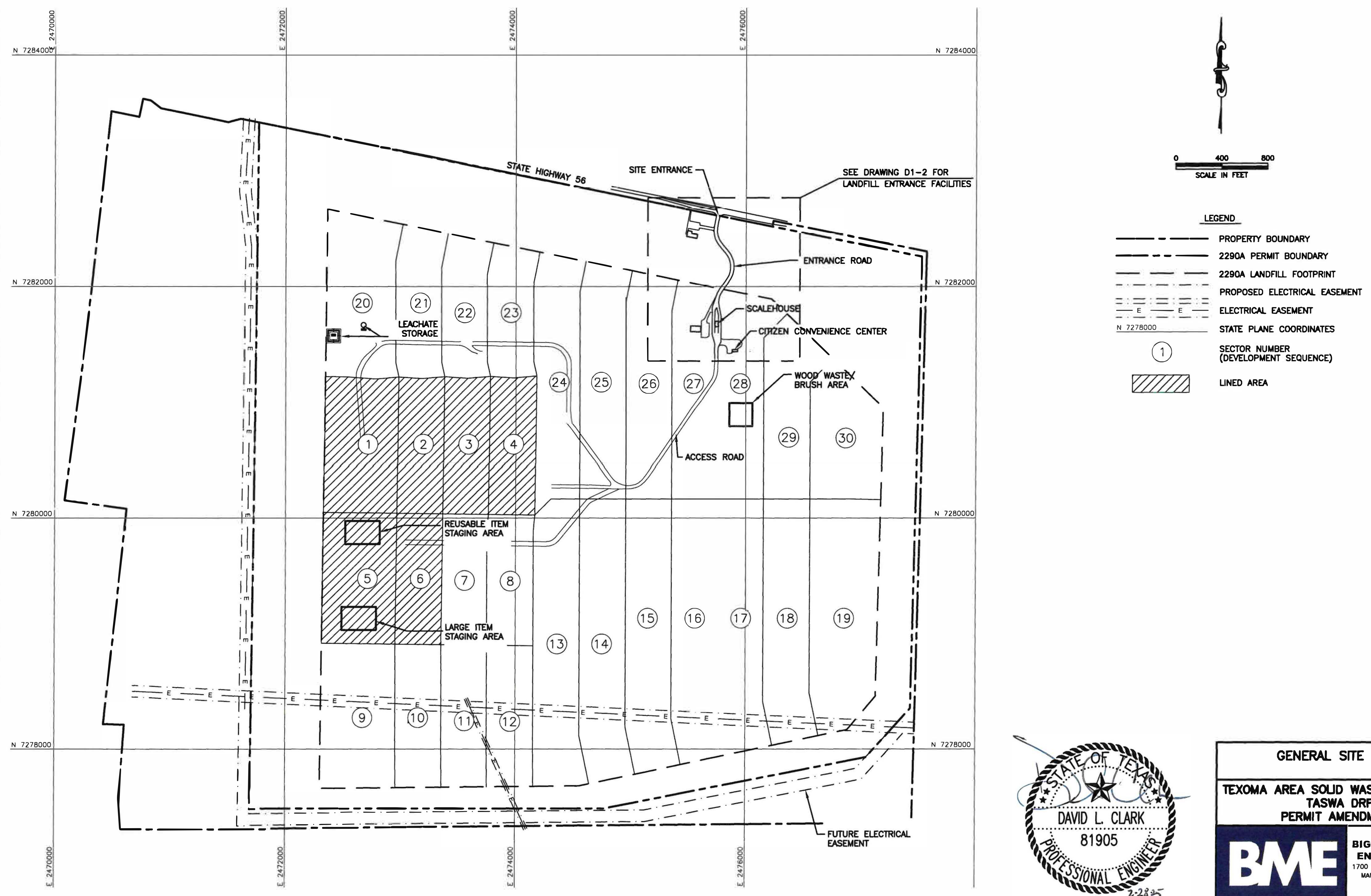

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GENERAL SITE PLAN

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
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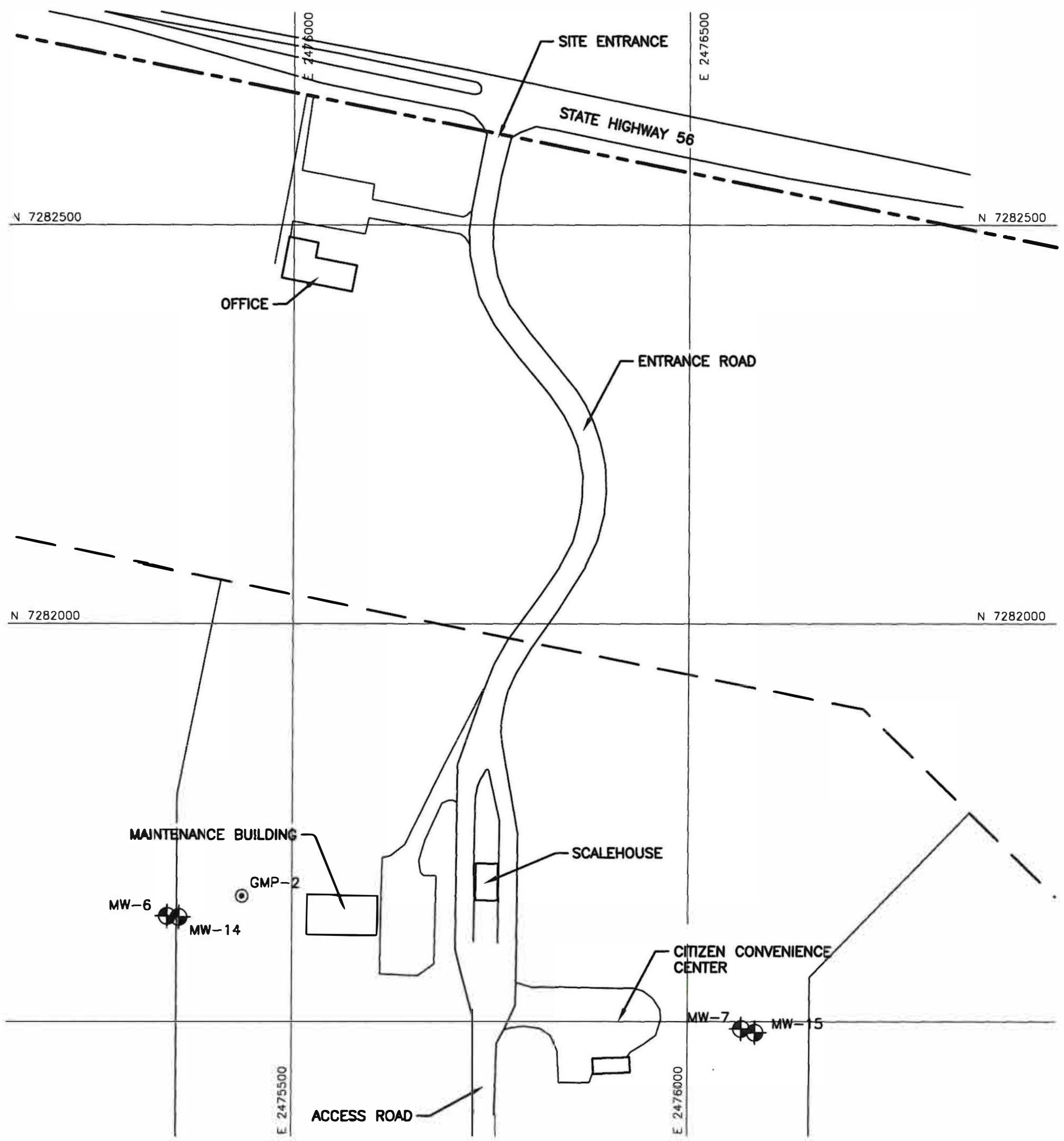
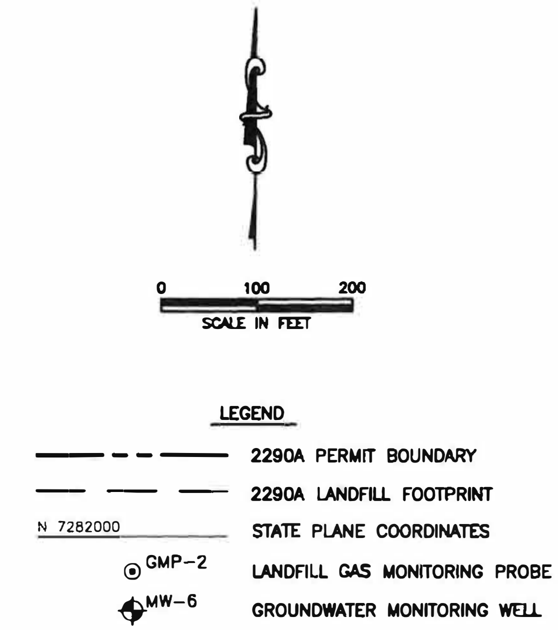
TBPG FIRM NO. 50222

DRAWING
D1.1





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LANDFILL ENTRANCE FACILITIES

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DRAWING
D1.2

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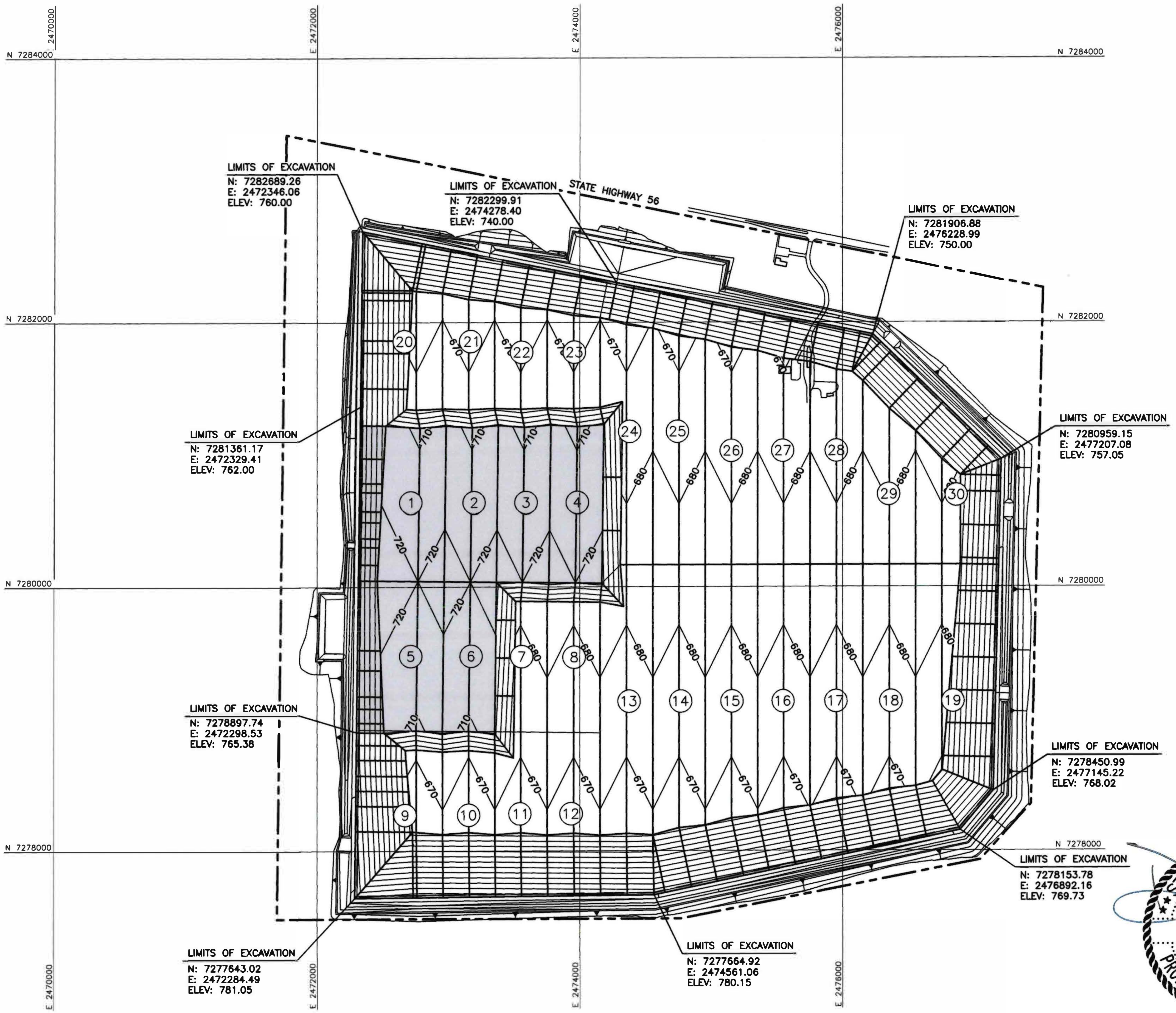

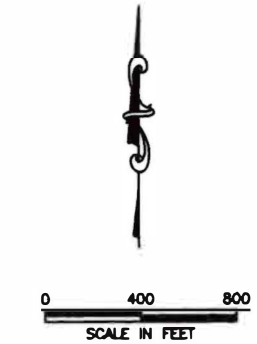

LEGEND

	2290A PERMIT BOUNDARY
	2290A LANDFILL FOOTPRINT
N 7279000	STATE PLANE COORDINATES
	LINED AREA
670	EXCAVATION CONTOUR
(10)	SECTOR NUMBER (DEVELOPMENT SEQUENCE)

NOTES:

1. ELEVATION OF DEEPEST EXCAVATION IS 663.9 FT-MSL.
2. SECTORS 1–6 HAVE BEEN LINED AND RECEIVED WASTE FILL.

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EXCAVATION PLAN

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DRAWING
D1.3

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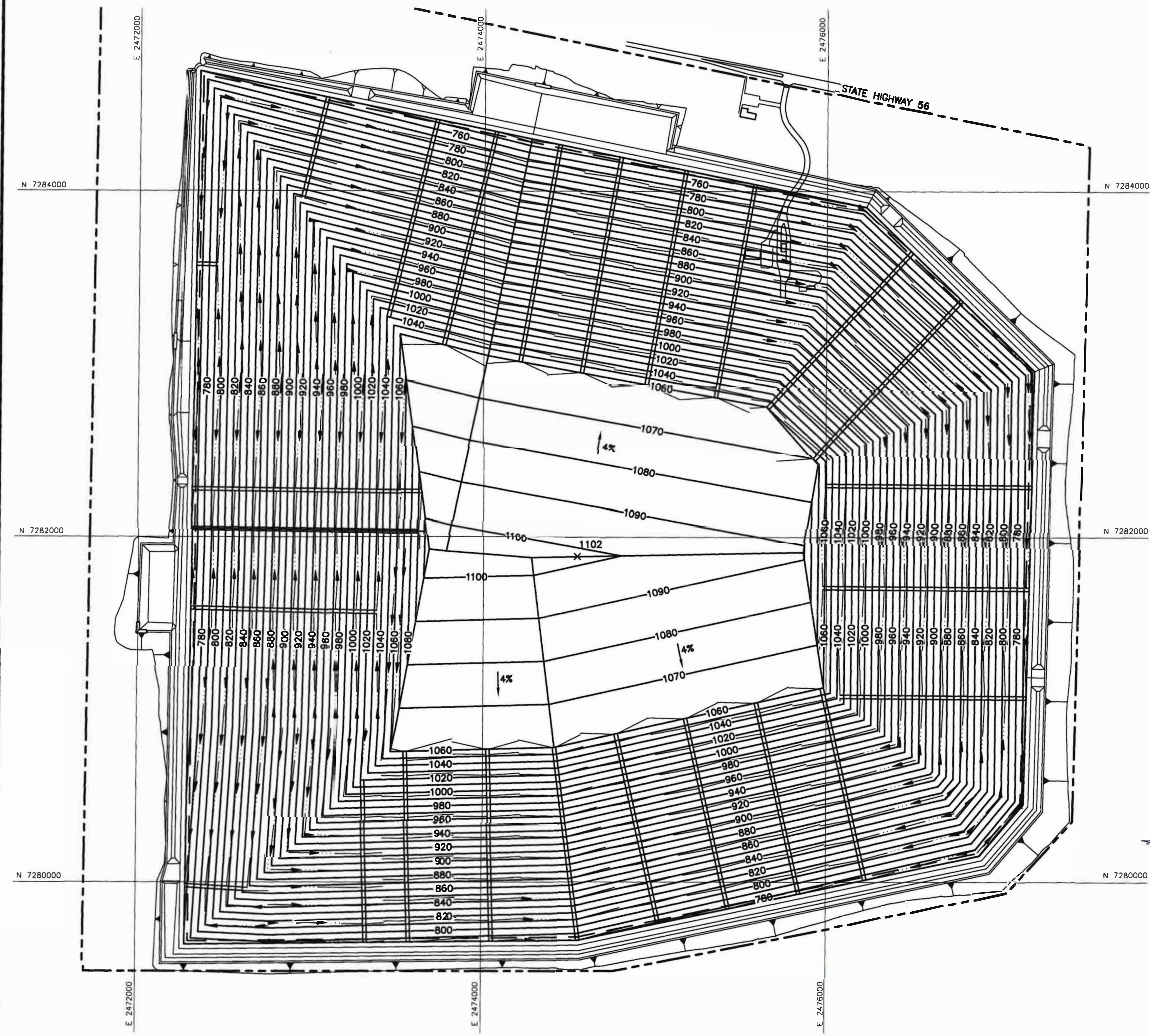

0 300 600
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- N 7279000 STATE PLANE COORDINATES
- 1000 FINAL COVER CONTOUR
- SWALE
- LETDOWN CHUTE

NOTES:

1. PROPOSED CONTOURS DEPICT TOP OF FINAL COVER GRADES.
2. MAXIMUM FINAL COVER ELEVATION = 1106.7 FT-MSL.
3. MAXIMUM TOP OF WASTE ELEVATION = 1102.2 FT-MSL.

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LANDFILL COMPLETION PLAN

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TASWA DRF
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TBPG FIRM NO. 50222

DRAWING
D1.4

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TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

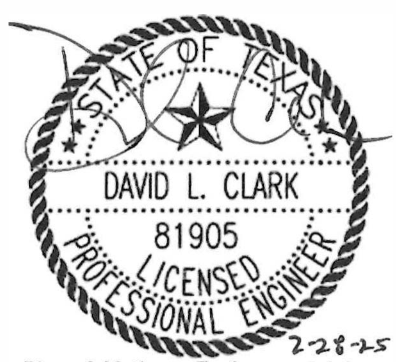
PART III – FACILITY INVESTIGATION AND DESIGN

ATTACHMENT D2
CROSS SECTIONS

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025



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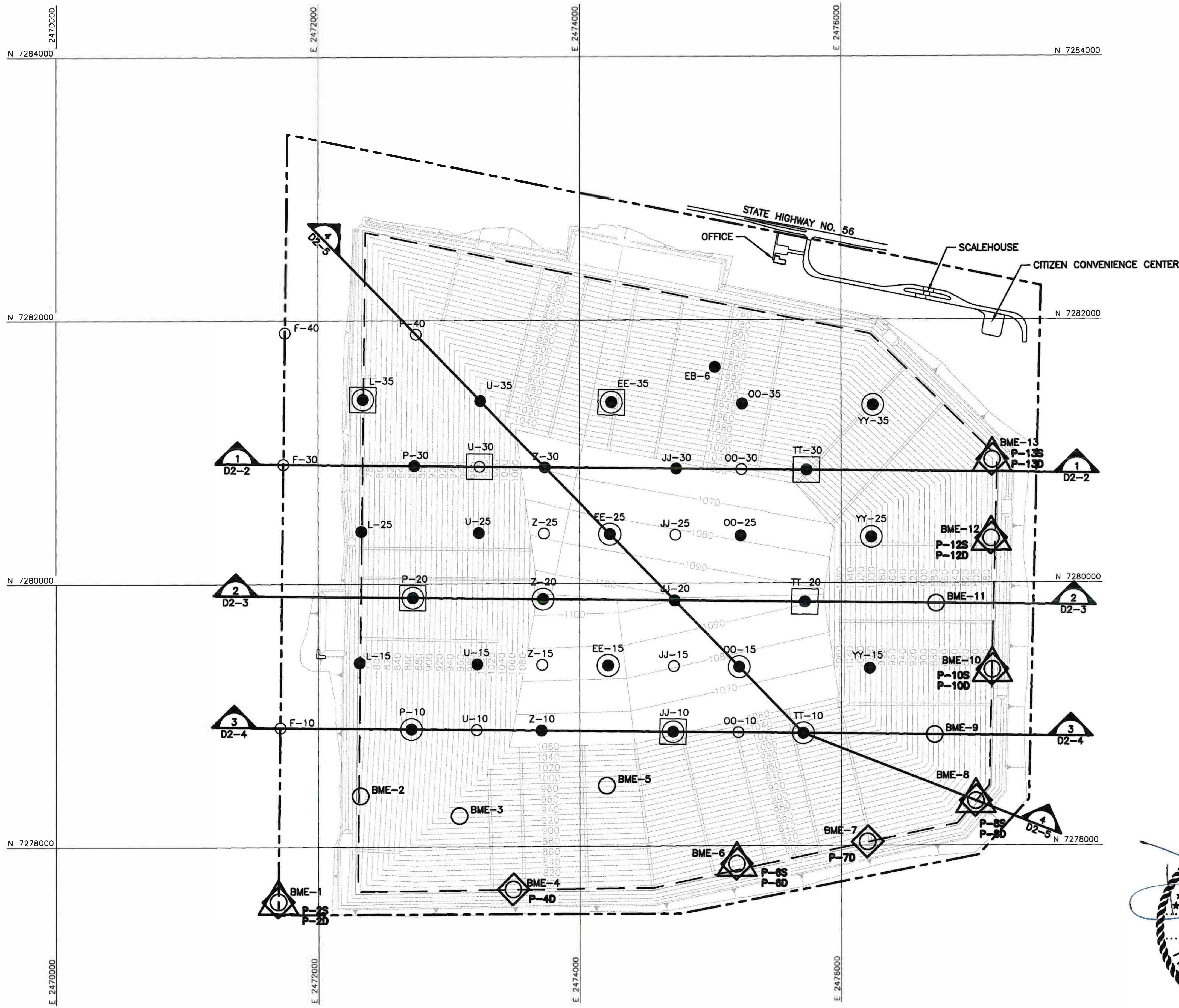

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SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- 750 FINAL COVER CONTOUR
- N 7279000 STATE PLANE COORDINATES
- JJ-30 HISTORICAL BORINGS > 30' BELOW EDE
- Z-25 HISTORICAL BORINGS > 5' BELOW EDE
- WOODBINE PIEZOMETERS
- SHALE PIEZOMETERS
- EXISTING MONITORING WELL
- BME-3 NEW BORING > 30' BELOW EDE
- P-10D NEW LAYER V PIEZOMETER
- P-10S NEW LAYER II/III PIEZOMETER

NOTES:

1. CONTOURS DEPICT TOP OF FINAL COVER GRADES.

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CROSS SECTION LOCATION MAP

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DRAWING
D2.1

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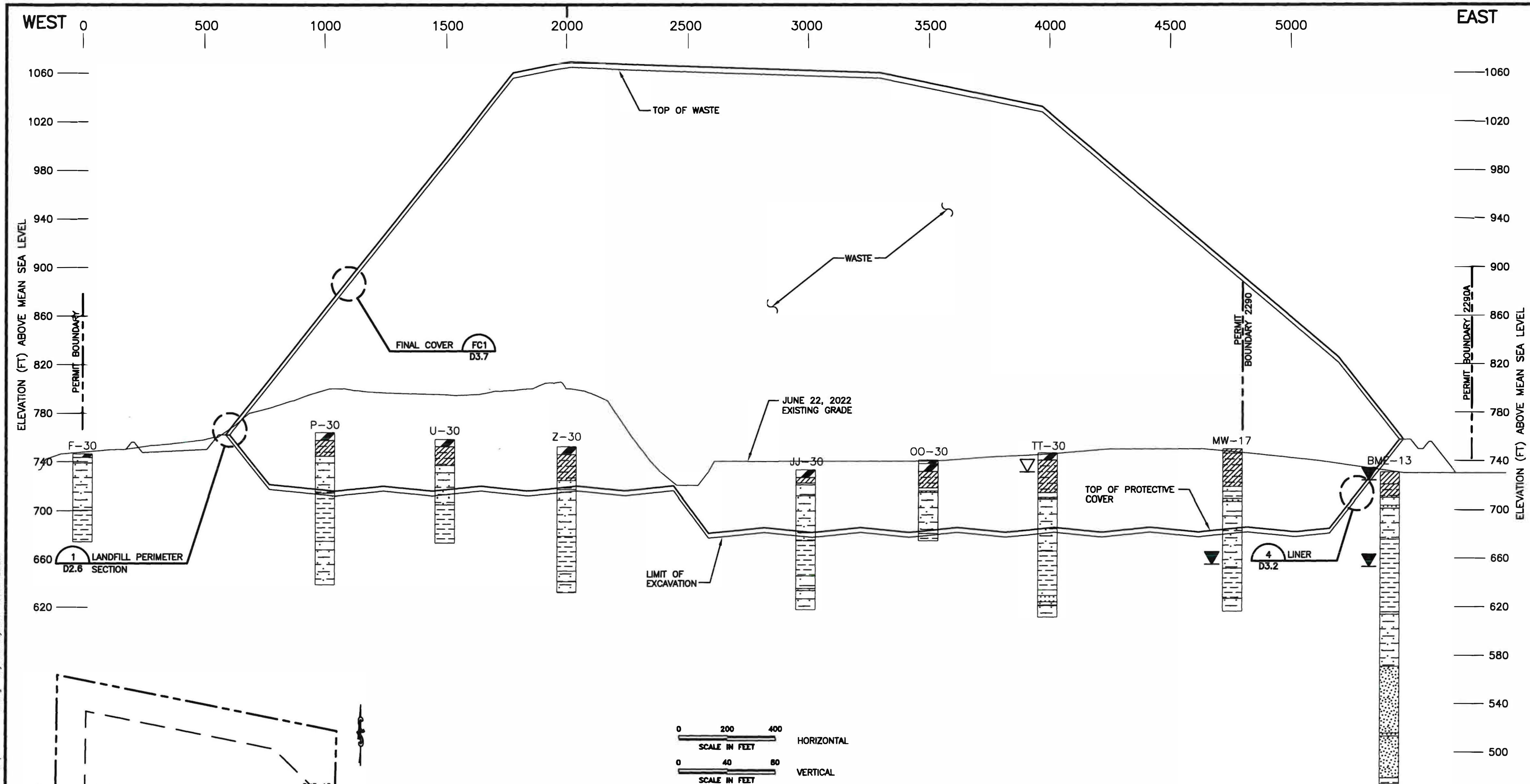

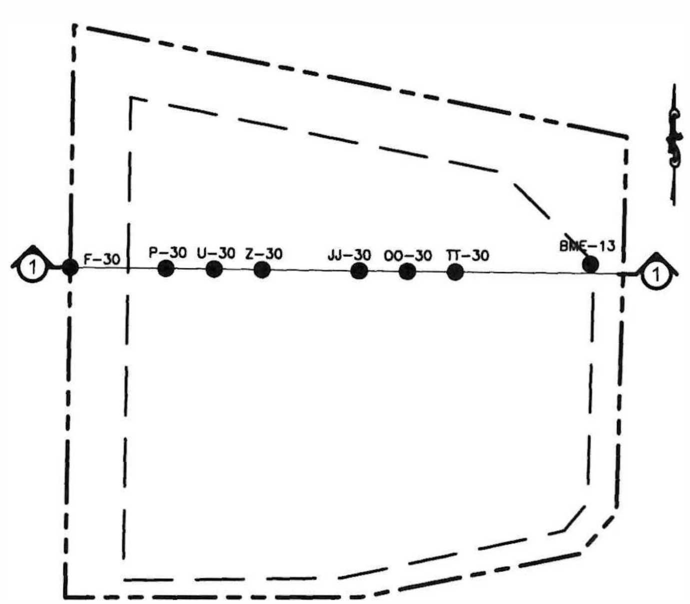

KEY MAP

0 200 400
SCALE IN FEET
HORIZONTAL

0 40 80
SCALE IN FEET
VERTICAL

LEGEND

- CLAY
- SHALY CLAY
- SHALY SAND
- SHALE W/ SAND
- SHALE
- SANDSTONE
- GROUNDWATER LEVEL ON JUNE 29, 2000
- GROUNDWATER LEVEL ON JULY 29, 2022

NOTES:

1. CROSS SECTION LOCATION MAP IS FIGURE D2-1.
2. BOREHOLES DRILLED WITH MUD ROTARY. STABLE WATER LEVELS SHOWN ARE FROM THE INSTALLED WATER LEVEL PIEZOMETER OR ESTABLISHED MONITORING WELL.

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CROSS SECTION 1

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TBPG FIRM NO. 50222

DRAWING
D2.2

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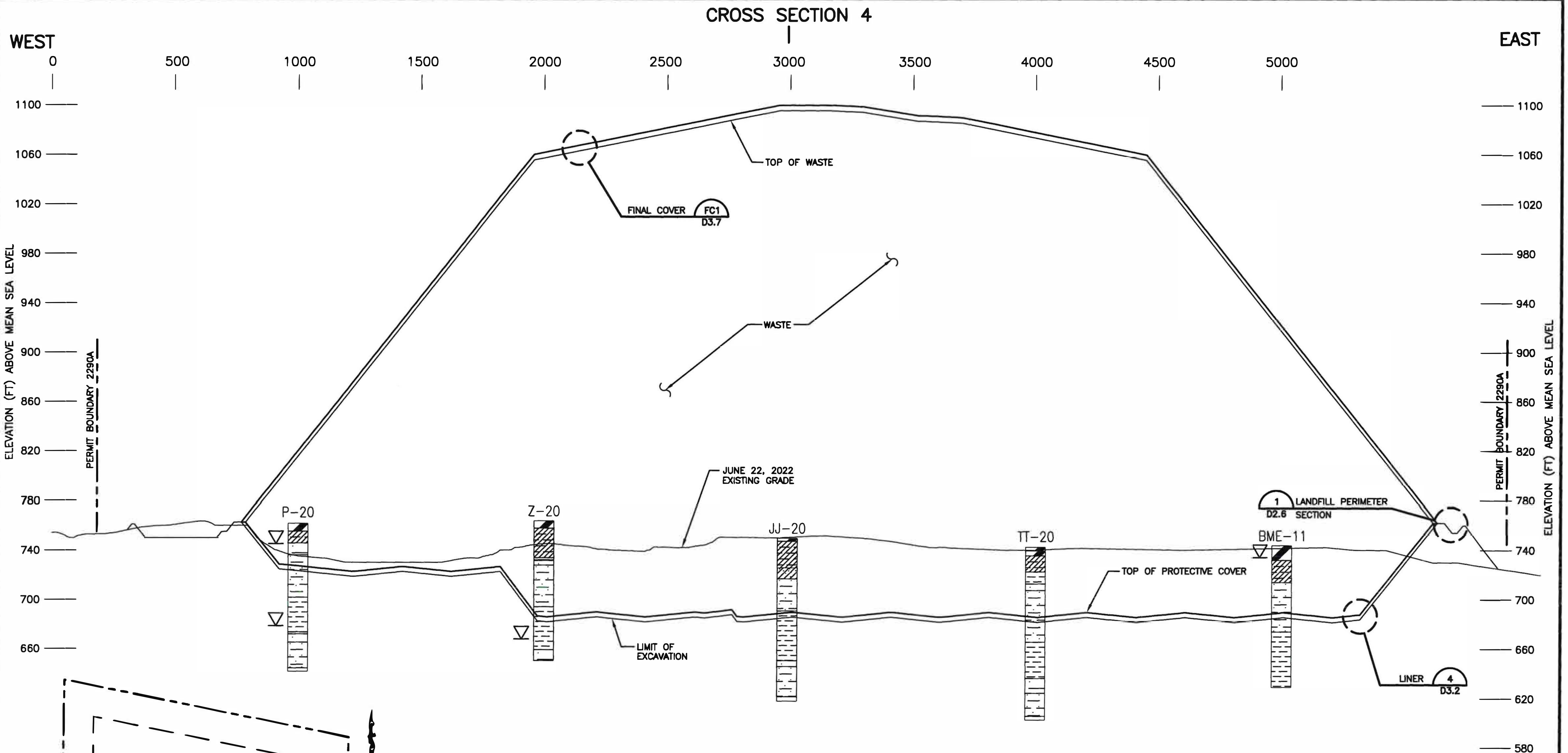

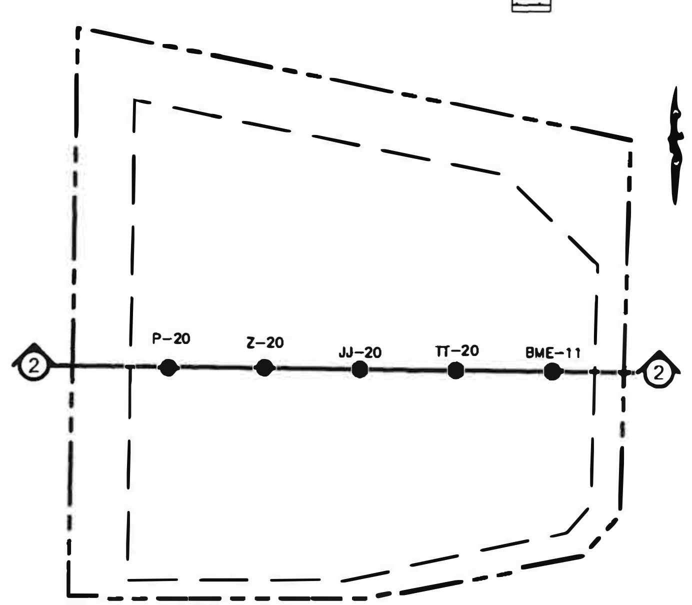

KEY MAP

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SCALE IN FEET
HORIZONTAL

0 40 80
SCALE IN FEET
VERTICAL

LEGEND

CLAY	SHALE W/ SAND
SHALY CLAY	SHALE
SANDY CLAY	SANDSTONE
SHALY SAND	GROUNDWATER LEVEL ON JUNE 29, 2000

NOTES:

1. CROSS SECTION LOCATION MAP IS FIGURE D2-1.
2. BOREHOLES DRILLED WITH MUD ROTARY. STABLE WATER LEVELS SHOWN ARE FROM THE INSTALLED WATER LEVEL PIEZOMETER OR ESTABLISHED MONITORING WELL.

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CROSS SECTION 2

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TBPG FIRM NO. 50222

DRAWING
D2.3

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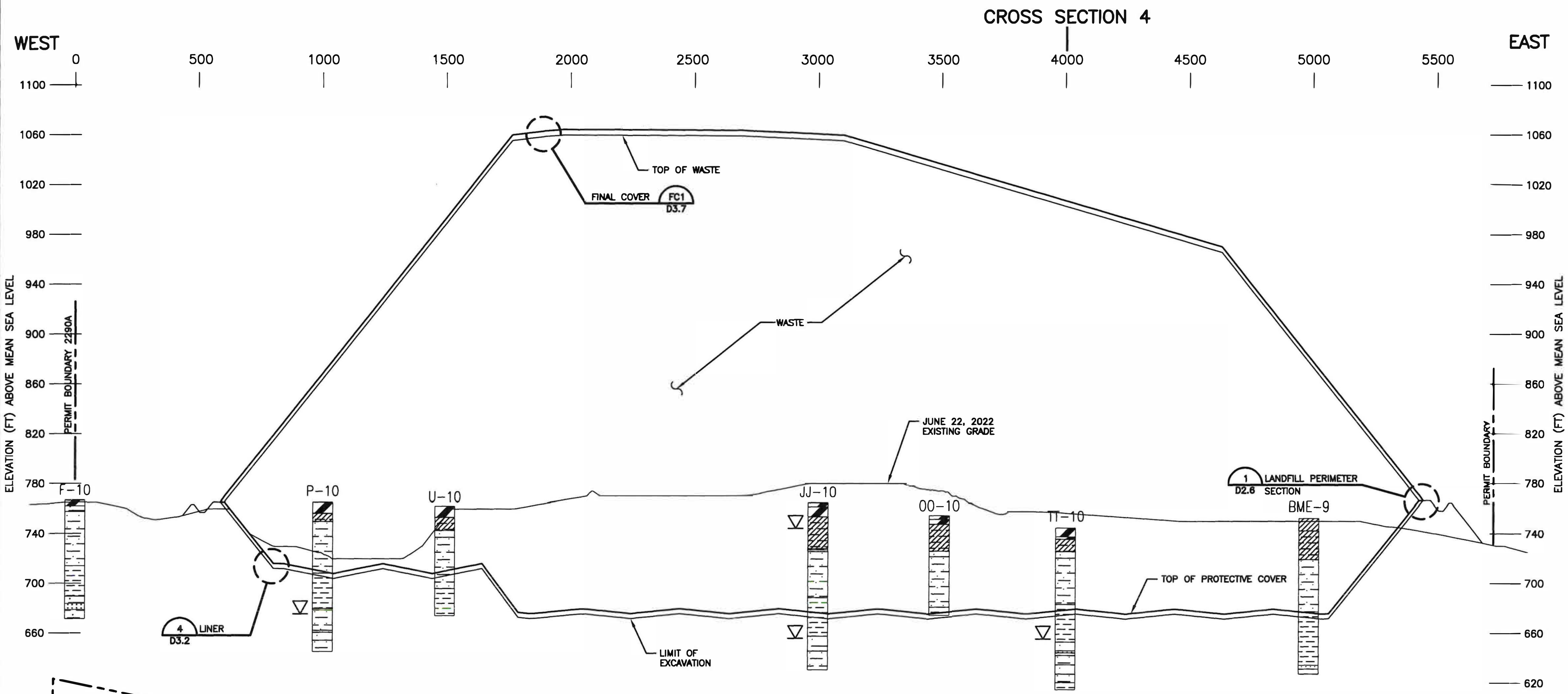

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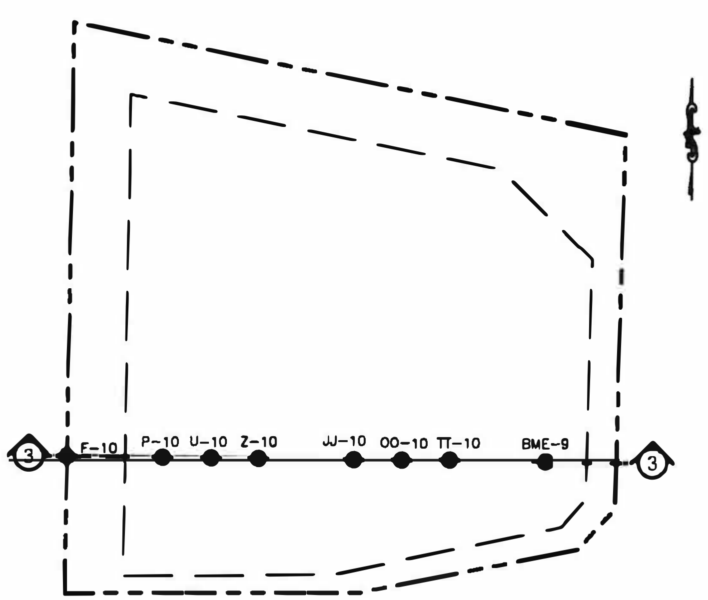
0 40 80
SCALE IN FEET
VERTICAL



KEY MAP

LEGEND

- CLAY
- SHALY CLAY
- SHALY SAND
- SHALE W/ SAND
- SHALE
- SANDSTONE
- SANDSTONE W/ SHALE
- GROUNDWATER LEVEL ON JUNE 29, 2000

NOTES:

1. CROSS SECTION LOCATION MAP IS FIGURE D2-1.
2. BOREHOLES DRILLED WITH MUD ROTARY. STABLE WATER LEVELS SHOWN ARE FROM THE INSTALLED WATER LEVEL PIEZOMETER OR ESTABLISHED MONITORING WELL.

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CROSS SECTION 3

TEXOMA AREA SOLID WASTE AUTHORITY
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DRAWING
D2.4

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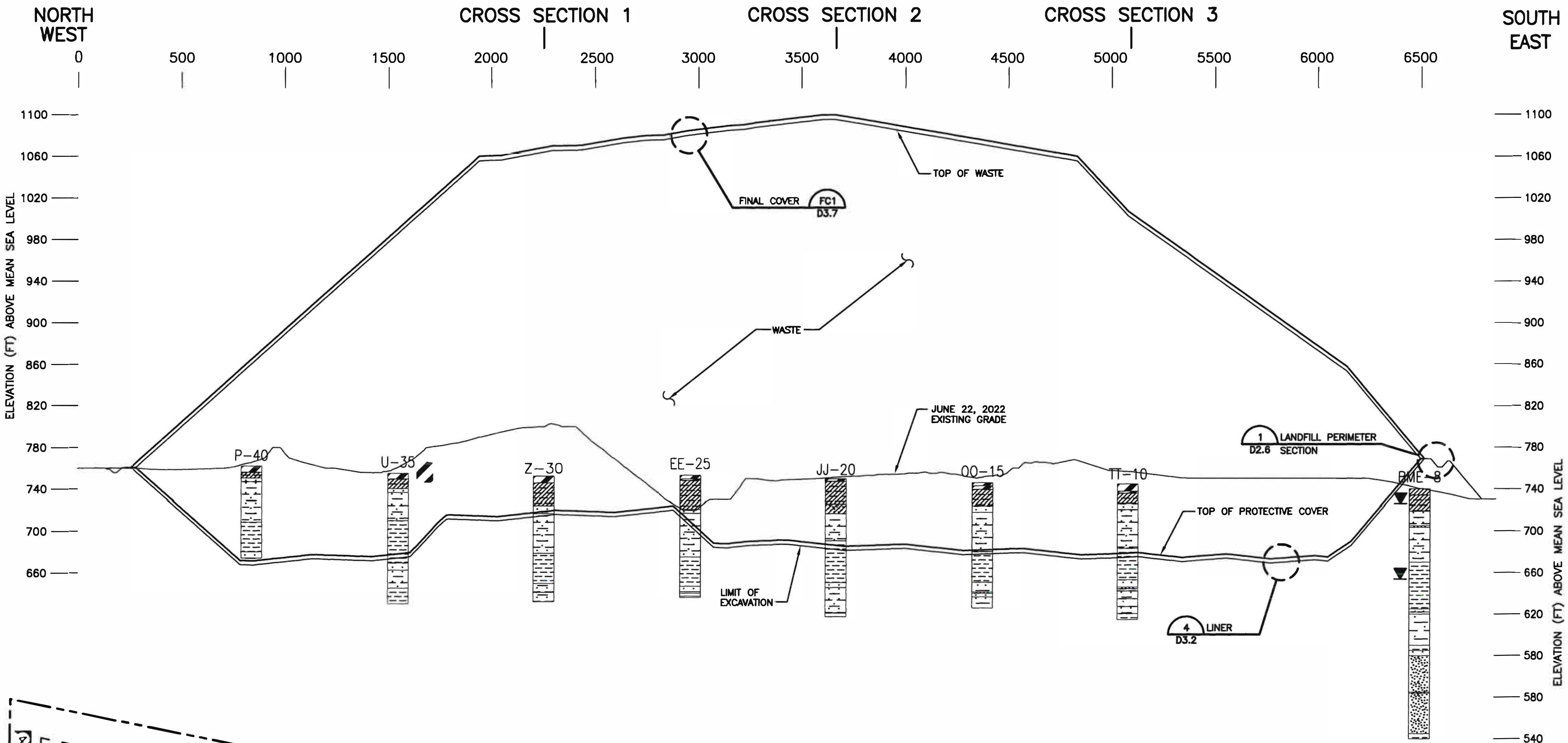

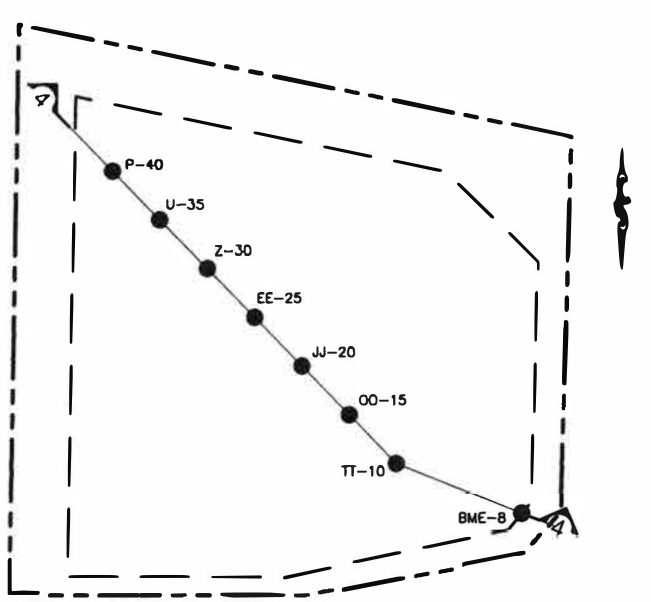

KEY MAP

0 250 500
SCALE IN FEET
HORIZONTAL

0 50 100
SCALE IN FEET
VERTICAL

LEGEND

- CLAY (CH)
- CLAY (CL)
- SHALY CLAY
- SANDY CLAY
- SHALY SAND
- SHALE W/ SAND
- SHALE
- SANDSTONE
- GROUNDWATER LEVEL ON JULY 29, 2022

NOTES:

1. CROSS SECTION LOCATION MAP IS FIGURE D2-1.
2. BOREHOLES DRILLED WITH MUD ROTARY. STABLE WATER LEVELS SHOWN ARE FROM THE INSTALLED WATER LEVEL PIEZOMETER OR ESTABLISHED MONITORING WELL.

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CROSS SECTION 4

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DRAWING
D2.5

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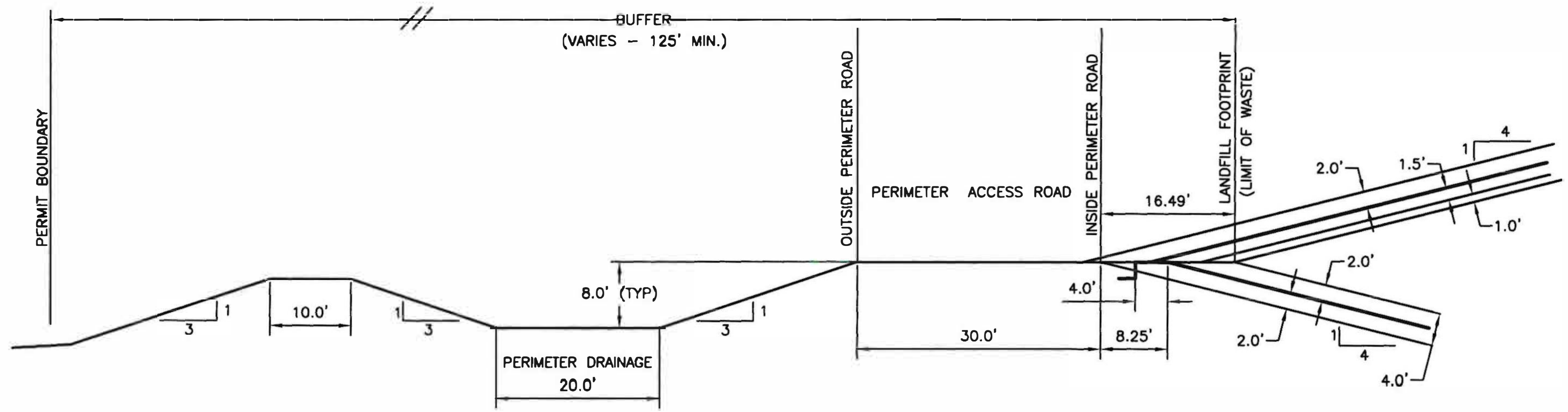

LANDFILL PERIMETER SECTION 1 D2.6

0 10 20
SCALE IN FEET

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LANDFILL PERIMETER SECTION

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TBPG FIRM NO. 50222

DRAWING
D2.6

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TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN

ATTACHMENT D3
CONSTRUCTION DESIGN DETAILS

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

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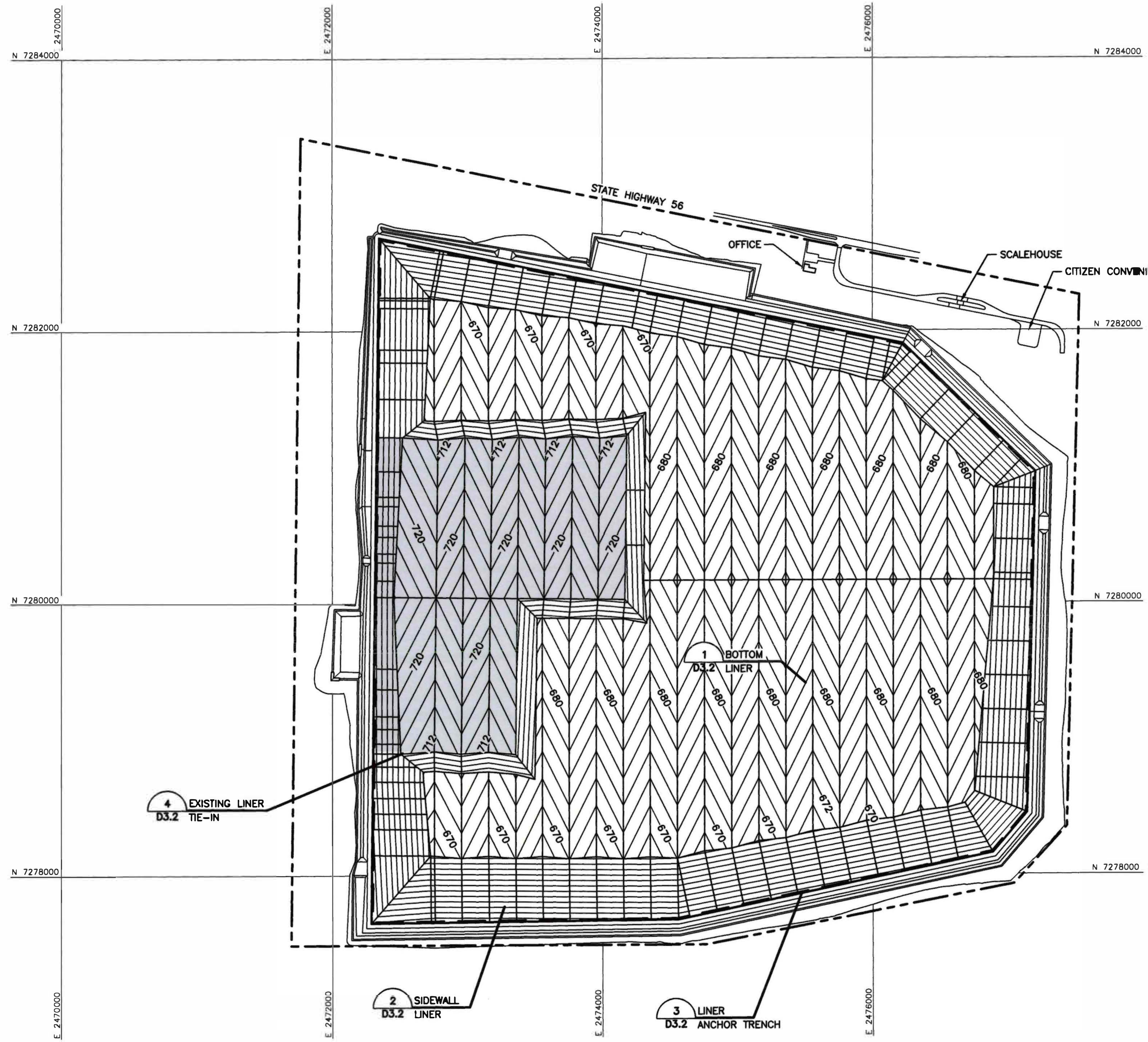

0 400 800
SCALE IN FEET

LEGEND

2290A PERMIT BOUNDARY

2290A LANDFILL FOOTPRINT

N 7279000 STATE PLANE COORDINATES

LINED AREA

670 LINER CONTOUR

(17) SECTOR NUMBER (DEVELOPMENT SEQUENCE)

NOTES:

1. SECTORS 1-6 HAVE BEEN LINED AND RECEIVED WASTE FILL.

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2-28-25

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LINER PLAN

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

BME

BIGGS & MATHEWS ENVIRONMENTAL
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MANSFIELD, TEXAS 76063
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
D3.1

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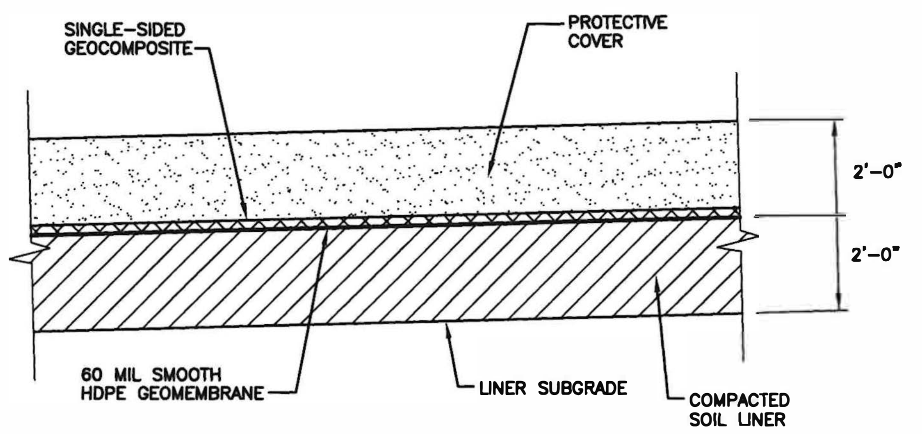
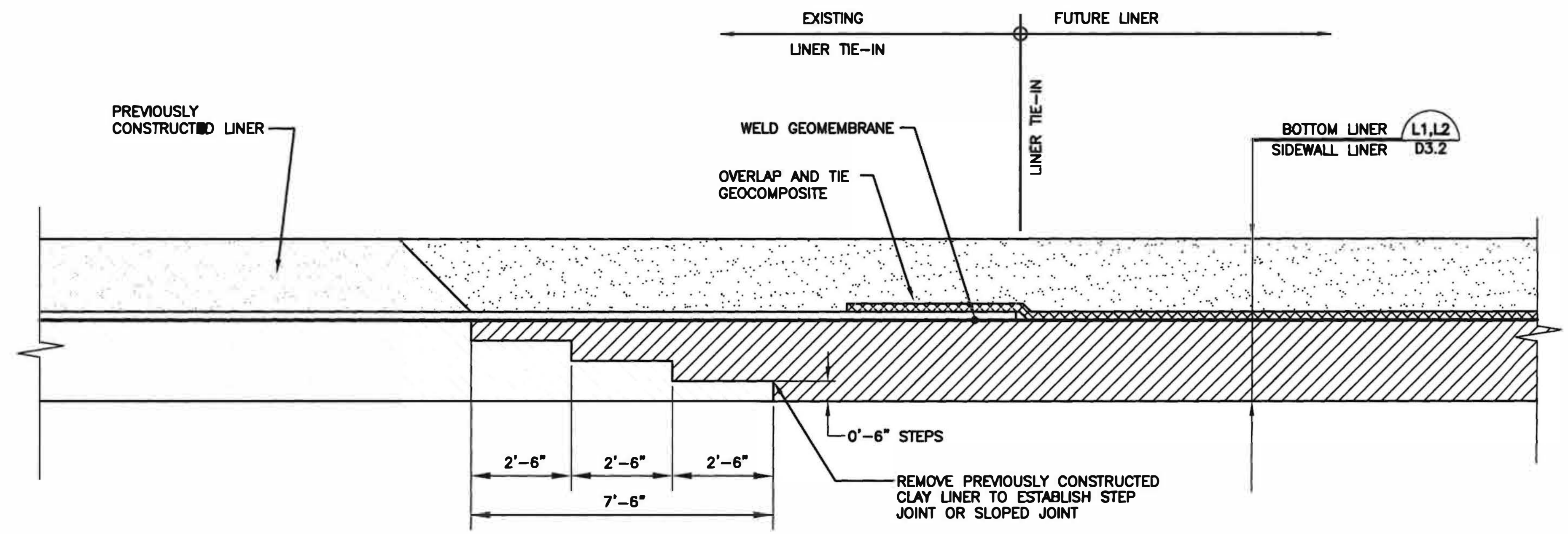


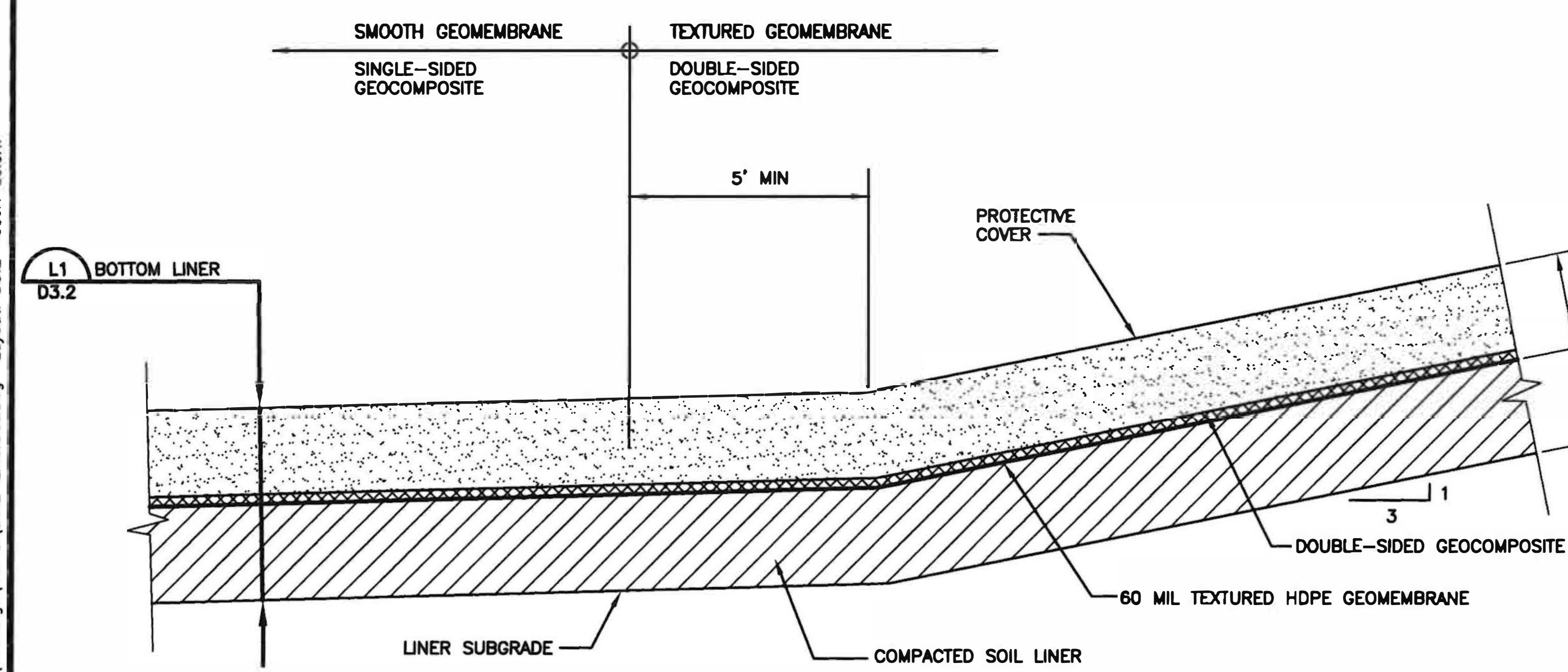
BOTTOM LINER (L1 / D3.2)

SCALE IN FEET 0 2 4



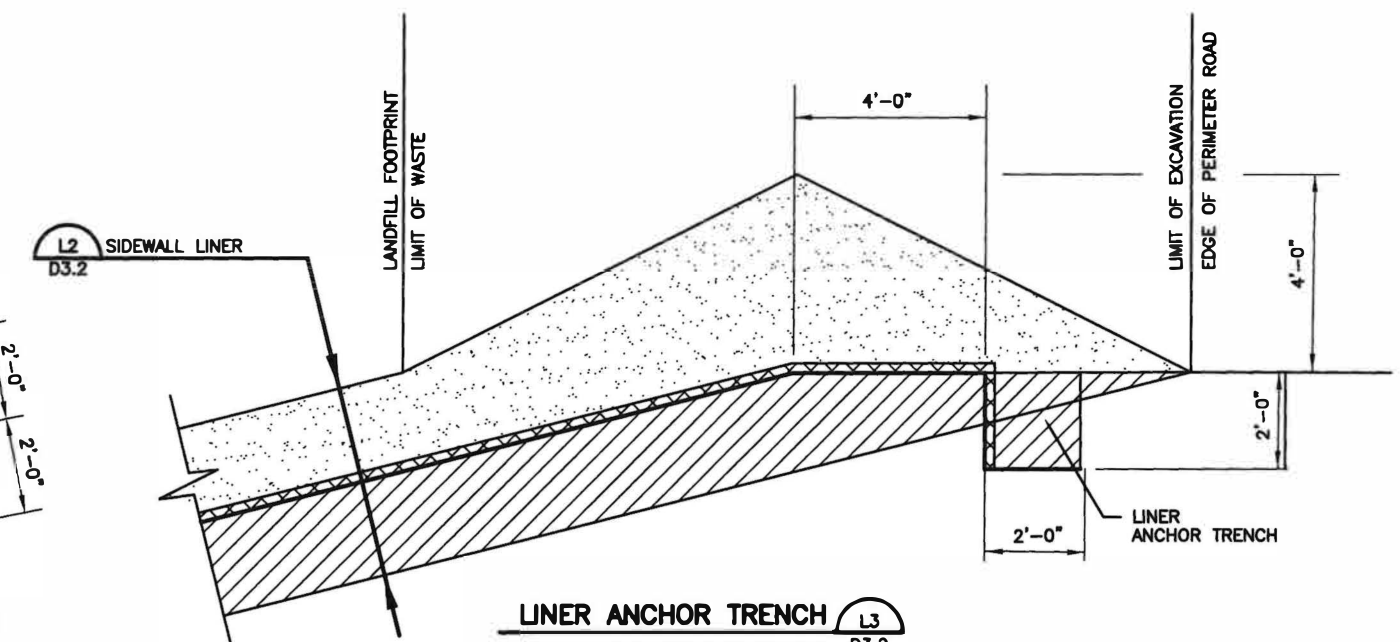
EXISTING LINER TIE-IN (L4 / D3.3)

SCALE IN FEET 0 2 4



SIDEWALL LINER (L2 / D3.2)

SCALE IN FEET 0 2 4



LINER ANCHOR TRENCH (L3 / D3.2)

SCALE IN FEET 0 2 4

NOTES:

1. REFER TO ATTACHMENT D7 FOR LINER INSTALLATION AND MATERIAL REQUIREMENTS.

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LINER DETAILS

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
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817-563-1144

TBPE FIRM NO. F-256

TBPG FIRM NO. 50222

DRAWING
D3.2

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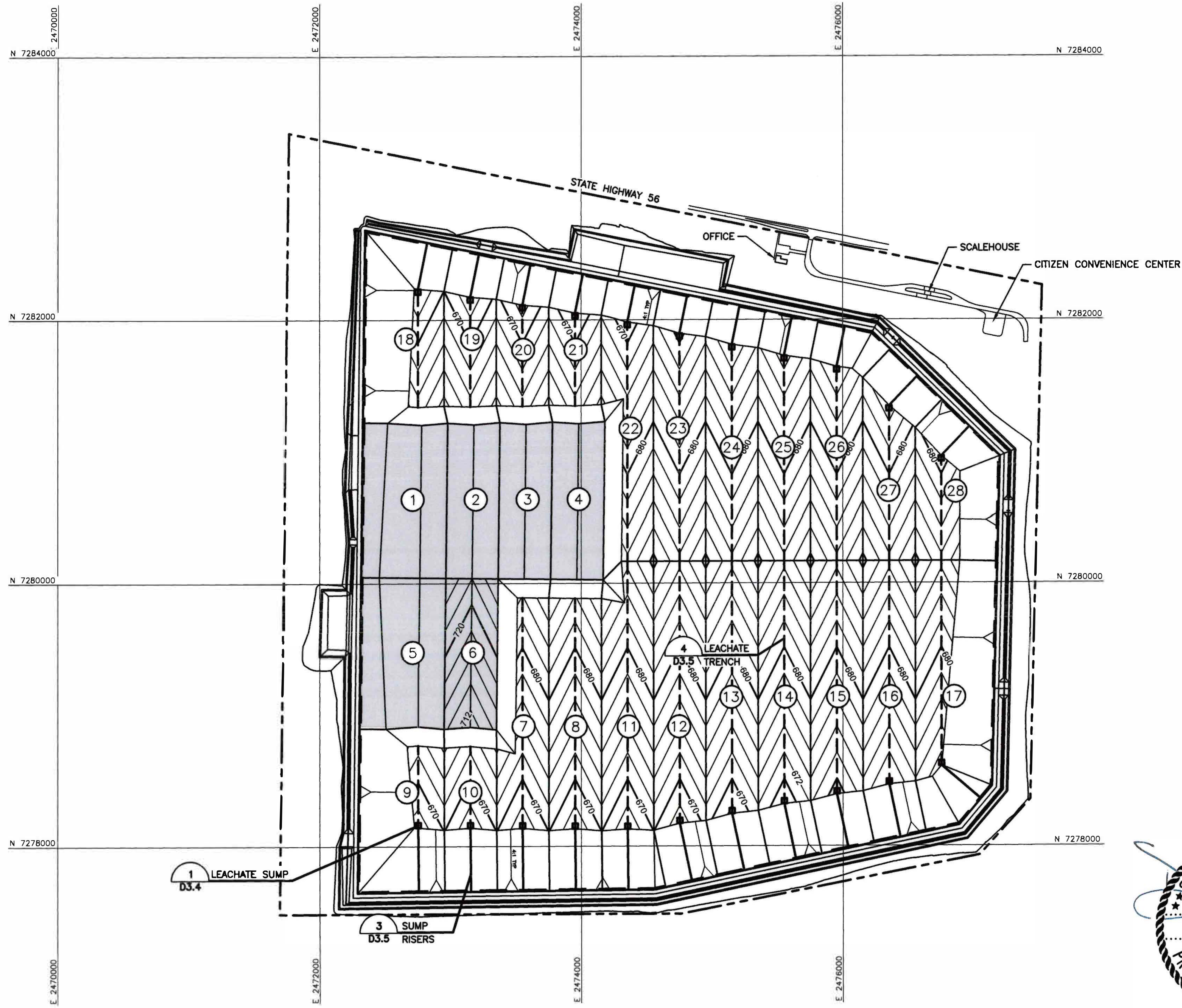

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- N 7279000 — STATE PLANE COORDINATES
- LINED AREA
- 670 — LINER CONTOUR
- (17) — SECTOR NUMBER (DEVELOPMENT SEQUENCE)

NOTES:

1. SECTORS 1–6 HAVE BEEN LINED AND RECEIVED WASTE FILL.

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LEACHATE COLLECTION SYSTEM PLAN	
TEXOMA AREA SOLID WASTE AUTHORITY TASWA DRF PERMIT AMENDMENT	
BME	BIGGS & MATHEWS ENVIRONMENTAL 1700 ROBERT ROAD, STE. 100 MANSFIELD, TEXAS 76063 817-563-1144
TBPE FIRM NO. F-256 TBPG FIRM NO. 50222	DRAWING D3.3

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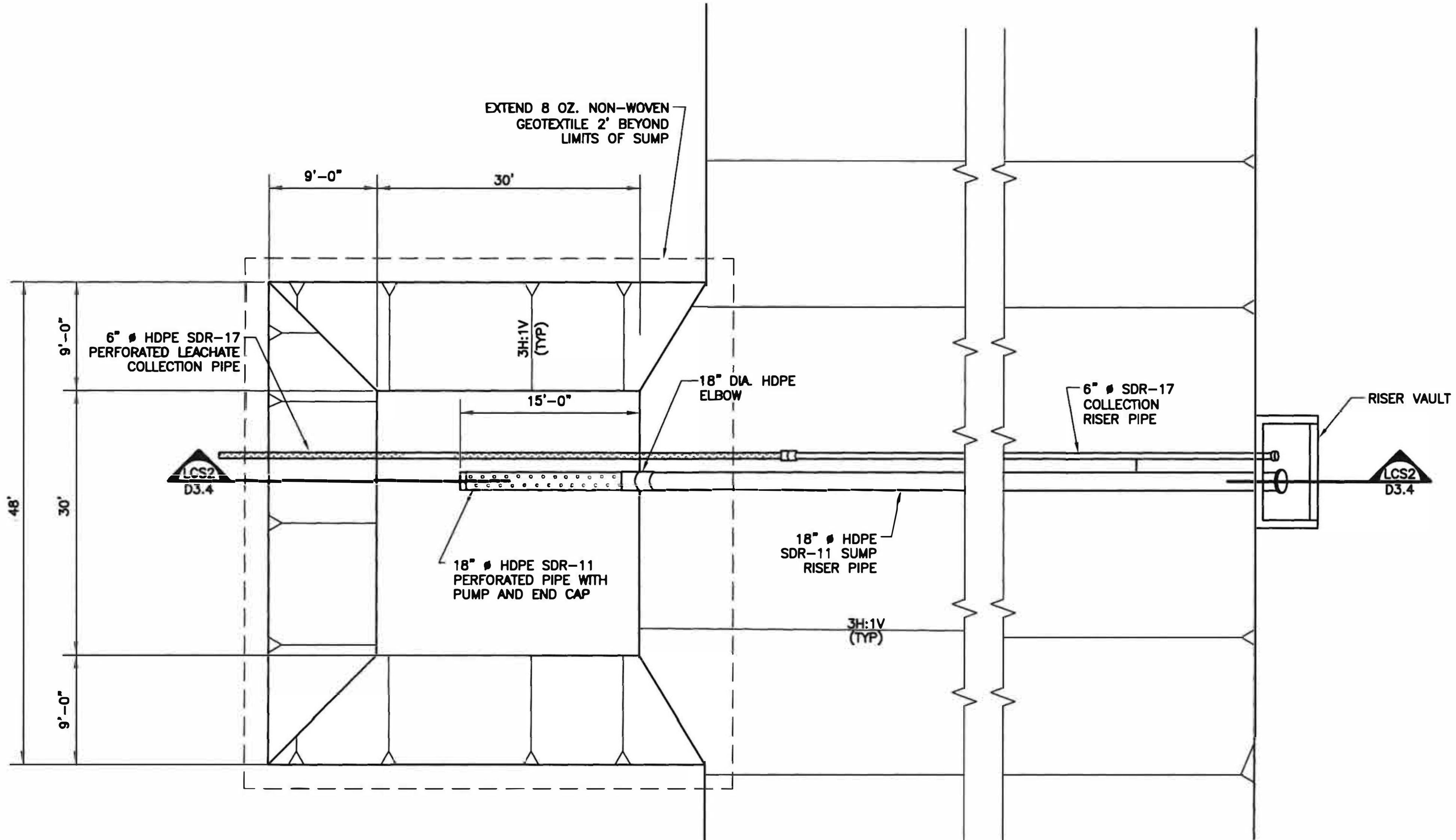
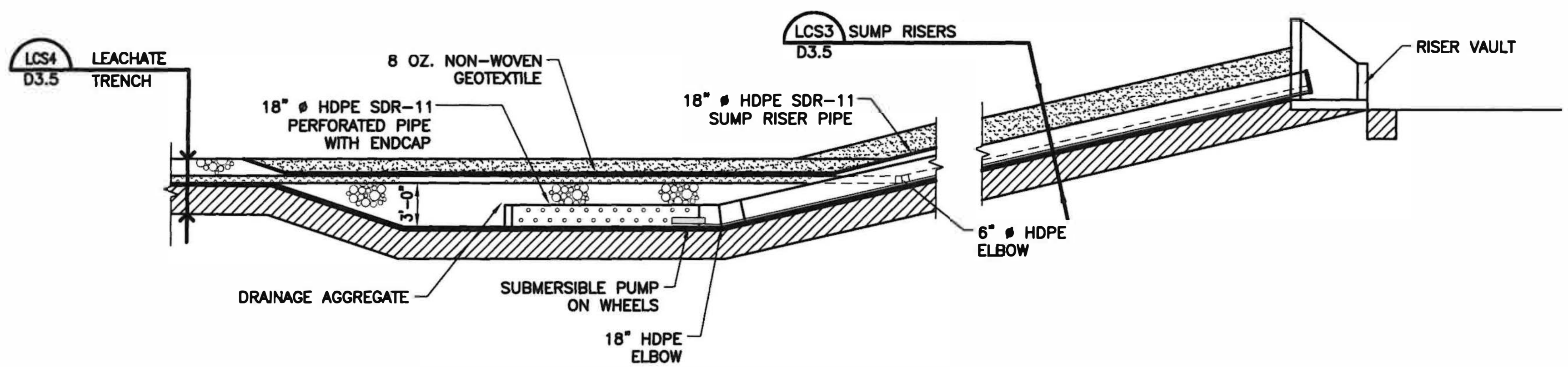


LEACHATE SUMP LCS1 D3.4

0 6 12
SCALE IN FEET

NOTES:

1. DRAINAGE AGGREGATE NOT SHOWN FOR CLARITY.
2. REFER TO ATTACHMENTS D6 AND D7 FOR INSTALLATION AND MATERIAL REQUIREMENTS.
3. REFER TO ATTACHMENT D6, APPENDIX D6-A FOR LEACHATE SUMP DESIGN CALCULATIONS.



LEACHATE SUMP AND RISER LCS2 D3.4

0 6 12
SCALE IN FEET

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LEACHATE COLLECTION SYSTEM DETAILS

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

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TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
D3.4

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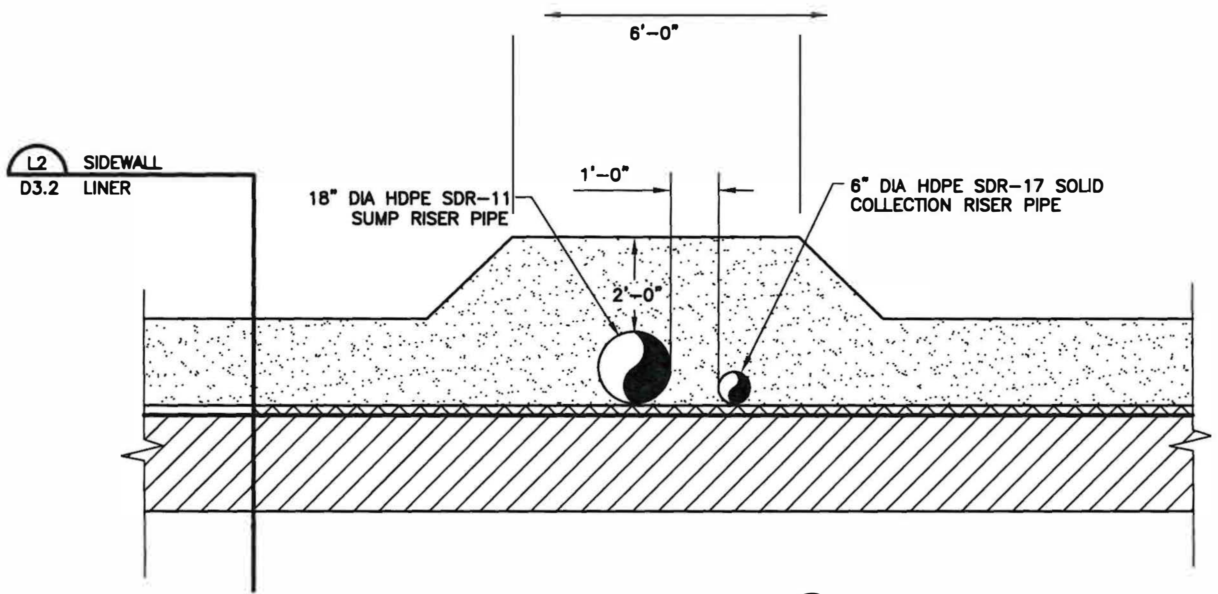
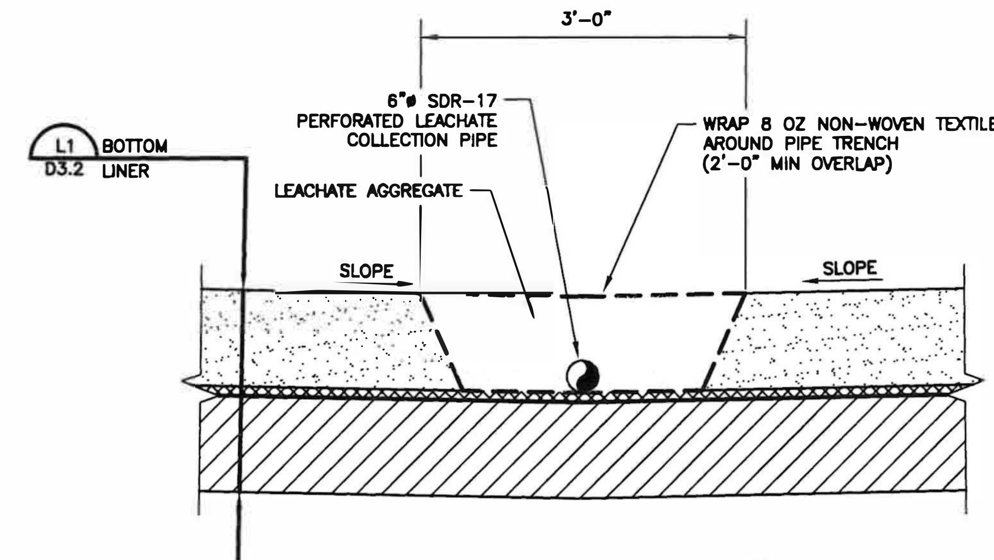


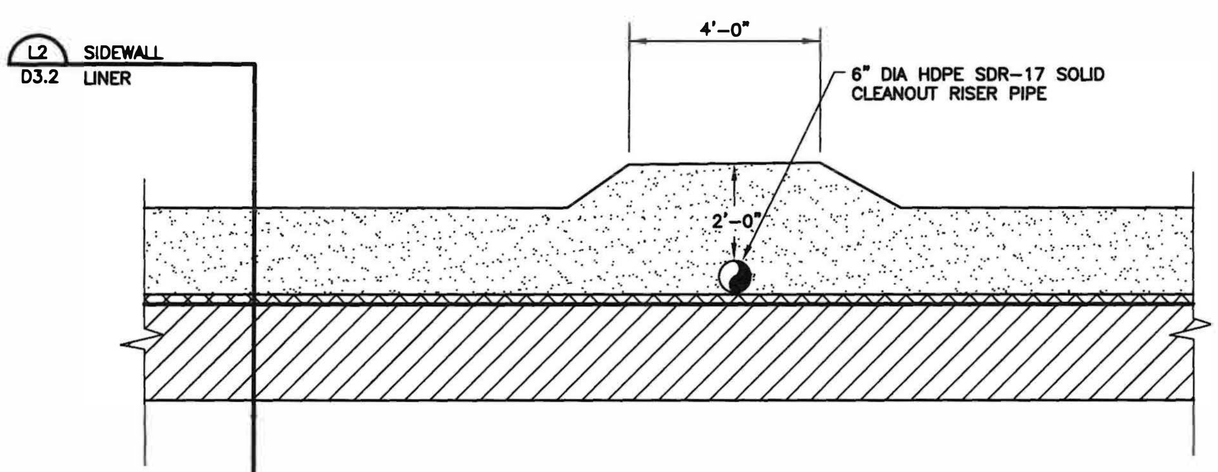
SUMP RISERS LCS3 D3.5

0 2 4
SCALE IN FEET



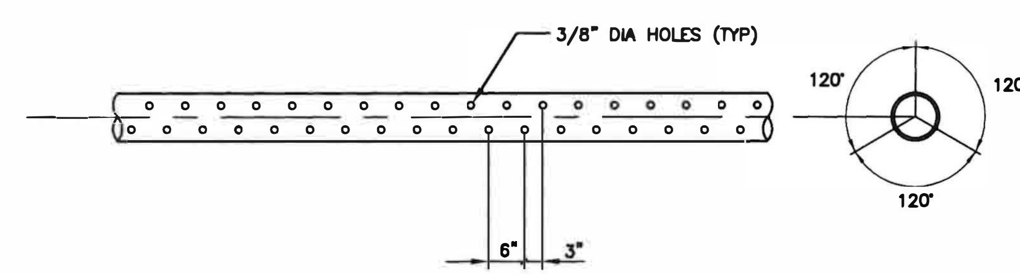
LEACHATE TRENCH LCS4 D3.5

0 2 4
SCALE IN FEET



CLEANOUT RISER LCS5 D3.5

0 2 4
SCALE IN FEET



PERFORATED PIPE LCS6 D3.5
NTS

NOTES:

1. REFER TO ATTACHMENTS D6 AND D7 FOR INSTALLATION AND MATERIAL REQUIREMENTS.

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LEACHATE COLLECTION SYSTEM DETAILS	
TEXOMA AREA SOLID WASTE AUTHORITY TASWA RDF PERMIT AMENDMENT	
BME	BIGGS & MATHEWS ENVIRONMENTAL 1700 ROBERT ROAD, STE. 100 MANSFIELD, TEXAS 76063 817-563-1144
TBPE FIRM NO. F-256 TBPG FIRM NO. 50222	DRAWING D3.5

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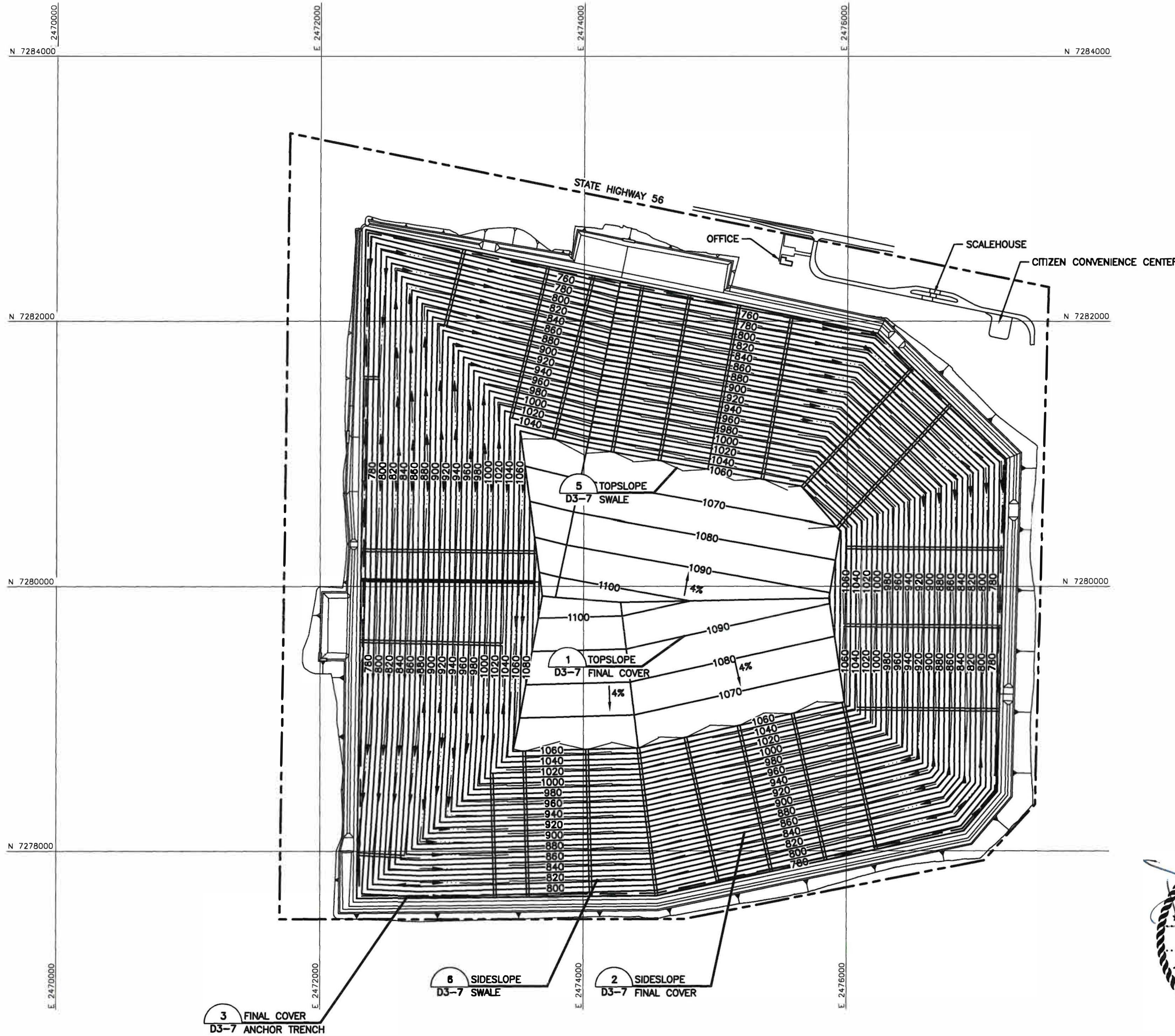

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- N 7279000 STATE PLANE COORDINATES
- 1000 FINAL COVER CONTOUR
- SWALE
- LETDOWN CHUTE

NOTES:

1. PROPOSED CONTOURS DEPICT TOP OF FINAL COVER GRADES.

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LANDFILL COMPLETION PLAN

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA RDF
PERMIT AMENDMENT

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MANSFIELD, TEXAS 76063
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
D3.6

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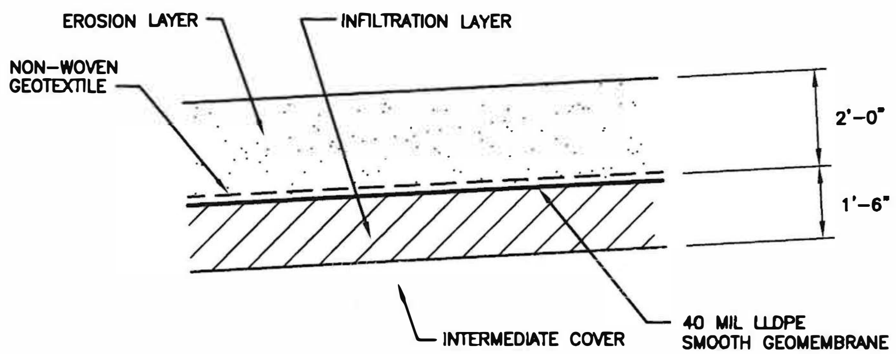
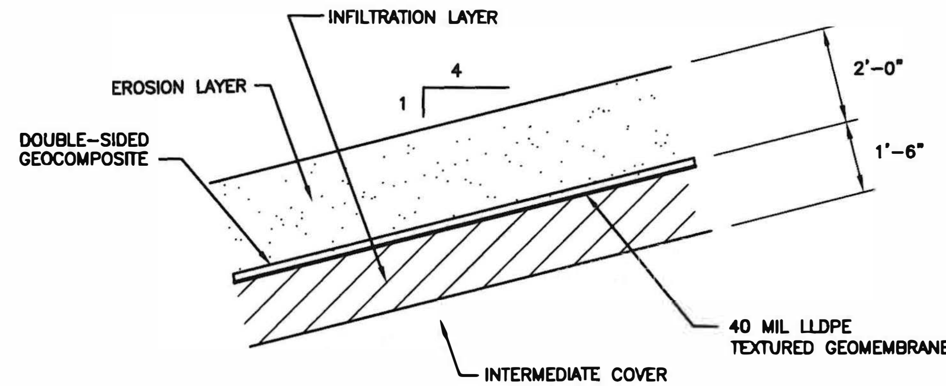


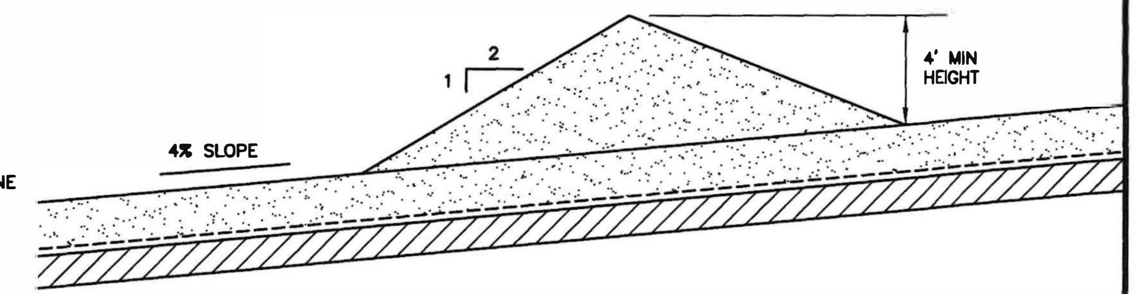
TOPSLOPE FINAL COVER (FC1, D3-7)

0 2 4 SCALE IN FEET



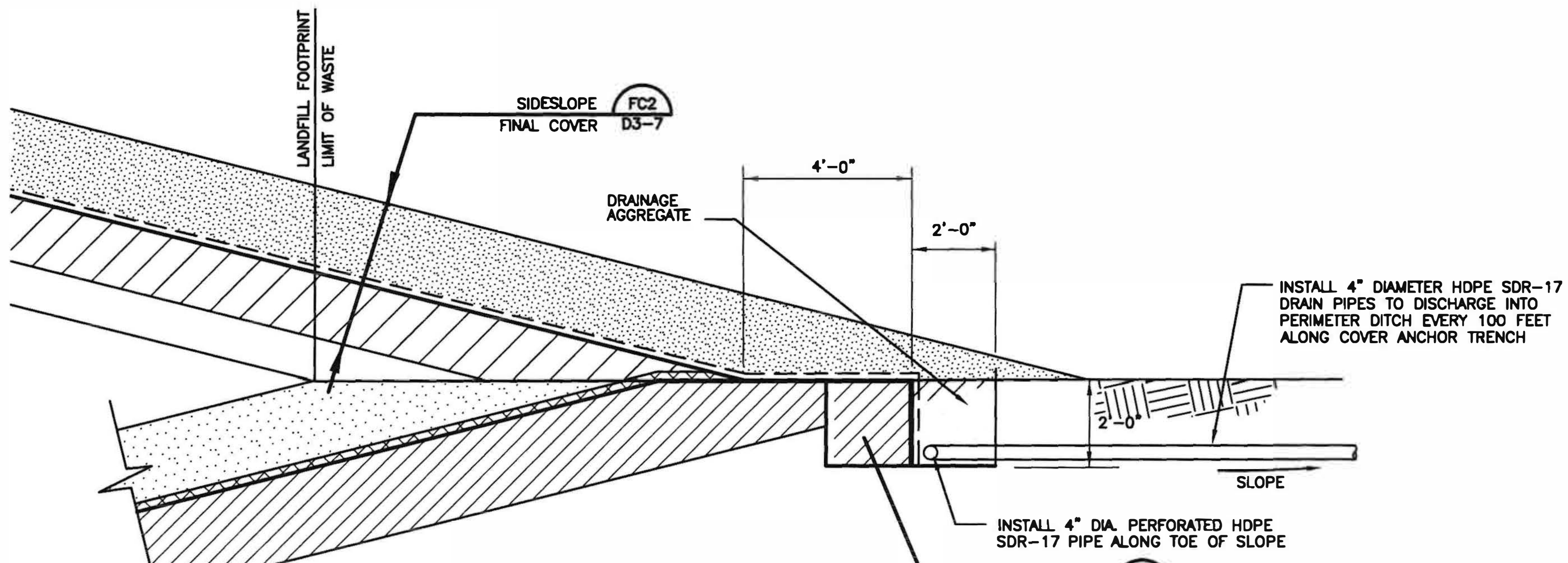
SIDESLOPE FINAL COVER (FC2, D3-7)

0 2 4 SCALE IN FEET



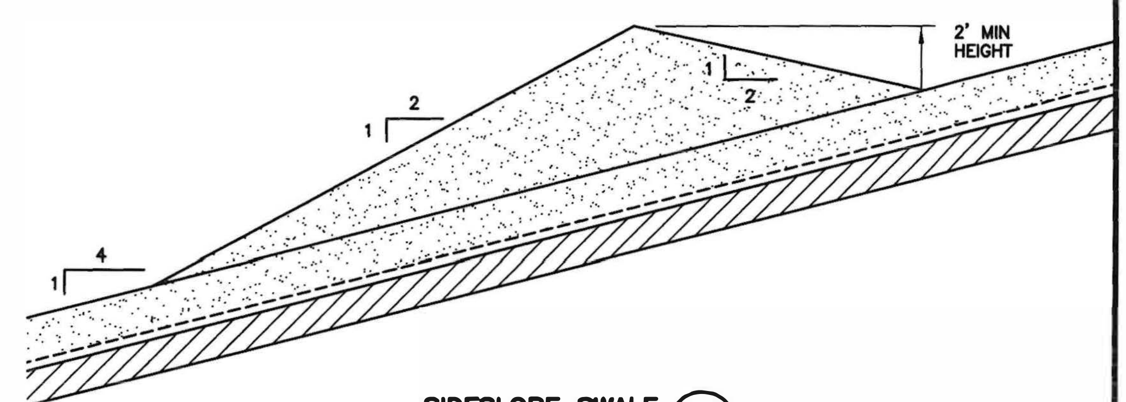
TOPSLOPE SWALE (FC5, D3-7)

0 4 8 SCALE IN FEET



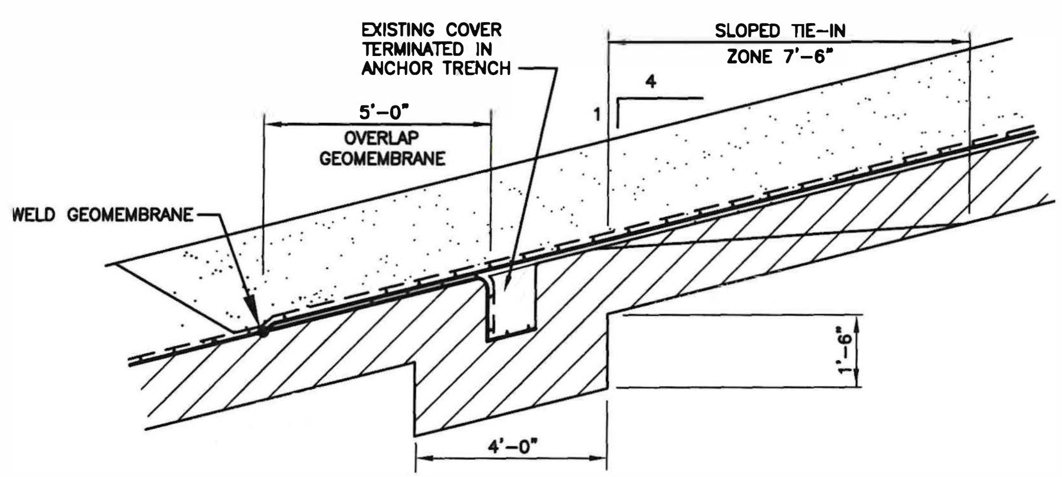
FINAL COVER ANCHOR TRENCH (FC3, D3-7)

0 2 4 SCALE IN FEET



SIDESLOPE SWALE (FC6, D3-7)

0 4 8 SCALE IN FEET



EXISTING SIDESLOPE FINAL COVER TIE-IN (FC4, D3-7)

0 2 4 SCALE IN FEET

NOTE:

1. REFER TO ATTACHMENT D8 FOR COVER INSTALLATION AND MATERIAL REQUIREMENTS.

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FINAL COVER DETAILS	
TEXOMA AREA SOLID WASTE AUTHORITY TASWA DRF PERMIT AMENDMENT	
BME	BIGGS & MATHEWS ENVIRONMENTAL 1700 ROBERT ROAD, STE. 100 MANSFIELD, TEXAS 76063 817-563-1144
TBPE FIRM NO. F-256 TBPG FIRM NO. 50222	DRAWING D3.7

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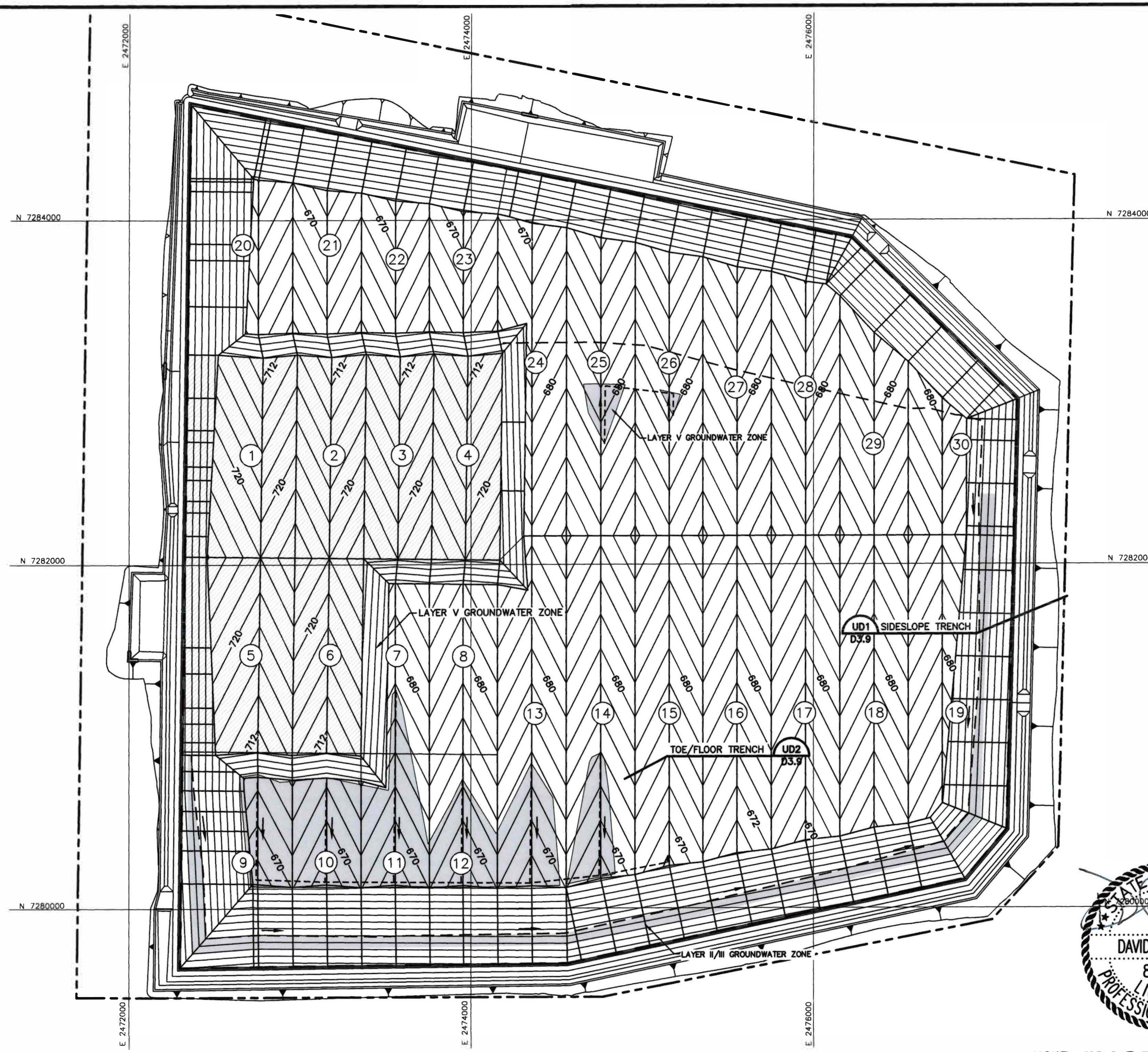

0 250 500
SCALE IN FEET

LEGEND

- 2290A PERMIT BOUNDARY
- 2290A LANDFILL FOOTPRINT
- N 7279000 — STATE PLANE COORDINATES
- DEWATERING TRENCH
- GROUNDWATER ZONE
- EXISTING LINED AREA

NOTES:

1. LAYER II/III GROUNDWATER WILL BE INTERCEPTED ON THE SIDESLOPE AND TYPICALLY DAYLIGHTED TO THE ADJACENT OPEN EXCAVATION. A SUMP/PIUMP WILL BE PROVIDED WHEN DAYLIGHTING SIDESLOPE DEWATERING TRENCH IS NOT FEASIBLE.
2. GRADING OF SIDESLOPE DEWATERING TRENCH WILL BE DETERMINED DURING SECTOR DEVELOPMENT BASED ON FIELD CONDITIONS DURING EXCAVATION.
3. IAYER V GROUNDWATER WILL BE COLLECTED IN DEWATERING TRENCHES BENEATH THE LEACHATE COLLECTION TRENCH AND ALONG THE TOE OF THE SLOPE WHERE LAYER V GROUNDWATER IS ENCOUNTERED IN THE BOTTOM OF THE EXCAVATION.
4. LAYER V DEWATERING TRENCHES WILL BE DAYLIGHTED TO ADJACENT OPEN EXCAVATION OR COLLECTED IN CLOSED SUMPS AND PUMPED INTO THE STORMWATER DISCHARGE SYSTEM.

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UNDERDRAIN PLAN

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

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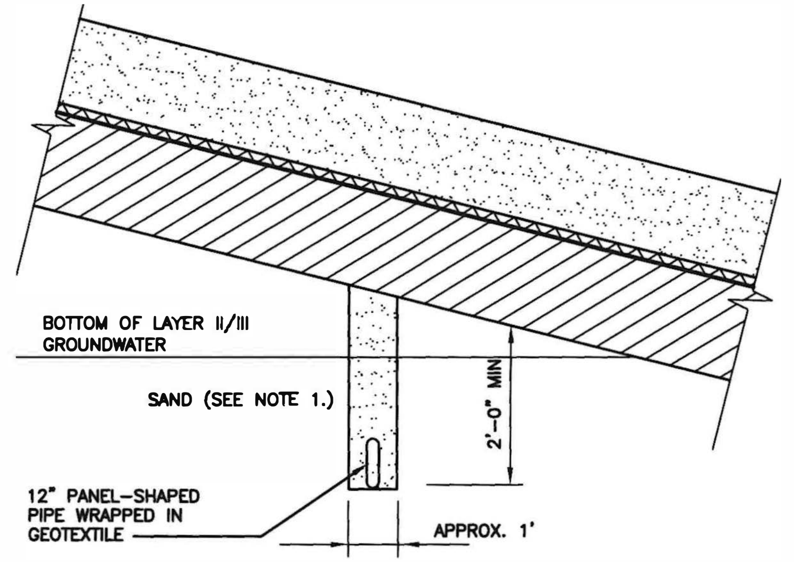
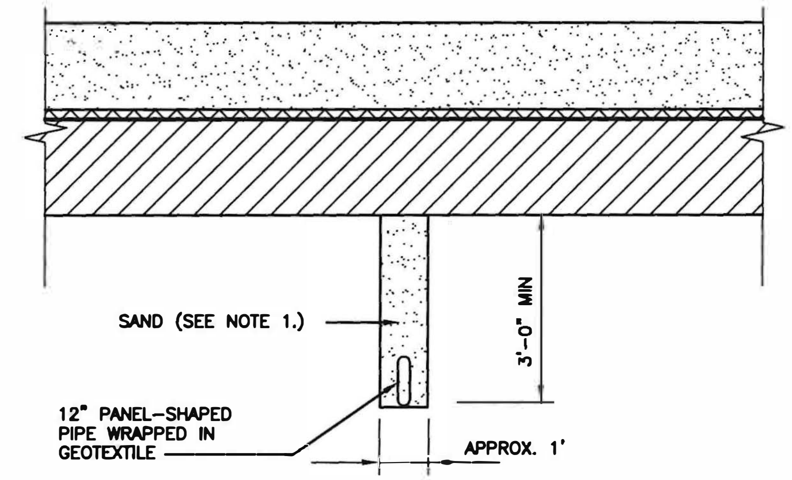
MANSFIELD, TEXAS 76063
817-563-1144
TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
D3.8



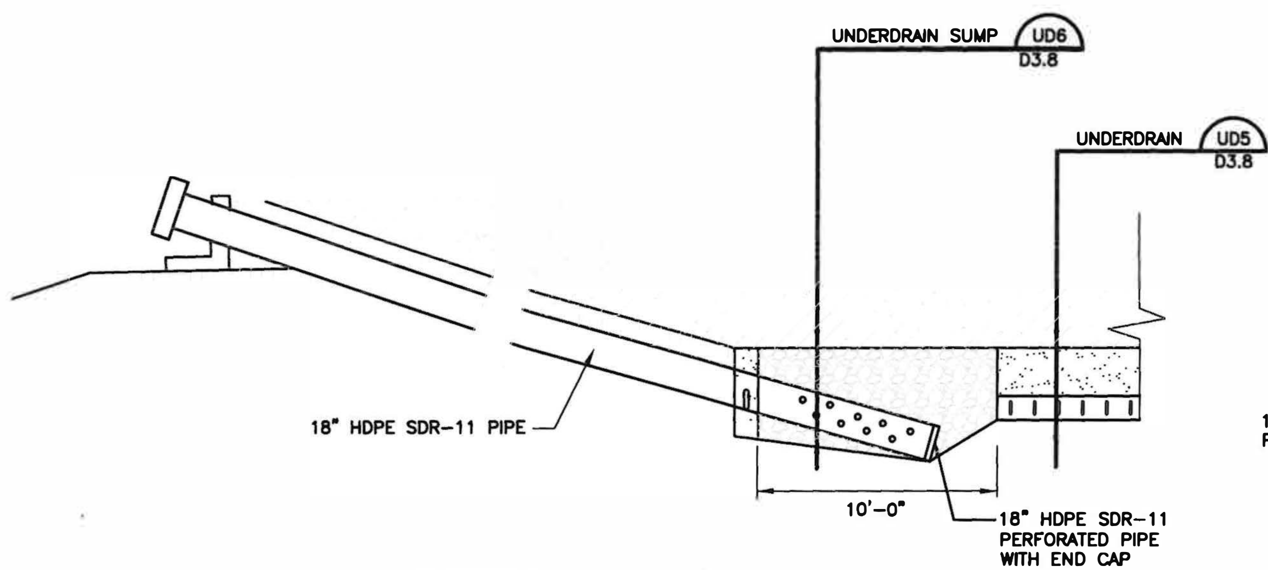
SIDESLOPE TRENCH UD1 D3.8

0 2 4
SCALE IN FEET



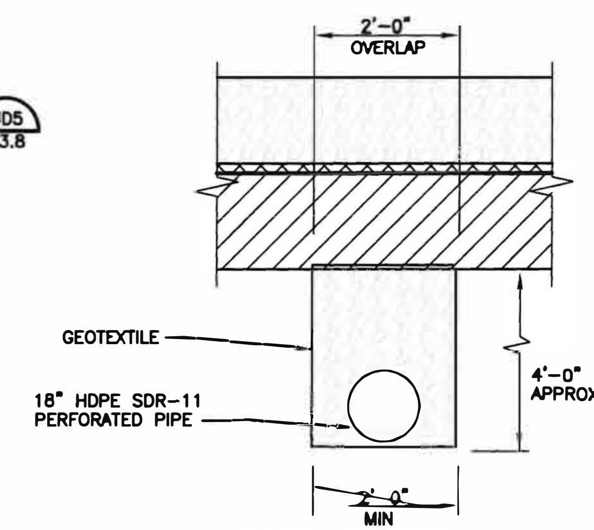
TOE/FLOOR TRENCH UD2 D3.8

0 2 4
SCALE IN FEET



UNDERDRAIN RISER UD4 D3.8

0 4 8
SCALE IN FEET



UNDERDRAIN SUMP UD3 D3.8

0 2 4
SCALE IN FEET

NOTE:

1. UNDERDRAIN SAND BACKFILL SHALL HAVE A PERMEABILITY OF $1x10^{-4}$ cm/sec. OR GREATER.
2. 4" PERFORATED PIPE AND AGGREGATE MAY BE SUBSTITUTED FOR PANEL-SHAPED PIPE.

ISSUED FOR PERMITTING PURPOSES ONLY

UNDERDRAIN DETAILS	
TEXOMA AREA SOLID WASTE AUTHORITY TASWA DRF PERMIT AMENDMENT	
BME	BIGGS & MATHEWS ENVIRONMENTAL 1700 ROBERT ROAD, STE. 100 MANSFIELD, TEXAS 76063 817-563-1144
TBPE FIRM NO. F-256 TBPG FIRM NO. 50222	DRAWING D3.9

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TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN

ATTACHMENT D4
SITE LIFE

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

STATE OF TEXAS
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2-28-25
Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

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2-28-25
Biggs & Mathews Environmental, Inc.
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CONTENTS

30 TAC §330.63(d)(4)(D)

TABLES AND CALCULATION SHEETS

1 SITE LIFE

1.1 Solid Waste Generation

The TASWA Disposal and Recycling Facility (TASWA DRF) accepts waste generated in Cooke and Grayson Counties, and surrounding areas. The TASWA DRF accepts waste 6 days per week (312 days per year) and currently receives approximately 270,000 tons of waste per year. It is anticipated that the waste acceptance rate will increase 1-2 percent each year for the life of the facility based on population and waste generation projections for Cooke and Grayson, and surrounding counties.

1.2 Airspace Utilization

An airspace utilization factor of 0.4 tons per cubic yard will be used to calculate the projected site life based on previous performance at the facility.

1.3 Landfill Capacity

The total landfill capacity or total airspace is defined as the volume between the liner and final cover and is approximately 183,500,000 cubic yards (cy).

1.4 Site Life Calculations

The remaining airspace for the site is approximately 176,500,0000 cubic yards. The remaining site life was calculated by multiplying the remaining airspace by the airspace utilization factor of 0.4.

Based on an estimated annual waste increase of 2 percent, The site will reach the approximate total landfill disposal capacity in approximately 92 years.

CAPACITY AND SITE LIFE

Required:

1. Estimate the remaining site life for the TASWA Facility.

Assumptions:

1. The waste acceptance rate will increase at an annual rate of 2%.
2. Beginning Waste Accepted = 270,000 tons
3. Airspace Utilization Factor = 0.4
4. The facility accepts waste 312 days per year (6 days a week).

Solution:

AUF:	0.4	
Year 1 Waste:	270,000	tons
Days Operating	312	

Total Capacity =	183,500,000	cy
Approximate Capacity Used =	7,000,000	cy
Total remaining waste volume =	176,500,000	cy
Total remaining waste tonnage =	70,600,000	tons

Year	Annual Waste (tons)	Daily Waste (tons/day)	Accumulated Waste (tons)	Remaining Capacity (tons)	Annual Waste (cy)	Accumulated Waste (cy)	Remaining Capacity (cy)
1	270,000	865	270,000	70,330,000	675,000	675,000	175,825,000
2	275,400	883	545,400	70,054,600	688,500	1,363,500	175,136,500
3	280,908	900	826,308	69,773,692	702,270	2,065,770	174,434,230
4	286,526	918	1,112,834	69,487,166	716,315	2,782,085	173,717,915
5	292,257	937	1,405,091	69,194,909	730,642	3,512,727	172,987,273
10	322,675	1,034	2,956,425	67,643,575	806,687	7,391,062	169,108,938
20	393,339	1,261	6,560,290	64,039,710	983,348	16,400,725	160,099,275
30	479,478	1,537	10,953,381	59,646,619	1,198,695	27,383,453	149,116,547
40	584,481	1,873	16,308,535	54,291,465	1,461,203	40,771,339	135,728,661
50	712,479	2,284	22,836,438	47,763,562	1,781,198	57,091,096	119,408,904
60	868,508	2,784	30,793,916	39,806,084	2,171,270	76,984,789	99,515,211
70	1,058,707	3,393	40,494,036	30,105,964	2,646,766	101,235,090	75,264,910
80	1,290,557	4,136	52,318,429	18,281,571	3,226,394	130,796,072	45,703,928

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT D5
GEOTECHNICAL DESIGN

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

STATE OF TEXAS
DAVID L. CLARK
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2-28-25

Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

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Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

CONTENTS

1 GEOTECHNICAL TESTING

30 TAC §330.63(e)(5)

The geotechnical report is based on the previous and current field explorations described in Attachment E. Geotechnical tests were performed on samples recovered from the borings to evaluate the physical and engineering properties of the subsurface materials. The results of the laboratory tests are provided in Attachment E, Appendix E5 and on the boring logs in Attachment E, Appendix E2.

Numerous tests for Atterberg limits, gradation, and percent passing the number 200 sieve have been performed during the current and previous field explorations. These test results were used to classify the soils according to the Unified Soil Classification System (USCS) and to evaluate the engineering properties of the soils.

Unit dry weight and natural moisture content tests were performed to determine the physical properties of the soils. These test results were used in the evaluation of slope stability and in the settlement and heave analysis.

Hydraulic conductivity tests have been performed on undisturbed and remolded samples from the current and previous explorations on the units that will form the bottom and sides of the proposed excavations as well as on compacted soil liner from Sectors 1 through 6. In addition, field tests from the current and previous explorations were used to confirm the horizontal permeability of the excavation sidewall soils. The laboratory and field test results were used to evaluate the hydrogeologic parameters of the site and the hydraulic conductivity of engineered fill constructed from on-site materials.

Triaxial shear strength tests were performed on selected samples to evaluate the shear strength of the soils. These test results were used to evaluate slope stability.

2 SUBSURFACE MATERIALS

30 TAC §330.63(e)(5)

The information from the field explorations provided in Attachment E indicates that the subsurface materials at the site consist of clay, sandy clay, shaly clay, shale, sand, and sandstone. The general soil units that have been identified at the site are summarized in Table 1. Detailed lithologic descriptions of each stratigraphic unit are included in Attachment E.

Table 1
Generalized Site Stratigraphy

Geologic Unit	Lithology
Layer I	Clay and Shaly Clay
Layer II	Shaly Sandstone and Shale
Layer III	Shale w/sand
Layer IV	Shale
Layer V	Sandstone, Shaly Sand
Layer VI	Shale and Shale w/sand

2.1 Material Properties

The laboratory test results are included in Attachment E, Appendix E5 and are summarized on Table D5-2. These test results were reviewed along with the boring logs to develop generalized soil properties for use in the analyses. As shown on the cross sections in Attachment D2, the landfill excavation may encounter clay, sandy clay, shaly clay, and shale.

2.2 Material Requirements

Soils will be required for construction of the compacted soil liner and protective cover components of the liner system, and for the infiltration layer and erosion layer components of the final cover system. Soils will also be required for operational cover (daily, weekly, and intermediate) and general earthfill. Typical material requirements for the various landfill components are summarized in Table 3.

The compacted soil liner and final cover infiltration layer must be constructed from soils that can be compacted to form a low hydraulic conductivity barrier. The classification and hydraulic conductivity test results indicate that the clayey soils excavated from the site will be satisfactory for use as compacted soil liner and infiltration layer material.

Protective cover and erosion layer soils must not contain large rocks. Operational cover soils must not have been previously mixed with waste and erosion layer material must be capable of sustaining vegetation. The test results and boring logs indicate that any of the soil material excavated from the site will be suitable for use as operational and protective cover and that the surficial soils will be suitable for use as the final cover system erosion layer. The classification test results also indicate that the on-site soils are suitable for use as general earthfill.

Table 2
Average Properties of On-Site Materials

Layer	USCS Classification	Liquid Limit %	Plastic Limit %	Plasticity Index %	Passing 200 Sieve %	In Situ Permeability (cm/sec)	Remolded Permeability (cm/sec)
I	CH	72	26	45	88	2.9×10^{-8}	3.5×10^{-8}
II	SP and ML	36	26	10	35	Slug	
III	CL	49	21	28	80		
IV	CH	68	26	42	87	1.2×10^{-8}	3.7×10^{-9}
V	SP and CL	41	24	17	29	Slug	
VI	CH	63	25	38	70		

Remolded permeability tests were performed on soil most likely to be used for compacted soil liner.

Table 3
Typical Soil Requirements for Landfill Construction

Landfill Component	Classification	LL	PI	% - 200	Hydraulic Conductivity cm/sec	Material Source
Soil Liner	SC, CL, CH, MH	30 min	15 min	30 min	1×10^{-7} max	On-site
Infiltration Layer	SC, CL, CH, MH	30 min	15 min	30 min	1×10^{-5} max	
Protective Cover	SP, SW, SM, SC, CL, CH, ML, MH	No large rocks				
Erosion Layer	SC, CL, CH, SM, ML, CL-ML	Suitable to support plant growth				
Operational Cover (Daily, Weekly, and Intermediate Cover)	SP, SC, CL, CH, CL-ML, MH, ML	Not mixed with waste				
General Fill	SC, CL, CH, ML, CL-ML, MH	NA	5 min	15 min	NA	

3 EARTHWORK

30 TAC §330.337(e)

3.1 Excavation

The cross sections in Attachment D2 show that the excavation will be up to 90 feet below the surrounding ground surface. The excavations will encounter materials identified as Layers I, II, III and IV. The excavated materials should be visually classified and may be stockpiled separately according to the construction material properties outlined in Table 3. Prior to use the soils must be tested for suitability in accordance with Attachment D7 and Attachment D8. Excavation and construction below the groundwater table is discussed in Section 4 and the stability of excavation slopes is discussed in Section 6.

3.2 Earthfill

General fill should consist of on-site soils which are free of organic or other objectionable materials. General fill should be spread in maximum 9-inch-thick loose lifts. General fill should be compacted to a minimum of 95 percent of maximum dry density as defined by the standard Proctor test (ASTM D698), within a range of two percentage points below to four percentage points above optimum moisture content. A minimum of one standard proctor test should be performed on each representative soil used as general fill material.

4 CONSTRUCTION BELOW THE GROUNDWATER TABLE

30 TAC §330.337

4.1 Groundwater Elevations

Groundwater may be encountered in the Layer II material and upper Layer III material where the groundwater acts as one hydrogeologic unit. The excavation is anticipated to be founded in the Layer IV material above groundwater found in Layer V. The highest recorded groundwater elevations for each monitor well and piezometer across the site are included in Attachment D7 and are segregated into upper (Layer II and upper Layer III) groundwater elevations and lower (Layer V) groundwater elevations.

4.2 Temporary Dewatering System

As shown in Attachment D3, the excavations will extend below the highest recorded groundwater elevations across the remaining sectors to be developed. Areas where the liner is to be constructed below the highest measured groundwater elevations will be dewatered during and after construction by a temporary dewatering system. The temporary dewatering system will consist of a network of underdrains that discharge into open sumps beyond the lined areas or closed sumps beneath the lined areas. The underdrains will consist of HDPE panel-shaped pipe wrapped in a geotextile and encased in a sand-filled trench or a trench with perforated PVC or HDPE pipe surrounded by aggregate and wrapped in a geotextile. If closed sumps are utilized, groundwater will be pumped from the sumps into the perimeter drainage system. The temporary dewatering system will be operated until sufficient ballast has been placed to offset the hydrostatic forces.

The anticipated location of the temporary dewatering system based on the information from the boring logs is shown in Attachment D3. The design procedures and typical details of the temporary dewatering system are provided in Attachment D7. Design and installation of the temporary dewatering system will be documented in the Soils and Liner Evaluation Report (SLER) in accordance with Attachment D7.

4.3 Hydrostatic Uplift

Liners constructed below the groundwater table may experience hydrostatic pressure. Resistance to uplift from hydrostatic forces will be provided by the weight of the protective cover, waste, daily cover, weekly cover, intermediate cover, and final cover system. The temporary dewatering system will be operated to keep the groundwater lowered until sufficient ballast has been placed to offset hydrostatic forces.

The ballast requirements for each cell will be based on the highest recorded groundwater. Ballast calculations provided in Attachment D7 show that the landfill components overlying the liner will provide sufficient ballast to offset the hydrostatic forces with a minimum factor of safety of 1.5.

The highest recorded groundwater elevations in the upper (Layer II and upper III) zone and the lower (Layer V) zone will be updated before the construction of each cell and adjusted upward if necessary. The ballast design will be verified to be adequate for the design groundwater elevations prior to the construction of each cell. Ballast calculation, placement, and documentation procedures are provided in Attachment D7.

The facility will submit a Ballast Evaluation Report (BER) to the TCEQ once it is determined that ballasting or dewatering is no longer necessary. If the TCEQ does not provide a response within 14 days of the date of receipt of the BER, the facility will discontinue dewatering or ballasting operations. Operational procedures for ballast placement are discussed in Part IV. Documentation requirements are discussed in Attachment D7.

5 SETTLEMENT AND HEAVE ANALYSIS

30 TAC §330.337(e)

5.1 Subgrade Heave

Heave or rebound can occur in cohesive soils after the removal of overburden. Heave occurs relatively soon after excavating the overburden and is directly related to the depth of the excavation. The potential heave in the subgrade beneath the floor of the excavation was calculated from the recompression index of the foundation soils and the unit weights of the overburden soils. The predicted heave is about 2 inches. Since the heave occurs during and soon after excavation, it will not adversely affect the performance of the liner systems. Subgrade heave calculations are presented in Appendix D5A.

5.2 Subgrade Settlement

Settlement may occur due to consolidation of cohesive soils from the weight of the landfill components (i.e., liner, solid waste and daily cover, and final cover systems). The predicted maximum differential settlement is about 3 inches. Settlement of the liners should be uniform and is within the strain tolerance of the liner systems. Furthermore, subgrade settlement will occur slowly as the waste is deposited allowing redistribution of stresses within the layers. The predicted maximum differential settlement should be distributed over the distance from the top of slope to the toe of slope. Subgrade settlement calculations are presented in Appendix D5A.

5.3 Solid Waste Settlement

Consolidation and decomposition can produce settlement within the solid waste. Primary consolidation results from stress increase and occurs soon after load application and secondary consolidation results from the decomposition of solid waste. Due to the length of time that it will take to construct and fill the landfill, most of the consolidation in the waste will have occurred prior to construction of the final cover system. Minor settlement that occurs after the construction of the final cover system will be corrected by the addition of erosion layer material in accordance with Attachment I.

6 SLOPE STABILITY ANALYSES

30 TAC §330.337(e)

Slope stability analyses were performed on representative sections to predict the stability of the excavation slope, liner slope, interim waste slope, final waste slope and final cover slope. The geometry of the sections was developed from the proposed excavation and final cover plans and from data on logs of borings drilled in the vicinity of each section.

A summary of the unit weights and strength parameters that were used for the stability analyses in included in Appendix D5B. The excavation will encounter materials identified as Layer I through IV. Layers V and VI are below the excavation grades. The unit weight and strength parameters for the various layers were selected based on a review of the historic and expansion boring logs and laboratory and field test results. The unit weights and strength parameters for solid waste were selected based on engineering judgment and published values. The strength parameters for the liner and cover geosynthetics were selected based on the direct shear testing of various interfaces. A summary of the results of the direct shear testing and strength parameters used in stability analyses is included in Appendix D5B.

The excavation slope was analyzed for short-term conditions using total stress parameters and long-term conditions using effective stress parameters. The interim waste slope was analyzed with a sliding block failure mode through the liner system. The final waste slope was analyzed for long-term conditions using effective stress parameters. Although the site is not located in a Seismic Impact Zone as defined in 30 TAC §330.557, seismic loading of the excavation and final waste slope was analyzed using a horizontal coefficient of 0.11g. GEOSTASE, a slope stability program, was used to analyze the stability of the excavation slopes, interim waste slopes, and final waste slopes. The results of the stability analyses indicate that the proposed slopes are stable under the conditions analyzed. Table 4 summarizes the results of the stability analyses and compares the calculated factor of safety to the recommended minimum factor of safety. The recommended minimum factors of safety were selected from the Corps of Engineers "Design and Construction of Levees" manual (EM 1110-2-1913). The slope stability analyses are provided in Appendix D5B.

Table 4
Summary of Slope Stability Analyses

Condition	Minimum Calculated Factor of Safety	Recommended Factor of Safety	Acceptable Factor of Safety
Excavated Slope			
Short Term	2.4	1.3	Yes
Long Term	2.4	1.5	Yes
Short Term with Seismic loading	1.6	1.2	Yes
Long Term with Seismic loading	1.6	1.2	Yes
Interim Waste Slope			
Sliding Block Failure	1.7	1.3	Yes
Final Waste Slope			
Circular Arc Failure	2.0	1.5	
Circular Arc Failure with Seismic	1.3	1.2	Yes
Liner Veneer			
Protective Cover/Geocomposite	15.1	1.5	Yes
Geocomposite/Geomembrane	25.5	1.5	Yes
Geomembrane/Soil Liner	5.7	1.5	Yes
Final Cover Veneer (Sideslope)			
Erosion Layer/Geocomposite	2.8	1.5	Yes
Geocomposite/Geomembrane	3.5	1.5	Yes
Geomembrane/Infiltration Layer	3.5	1.5	Yes

The slope stability analyses are only valid for the conditions that were analyzed. Any changes to the excavation plan, dewatering system, ballast system, liner system, final cover system or landfill completion plan will necessitate that the slope stability analyses be revised to reflect the actual conditions. Interim 3H:1V waste slopes up to 160 feet in height have been demonstrated to be stable. Temporary construction slopes should not be steeper than the interim slopes and concentrated loadings such as heavy equipment and soil stockpiles should not be placed near the crest of slopes unless additional slope stability analyses are performed.

7 LINER CONSTRUCTION

30 TAC §330.331

Liner construction has been completed in Sectors 1 through 6 and documented in the SLERs and Geomembrane Liner Evaluation Reports (GLERs) for each sector.

The liner system for the TASWA DRF will consist of a 2-foot-thick compacted soil liner overlain by a 60-mil HDPE geomembrane, a geocomposite drainage layer, and a 2-foot-thick layer of protective soil cover. The liner details are provided in Attachment D3.

7.1 Subgrade Preparation

The liner subgrade must be firm and stable. Prior to beginning liner construction, the subgrade should be proof-rolled with heavy, rubber-tired construction equipment to detect soft areas. Isolated soft areas should be undercut then backfilled with compacted earthfill.

7.2 Compacted Soil Liner

The soil liner material must consist of relatively homogeneous cohesive materials, which are free of debris, rocks greater than 1-inch in diameter, plant materials, frozen materials, foreign objects, and organic material. Suitable materials should be available from proposed excavations or on-site borrow sources. Laboratory tests indicate that the remolded cohesive soils will meet the compacted soil liner requirements listed in 30 TAC §330.339(c)(5). The soil liner properties summarized in Table 5 are specified in Attachment D7.

Table 5
Soil Liner Properties

Test	Specifications
In-Place Density	95% of Standard Proctor (ASTM D 698) minimum
In-Place Moisture Content	Standard Proctor Optimum Moisture Content (OMC) to 4 percentage points above OMC
Hydraulic Conductivity	1.0 x 10^{-7} cm/sec or less
Plasticity Index	15 minimum
Liquid Limit	30 minimum
Percent Passing No. 200 Mesh Sieve	30 minimum
Percent Passing 1-inch Sieve	100

Preconstruction sampling must be performed on soils to be used as liner material. At a minimum, one liquid limit, plastic limit, percent passing the No. 200 sieve, standard Proctor (ASTM D 698), and hydraulic conductivity test should be performed for each borrow material type prior to use as liner material.

The soil liner material should be placed in maximum 8-inch loose lifts to produce compacted lift thickness of approximately six inches. The material should be compacted to a minimum of 95 percent of the maximum dry density determined by standard Proctor (ASTM D 698) at a moisture content between optimum moisture and four percentage points above optimum moisture. Rocks within the liner should be less than one inch in diameter and should not total more than 10 percent by weight. The material should be processed to a maximum particle size of one inch or less and water added as needed to adjust the moisture content. Soil processing may be achieved using a disc or soil pulverizer. Water should be applied as necessary to the material and worked into the material with the compaction equipment. Water used for the soil liner compaction must not be contaminated by waste or any objectionable material.

The soil liner must be compacted with a pad/tamping-foot or prong-foot roller. The compactor should weigh at least 40,000 pounds and make at least four passes across the area being compacted. The lift thickness shall be controlled to achieve total penetration into the top of the previously compacted lift; therefore, the lift thickness must not be greater than the pad or prong length. Cleaning devices on the compaction roller must be in place and maintained to prevent the prongs or pad feet from becoming clogged to the point that they cannot achieve full penetration. Soil liner shall not be compacted with a bulldozer, rubber-tired (pneumatic) roller, flat-wheel roller, scraper, truck, or any tracked equipment unless it is used to pull a footed roller.

Tie-ins with previously constructed soil liners shall be constructed using a sloped or stair-step transition as described in Attachment D7.

7.3 Protective Cover

The protective cover should be constructed of soils that are free of debris, large rocks, plant materials, frozen materials, foreign objects, and organic material. Suitable protective cover materials should be available from proposed excavations or on-site borrow sources.

7.4 Liner Testing and Documentation

CQA testing of the soil liner must be performed as the liner is being constructed. Liner system testing is addressed in Attachment D7. The construction methods and test procedures documented in the SLER and GLER must be consistent with the requirements of Attachment D7.

8 COVER CONSTRUCTION

30 TAC §§330.165, 330.457

8.1 Daily, Weekly, and Intermediate Cover

The daily, weekly, and intermediate cover should be constructed of soils that are free of waste and debris. Suitable cover materials should be available from the proposed excavations or on-site borrow sources. Requirements for the placement of daily, weekly, and intermediate cover are provided in Part IV.

8.2 Final Cover

The final cover system for the TASWA DRF will consist of an 18-inch-thick compacted soil infiltration layer overlain by a geomembrane, a drainage/cushion layer, and a 24-inch-thick erosion layer. The final cover system requirements are provided in Attachment D8 and the final cover system details are provided in Attachment D3.

The infiltration layer material must consist of relatively homogeneous cohesive materials that are free of debris, rocks greater than one inch in diameter, plant materials, frozen materials, foreign objects, and organic material. The infiltration layer should be constructed directly over the intermediate cover once the waste has reached final grades. The infiltration layer construction procedure should be the same as those outlined in Section 7 for liner construction.

The erosion layer should consist of: (1) topsoil stockpiled during the excavation process, (2) on-site soils which has been modified to be capable of sustaining vegetation, or (3) an imported material suitable to sustain vegetation growth. This layer may be spread and placed in one lift over the drainage layer. After spreading, the layer should be rolled lightly to reduce future erosion, although not to the extent that compaction would inhibit plant growth.

8.3 Final Cover Testing and Documentation

CQA testing of the final cover system must be performed during construction. Final cover system requirements are outlined in Attachment D8.

APPENDIX D5A
SETTLEMENT/HEAVE ANALYSIS

Settlement/Heave Analysis

Required: Estimate the following:

1) Subgrade heave
2) Subgrade settlement
3) Strain on liner from differential settlement

References:

1) *Essentials of Soil Mechanics and Foundations*, 2nd Edition, McCarthy, Reston Publishing.
2) *TM 5-818-1 Soils and Geology Procedures for Foundation Design of Buildings and Other Structures,* US Army COE, October 1983.
3) Daniel, David E. *Geotechnical Practice for Waste Disposal*, Chapman and Hall, Boundary Row, London, 1993.

Assumptions:

1) Typical material properties are shown below:

Material	Description	Moisture[a] %	Dry Wt[a] pcf	Wet Wt[b] pcf	C_c[a]	C_r[a]	P_c[a] tsf
Layer I	Clay	30.0	90.0	117.0	na	na	na
Layer II	Sandstone/Shale	18.9	109.7	130.4	na	na	na
Layer III	Shale w/sand	17.0	109.0	127.5	0.0741	0.0161	4.45
Layer IV	Shale	17.0	109.0	127.5	0.1171	0.0248	5.9
Layer V	Sandstone/Sand	20.0	112.0	134.4	na	na	na
Layer VI	Shale	18.0	109.0	128.6	0.0769	0.0177	6.6
Final Cover[c]	Clay	24.0	91.0	112.8	na	na	na
Solid Waste[c]	Waste/Cover	na	na	50.0	na	na	na
Liner[c]	Clay	24.0	91.0	112.8	na	na	na

[a] Average laboratory test values from previous investigation

[b] Wet Wt = Dry Wt x (1 + Moisture)

[c] Assumed

2) Excavation bottom will be within the Layer IV shale.
Layer V is a relatively thin layer of lower plasticity material and settlement/heave potential is considered neglible. Analysis pont for Layer IV will be base of Layer IV.
Analysis point for Layer VI will be 10 ft below the top of Layer VI.

Solution:

1) **Subgrade Heave**

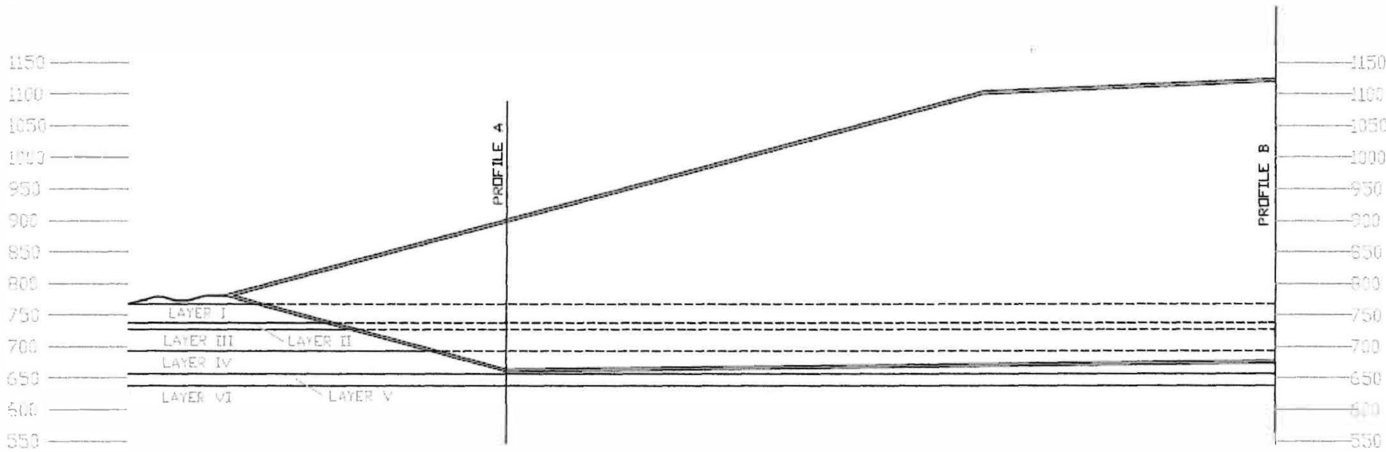
The heave in the subgrade is estimated from the equation:

$$R = [H / (1 + e_o)][C_r log(P_f / P_o)]$$

where:

R = heave in feet
C_r = recompression index
H = layer thickness in feet
P_o = initial overburden pressure in tsf
P_f = final overburden pressure in tsf
e_o = initial void ratio

Settlement/Heave Analysis



Profile A and B have similar excavation profiles

Determine the initial and final overburden pressures.

Layer	Overburden			Unit Wt	P_o	
IV	Final Cover	0.0		112.8	0.00	0.00
	Solid Waste	0.0		50.0	0.00	0.00
	Liner	0.0		112.8	0.00	0.00
	I	30.0	0.0	117.0	1.76	0.00
	II	10.0	0.0	130.4	0.65	0.00
	III	35.0	0.0	127.5	2.23	0.00
	IV	35.0	5.0	127.5	2.23	0.32
IV Total					**6.87**	**0.32**
VI	Final Cover	0.0		112.8	0.00	0.00
	Solid Waste	0.0		50.0	0.00	0.00
	Liner	0.0		112.8	0.00	0.00
	I	30.0	0.0	117.0	1.76	0.00
	II	10.0	0.0	130.4	0.65	0.00
	III	35.0	0.0	127.5	2.23	0.00
	IV	35.0	5.0	127.5	2.23	0.32
	V	20.0	20.0	134.4	1.34	1.34
	VI	10.0	10.0	128.6	0.64	0.64
VI Total					**8.86**	**2.31**

Determine the heave in the subgrade.

Layer	H ft	P_o tsf	P_f tsf	C_r	e_o	R ft
IV	5.0	6.87	0.32	0.0248	0.62	-0.10
VI	10.0	8.86	2.31	0.0177	0.57	-0.07
						-0.17

Typical Subgrade Heave: **0.17** **ft**
2.0 in

Settlement/Heave Analysis

2) Subgrade Settlement

Settlement is estimated from the equation:

$$S = [H / (1 + e_o)][C_r log(P_c / P_o) + C_c log(P_f / P_c)]$$

where:
- S = settlement in feet
- C_c = compression index
- C_r = recompression index
- H = layer thickness in feet
- P_o = initial overburden pressure in tsf
- P_c = preconsolidation pressure in tsf
- P_f = final overburden pressure in tsf
- e_o = initial void ratio

Overburden pressure is the sum of the overburden thickness of each material multiplied by it's unit weight. The initial and final overburden pressures are calculated at the analysis point of each layer being analyzed. The thickness of each material above the analysis point is determined as follows and shown in the sections.

2a) Center of Landfill (Profile B)

Determine the initial and final overburden pressures.

Layer	Overburden		H_f	Unit Wt		P_f
IV	Final Cover	0.0	4.5	112.8	0.00	0.25
	Solid Waste	0.0	442.0	50.0	0.00	11.05
	Liner	0.0	4.0	112.8	0.00	0.23
	I	30.0	0.0	117.0	1.76	0.00
	II	10.0	0.0	130.4	0.65	0.00
	III	35.0	0.0	127.5	2.23	0.00
	IV	35.0	5.0	127.5	2.23	0.32
IV Total					**6.87**	**11.85**
VI	Final Cover	0.0	4.5	112.8	0.00	0.25
	Solid Waste	0.0	442.0	50.0	0.00	11.05
	Liner	0.0	4.0	112.8	0.00	0.23
	I	30.0	0.0	117.0	1.76	0.00
	II	10.0	0.0	130.4	0.65	0.00
	III	35.0	0.0	127.5	2.23	0.00
	IV	35.0	5.0	127.5	2.23	0.32
	V	20.0	20.0	134.4	1.34	1.34
	VI	10.0	10.0	128.6	0.64	0.64
VI Total					**8.86**	**13.84**

Determine settlement in the subgrade.

Layer	H ft	P_o tsf	P_c tsf	P_f tsf	C_r	C_c	e_o	S ft
IV	5.0	6.87	5.90	11.85	0.0248	0.1171	0.62	0.10
VI	10.0	0.64	6.60	13.84	0.0177	0.0769	0.57	0.27
								0.38

Settlement/Heave Analysis

2b) Toe of Slope (Profile A)

Determine the initial and final overburden pressures.

Layer	Overburden	H_o	H_f	Unit Wt	P_o	P_f
IV	Final Cover	0.0	4.5	112.8	0.00	0.25
	Solid Waste	0.0	233.0	50.0	0.00	5.83
	Liner	0.0	4.0	112.8	0.00	0.23
	I	30.0	0.0	117.0	1.76	0.00
	II	10.0	0.0	130.4	0.65	0.00
	III	35.0	0.0	127.5	2.23	0.00
	IV	35.0	5.0	127.5	2.23	0.32
IV Total					**6.87**	**6.62**
VI	Final Cover	0.0	4.5	112.8	0.00	0.25
	Solid Waste	0.0	233.0	50.0	0.00	5.83
	Liner	0.0	4.0	112.8	0.00	0.23
	I	30.0	0.0	117.0	1.76	0.00
	II	10.0	0.0	130.4	0.65	0.00
	III	35.0	0.0	127.5	2.23	0.00
	IV	35.0	5.0	127.5	2.23	0.32
	V	20.0	20.0	134.4	1.34	1.34
	VI	10.0	10.0	128.6	0.64	0.64
VI Total					**8.86**	**8.61**

Determine settlement in the subgrade.

Layer	H ft	P_o tsf	P_c tsf	P_f tsf	C_r	C_c	e_o	S ft
I	18.0	6.87	5.90	6.62	0.0248	0.1171	0.62	0.05
III	40.0	8.86	6.60	8.61	0.0177	0.0769	0.57	0.17
								0.22

Subgrade heave =	**0.17**	**ft**	**2.0 in**	
Settlement at perimeter	**0.00**	**ft**	**0.0 in**	
Settlement at center =	**0.38**	**ft**	**4.5 in**	
Settlement at toe =	**0.22**	**ft**	**2.6 in**	
Differential settlement =	**0.22**	**ft**	**2.6 in**	**(From perimeter to toe of slope)**

Settlement/Heave Analysis

3) Compacted Soil Liner Strain

From Reference 3, the allowable tensile strain in the compacted soil liner is 0.1%.

Settlement calcs indicate the maximum differential settlement betweeen the perimeter and toe of slope.
The typical horizontal distance between perimeter and toe of slope is: 432 ft

Initial Surface

Horizontal distance =	432	ft
Slope =	25.0%	
ΔElevation=	108	ft
tanθ =	ΔElevation/Horizontal distance	
tanθ =	0.2500	
θ =	0.244978663	rad
cosθ =	Horizontal distance/Initial surface	
Initial Surface =	445.29541	ft

Final Surface

ΔS=	0.22	ft
ΔElevation=	108.22	ft
tanθ =	ΔElevation/Horizontal distance	
tanθ =	0.2505	
θ =	0.245448676	rad
cosθ =	Horizontal distance/Final surface	
Final Surface =	445.34779	ft

Strain

Strain =	ΔL/L	
=	(Final Surface - Initial Surface)/Initial Surface	
=	1.18E-04	ft/ft
=	0.012	%

Therefore, differential settlement will not be detrimental to the clay liner since the predicted strain is significantly less than allowable strain (0.1%).

APPENDIX D5B
SLOPE STABILITY ANALYSES

Slope Stability Parameters

Required: Select the appropriate soil parameters for the slope stability analyses.

References:

1) *Attachment E - Geology Report,* TASWA DRF Permit Application.
2) Table 8-3.1 Typical Engineering Properties of Compacted Materials, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures,* Naval Facilities Engineering
3) Tests performed by TRI for Biggs & Mathews Environmental (Appendix D5-C).
4) Qian, X, Koerner, R.M., and Gray, Donald H., *Geotechnical Aspects of Landfill Design and Construction,* Prentice Hall, 2002.
5) Bouazza, A., Zornberg, J.G., and Adam, D., *Geosynthetics in waste containment facilities: recent advances,* 2002.

Solution: The following materials may be included in the slope stability analyses.

Physical Properties							
Material	Description	Wet Wt	Sat Wt	Total Stress		Effective Stress	
		pcf	pcf	cohesion (psf)	friction (deg)	cohesion (psf)	friction (deg)
Fill	Clay	120	124	500	10	250	15
Layer I	Clay and Shaly Clay	117	119	120	26	300	32
Layer II	Shaly Sandstone, Shale	131	132	0	35	0	35
Layer III	Shale w/Sand	127	130	2000	32	80	54
Layer IV	Shale	124	128	2000	26	1000	35
Layer V	Sandstone, Shaly Sand	130	132	0	35	0	35
Layer VI	Shale, Shale w/Sand	124	128	2000	26	1000	35
Solid Waste	Solid Waste	44	50	250	23	250	23
Liner	Clay / Synthetics	120	124	---	---	273	13.5
Final Cover	Clay / Synthetics	120	124	---	---	12	32.6

Average laboratory test values used where available. References 2, 3, and 4 used for typical material properties otherwise.

Total stress parameters to be used to analyze short-term stability and effective stress parameters to be used to analyze long-term stability.

Interface parameters for the geosynthetics will be used to evaluate the liner and cover veneer stability.

Liner Strength Parameters for Veneer Slope Stability		
Material Interface	Friction Angle (Degrees	Cohesion (psf)
Protective Cover/Geocomposite	12.8 [a]	811 [a]
Geocomposite/Geomembrane/Soil Li	11.4 [a]	1409 [a]
Geomembrane/Soil Liner	13.5 [a]	273 [a]
Final Cover Strength Parameters for Veneer Slope Stability		
Material Interface	Friction Angle (Degrees	Cohesion (psf)
Erosion Layer/Geocomposite	32.6 [a]	12 [a]
Geocomposite/Geomembrane	31.8 [a]	59 [a]
Geomembrane/Infiltration Layer	31.8 [a]	60 [a]

a Reference 3.

Based on USGS long-term National Seismic Hazard Map (2014), site is located in a low hazard zone. Although site is not located in a Seisic Impact Zone as defined by 330.557, run siesmic analysis on excavation and long-term waste fill slope.

Seismic loading to be modeled using psuedo-static horizontal seismic coefficient kh= 0.11g

Geosynthetic Stability Parameters

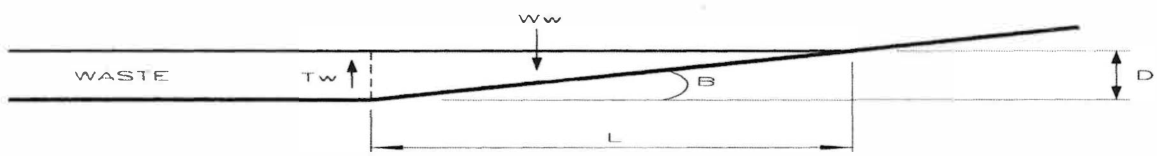
Geosynthetic Stability Analyses

Required:
1) Check tensile stress in geosynthetics.
2) Size geosynthetics anchor trench.
3) Perform veneer stability analysis of liner and cover systems.

References:
1) *Designing with Geosynthetics,* 2nd Edition, Koerner, Prentice Hall.
2) *An Engineering Manual for Slope Stability Studies*, 2nd Edition, Duncan, Buchignani, Dept. of Civil Engineering, University of California.

Solution:
1) ***Tensile Stress in Geomembrane***

Forces on the liner are shown below:



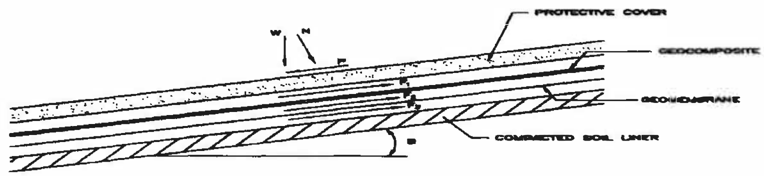
β =	slope angle =	14.03 deg
γ_w =	unit weight of solid waste =	44 pcf
Φ =	internal angle of friction for solid waste =	23 deg
D =	waste lift thickness =	20 ft
L =	length of lift =	80 ft
ko =	$1 - \sin \Phi$ =	0.6093

Calculate the forces on the liner:

W_w =	weight of solid waste = $DL\gamma_w/2$ =	35,200 plf
T_w =	friction at edge of waste = $k_o(D^2\gamma_w/2)\tan\Phi$ =	2,276 plf
W =	net force of waste = $W_w - T_w$ =	32,924 plf

Geosynthetic Stability Parameters

Forces within the composite liner system are shown below:



A_1 =	friction angle between protective cover/geocomposite =	12.8 deg
A_2 =	friction angle between geocomposite/geomembrane/soil liner =	11.4 deg
A_3 =	friction angle between geomembrane/soil liner =	13.5 deg
C_1 =	cohesion between protective cover/geocomposite =	811.0 psf
C_2 =	cohesion between geocomposite/geomembrane/soil liner =	1409.0 psf
C_3 =	cohesion between geomembrane/soil liner =	273.0 psf

Calculate the forces within the liner system:

N =	normal force on liner = $W\cos\beta$ =	31,942 plf
P =	shearing force on liner = $W\sin\beta$ =	7,982 plf

Calculate the resistance in the liner system:

F_1 = $N\tan A_1 + C_1 L/\cos\beta$ = 74,132 plf

Since $F_1 > P$ the protective cover is stable and the entire force P is transferred to the next layer.

F_2 = $N\tan A_2 + C_2 L/\cos\beta$ = 122,627 plf

Since $F_2 > P$ the geocomposite is stable and the entire force P is transferred to the next layer.

F_3 = $N\tan A_3 + C_3 L/\cos\beta$ = 30,180 plf

Since $F_3 > P$ the geomembrane is stable and the entire force P is transferred to the next layer.

There is no tensile stress in the gecomposite or in the geomembrane.

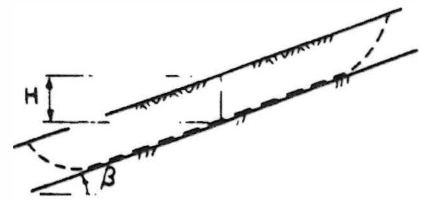
2) *Anchor Trench*

Since there is no tensile stress in the geosynthetics an anchor trench will not be required for stability. Anchor trenches will be sized to meet construction needs.

Geosynthetic Stability Parameters

3) *Veneer Slope Analysis*

Use the procedures and charts from reference 2 to evaluate the stability of the liner and cover systems.



γ = total unit weight of soil

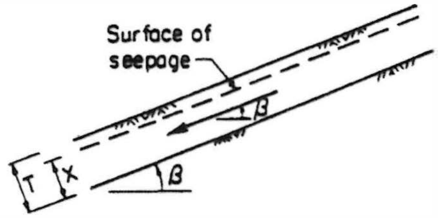
γ_w = unit weight of water

c' = cohesion intercept } Effective Stress

ϕ' = friction angle }

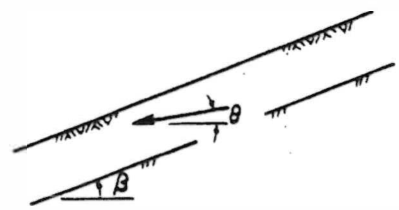
r_u = pore pressure ratio = $\frac{u}{\gamma H}$

u = pore pressure at depth H



Seepage parallel to slope

$$r_u = \frac{X}{T}\frac{\gamma_w}{\gamma}\cos^2\beta$$



Seepage emerging from slope

$$r_u = \frac{\gamma_w}{\gamma}\frac{1}{1+\tan\beta\tan\theta}$$

Steps:

① Determine r_u from measured pore pressures or formulas at right

② Determine a and b from charts below

③ Calculate $F = a\frac{\tan\phi'}{\tan\beta} + b\frac{c'}{\gamma H}$

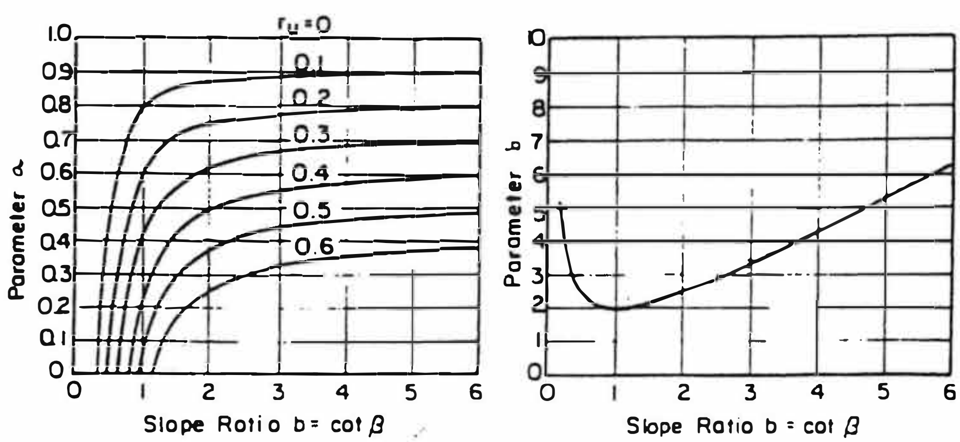


Fig. 10 STABILITY CHARTS FOR INFINITE SLOPES.

Geosynthetic Stability Parameters

Calculate the factor of safety at each interface in the composite liner system.

Protective cover/geocomposite

Φ =	12.8	deg
β =	14.04	deg
C =	811	psf
u =	0.0	
γ =	120.0	pcf
r_u =	0.00	
H =	2	ft
a =	1.0	
b =	4.2	

FS @ protective cover/geocomposite = 15.1

Geocomposite/geomembrane/soil liner

Φ =	11.4	deg
β =	14.04	deg
C =	1409	psf
u =	0.0	
γ =	120.0	pcf
r_u =	0	
H =	2	ft
a =	1.0	
b =	4.2	

FS @ geocomposite/geomembrane/soil liner = 25.5

Geomembrane/soil liner

Φ =	13.5	deg
β =	14.04	deg
C =	273	psf
u =	0.0	
γ =	120.0	pcf
r_u =	0	
H =	2	ft
a =	1.0	
b =	4.2	

FS @ geomembrane/soil liner = 5.7

Geosynthetic Stability Parameters

Calculate the factor of safety at each interface in the composite final cover system.

Erosion layer/geocomposite

$\Phi =$	32.6	deg
$\beta =$	14.04	deg
$C =$	12	psf
$u =$	0.0	
$\gamma =$	120.0	pcf
$r_u =$	0	
$H =$	2	ft
$a =$	1.0	
$b =$	4.2	

FS @ erosion layer/geocomposite = 2.8

Geocomposite/geomembrane

$\Phi =$	31.8	deg
$\beta =$	14.04	deg
$C =$	59	psf
$u =$	0.0	
$\gamma =$	120.0	pcf
$r_u =$	0	
$H =$	2	ft
$a =$	1.0	
$b =$	4.2	

FS @ geocomposite/geomembrane = 3.5

Geomembrane/infiltration layer

$\Phi =$	31.8	deg
$\beta =$	14.04	deg
$C =$	60	psf
$u =$	0.0	
$\gamma =$	120.0	pcf
$r_u =$	0	
$H =$	2	ft
$a =$	1.0	
$b =$	4.2	

FS @ geomembrane/infiltration layer = 3.5

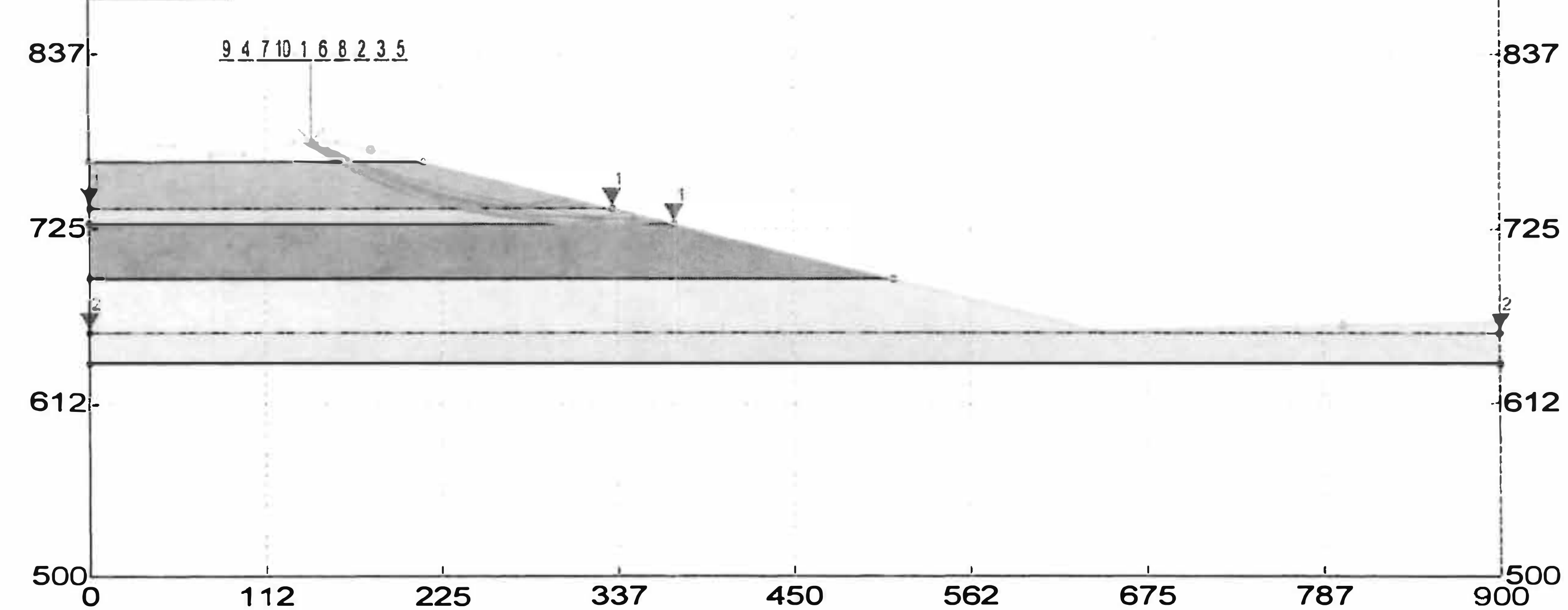
TASWA RDF
Excavation (Short Term)

BME

\Excav_ST.gsd

No.	FS
1	2.45
2	2.50
3	2.51
4	2.54
5	2.55
6	2.56
7	2.56
8	2.57
9	2.58
10	2.59

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	500.0	10.0	0.000	0.0	0	
2	Layer I	117.0	119.0	120.0	26.3	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	2000.0	32.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	2000.0	26.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	2000.0	26.0	0.000	0.0	0	



GEOSTASE FS = 2.45

Simplified Janbu Method

GEOSTASE Slope Stability Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

D5B.7

*** GEOSTASE(R) ***

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_ST.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_ST.OUT

Unit System: English

PROJECT: TASWA RDF

DESCRIPTION: Excavation (Short Term)

BOUNDARY DATA

12 Surface Boundaries
18 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	213.700	768.000	1
8	213.700	768.000	333.600	738.000	2
9	333.600	738.000	373.600	728.000	3
10	373.600	728.000	513.600	693.000	4
11	513.600	693.000	643.000	660.000	5
12	643.000	660.000	900.000	665.700	5
13	0.000	768.000	213.700	768.000	2
14	0.000	738.000	333.600	738.000	3
15	0.000	728.000	373.600	728.000	4
16	0.000	693.000	513.600	693.000	5
17	0.000	658.000	900.000	658.000	6
18	0.000	638.000	900.000	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 500.000(ft)

MOHR-COULOMB SOIL PARAMETERS

7 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	500.00	10.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	120.00	26.30	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	2000.00	32.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	2000.00	26.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	2000.00	26.00	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	900.00	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

TRIAL FAILURE SURFACE DATA

Circular Trial Failure Surfaces Have Been Generated Using A Random Procedure.

3000 Trial Surfaces Have Been Generated.

3000 Surfaces Generated at Increments of 0.2801(in) Equally Spaced Within the Start Range

Along The Specified Surface Between X = 80.00(ft)
and X = 150.00(ft)

Each Surface Enters within a Range Between X = 180.00(ft)
and X = 800.00(ft)

Unless XCLUDE Lines Were Specified, The Minimum Elevation
To Which A Surface Extends Is Y = 500.00(ft)

Specified Maximum Radius = 10000.000(ft)

10.000(ft) Line Segments Were Used For Each Trial Failure Surface.

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 3000

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 0 Iterations.

Number of Trial Surfaces with Non-Converged FS = 165

Number of Trial Surfaces With Valid FS = 2835

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 5.5 %

Statistical Data On All Valid FS Values:
FS Max = 827.684 FS Min = 2.453 FS Ave = 9.888
Standard Deviation = 33.016 Coefficient of Variation = 333.90 %

Critical Surface is Sequence Number 2658 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

BACK-CALCULATED CIRCULAR SURFACE PARAMETERS:

Circle Center At X = 326.631945(ft) ; Y = 1076.573058(ft); and Radius = 348.491012(ft)

Circular Trial Failure Surface Generated With 25 Coordinate Points

Point No.	X-Coord. (ft)	Y-Coord. (ft)
1	142.017	781.000
2	150.574	775.825
3	159.276	770.897
4	168.115	766.221
5	177.085	761.801
6	186.178	757.639
7	195.387	753.741
8	204.704	750.108
9	214.121	746.744
10	223.631	743.652
11	233.225	740.833
12	242.897	738.291
13	252.637	736.028
14	262.439	734.045
15	272.293	732.345
16	282.192	730.927
17	292.128	729.794
18	302.092	728.947
19	312.076	728.386
20	322.072	728.112
21	332.072	728.125
22	342.068	728.424
23	352.051	729.010
24	362.012	729.883
25	364.779	730.205

Factor Of Safety For The Critical or Specified Surface = 2.453

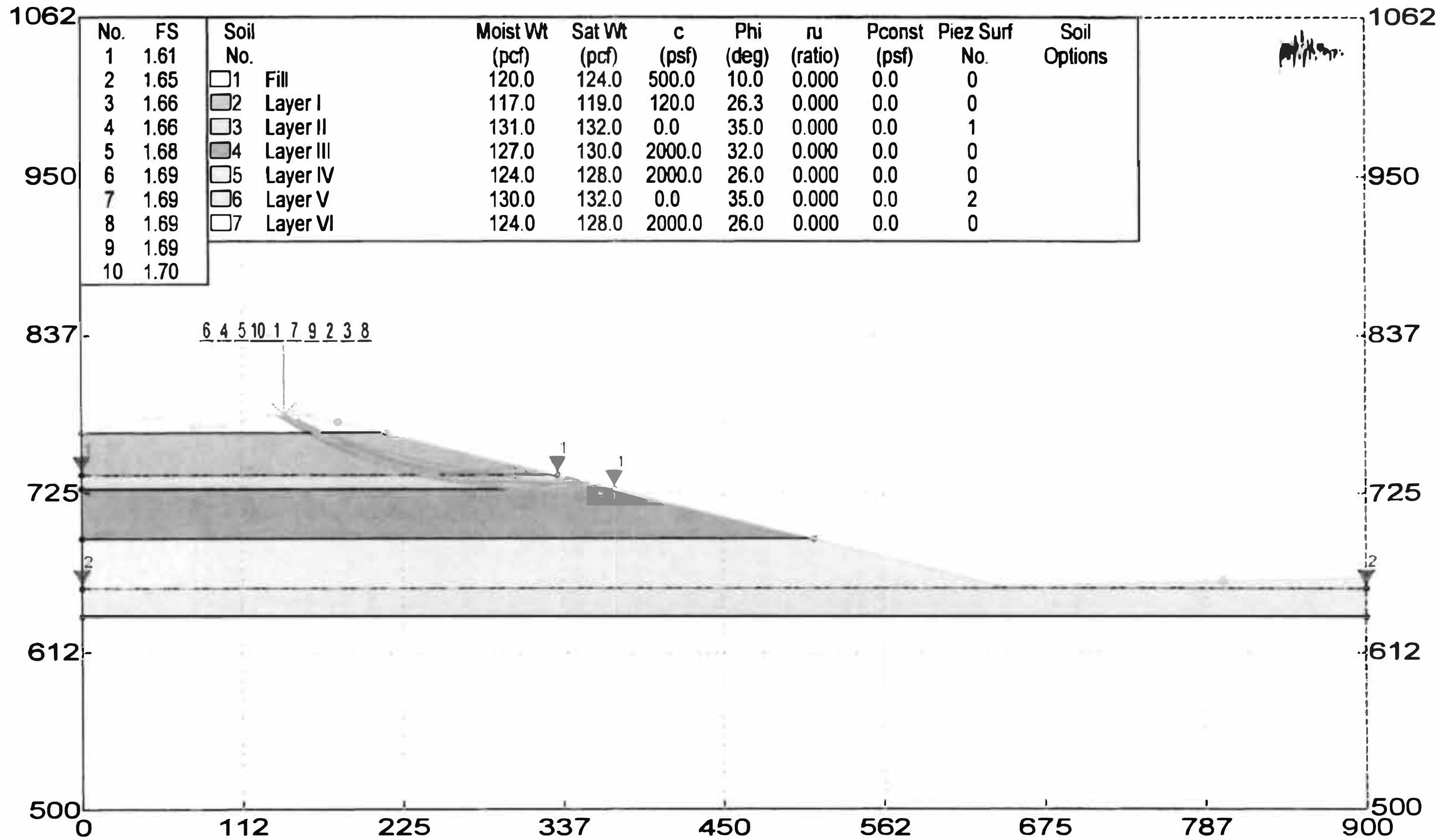
TASWA RDF
Excavation (Short Term) with Seismic Loading

BME

\Excav_ST w-Seismic.gsd

No.	FS
1	1.61
2	1.65
3	1.66
4	1.66
5	1.68
6	1.69
7	1.69
8	1.69
9	1.69
10	1.70

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	500.0	10.0	0.000	0.0	0	
2	Layer I	117.0	119.0	120.0	26.3	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	2000.0	32.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	2000.0	26.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	2000.0	26.0	0.000	0.0	0	



D5B.12

GEOSTASE FS = 1.61

Simplified Janbu Method

kh = 0.11000

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

GEOSTASE

Slope Stability Analysis

*** GEOSTASE(R) ***

** GEOSTASE(R) (c)Copyright by Garry H. Gregory, Ph.D., P.E.,D.GE **

** Current Version 4.30.31-Double Precision, August 2019 **

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_ST w-Seismic.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_ST w-Seismic.OUT

Unit System: English

PROJECT: TASWA RDF

DESCRIPTION: Excavation (Short Term) with Seismic Loading

BOUNDARY DATA

12 Surface Boundaries
18 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	213.700	768.000	1
8	213.700	768.000	333.600	738.000	2
9	333.600	738.000	373.600	728.000	3
10	373.600	728.000	513.600	693.000	4
11	513.600	693.000	643.000	660.000	5
12	643.000	660.000	900.000	665.700	5
13	0.000	768.000	213.700	768.000	2
14	0.000	738.000	333.600	738.000	3
15	0.000	728.000	373.600	728.000	4
16	0.000	693.000	513.600	693.000	5
17	0.000	658.000	900.000	658.000	6
18	0.000	638.000	900.000	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 500.000(ft)

MOHR-COULOMB SOIL PARAMETERS

7 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	500.00	10.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	120.00	26.30	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	2000.00	32.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	2000.00	26.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	2000.00	26.00	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	900.00	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.000(g)
Default Velocity = 0.000(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = -.11000(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000

Horizontal Seismic Force is Applied at Center of Gravity of Slices

TRIAL FAILURE SURFACE DATA

Circular Trial Failure Surfaces Have Been Generated Using A Random Procedure.

3000 Trial Surfaces Have Been Generated.

3000 Surfaces Generated at Increments of 0.2801(in) Equally Spaced Within the Start Range

Along The Specified Surface Between X = 80.00(ft)
and X = 150.00(ft)

Each Surface Enters within a Range Between X = 180.00(ft)
and X = 800.00(ft)

Unless XCLUDE Lines Were Specified, The Minimum Elevation
To Which A Surface Extends Is Y = 500.00(ft)

Specified Maximum Radius = 10000.000(ft)

10.000(ft) Line Segments Were Used For Each Trial Failure Surface.

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 3000

Number of Trial Surfaces With Valid FS = 3000

Statistical Data On All Valid FS Values:
FS Max = 18.047 FS Min = 1.613 FS Ave = 3.691
Standard Deviation = 2.153 Coefficient of Variation = 58.34 %

Critical Surface is Sequence Number 2658 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

BACK-CALCULATED CIRCULAR SURFACE PARAMETERS:

Circle Center At X = 326.631945(ft) ; Y = 1076.573058(ft); and Radius = 348.491012(ft)

Circular Trial Failure Surface Generated With 25 Coordinate Points

Point No.	X-Coord. (ft)	Y-Coord. (ft)
1	142.017	781.000
2	150.574	775.825
3	159.276	770.897

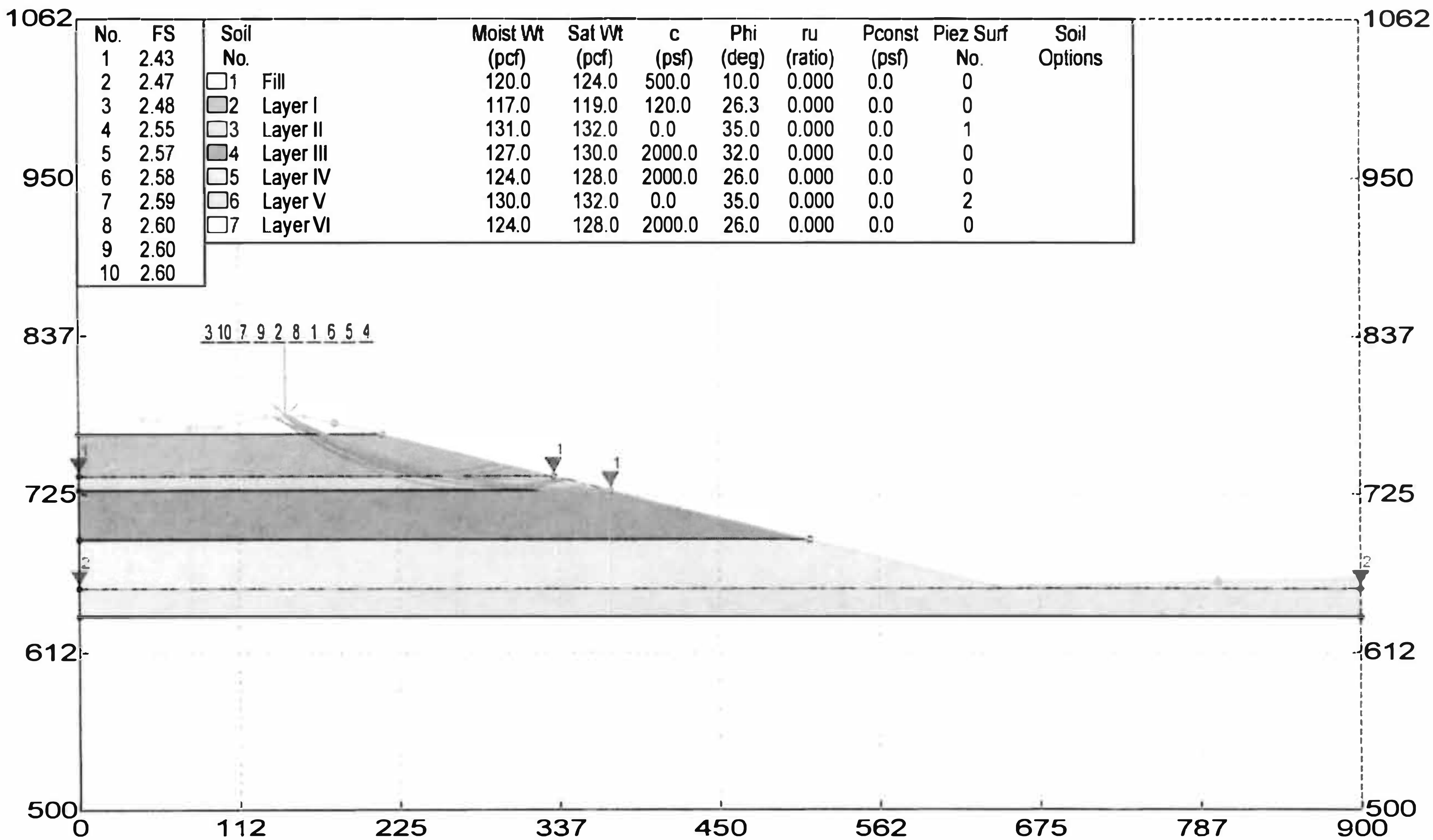
4	168.115	766.221
5	177.085	761.801
6	186.178	757.639
7	195.387	753.741
8	204.704	750.108
9	214.121	746.744
10	223.631	743.652
11	233.225	740.833
12	242.897	738.291
13	252.637	736.028
14	262.439	734.045
15	272.293	732.345
16	282.192	730.927
17	292.128	729.794
18	302.092	728.947
19	312.076	728.386
20	322.072	728.112
21	332.072	728.125
22	342.068	728.424
23	352.051	729.010
24	362.012	729.883
25	364.779	730.205

Factor Of Safety For The Critical or Specified Surface = 1.613

TASWA RDF
Excavation (Long Term)

BME \Excav_LT.gsd

D5B.17



No.	FS
1	2.43
2	2.47
3	2.48
4	2.55
5	2.57
6	2.58
7	2.59
8	2.60
9	2.60
10	2.60

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	500.0	10.0	0.000	0.0	0	
2	Layer I	117.0	119.0	120.0	26.3	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	2000.0	32.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	2000.0	26.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	2000.0	26.0	0.000	0.0	0	

GEOSTASE FS = 2.43

Simplified Janbu Method

GEOSTASE Slope Stability Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

*** GEOSTASE(R) ***

** GEOSTASE(R) (c)Copyright by Garry H. Gregory, Ph.D., P.E.,D.GE **

** Current Version 4.30.31-Double Precision, August 2019 **

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_LT.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_LT.OUT

Unit System: English

PROJECT: TASWA RDF

DESCRIPTION: Excavation (Long Term)

BOUNDARY DATA

12 Surface Boundaries
18 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	213.700	768.000	1
8	213.700	768.000	333.600	738.000	2
9	333.600	738.000	373.600	728.000	3
10	373.600	728.000	513.600	693.000	4
11	513.600	693.000	643.000	660.000	5
12	643.000	660.000	900.000	665.700	5
13	0.000	768.000	213.700	768.000	2
14	0.000	738.000	333.600	738.000	3
15	0.000	728.000	373.600	728.000	4
16	0.000	693.000	513.600	693.000	5
17	0.000	658.000	900.000	658.000	6
18	0.000	638.000	900.000	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 500.000(ft)

MOHR-COULOMB SOIL PARAMETERS

7 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	500.00	10.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	120.00	26.30	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	2000.00	32.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	2000.00	26.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	2000.00	26.00	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	900.00	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

TRIAL FAILURE SURFACE DATA

Circular Trial Failure Surfaces Have Been Generated Using A Random Procedure.

3000 Trial Surfaces Have Been Generated.

3000 Surfaces Generated at Increments of 0.2801(in) Equally Spaced Within the Start Range

Along The Specified Surface Between X = 80.00(ft)
and X = 150.00(ft)

Each Surface Enters within a Range Between X = 180.00(ft)
and X = 800.00(ft)

Unless XCLUDE Lines Were Specified, The Minimum Elevation
To Which A Surface Extends Is Y = 500.00(ft)

Specified Maximum Radius = 10000.000(ft)

5.000(ft) Line Segments Were Used For Each Trial Failure Surface.

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 3000

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 0 Iterations.

Number of Trial Surfaces with Non-Converged FS = 154

Number of Trial Surfaces With Valid FS = 2846

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 5.1 %

Statistical Data On All Valid FS Values:
FS Max = 445.127 FS Min = 2.427 FS Ave = 9.465
Standard Deviation = 22.922 Coefficient of Variation = 242.17 %

Critical Surface is Sequence Number 2807 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

BACK-CALCULATED CIRCULAR SURFACE PARAMETERS:

Circle Center At X = 356.538618(ft) ; Y = 1174.811687(ft); and Radius = 446.796356(ft)

Circular Trial Failure Surface Generated With 49 Coordinate Points

Point No.	X-Coord. (ft)	Y-Coord. (ft)
1	145.495	781.000
2	149.915	778.663
3	154.361	776.376
4	158.833	774.138
5	163.329	771.951
6	167.849	769.814
7	172.393	767.728

8	176.960	765.692
9	181.550	763.708
10	186.161	761.776
11	190.794	759.895
12	195.448	758.066
13	200.121	756.290
14	204.815	754.566
15	209.527	752.894
16	214.258	751.275
17	219.006	749.710
18	223.772	748.197
19	228.554	746.738
20	233.353	745.333
21	238.167	743.981
22	242.995	742.683
23	247.838	741.440
24	252.695	740.250
25	257.564	739.116
26	262.446	738.035
27	267.340	737.010
28	272.245	736.039
29	277.160	735.123
30	282.086	734.262
31	287.020	733.457
32	291.964	732.706
33	296.915	732.011
34	301.874	731.372
35	306.840	730.788
36	311.812	730.260
37	316.789	729.787
38	321.772	729.370
39	326.759	729.009
40	331.750	728.704
41	336.743	728.454
42	341.740	728.260
43	346.738	728.123
44	351.737	728.041
45	356.737	728.015
46	361.737	728.046
47	366.736	728.132
48	371.734	728.274
49	372.399	728.300

Factor Of Safety For The Critical or Specified Surface = 2.427

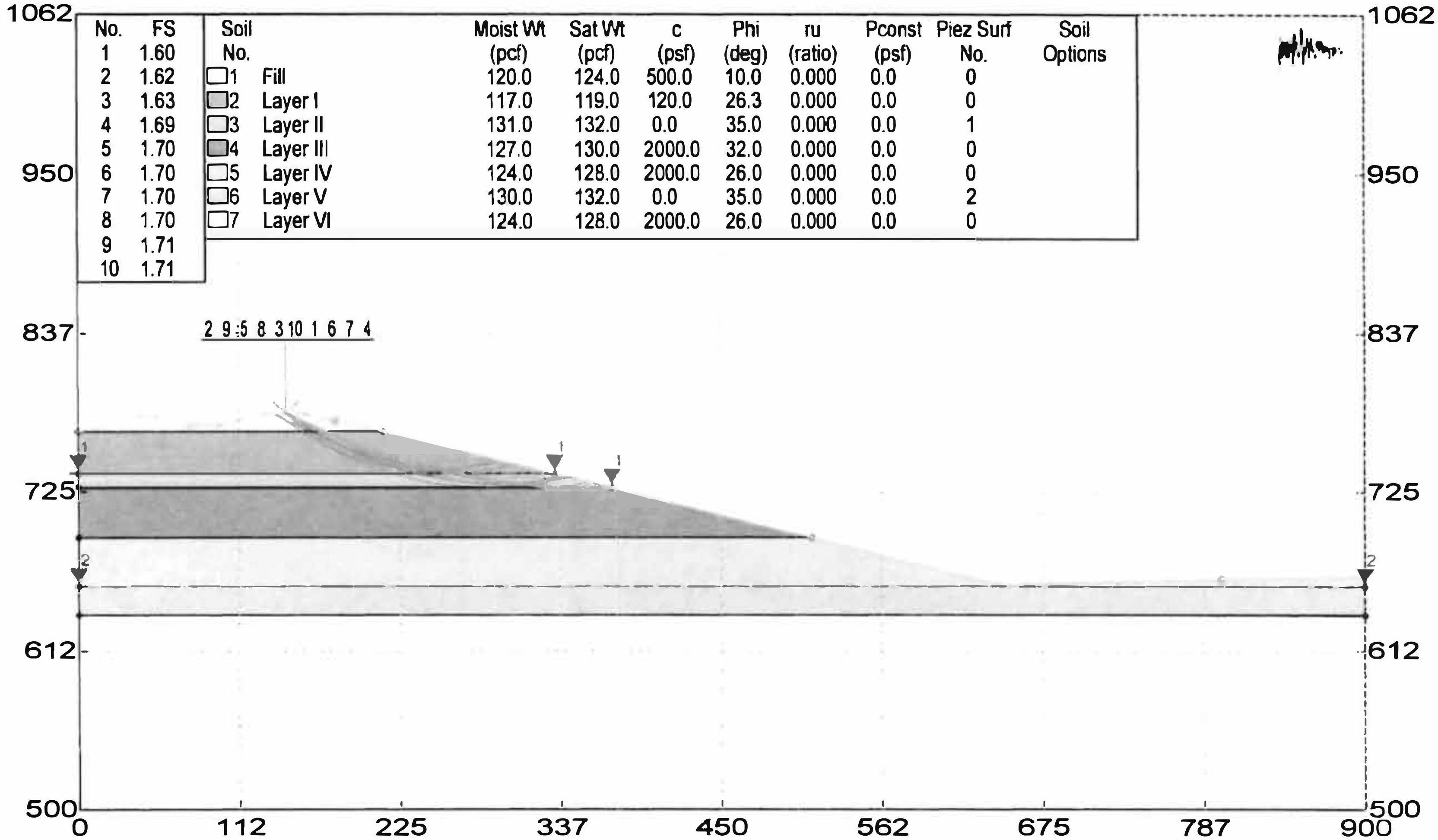
TASWA RDF
Excavation (Long Term) with Seismic

BME

\Excav_LT w-Seismic.gsd

No.	FS
1	1.60
2	1.62
3	1.63
4	1.69
5	1.70
6	1.70
7	1.70
8	1.70
9	1.71
10	1.71

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	500.0	10.0	0.000	0.0	0	
2	Layer I	117.0	119.0	120.0	26.3	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	2000.0	32.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	2000.0	26.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	2000.0	26.0	0.000	0.0	0	



D5B.22

GEOSTASE FS = 1.60

Simplified Janbu Method

kh = 0.11000

GEOSTASE Slope Stability Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

*** GEOSTASE(R) ***

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** Current Version 4.30.31-Double Precision, August 2019 **

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_LT w-Seismic.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Excav_LT w-Seismic.OUT

Unit System: English

PROJECT: TASWA RDF

DESCRIPTION: Excavation (Long Term) with Seismic

BOUNDARY DATA

12 Surface Boundaries
18 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	213.700	768.000	1
8	213.700	768.000	333.600	738.000	2
9	333.600	738.000	373.600	728.000	3
10	373.600	728.000	513.600	693.000	4
11	513.600	693.000	643.000	660.000	5
12	643.000	660.000	900.000	665.700	5
13	0.000	768.000	213.700	768.000	2
14	0.000	738.000	333.600	738.000	3
15	0.000	728.000	373.600	728.000	4
16	0.000	693.000	513.600	693.000	5
17	0.000	658.000	900.000	658.000	6
18	0.000	638.000	900.000	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 500.000(ft)

MOHR-COULOMB SOIL PARAMETERS

7 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	500.00	10.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	120.00	26.30	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	2000.00	32.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	2000.00	26.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	2000.00	26.00	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	900.00	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.000(g)
Default Velocity = 0.000(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = -.11000(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000

Horizontal Seismic Force is Applied at Center of Gravity of Slices

TRIAL FAILURE SURFACE DATA

Circular Trial Failure Surfaces Have Been Generated Using A Random Procedure.

3000 Trial Surfaces Have Been Generated.

3000 Surfaces Generated at Increments of 0.2801(in) Equally Spaced Within the Start Range

Along The Specified Surface Between X = 80.00(ft)
and X = 150.00(ft)

Each Surface Enters within a Range Between X = 180.00(ft)
and X = 800.00(ft)

Unless XCLUDE Lines Were Specified, The Minimum Elevation
To Which A Surface Extends Is Y = 500.00(ft)

Specified Maximum Radius = 10000.000(ft)

5.000(ft) Line Segments Were Used For Each Trial Failure Surface.

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 3000

Number of Trial Surfaces With Valid FS = 3000

Statistical Data On All Valid FS Values:
FS Max = 17.535 FS Min = 1.599 FS Ave = 3.684
Standard Deviation = 2.185 Coefficient of Variation = 59.33 %

Critical Surface is Sequence Number 2807 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

BACK-CALCULATED CIRCULAR SURFACE PARAMETERS:

Circle Center At X = 356.538618(ft) ; Y = 1174.811687(ft); and Radius = 446.796356(ft)

Circular Trial Failure Surface Generated With 49 Coordinate Points

Point No.	X-Coord. (ft)	Y-Coord. (ft)
1	145.495	781.000
2	149.915	778.663
3	154.361	776.376

4	158.833	774.138
5	163.329	771.951
6	167.849	769.814
7	172.393	767.728
8	176.960	765.692
9	181.550	763.708
10	186.161	761.776
11	190.794	759.895
12	195.448	758.066
13	200.121	756.290
14	204.815	754.566
15	209.527	752.894
16	214.258	751.275
17	219.006	749.710
18	223.772	748.197
19	228.554	746.738
20	233.353	745.333
21	238.167	743.981
22	242.995	742.683
23	247.838	741.440
24	252.695	740.250
25	257.564	739.116
26	262.446	738.035
27	267.340	737.010
28	272.245	736.039
29	277.160	735.123
30	282.086	734.262
31	287.020	733.457
32	291.964	732.706
33	296.915	732.011
34	301.874	731.372
35	306.840	730.788
36	311.812	730.260
37	316.789	729.787
38	321.772	729.370
39	326.759	729.009
40	331.750	728.704
41	336.743	728.454
42	341.740	728.260
43	346.738	728.123
44	351.737	728.041
45	356.737	728.015
46	361.737	728.046
47	366.736	728.132
48	371.734	728.274
49	372.399	728.300

Factor Of Safety For The Critical or Specified Surface = 1.599

TASWA DRF
Interim Waste Fill

BME

\Interim Waste.gsd

No.	FS
1	1.72
2	1.72
3	1.72
4	1.72
5	1.72
6	1.72
7	1.72
8	1.72
9	1.72
10	1.72

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	250.0	15.0	0.000	0.0	0	
2	Layer I	117.0	119.0	300.0	32.0	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	80.0	54.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	1000.0	35.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	1000.0	35.0	0.000	0.0	0	
8	Waste	44.0	50.0	250.0	23.0	0.000	0.0	0	
9	Liner	120.0	124.0	273.0	13.5	0.000	0.0	0	

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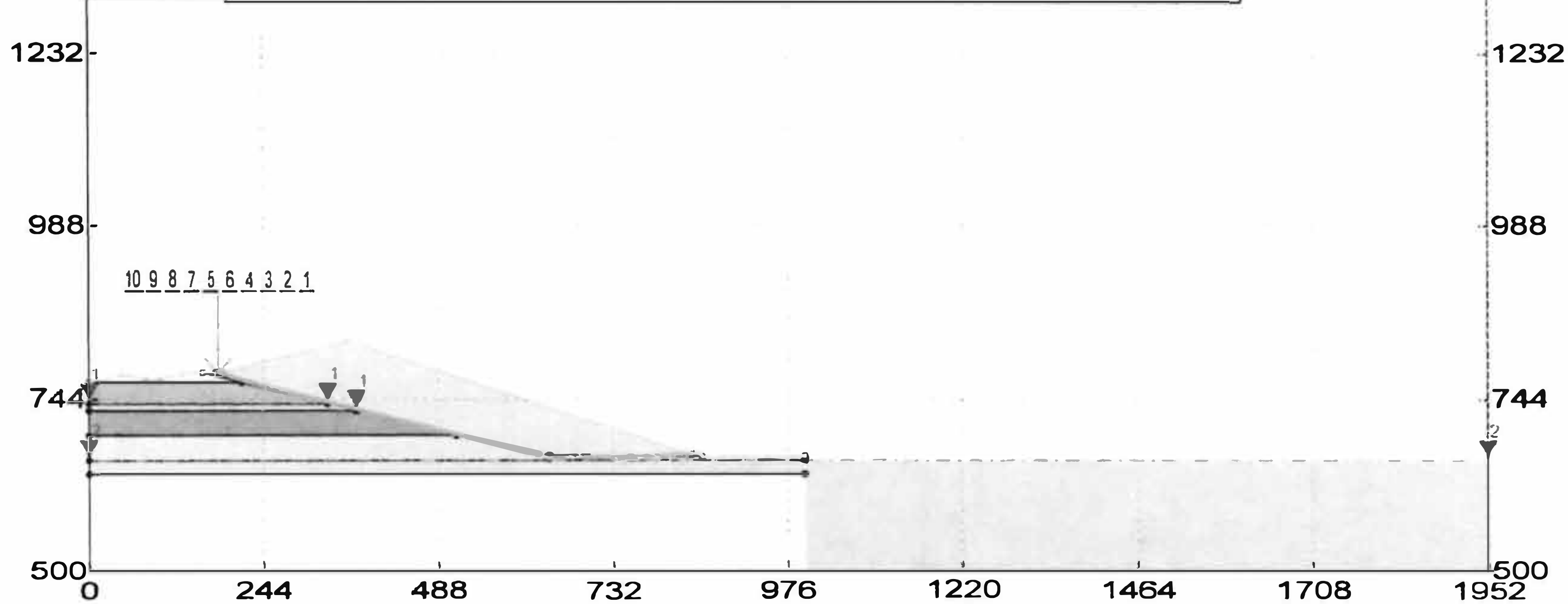

GEOSTASE FS = 1.72

Simplified Janbu Method

GEOSTASE
Slope Stability
Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

*** GEOSTASE(R) ***

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** Current Version 4.30.31-Double Precision, August 2019 **

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Interim Waste.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Interim Waste.OUT

Unit System: English

PROJECT: TASWA DRF

DESCRIPTION: Interim Waste Fill

BOUNDARY DATA

12 Surface Boundaries
27 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	177.000	781.000	9
8	177.000	781.000	361.500	827.000	8
9	361.500	827.000	843.000	667.000	8
10	843.000	667.000	853.000	667.000	9
11	853.000	667.000	857.000	663.000	9
12	857.000	663.000	1000.000	664.000	7
13	177.000	781.000	643.000	664.600	9
14	643.000	664.600	843.000	667.000	9
15	159.000	781.000	213.700	768.000	1
16	0.000	768.000	213.700	768.000	2
17	213.700	768.000	333.600	738.000	2
18	0.000	738.000	333.600	738.000	3
19	333.600	738.000	373.600	728.000	3
20	0.000	728.000	373.600	728.000	4
21	373.600	728.000	513.600	693.000	4

22	0.000	693.000	513.600	693.000	5
23	513.600	693.000	643.000	660.600	5
24	643.000	660.600	857.000	663.000	5
25	857.000	663.000	1000.000	664.000	5
26	0.000	658.000	1000.000	658.000	6
27	0.000	638.000	1000.000	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 500.000(ft)

MOHR-COULOMB SOIL PARAMETERS

9 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	250.00	15.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	300.00	32.00	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	80.00	54.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	1000.00	35.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	1000.00	35.00	0.000	0.0	0	0
8 Waste	44.0	50.0	250.00	23.00	0.000	0.0	0	0
9 Liner	120.0	124.0	273.00	13.50	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	1952.90	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

3 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 5.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	186.20	774.90	200.70	774.90	0.50
2	643.00	660.40	647.00	664.70	0.50
3	839.00	662.60	842.20	667.00	0.50

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 1000

Number of Trial Surfaces With Valid FS = 1000

Statistical Data On All Valid FS Values:
FS Max = 2.652 FS Min = 1.718 FS Ave = 1.802
Standard Deviation = 0.127 Coefficient of Variation = 7.04 %

Critical Surface is Sequence Number 51 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

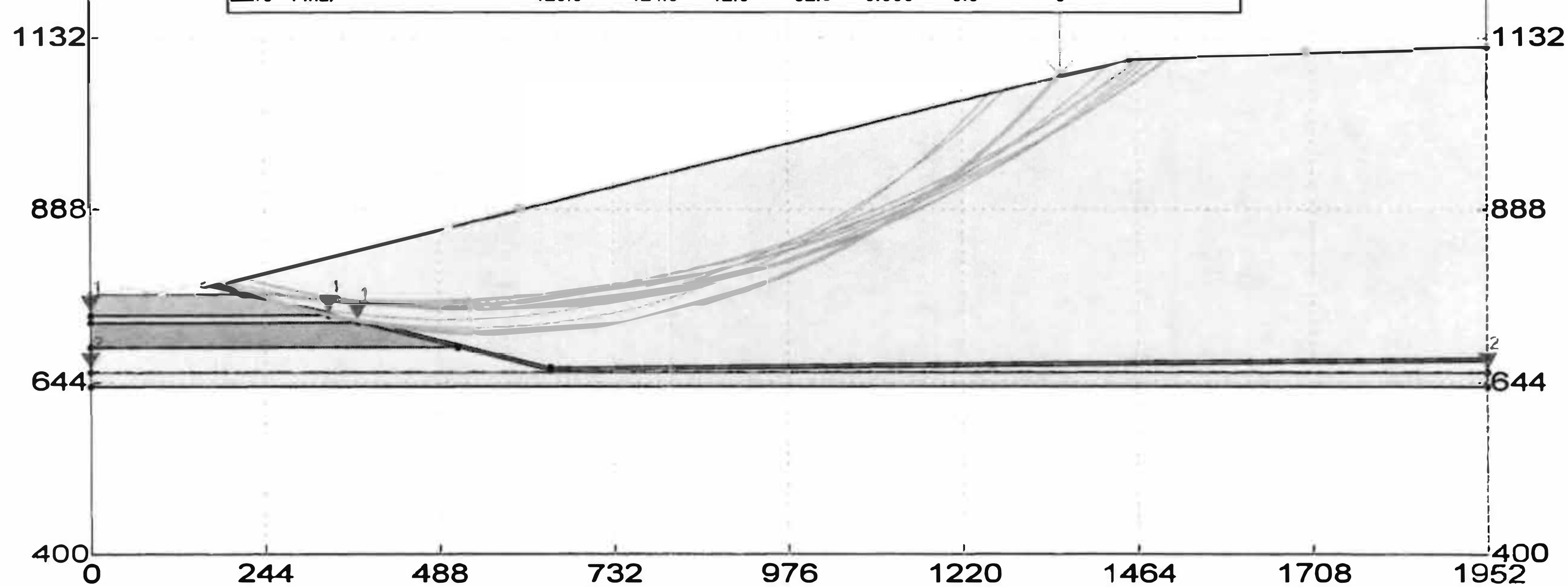
Factor Of Safety For The Critical or Specified Surface = 1.718

TASWA DRF
Waste Fill

BME \Waste.gsd

No.	FS
1	1.99
2	2.00
3	2.00
4	2.00
5	2.00
6	2.01
7	2.01
8	2.01
9	2.01
10	2.02

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	250.0	15.0	0.000	0.0	0	
2	Layer I	117.0	119.0	300.0	32.0	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	80.0	54.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	1000.0	35.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	1000.0	35.0	0.000	0.0	0	
8	Waste	44.0	50.0	250.0	23.0	0.000	0.0	0	
9	Liner	120.0	124.0	273.0	13.5	0.000	0.0	0	
10	Final	120.0	124.0	12.0	32.6	0.000	0.0	0	



D5B.31

GEOSTASE FS = 1.99

Simplified Janbu Method

GEOSTASE Slope Stability Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

*** GEOSTASE(R) ***

** GEOSTASE(R) (c)Copyright by Garry H. Gregory, Ph.D., P.E.,D.GE **

** Current Version 4.30.31-Double Precision, August 2019 **

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Waste.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Waste.OUT

Unit System: English

PROJECT: TASWA DRF

DESCRIPTION: Waste Fill

BOUNDARY DATA

8 Surface Boundaries
25 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	1452.700	1104.400	10
8	1452.700	1104.400	1952.900	1124.500	10
9	159.000	781.000	177.000	781.000	9
10	177.000	781.000	1452.700	1100.000	8
11	1452.700	1100.000	1952.900	1120.000	8
12	177.000	781.000	643.000	664.600	9
13	643.000	664.600	1952.900	678.000	9
14	159.000	781.000	213.700	768.000	1
15	0.000	768.000	213.700	768.000	2
16	213.700	768.000	333.600	738.000	2
17	0.000	738.000	333.600	738.000	3
18	333.600	738.000	373.600	728.000	3
19	0.000	728.000	373.600	728.000	4

20	373.600	728.000	513.600	693.000	4
21	0.000	693.000	513.600	693.000	5
22	513.600	693.000	643.000	660.600	5
23	643.000	660.600	1952.900	674.000	5
24	0.000	658.000	1952.900	658.000	6
25	0.000	638.000	1952.900	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 400.000(ft)

MOHR-COULOMB SOIL PARAMETERS

10 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	250.00	15.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	300.00	32.00	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	80.00	54.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	1000.00	35.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	1000.00	35.00	0.000	0.0	0	0
8 Waste	44.0	50.0	250.00	23.00	0.000	0.0	0	0
9 Liner	120.0	124.0	273.00	13.50	0.000	0.0	0	0
10 Final	120.0	124.0	12.00	32.60	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	1952.90	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

TRIAL FAILURE SURFACE DATA

Circular Trial Failure Surfaces Have Been Generated Using A Random Procedure.

3000 Trial Surfaces Have Been Generated.

3000 Surfaces Generated at Increments of 1.6005(in) Equally Spaced Within the Start Range

Along The Specified Surface Between X = 100.00(ft)
and X = 500.00(ft)

Each Surface Enters within a Range Between X = 600.00(ft)
and X =1700.00(ft)

Unless XCLUDE Lines Were Specified, The Minimum Elevation
To Which A Surface Extends Is Y = 400.00(ft)

Specified Maximum Radius = 10000.000(ft)

5.000(ft) Line Segments Were Used For Each Trial Failure Surface.

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 3000

Number of Trial Surfaces With Valid FS = 3000

Statistical Data On All Valid FS Values:
FS Max = 11.652 FS Min = 1.987 FS Ave = 3.135
Standard Deviation = 1.483 Coefficient of Variation = 47.29 %

Critical Surface is Sequence Number 605 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

BACK-CALCULATED CIRCULAR SURFACE PARAMETERS:

Circle Center At X = 564.801283(ft) ; Y = 1750.346498(ft); and Radius = 1037.715791(ft)

Circular Trial Failure Surface Generated With261 Coordinate Points

Point No.	X-Coord. (ft)	Y-Coord. (ft)
1	180.560	786.390
2	185.209	784.549
3	189.867	782.732
4	194.534	780.936

5	199.209	779.164
6	203.893	777.413
7	208.585	775.686
8	213.285	773.981
9	217.993	772.298
10	222.710	770.639
11	227.434	769.002
12	232.167	767.388
13	236.907	765.796
14	241.654	764.228
15	246.409	762.682
16	251.172	761.160
17	255.942	759.660
18	260.719	758.183
19	265.503	756.730
20	270.294	755.299
21	275.091	753.892
22	279.896	752.507
23	284.707	751.146
24	289.525	749.808
25	294.349	748.493
26	299.179	747.202
27	304.016	745.934
28	308.858	744.689
29	313.707	743.467
30	318.561	742.269
31	323.421	741.094
32	328.287	739.943
33	333.158	738.815
34	338.034	737.711
35	342.916	736.630
36	347.803	735.573
37	352.695	734.539
38	357.592	733.529
39	362.494	732.542
40	367.400	731.579
41	372.311	730.640
42	377.226	729.724
43	382.146	728.832
44	387.070	727.964
45	391.998	727.120
46	396.931	726.299
47	401.867	725.502
48	406.807	724.729
49	411.750	723.979
50	416.697	723.254
51	421.648	722.552
52	426.602	721.874
53	431.559	721.220
54	436.519	720.590
55	441.482	719.984
56	446.448	719.402
57	451.417	718.844
58	456.388	718.309
59	461.362	717.799
60	466.338	717.313
61	471.317	716.850
62	476.297	716.412
63	481.280	715.997
64	486.265	715.607
65	491.252	715.240

66	496.240	714.898
67	501.230	714.580
68	506.221	714.285
69	511.214	714.015
70	516.208	713.769
71	521.203	713.547
72	526.199	713.349
73	531.196	713.175
74	536.193	713.025
75	541.192	712.899
76	546.191	712.798
77	551.190	712.720
78	556.190	712.666
79	561.190	712.637
80	566.190	712.632
81	571.190	712.650
82	576.190	712.693
83	581.189	712.760
84	586.188	712.851
85	591.187	712.966
86	596.185	713.105
87	601.182	713.269
88	606.179	713.456
89	611.174	713.667
90	616.169	713.903
91	621.162	714.162
92	626.154	714.446
93	631.145	714.754
94	636.134	715.085
95	641.121	715.441
96	646.107	715.821
97	651.090	716.225
98	656.072	716.652
99	661.051	717.104
100	666.029	717.580
101	671.004	718.080
102	675.976	718.603
103	680.946	719.151
104	685.913	719.722
105	690.878	720.318
106	695.839	720.937
107	700.798	721.581
108	705.753	722.248
109	710.705	722.939
110	715.654	723.654
111	720.599	724.393
112	725.540	725.155
113	730.478	725.942
114	735.412	726.752
115	740.342	727.586
116	745.268	728.443
117	750.189	729.325
118	755.107	730.230
119	760.020	731.159
120	764.928	732.111
121	769.832	733.087
122	774.731	734.087
123	779.625	735.110
124	784.514	736.157
125	789.399	737.227
126	794.277	738.321

127	799.151	739.439
128	804.019	740.580
129	808.882	741.744
130	813.738	742.932
131	818.590	744.143
132	823.435	745.377
133	828.274	746.635
134	833.107	747.916
135	837.934	749.221
136	842.754	750.548
137	847.569	751.899
138	852.376	753.273
139	857.177	754.671
140	861.971	756.091
141	866.758	757.534
142	871.538	759.001
143	876.311	760.490
144	881.077	762.003
145	885.835	763.538
146	890.586	765.096
147	895.330	766.677
148	900.065	768.281
149	904.793	769.908
150	909.513	771.558
151	914.226	773.230
152	918.929	774.925
153	923.625	776.643
154	928.313	778.383
155	932.992	780.145
156	937.662	781.931
157	942.324	783.739
158	946.977	785.569
159	951.621	787.421
160	956.256	789.296
161	960.882	791.194
162	965.499	793.113
163	970.106	795.055
164	974.705	797.019
165	979.293	799.005
166	983.872	801.013
167	988.441	803.043
168	993.001	805.096
169	997.550	807.170
170	1002.090	809.266
171	1006.619	811.384
172	1011.138	813.523
173	1015.647	815.685
174	1020.145	817.868
175	1024.633	820.073
176	1029.110	822.299
177	1033.576	824.547
178	1038.031	826.817
179	1042.475	829.107
180	1046.909	831.420
181	1051.331	833.753
182	1055.741	836.108
183	1060.141	838.484
184	1064.529	840.881
185	1068.905	843.300
186	1073.269	845.739
187	1077.622	848.200

188	1081.963	850.681
189	1086.292	853.183
190	1090.608	855.706
191	1094.913	858.250
192	1099.205	860.815
193	1103.485	863.400
194	1107.752	866.006
195	1112.007	868.632
196	1116.249	871.279
197	1120.478	873.946
198	1124.694	876.634
199	1128.898	879.342
200	1133.088	882.070
201	1137.265	884.818
202	1141.428	887.586
203	1145.579	890.375
204	1149.716	893.183
205	1153.839	896.011
206	1157.948	898.859
207	1162.044	901.727
208	1166.126	904.615
209	1170.194	907.522
210	1174.248	910.448
211	1178.288	913.395
212	1182.313	916.360
213	1186.325	919.345
214	1190.321	922.350
215	1194.304	925.373
216	1198.271	928.416
217	1202.224	931.478
218	1206.162	934.558
219	1210.086	937.658
220	1213.994	940.777
221	1217.887	943.914
222	1221.765	947.070
223	1225.628	950.245
224	1229.475	953.438
225	1233.307	956.650
226	1237.124	959.880
227	1240.925	963.129
228	1244.710	966.396
229	1248.479	969.681
230	1252.233	972.984
231	1255.970	976.305
232	1259.692	979.645
233	1263.397	983.002
234	1267.086	986.377
235	1270.759	989.769
236	1274.415	993.180
237	1278.055	996.607
238	1281.679	1000.053
239	1285.286	1003.516
240	1288.876	1006.996
241	1292.449	1010.493
242	1296.005	1014.008
243	1299.545	1017.540
244	1303.067	1021.088
245	1306.572	1024.654
246	1310.060	1028.236
247	1313.531	1031.836
248	1316.984	1035.451

249	1320.420	1039.084
250	1323.838	1042.733
251	1327.239	1046.398
252	1330.622	1050.080
253	1333.987	1053.778
254	1337.334	1057.493
255	1340.664	1061.223
256	1343.975	1064.969
257	1347.268	1068.731
258	1350.544	1072.509
259	1353.800	1076.303
260	1357.039	1080.113
261	1357.438	1080.586

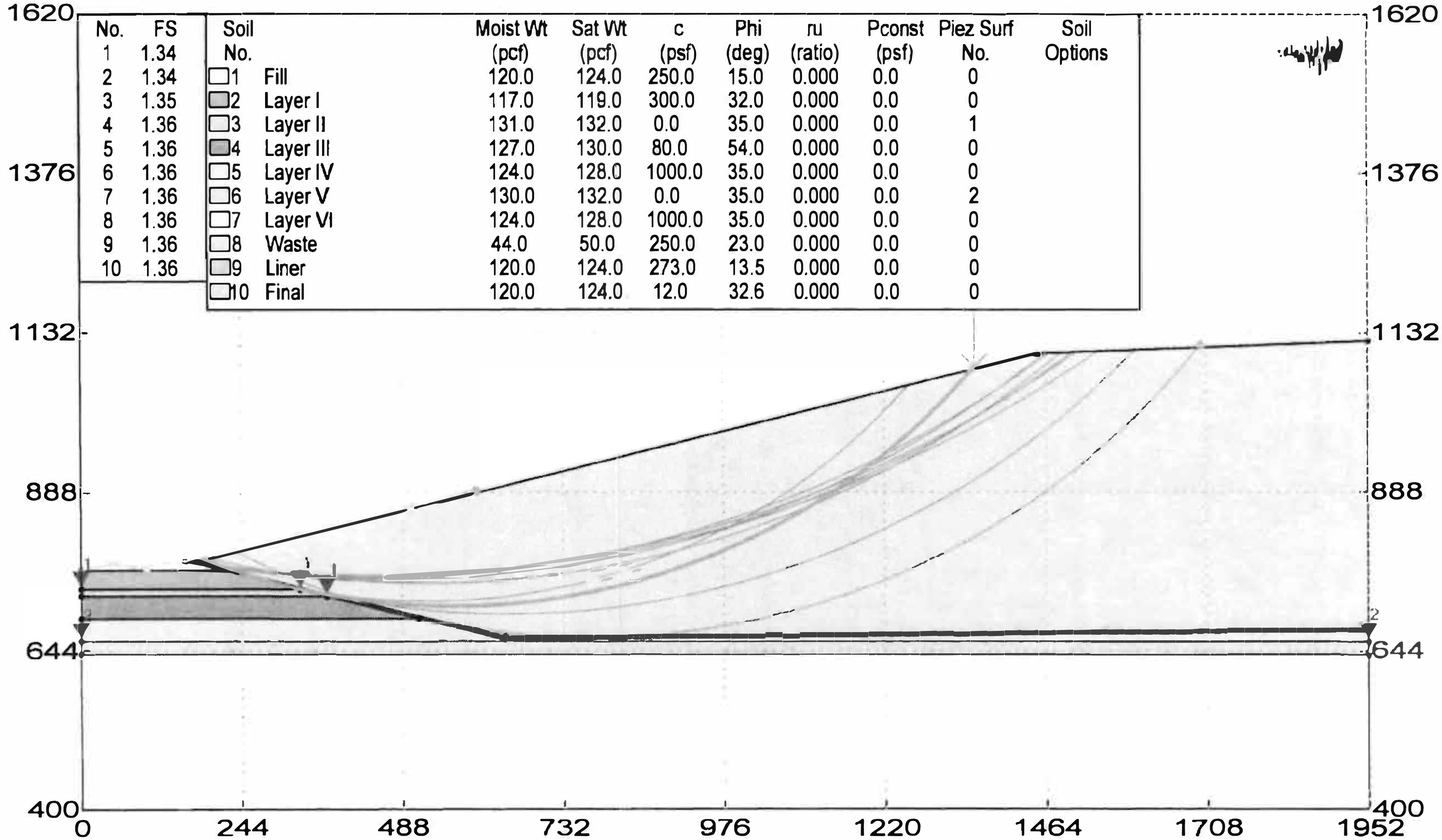
Factor Of Safety For The Critical or Specified Surface = 1.987

TASWA DRF
Waste Fill with Seismic Loading

BME

\Waste w-Seismic.gsd

D5B.40



No.	FS
1	1.34
2	1.34
3	1.35
4	1.36
5	1.36
6	1.36
7	1.36
8	1.36
9	1.36
10	1.36

Soil No.		Moist Wt (pcf)	Sat Wt (pcf)	c (psf)	Phi (deg)	ru (ratio)	Pconst (psf)	Piez Surf No.	Soil Options
1	Fill	120.0	124.0	250.0	15.0	0.000	0.0	0	
2	Layer I	117.0	119.0	300.0	32.0	0.000	0.0	0	
3	Layer II	131.0	132.0	0.0	35.0	0.000	0.0	1	
4	Layer III	127.0	130.0	80.0	54.0	0.000	0.0	0	
5	Layer IV	124.0	128.0	1000.0	35.0	0.000	0.0	0	
6	Layer V	130.0	132.0	0.0	35.0	0.000	0.0	2	
7	Layer VI	124.0	128.0	1000.0	35.0	0.000	0.0	0	
8	Waste	44.0	50.0	250.0	23.0	0.000	0.0	0	
9	Liner	120.0	124.0	273.0	13.5	0.000	0.0	0	
10	Final	120.0	124.0	12.0	32.6	0.000	0.0	0	

GEOSTASE FS = 1.34

Simplified Janbu Method

kh = 0.11000

GEOSTASE

Slope Stability Analysis

*** GEOSTASE(R) ***

Analysis Date: 8/ 2/ 2022
Analysis Time:
Analysis By: BME

Input File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Waste w-Seismic.gsd

Output File Name: O:\TASWA\P\Working\Geotech\Slope Stability\Waste w-Seismic.OUT

Unit System: English

PROJECT: TASWA DRF

DESCRIPTION: Waste Fill with Seismic Loading

BOUNDARY DATA

8 Surface Boundaries
25 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	768.000	45.000	779.000	1
2	45.000	779.000	55.000	779.000	1
3	55.000	779.000	79.000	773.000	1
4	79.000	773.000	99.000	773.000	1
5	99.000	773.000	131.000	781.000	1
6	131.000	781.000	159.000	781.000	1
7	159.000	781.000	1452.700	1104.400	10
8	1452.700	1104.400	1952.900	1124.500	10
9	159.000	781.000	177.000	781.000	9
10	177.000	781.000	1452.700	1100.000	8
11	1452.700	1100.000	1952.900	1120.000	8
12	177.000	781.000	643.000	664.600	9
13	643.000	664.600	1952.900	678.000	9
14	159.000	781.000	213.700	768.000	1
15	0.000	768.000	213.700	768.000	2
16	213.700	768.000	333.600	738.000	2
17	0.000	738.000	333.600	738.000	3
18	333.600	738.000	373.600	728.000	3
19	0.000	728.000	373.600	728.000	4

20	373.600	728.000	513.600	693.000	4
21	0.000	693.000	513.600	693.000	5
22	513.600	693.000	643.000	660.600	5
23	643.000	660.600	1952.900	674.000	5
24	0.000	658.000	1952.900	658.000	6
25	0.000	638.000	1952.900	638.000	7

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 400.000(ft)

MOHR-COULOMB SOIL PARAMETERS

10 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill	120.0	124.0	250.00	15.00	0.000	0.0	0	0
2 Layer I	117.0	119.0	300.00	32.00	0.000	0.0	0	0
3 Layer II	131.0	132.0	0.00	35.00	0.000	0.0	1	0
4 Layer III	127.0	130.0	80.00	54.00	0.000	0.0	0	0
5 Layer IV	124.0	128.0	1000.00	35.00	0.000	0.0	0	0
6 Layer V	130.0	132.0	0.00	35.00	0.000	0.0	2	0
7 Layer VI	124.0	128.0	1000.00	35.00	0.000	0.0	0	0
8 Waste	44.0	50.0	250.00	23.00	0.000	0.0	0	0
9 Liner	120.0	124.0	273.00	13.50	0.000	0.0	0	0
10 Final	120.0	124.0	12.00	32.60	0.000	0.0	0	0

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 3 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	738.00
2	333.60	738.00
3	373.60	728.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	658.00
2	1952.90	658.00

Drained Shear Strength Reduction Factor applied after first stage = 1.0000

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.000(g)
Default Velocity = 0.000(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.11000(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

TRIAL FAILURE SURFACE DATA

Circular Trial Failure Surfaces Have Been Generated Using A Random Procedure.

3000 Trial Surfaces Have Been Generated.

3000 Surfaces Generated at Increments of 1.6005(in) Equally Spaced Within the Start Range

Along The Specified Surface Between X = 100.00(ft)
and X = 500.00(ft)

Each Surface Enters within a Range Between X = 600.00(ft)
and X =1700.00(ft)

Unless XCLUDE Lines Were Specified, The Minimum Elevation
To Which A Surface Extends Is Y = 400.00(ft)

Specified Maximum Radius = 10000.000(ft)

5.000(ft) Line Segments Were Used For Each Trial Failure Surface.

The Simplified Janbu Method Was Selected for FS Analysis.

Total Number of Trial Surfaces Attempted = 3000

Number of Trial Surfaces With Valid FS = 3000

Statistical Data On All Valid FS Values:
FS Max = 5.803 FS Min = 1.341 FS Ave = 2.012
Standard Deviation = 0.741 Coefficient of Variation = 36.82 %

Critical Surface is Sequence Number 605 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

BACK-CALCULATED CIRCULAR SURFACE PARAMETERS:

Circle Center At X = 564.801283(ft) ; Y = 1750.346498(ft); and Radius

= 1037.715791(ft)

Circular Trial Failure Surface Generated With261 Coordinate Points

Point No.	X-Coord. (ft)	Y-Coord. (ft)
1	180.560	786.390
2	185.209	784.549
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5	199.209	779.164
6	203.893	777.413
7	208.585	775.686
8	213.285	773.981
9	217.993	772.298
10	222.710	770.639
11	227.434	769.002
12	232.167	767.388
13	236.907	765.796
14	241.654	764.228
15	246.409	762.682
16	251.172	761.160
17	255.942	759.660
18	260.719	758.183
19	265.503	756.730
20	270.294	755.299
21	275.091	753.892
22	279.896	752.507
23	284.707	751.146
24	289.525	749.808
25	294.349	748.493
26	299.179	747.202
27	304.016	745.934
28	308.858	744.689
29	313.707	743.467
30	318.561	742.269
31	323.421	741.094
32	328.287	739.943
33	333.158	738.815
34	338.034	737.711
35	342.916	736.630
36	347.803	735.573
37	352.695	734.539
38	357.592	733.529
39	362.494	732.542
40	367.400	731.579
41	372.311	730.640
42	377.226	729.724
43	382.146	728.832
44	387.070	727.964
45	391.998	727.120
46	396.931	726.299
47	401.867	725.502
48	406.807	724.729
49	411.750	723.979
50	416.697	723.254
51	421.648	722.552
52	426.602	721.874
53	431.559	721.220
54	436.519	720.590

55	441.482	719.984
56	446.448	719.402
57	451.417	718.844
58	456.388	718.309
59	461.362	717.799
60	466.338	717.313
61	471.317	716.850
62	476.297	716.412
63	481.280	715.997
64	486.265	715.607
65	491.252	715.240
66	496.240	714.898
67	501.230	714.580
68	506.221	714.285
69	511.214	714.015
70	516.208	713.769
71	521.203	713.547
72	526.199	713.349
73	531.196	713.175
74	536.193	713.025
75	541.192	712.899
76	546.191	712.798
77	551.190	712.720
78	556.190	712.666
79	561.190	712.637
80	566.190	712.632
81	571.190	712.650
82	576.190	712.693
83	581.189	712.760
84	586.188	712.851
85	591.187	712.966
86	596.185	713.105
87	601.182	713.269
88	606.179	713.456
89	611.174	713.667
90	616.169	713.903
91	621.162	714.162
92	626.154	714.446
93	631.145	714.754
94	636.134	715.085
95	641.121	715.441
96	646.107	715.821
97	651.090	716.225
98	656.072	716.652
99	661.051	717.104
100	666.029	717.580
101	671.004	718.080
102	675.976	718.603
103	680.946	719.151
104	685.913	719.722
105	690.878	720.318
106	695.839	720.937
107	700.798	721.581
108	705.753	722.248
109	710.705	722.939
110	715.654	723.654
111	720.599	724.393
112	725.540	725.155
113	730.478	725.942
114	735.412	726.752
115	740.342	727.586

116	745.268	728.443
117	750.189	729.325
118	755.107	730.230
119	760.020	731.159
120	764.928	732.111
121	769.832	733.087
122	774.731	734.087
123	779.625	735.110
124	784.514	736.157
125	789.399	737.227
126	794.277	738.321
127	799.151	739.439
128	804.019	740.580
129	808.882	741.744
130	813.738	742.932
131	818.590	744.143
132	823.435	745.377
133	828.274	746.635
134	833.107	747.916
135	837.934	749.221
136	842.754	750.548
137	847.569	751.899
138	852.376	753.273
139	857.177	754.671
140	861.971	756.091
141	866.758	757.534
142	871.538	759.001
143	876.311	760.490
144	881.077	762.003
145	885.835	763.538
146	890.586	765.096
147	895.330	766.677
148	900.065	768.281
149	904.793	769.908
150	909.513	771.558
151	914.226	773.230
152	918.929	774.925
153	923.625	776.643
154	928.313	778.383
155	932.992	780.145
156	937.662	781.931
157	942.324	783.739
158	946.977	785.569
159	951.621	787.421
160	956.256	789.296
161	960.882	791.194
162	965.499	793.113
163	970.106	795.055
164	974.705	797.019
165	979.293	799.005
166	983.872	801.013
167	988.441	803.043
168	993.001	805.096
169	997.550	807.170
170	1002.090	809.266
171	1006.619	811.384
172	1011.138	813.523
173	1015.647	815.685
174	1020.145	817.868
175	1024.633	820.073
176	1029.110	822.299

177	1033.576	824.547
178	1038.031	826.817
179	1042.475	829.107
180	1046.909	831.420
181	1051.331	833.753
182	1055.741	836.108
183	1060.141	838.484
184	1064.529	840.881
185	1068.905	843.300
186	1073.269	845.739
187	1077.622	848.200
188	1081.963	850.681
189	1086.292	853.183
190	1090.608	855.706
191	1094.913	858.250
192	1099.205	860.815
193	1103.485	863.400
194	1107.752	866.006
195	1112.007	868.632
196	1116.249	871.279
197	1120.478	873.946
198	1124.694	876.634
199	1128.898	879.342
200	1133.088	882.070
201	1137.265	884.818
202	1141.428	887.586
203	1145.579	890.375
204	1149.716	893.183
205	1153.839	896.011
206	1157.948	898.859
207	1162.044	901.727
208	1166.126	904.615
209	1170.194	907.522
210	1174.248	910.448
211	1178.288	913.395
212	1182.313	916.360
213	1186.325	919.345
214	1190.321	922.350
215	1194.304	925.373
216	1198.271	928.416
217	1202.224	931.478
218	1206.162	934.558
219	1210.086	937.658
220	1213.994	940.777
221	1217.887	943.914
222	1221.765	947.070
223	1225.628	950.245
224	1229.475	953.438
225	1233.307	956.650
226	1237.124	959.880
227	1240.925	963.129
228	1244.710	966.396
229	1248.479	969.681
230	1252.233	972.984
231	1255.970	976.305
232	1259.692	979.645
233	1263.397	983.002
234	1267.086	986.377
235	1270.759	989.769
236	1274.415	993.180
237	1278.055	996.607

238	1281.679	1000.053
239	1285.286	1003.516
240	1288.876	1006.996
241	1292.449	1010.493
242	1296.005	1014.008
243	1299.545	1017.540
244	1303.067	1021.088
245	1306.572	1024.654
246	1310.060	1028.236
247	1313.531	1031.836
248	1316.984	1035.451
249	1320.420	1039.084
250	1323.838	1042.733
251	1327.239	1046.398
252	1330.622	1050.080
253	1333.987	1053.778
254	1337.334	1057.493
255	1340.664	1061.223
256	1343.975	1064.969
257	1347.268	1068.731
258	1350.544	1072.509
259	1353.800	1076.303
260	1357.039	1080.113
261	1357.438	1080.586

Factor Of Safety For The Critical or Specified Surface = 1.341

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT D6
LEACHATE AND CONTAMINATED WATER MANAGEMENT PLAN

Prepared for

TEXOMA AREA SOLID WASTE AUTHORITY

February 2025

Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

Prepared by

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Firm Registration No. F-256

CONTENTS

30 TAC §§330.65(c), 330.177, 330.207, 330.227, 330.331(a)(2), 330.333, 330.337(d)

1 INTRODUCTION

30 TAC §§330.65(c), 330.177, 330.207, 330.227, 330.331(a)(2), 330.333, 330.337(d)

1.1 Purpose

This Leachate and Contaminated Water Management Plan has been prepared for the TASWA DRF consistent with 30 TAC §§330.65(c), 330.177, 330.207, 330.227, 330.331(a)(2), 330.333, and 330.337(d). This plan provides the details of the collection, storage, treatment, and disposal of contaminated water, leachate, and gas condensate from the leachate collection system, gas collection and control system, and site operations.

1.2 Definitions

Leachate is defined in §330.3(80) as a liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste.

Contaminated water is defined in §330.3(36) as leachate, gas condensate, or water that has come into contact with waste.

Gas condensate is defined in §330.3(57) as the liquid generated as a result of any gas recovery process at a municipal solid waste facility.

2 LEACHATE MANAGEMENT

30 TAC §§330.227, 330.331(a)(2), 330.333, 330.337(d)

2.1 Leachate Generation

Leachate is generated as water infiltrates and percolates through layers of solid waste. The quantity of leachate that is generated depends upon rainfall, site topography, type of cover, operating procedures, and waste characteristics. The Hydrologic Evaluation of Landfill Performance (HELP) model was used to predict the quantity of leachate that will be generated at the TASWA DRF. The HELP model is a water balance model that uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage. Leachate generation was evaluated for both active and closed landfill conditions. An explanation and results of the HELP model are included in Appendix D6B.

2.2 Leachate Collection

The TASWA DRF disposal areas will accept Type I waste and will have leachate collection systems in accordance with 30 TAC §330.333. All leachate collection systems in Sectors 1-6 have been constructed and approved under MSW Permit No. 2290. Details of the existing leachate collection system are documented in the Geomembrane Liner Evaluation Reports (GLERs).

2.2.1 Leachate Collection System Design

The leachate collection system (LCS) will consist of the following:

- A geocomposite leachate collection layer
- The leachate collection trenches and piping
- Leachate collection pipe risers
- The leachate collection sumps and pumps

Each cell will have the configuration described below:

- Leachate collection pipes will have a nominal spacing of 400 feet.
- Leachate collection trenches will have a minimum slope of 1 percent.
- Cross-slopes into the leachate collection trench will be a minimum of 2 percent.

The LCS plan and details are provided in Attachment D3.

The LCS has been designed in accordance with 30 TAC §§330.331(a)(2) and 330.333 to:

- Maintain less than 30 cm (approximately 12 inches) depth of leachate over the liner (see Appendix D6B).
- Be constructed of materials that are chemically resistant to the leachate expected to be generated. The components of the leachate collection system have been designed with materials that are inert to leachates typically produced by municipal solid waste facilities. Drainage nets and pipes will be high density polyethylene (HDPE). Aggregates will be resistant to carbonate loss. Geotextiles have been designed with factors of safety for biological and chemical clogging (see Appendix D6A).
- Be constructed of materials that have sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and by any equipment used at the landfill (see Appendix D6A).
- Function through the scheduled closure and postclosure care period of the landfill considering:
  - Estimated rate of leachate removal (Appendix D6A)
  - Capacity of sumps (Appendix D6A)
  - Pipe material and strength (Appendix D6A)
  - Pipe network spacing and grading (Attachment D3)
  - Collection sump materials and strength (Appendix D6A)
  - Drainage media specifications and performance (Appendix D6A)
  - Demonstration that pipes and perforations will be resistant to clogging and can be cleaned (Sections 2.2.3 through 2.2.5)

In accordance with 30 TAC §330.337(d), the LCS has been designed to handle both the leachate generated and the groundwater inflow from materials beneath and lateral to the liner system (Appendix D6A).

2.2.2 Leachate Collection Layer

The leachate collection layer consists of geocomposite drainage net installed above the geomembrane. Single-sided geocomposite (nonwoven geotextile bonded to the top of HDPE drainage net) will be installed on the floor and double-sided geocomposite (nonwoven geotextile bonded to the top and bottom of HDPE drainage net) will be installed on the sidewalls. Leachate collection layer design calculations are presented in Appendix D6A. The geocomposite properties are provided in Attachment D7.

2.2.3 Geotextile

The drainage aggregate will be covered by a geotextile to prevent migration of the protective cover soil into the LCS. The geotextile will be inert to commonly encountered chemicals, hydrocarbons, and mildew, and will be rot resistant. Geotextile design calculations are presented in Appendix D6A. The geotextile properties are provided in Attachment D7.

2.2.4 Leachate Aggregate

Leachate aggregate will be placed in the collection trenches and in the sumps. The aggregate shall consist of manufactured or natural materials having the properties listed in Attachment D7.

In addition, aggregates must meet the following criteria:

For circular pipe perforations, the ratio:

$$\frac{\text{85 Percent Size of Aggregate}}{\text{Perforation Hole Diameter}} > 1.7$$

For slotted pipe perforations, the ratio:

$$\frac{\text{85 Percent of Aggregate Material}}{\text{Perforation Slot Width}} > 2.0$$

Chimney drains will be installed above the leachate collection pipes and will extend through the protective cover. The chimney drains will be constructed from the same drainage aggregate described above. Details illustrating the construction of the chimney drains are included in Attachment D3.

2.2.5 Leachate Collection Trenches and Piping

The leachate collection layer will slope toward the leachate collection trenches. The leachate piping includes perforated collection trench pipes and the solid sidewall riser pipes. Sidewall risers will extend to the top of the perimeter berm to provide access for cleaning the leachate collection pipes and sump risers. The leachate piping shall meet the criteria listed in Attachment D7.

Each collection trench will contain a 6-inch-diameter perforated leachate collection pipe surrounded by drainage aggregate. The leachate collection trench will convey the leachate to sumps located along the toe of the side slopes. The leachate collection pipes have been designed for the critical loading condition expected at the site. Both the overburden load (due to the weight of the waste and soil layers over the pipe) and the construction load (due to the weight of equipment and operations layers) were considered. Leachate collection system details are provided in Attachment D3. Leachate collection pipe design calculations are provided in Appendix D6A.

2.2.6 Leachate Sumps

The leachate sumps will consist of a 3-foot-deep square area. The sumps will have a minimum dimension of 48 by 48 feet at the landfill floor and 30 by 30 feet at the sump base. Details of the leachate sumps are provided in Attachment D3. Each sump will be backfilled with leachate drainage aggregate. Sump capacity and strength calculations are presented in Appendix D6A. Leachate will be transferred from the sumps by submersible pumps, as discussed in Section 2.4. The submersible pumps will be equipped with internal pressure transducers to measure the depth of the leachate in the sumps and a leachate level readout will be provided in the pump control panel. The pumps will be operated by an automatic start switch to limit the leachate level to the top of the sump. The allowable maximum leachate head is 30 cm (approximately 12 inches) on the liner (or 48 inches in the sump). Leachate sump material requirements are provided in Attachment D7.

2.3 Leachate Storage

Primary leachate storage will be provided by the leachate sumps, which are located within each landfill cell. Leachate will be pumped from the sumps through a leachate forcemain to the leachate storage tank facility. The tanks are located in the existing leachate storage facility shown in Attachment D3. The storage facility currently consists of two (2) 25,000-gallon storage tanks with a lined soil secondary containment berm and one (1) 100,000-gallon double-walled storage tank. The calculations in Appendix D6-D demonstrate that the secondary containment provides containment, with 6 inches of freeboard, for the leachate storage tanks and precipitation from the 25-year, 24-hour storm event.

2.4 Leachate Disposal

Leachate will be transported from the sumps or onsite leachate storage facility to a publicly owned treatment works (POTW). Leachate sampling and analysis will be limited to that facility's requirements. The results of any monitoring required by the disposal facility will be placed in the site operating record.

Leachate may be recirculated into an on-site landfill unit that is designed and constructed with a leachate collection system and a composite liner in accordance with §330.177. Leachate may also be recirculated by transferring into a tanker and spraying on the active area. Leachate will not be recirculated to the active area during rainy or wet periods. The automated leachate pumps will prevent leachate depth greater than 30 cm from accumulating over the liner and will be in operation during leachate recirculation activities. The application of leachate will not cause accumulation, ponding, or other operational problems. The TASWA DRF will ensure that recirculating will not result in vectors, odor, or other nuisance conditions.

3 CONTAMINATED WATER MANAGEMENT

30 TAC §330.207

3.1 Contaminated Water Generation

Surface water that comes into contact with waste, leachate, or gas condensate is considered to be contaminated water. Best management practices will be used to minimize contaminated water generation. Temporary diversion berms will be constructed around areas of exposed waste to minimize the amount of surface water that comes into contact with waste. Design calculations and typical details for temporary diversion berms are presented in Appendix D6C. Daily cover and intermediate cover will be placed over filled areas to minimize the area of exposed waste. Procedures for verifying the adequacy of daily and intermediate cover placement are provided in Part IV. If waste is exposed in areas where daily or intermediate cover has been previously placed, runoff from these areas will be considered to be contaminated water. Secondary containment will be provided around the leachate storage facility to contain leachate in case of a spill or leak. Gas condensate will be collected and segregated from surface water as described in Section 4.

3.2 Contaminated Water Collection and Containment

Temporary containment berms will be constructed around the active face to collect and contain surface water that has come into contact with waste. In addition to the planned containment berms around the active face, temporary containment berms will be constructed wherever needed to collect contaminated water. The design calculations and typical details for containment berms for a 25-year, 24-hour storm event are provided in Appendix D6C. The calculations show the dimensions for typical conditions, but additional storage capacity will be provided as site operating conditions dictate.

3.3 Contaminated Water Storage

Primary contaminated water storage will be provided by the containment berms, which will provide storage for the 25-year, 24-hour storm event.

3.4 Contaminated Water Disposal

Contaminated water will not be allowed to discharge into waters of the United States or discharged offsite without prior written approval. Contaminated water may be conveyed or transported to a POTW for treatment and disposal in accordance with §330.207(f). Sampling and analysis will be limited to the POTW's requirements. The results of any monitoring required by the disposal facility will be placed in the site operating record.

4 GAS CONDENSATE MANAGEMENT

30 TAC §330.207

4.1 Gas Condensate Generation

Gas condensate is the liquid generated during the gas recovery process at a municipal solid waste facility.

4.2 Gas Condensate Collection, Storage, and Disposal

Gas condensate will be collected in the gas collection and control system (GCCS) as described in Attachment G. The gas condensate will be conveyed from the GCCS to the on-site leachate storage facility or discharged directly into leachate sumps through the leachate cleanout risers. Gas condensate will be recirculated with leachate or disposed of per Section 2.4.

APPENDIX D6A
LEACHATE COLLECTION SYSTEM
DESIGN CALCULATIONS

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Leachate Collection System Flow Rates

Required: Determine the design flowrates for the following components of the leachate system.
1) Chimney, Collection Pipe, and Sump
2) Geotextile

References: 1) Appendix D6-B HELP Model Analyses.

Approach:
1) The largest contributing area to a sump occurs in Sector 14, which is approximately 19.4 acres.
2) The maximum flowrate for the collection pipe and sump will occur in Sector 14 due to its largest contributing area. The flowrates are calculated from the areas within Sector 14 that correspond to each case.
3) The maximum flowrate for the geotextile will occur in Sector 14 due to its combination of leachate pipe length and contributing area. The flowrates are calculated from the areas within Sector 14 that correspond to each case.

Solution:

1) Sector 14 - Collection Pipe and Sump Flow Rate

Case 1, Active face with 10 feet of waste =	0.4 acres
Case 2, Daily cover over 25 feet of waste =	6.3 acres
Case 3, Intermediate cover over 50 feet of waste =	6.3 acres
Case 4, Intermediate cover over 200 feet of waste =	6.3 acres

Calculate the leachate generation rate for the critical configuration.

CONDITION	AREA acres	AVERAGE RATE cf/yr/ac	AVERAGE cfs	PEAK RATE cf/day/ac	PEAK cfs
Case 1	0.4	22,405.0	0.000	467.0	0.002
Case 2	6.3	9,913.0	0.002	450.0	0.033
Case 3	6.3	10,006.0	0.002	445.0	0.033
Case 4	6.3	10,006.0	0.002	444.0	0.033
TOTAL	19.4		0.006		0.100

2) Sector 14 - Geotextile Flow Rate

Case 1, Active face with 10 feet of waste =	0.4 acres
Case 2, Daily cover over 25 feet of waste =	6.3 acres
Case 3, Intermediate cover over 50 feet of waste =	6.3 acres
Case 4, Intermediate cover over 200 feet of waste =	6.3 acres

Calculate the leachate generation rate for the critical configuration.

CONDITION	AREA acres	AVERAGE RATE cf/yr/ac	AVERAGE cfs	PEAK RATE cf/day/ac	PEAK cfs
Case 1	0.4	22,405.0	0.000	467.0	0.002
Case 2	6.3	9,913.0	0.002	450.0	0.033
Case 3	6.3	10,006.0	0.002	445.0	0.033
Case 4	6.3	10,006.0	0.002	444.0	0.033
TOTAL	19.4		0.006		0.100

Leachate Collection System Design

Required: Size the following elements of the leachate collection system:
1) Leachate Chimney
2) Leachate Collection Pipe
3) Leachate Sump

Assumptions:
1) The leachate chimney will extend the length of the collection trench.
2) Minimum leachate aggregate permeability shall be 0.01 cm/sec.
3) The leachate chimney should be sized to convey the peak flow rate to the sumps.
4) The collection pipe should be sized to convey the peak flow rate.
5) The leachate sump should be sized to store the average flow rate for 12 hours.

Solution:

1) ***Leachate Chimney***

Use Darcy's Equation to determine the width of the leachate chimney.

$$Q = KiA$$

where:	Q = design flowrate =		0.100	cfs
	K = hydraulic conductivity of aggregate =		0.01	cm/sec
		=	3.28E-04	fps
	i = hydraulic gradient = $\Delta h/\ell$			
	for vertical flow $\Delta h = \ell$		1	ft/ft
	L = length of trench =		1,600	ft
	A = cross section area = L x W			

Substitute and solve for W =	0.2	ft
Width provided =	**3.0**	**ft**

2) ***Leachate Collection Pipe***

Use Manning's Equation to size the leachate collection pipe.

$$Q = (1.486/n)AR^{2/3}S^{1/2}$$

where:	Q = design flowrate =		0.100	cfs
	n = Manning's number =		0.009	
	A = cross section area of pipe =		πdia^2/4	sf
	R = hydraulic radius of pipe =		dia/4	ft
	S = slope of pipe =		0.01	ft/ft

Substitute and solve for diameter =		0.23	ft
	=	2.7	in
Diameter provided =		**6.0**	**in**

Leachate Collection System Design

Determine the inflow capacity of the perforated leachate collection pipe using the following equation:

$$Q = Ca(2g\Delta h)^2$$

where:	C = coefficient of discharge =	0.61
	g = acceleration of gravity =	32.2 ft/sec^2
	Δh = maximum head on leachate pipe (ft) =	1.0 ft
	p = perforations per linear foot of pipe =	5 /ft
	d = diameter of perforations =	3/8 in
	a = orifice area ($p \times \pi (d/12)^2/4$) =	0.004 sf/ft
	q = inflow capacity per linear foot of pipe =	0.019 cfs/ft
	L = linear feet of collection pipe =	1,600 ft
Q = design flowrate =		0.10 cfs
Inflow capacity provided by perforated leachate pipe= q x L =		**30.0 cfs**

3) ***Leachate Collection Sump***

Size a square 3-foot deep sump with 3:1 side slopes from the following equation.

$$V = 1/3(L_t^2 h_t) - 1/3(L_b^2 h_b)$$

V = required sump volume (cf)

where: L_t = length of top side (ft)

L_b = length of bottom side (ft)

h_t = height of 3:1 pyramid with length L_t (ft)

h_b = height of 3:1 pyramid with length L_b (ft)

Q = average flowrate to the sump =	0.006 cfs
P = porosity of aggregate =	0.350
$V = Q \times 12\ hr\ /\ P$ =	776 cf

Substitute and solve for L_t = 24.2 ft

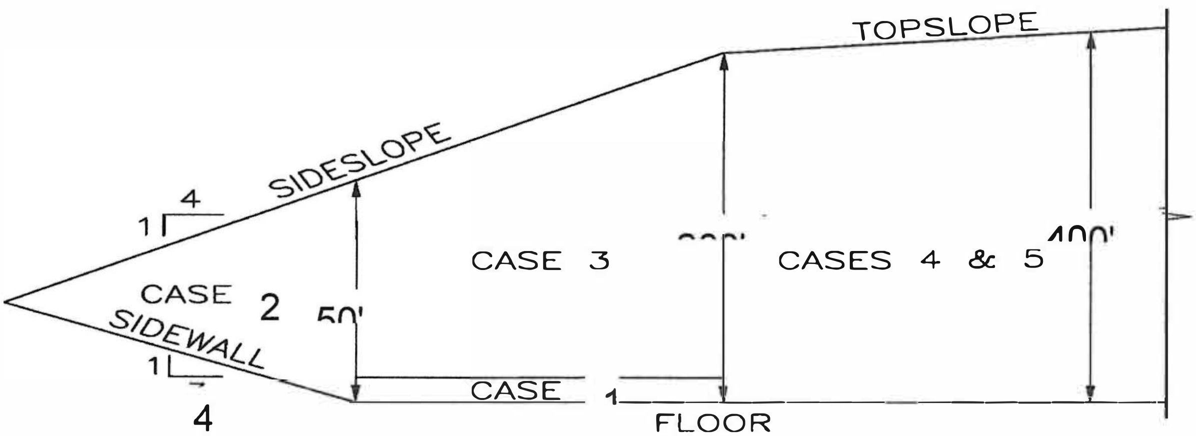
Length provided = 30.0 ft

Geocomposite Design

Required: Determine the minimum hydraulic conductivity for the sidewall and floor geocomposite.

References: 1) *Designing with Geosynthetics, Six* th Edition Vol. 1; Robert M. Koerner.

Solution: 1) Develop cases to represent the Disposal Area.



Case	Waste Depth ft	Cover Type
Sidewall LCS		
2	25	daily cover
Floor LCS		
1	10	active face - no cover
3	50	intermediate cover
4	200	intermediate cover
5	400	final cover

Geocomposite Design

2) Adjust the thickness of the geonet for the overburden of each case. Typical compressibility of geonet is 50% @ 20,000 psf. Assume linear compression between 0 and 20,000 psf.

Sidewall geonet	0.20	inch
Floor geonet	0.25	inch

Case	Layer	Depth ft	Unit Wt pcf	Load psf	t inch
1	protective cover	2.0	105.0	210.0	
	waste/daily cover	10.0	44.0	440.0	
		12.0		650.0	0.197
2	protective cover	2.0	105.0	210.0	
	waste/daily cover	25.0	44.0	1,100.0	
		27.0		1,310.0	0.242
3	protective cover	2.0	105.0	210.0	
	waste/daily cover	50.0	44.0	2,200.0	
		52.0		2,410.0	0.235
4	protective cover	2.0	105.0	210.0	
	waste/daily cover	200.0	44.0	8,800.0	
		202.0		9,010.0	0.194
5	protective cover	2.0	105.0	210.0	
	waste/daily cover	400.0	44.0	17,600.0	
	final cover	3.5	115.0	402.5	
		405.5		18,212.5	0.136

3) Specify the ultimate transmissivity for the geonet.

Transmissivity, m^2/sec	
Sidewall LCS	**Floor LCS**
1.00E-04	***1.00E-03***

4) Calculate the allowable transmissivity of the geocomposite from Reference 1, Equation 4.5a and Table 4.1.

$$T_{all} = T_{ult} \; (1 / RF_{CR} \; X \; RF_{IN} \; X \; RF_{CC} \; X \; RF_{BC})$$

RF_{CR} = creep reduction factor

RF_{IN} = intrusion reduction factor

RF_{CC} = chemical clogging reduction factor

RF_{BC} = biological clogging reduction factor

Case	RF_{CR}	RF_{IN}	RF_{CC}	RF_{BC}	T_{all} m^2/sec
			Sidewall LCS		
2	1.5	1.5	1.5	1.5	1.98E-05
			Floor LCS		
1	1.0	1.0	1.0	1.0	1.00E-03
3	1.5	1.5	1.5	1.5	1.98E-04
4	1.7	1.7	1.7	1.7	1.20E-04
5	2.0	2.0	2.0	2.0	6.25E-05

Geocomposite Design

5) Calculate the allowable hydraulic conductivity of the geocomposite from Reference 1, Equation 4.2.

$$k_{all} = T_{all} / t$$

Case	t inch	T_{all} m^2/sec	k_{all} cm/sec
Sidewall LCS			
2	0.24	1.98E-05	0.32
Floor LCS			
1	0.20	1.00E-03	20.01
3	0.23	1.98E-04	3.31
4	0.19	1.20E-04	2.43
5	0.14	6.25E-05	1.81

Geotextile Design

Required: Determine the minimum properties for:
1) Geotextile around leachate trench aggregate.
2) Geotextile component of geocomposite.

References: 1) *Designing with Geosynthetics, Six*th Edition Vol. 1; Robert M. Koerner.

Assumptions: 1) The protective cover will have at least 50% finer than the No. 200 sieve.
2) The leachate aggregate will be subangular, open graded stone.

Solution: 1) ***Leachate trench geotextile***

Calculate the allowable permittivity from the equation:

$$\Psi_{all} = q / \Delta hA$$

where: Ψ_{all} = *allowable* permittivity

q = peak inflow rate for leachate trench geotextile =	0.100	cfs
Δh = maximum allowable head =	1.0	ft
L = trench length =	1,600.0	ft
W = trench width =	5.0	ft
A = inflow area =	8000.0	sf

Substitute and solve for allowable permittivity = 1.3E-05 sec^{-1}

1a) Calculate the ultimate permittivity from Reference 1, Equation 2.25a.

$$\Psi_{all} = \Psi_{ult} \, (1 / RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC})$$

where:

RF_{SCB} = soil clogging/binding reduction factor =	3.0	(Ref. 1, Table 2.8b)
RF_{CR} = creep reduction factor =	1.5	(Ref. 1, Table 2.8b)
RF_{IN} = intrusion reduction factor =	1.2	(Ref. 1, Table 2.8b)
RF_{CC} = chemical clogging reduction factor =	1.5	(Ref. 1, Table 2.8b)
RF_{BC} = biological clogging reduction factor =	3.0	(Ref. 1, Table 2.8b)

Substitute and solve for ultimate permittivity = 3.0E-04 sec^{-1}

Determine the appropriate soil retention criteria from Reference 1, Figure 2.4a.

The AOS must be less than 0.22 mm for fine-grained, non-dispersive soils.

Leachate trench geotextile:	**calculated minimum permittivity =**	**3.0E-04 sec^{-1}**
	required permittivity =	**0.10 sec^{-1}**
	maximum AOS =	**0.22 mm**

Geotextile Design

2) ***Geocomposite geotextile***

Calculate the allowable permittivity from the equation:

$$\Psi_{all} = q / \Delta hA$$

where:	Ψ_{all} = *allowable* permittivity	
	q = peak inflow rate for critical condition =	0.100 cfs
	Δh = maximum allowable head =	1.0 ft
	A = area =	845,064 sf

Substitute and solve for allowable permittivity = 1.186E-07 sec^{-1}

Calculate the ultimate permittivity from Reference 1, Equation 2.25a.

$$\Psi_{all} = \Psi_{ult} \, (1 / RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC})$$

where:	RF_{SCB} = soil clogging/binding reduction factor =	3.0 (Ref. 1, Table 2.8b)
	RF_{CR} = creep reduction factor =	1.5 (Ref. 1, Table 2.8b)
	RF_{IN} = intrusion reduction factor =	1.2 (Ref. 1, Table 2.8b)
	RF_{CC} = chemical clogging reduction factor =	1.5 (Ref. 1, Table 2.8b)
	RF_{BC} = biological clogging reduction factor =	3.0 (Ref. 1, Table 2.8b)

Substitute and solve for ultimate permittivity = 2.9E-06 sec^{-1}

Determine the appropriate soil retention criteria from Reference 1, Figure 2.4a.

The AOS must be less than 0.22 mm for fine-grained, non-dispersive soils.

Geocomposite geotextile:	**minimum permittivity =**	**2.9E-06 sec^{-1}**
	required permittivity =	**0.10 sec^{-1}**
	maximum AOS =	**0.22 mm**

Groundwater Infiltration

Groundwater Infiltration

Required: Demonstrate the adequacy of the LCS to handle additional flow from groundwater infiltration.

References: 1) *Hydrologic Evaluation of Landfill Performance (HELP),* Engineering Documentation.

Approach: 1) Maximum groundwater infiltration will occur in Sector 14 due to highest groundwater elevation.

Solution: For good liner contact, soil leakage will occur from pinholes and installation defects.

Radius of leakage

Pinholes $R = 0.174h^{0.45}K^{-0.13}$ Ref. 1, Equation 163

where: R = radius of wetted area around pinhole (in)
h = hydraulic head beneath liner = 10 ft
K = hydraulic conductivity of clay liner = 1.00E-07 cm/sec
0.0034 in/day

R = 3.14 in

Defects $R = 0.222h^{0.45}K^{-0.13}$ Ref. 1, Equation 164

where: R = radius of wetted area around defect (in)
h = hydraulic head beneath liner = 10 ft
K = hydraulic conductivity of clay liner = 1.00E-07 cm/sec
0.0034 in/day

R = 4.01 in

Average hydraulic gradient

$i = 1 + [h / (2T\ln(R / r))]$ Ref. 1, Equation 152

where: i = average hydraulic gradient (in)
h = hydraulic head beneath liner = 10 ft
T = thickness of controlling layer = 24 in
R = radius of wetted area (in)
r = radius of flaw (in)

Pinholes	R =	3.14	in
	r =	0.02	in
	i =	1.49	in/in
Defects	R =	4.01	in
	r =	0.22	in
	i =	1.86	in/in

Leakage rate

$q = 0.877[(Kin\pi R^2) / 6,276,640]$ Ref. 1, Equation 151

where: q = leakage rate (in/day)
i = average hydraulic gradient (in)
n = density of flaws (no./ac)
T = thickness of controlling layer = 24 in
R = radius of wetted area (in)
K = hydraulic conductivity of clay liner = 0.0034 in/day

Groundwater Infiltration

Pinholes	n =	0.5	holes/ac
	i =	1.49	in/in
	R =	3.14	in
	q_p =	1.1007E-08	in/day/ac
Defects	n =	1	holes/ac
	i =	1.86	in/in
	R =	4.01	in
	q_d =	4.46348E-08	in/day/ac

Vapor diffusion

$q = K_m\ [(h + T) / T]$ — Ref. 1, Equation 141

where: q = leakage rate (in/day)

T = thickness of geomembrane = 0.06 in

h = hydraulic head beneath liner = 10 ft

K_m = hydraulic conductivity of geomembrane = 6.8E-09 in/day

q = 1.36068E-05 in/day/ac

Inflow rate $Q = q + q_p + q_d$ =

1.4E-05	in/day/ac
5.0E-02	cf/day/ac
5.7E-07	cfs/ac

Inflow will occur after the ballast is in place and the temporary dewatering system is turned off.

Sector 14 contributing area	19.39	ac
Sector 14 peak leachate rate =	0.100	cfs
Groundwater inflow rate/ac =	5.7E-07	cfs/ac
Sector 14 groundwater inflow rate =	1.1E-05	cfs
Total required inflow capacity = peak leachate + groundwater inflow =	**0.10**	**cfs**
q = inflow capacity per linear foot of pipe =	0.019	cfs/ft
L = Sector 14 linear feet of collection pipe =	1,600	ft
Provided inflow capacity = q x L =	**30.0**	**cfs**

Since the leachate collection pipe for Sector 14 provides for an inflow capacity of 30 cfs, the pipe has sufficient capacity to handle the peak leachate rate and groundwater inflow after the temporary dewatering system is turned off.

Leachate Collection Pipe Design

Required: Analyze the structural stability of the leachate collection and header pipes.

References:
1) *Essentials of Soil Mechanics and Foundations,* Second Edition; McCarthy, David F.; Reston Publishing Company, Inc.
2) *Handbook of PE Pipe, Second Edition;* Plastics Pipe Institue (PPI).

Assumptions:
1) The leachate collection pipe size of 6-inch (HDPE material) will be evaluated in this calculation.
2) Heaviest construction load will be a CAT 836H compactor.
3) Maximum overburden load will occur after final closure.

Solution: ***Construction Load***

Critical construction load occurs from drum load of CAT 836H compactor driving over leachate collection trench.

$F = W/n$ and $p = F/\pi r^2$

where:

F = force per drum (lbs)		
W = equipment weight =	122,600	lbs
n = number of drums =	4	
p = contact pressure =	46	psi
r = radius of contact (in)		

Substitute and solve for r = 14.6 inches

Determine the construction load from: $P_c = P_o + 1.5P_L$

where:
- P_c = total construction load (psi)
- P_o = overburden load (psi)
- P_L = live load (psi)

Determine the overburden load from: $P_o = z\gamma$

where:

z = backfill depth =	24.0	in
γ = backfill unit weight =	125.0	pcf

Substitute and solve for P_o = 1.7 psi

Determine the live load from Boussinesq equation for uniform circular loads.

$$P_L = p(1 - (1 + (r/z)^2)^{-3/2})$$

Substitute and solve for P_L = 17.3 psi

Substitute and solve for P_c = 27.6 psi

Critical construction load = 27.6 psi

Leachate Collection Pipe Design

Overburden Load

Critical overburden load occurs at the center of landfill after final cover has been constructed. Since the pipe is a flexible positive projecting conduit, use Martson's theory to estimate the overburden load.

$$W_c = \gamma B_c^{\,2} C_c \qquad \text{(Ref. 1, Equation 17-4a)}$$

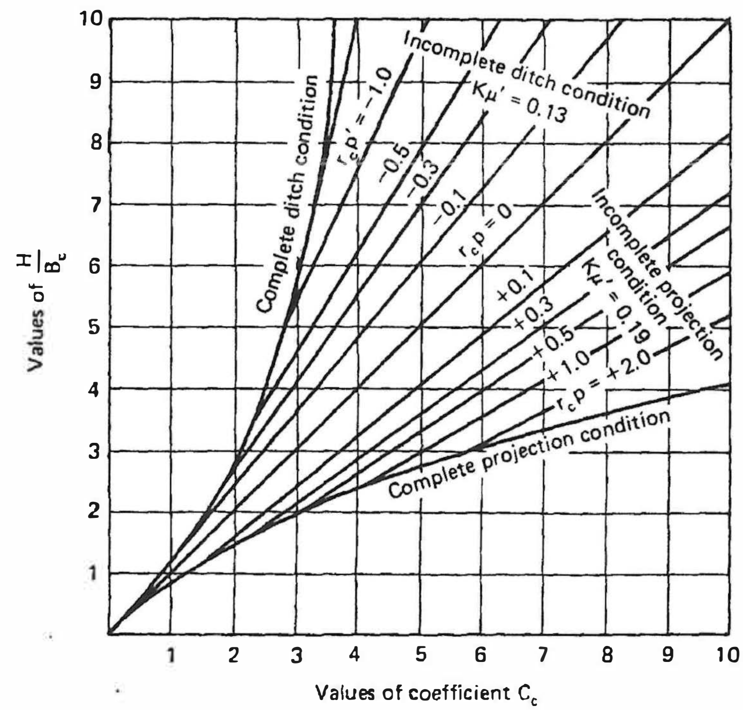
where: W_c = overburden load per ft of pipe (plf)

γ = unit weight of overburden (pcf)

Layer	Thickness (ft)	γ (pcf)	Load (psf)
cover	3.5	105	367.5
solid waste	400	44	17,600.0
aggregate	2	125	250.0
Total	405.5	274	18,217.5
Average γ		45	

B_c = pipe OD = 0.548 ft

Estimate C_c from Reference 1, Figure 17-8.



Leachate Collection Pipe Design

where:	r_c = settlement ratio (Ref. 1, Table 17-1) =	-0.2	
	pB_c = height of conduit above ground		
	p =	1	
	$r_c p$ =	-0.2	
	H = height of embankment =	405.5	ft
	H/B_c =	740.0	
From Fig. 17-8, $H/B_c = mC_c + b$			
	m =	1.29	
	b =	0	
	C_c =	574	

Substitute and solve for W_c = 7,739 plf

Overburden load = W_c / Dia = 98.1 psi

Critical overburden load = 98.1 psi

The overburden load shall be used for the design stress. Adjust the design stress to account for loss of strength due to perforations using the following equation.

$$P_D = 12P/(12 - l_p)$$

where:	P_D = design stress		
	P = critical stress =	98.1	psi
	l_p = cumulative length of perforations per foot of pipe		
	perforation diameter =	3/8	in
	number of holes per foot =	5	

Substitute and solve for l_p = 1.9 in/ft

Substitute and solve for P_D = 116.2 psi

Leachate pipe design stress = 116.2 psi

Leachate Collection Pipe Design

Structural Stability

Assume a standard dimension ratio of 17 for the analysis and predict the factor of safety for 1) wall crushing, 2) wall buckling, and 3) ring deflection.

1) Estimate the factor of safety against wall crushing from the following equation.

$$FS = S_Y/S_A$$

where:	S_Y = compressive yield strength of pipe =	1,500 psi
and	$S_A = P_D(SDR - 1)/2$	
	P_D =	116.2 psi
	SDR =	17
Substitute and solve for S_A =		929.8 psi

Factor of safety against wall crushing = 1.6

2) Estimate the factor of safety against wall buckling from the following equation.

$$FS = P_{cb}/P_D$$

where:	P_{cb} = critical buckling pressure		
	$P_{cb}^2 = 0.64(E')(P_c)$		
and	P_c = *critical collapse pressure*		
	$P_c = 2.32E/(SDR)^3$		
	E = modulus of elasticity =	20,000 psi (typical for HDPE)	
	E' = backfill modulus =	3,000 psi (typical for crushed stone)	
Substitute and solve for:		P_c =	9.4 psi
		P_{cb} =	134.7 psi

Factor of safety against wall buckling = 1.2

3) Estimate the factor of safety against ring deflection from the following equation.

$$FS = RD_{allow}/RD_{actual}$$

where:	RD_{allow} for SDR 17 pipe =	6 %	(Ref. 2)
and	RD_{actual} = soil strain around the pipe = ε_s		
	$\varepsilon_s = P_D/E'(100\%)$ =	3.9 %	

Factor of safety against ring deflection = 1.5

Leachate Riser Pipe Design

Required: Analyze the structural stability for the riser pipe.

References:

1) *Essentials of Soil Mechanics and Foundations,* Second Edition; McCarthy, David F.; Reston Publishing Company, Inc.
2) *Handbook of PE Pipe, Second Edition;* Plastics Pipe Institue (PPI).

Assumptions:

1) The riser pipe will be 18-inch HDPE.
2) Heaviest construction load will be a CAT 836H compactor.
3) Maximum overburden load will occur after final closure.

Solution: ***Construction Load***

Critical construction load occurs from drum load of CAT 836H compactor driving over the riser pipe on the 4H:1V sidewall slope.

β = sidewall slope = 14.0 deg

The equipment forces acting on the 4H:1V sidewall are:

W_V = vertical equipment weight
W_N = normal equipment weight

$F = W_N/n$ and $p = F/\pi r^2$

where: F = force per drum (lbs)

W_V =	122,600	lbs
$W_N = W_V \cos\beta$ =	118,958	lbs
n = number of drums =	4	
p = contact pressure =	48.5	psi
r = radius of contact (in)		

Substitute and solve for ***r*** = 14.0 inches

Determine the construction load from: $P_c = P_o + 1.5P_L$

where: P_c = total construction load (psi)
P_o = overburden load (psi)
P_L = live load (psi)

Leachate Riser Pipe Design

Determine the overburden load from: $P_o = z\gamma$

where: z = backfill depth = 24.0 in
γ = backfill unit weight = 125.0 pcf

Substitute and solve for P_o = 1.7 psi

Determine the live load from Boussinesq equation for uniform circular loads.

$$P_L = p(1 - (1 + (r/z)^2)^{-3/2})$$

Substitute and solve for P_L = 17.2 psi

Substitute and solve for P_c = 27.5 psi

Critical construction load = 27.5 psi

Normal Load

Since the riser pipe is placed on the 4H:1V sidewall slope, the design load will be normal to the riser pipe (L_N) and is calculated based on the vertical overburden load (L_V).

Critical overburden load occurs at toe of the slope after final cover has been constructed. Since the pipe is a flexible positive projecting conduit, use Martson's theory to estimate the overburden load.

$$W_c = \gamma B_c^2 C_c$$ (Ref. 1, Equation 17-4a)

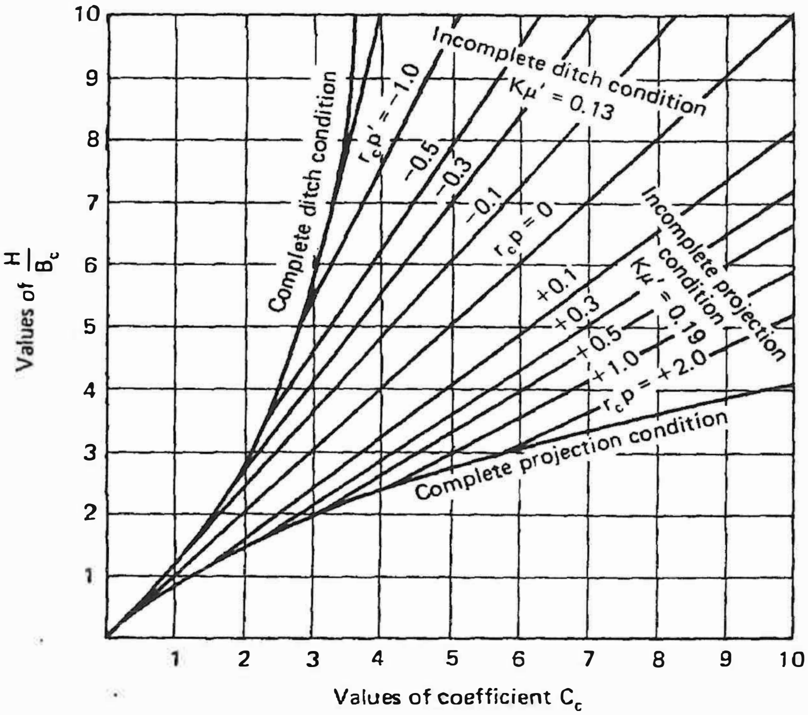
where: W_c = overburden load per ft of pipe (plf)
γ = unit weight of overburden (pcf)

Layer	Thickness (ft)	γ (pcf)	Load (psf)
cover	3.5	105	367.5
solid waste	250	44	11,000.0
clay	2	125	250.0
Total	255.5	274	11,617.5
Average γ		45	

B_c = pipe OD = 1.48 ft

Leachate Riser Pipe Design

Estimate C_c from Figure 17-8.



where:	r_c = settlement ratio (Ref. 1, Table 17-1) =	-0.2	
	pB_c = height of conduit above ground		
	p =	1	
	$r_c p$ =	-0.2	
	H = height of embankment =	255.5	ft
	H/B_c =	172.6	

From Fig. 17-1, $H/B_c = mC_c + b$

m =	1.29	
b =	0	
C_c =	134	

Substitute and solve for W_c =	13,329	plf
Overburden load = W_c / Dia =	62.5	psi
β = sidewall slope =	14.0	deg

L_V = 62.5 psi

$L_N = L_V \cos\beta$ = 60.7 psi

Critical normal load =	**60.7 psi**

Leachate Riser Pipe Design

Structural Stability

Assume a standard dimension ratio of 11 for the analysis and predict the factor of safety for 1) wall crushing, 2) wall buckling, and 3) ring deflection.

1) Estimate the factor of safety against wall crushing from the following equation.

$$FS = S_Y / S_A$$

where:	S_Y = compressive yield strength of pipe =	1,500	psi
and	$S_A = P(SDR - 1)/2$		
	P = *critical stress* =	60.7	psi
	SDR =	11	

Substitute and solve for SA = 303.4 psi

Factor of safety against wall crushing = 4.9

2) Estimate the factor of safety against wall buckling from the following equation.

$$FS = P_{cb} / P_D$$

where:	P_{cb} = critical buckling pressure		
	$P_{cb}^{\,2} = 0.64(E')(P_c)$		
and	P_c = *critical collapse pressure*		
	$P_c = 2.32E/(SDR)^3$		
	E = modulus of elasticity =	20,000	psi (typ. for HDPE)
	E' = backfill modulus =	1,500	psi (typ. for fine grained soils)

Substitute and solve for:

P_c = 34.9 psi

P_{cb} = 182.9 psi

Factor of safety against wall buckling = 3.0

3) Estimate the factor of safety against ring deflection from the following equation.

$$FS = RD_{allow} / RD_{actual}$$

where:	RD_{allow} for SDR 11 pipe =	5	% (Ref 2)
and	RD_{actual} = soil strain around the pipe = ε_s		
	$\varepsilon_s = P_D/E'(100\%)$ =	4.0	%

Factor of safety against ring deflection = 1.2

APPENDIX D6B
LEACHATE GENERATION MODEL

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Firm Registration No. F-256

LEACHATE GENERATION MODEL

HELP MODEL

The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 4.0, was used to predict the amount of runoff, evapotranspiration, drainage, leachate collection, and percolation through the liner. The HELP Model is a water balance model that uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, recirculation, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage.

The following stages of landfill development were modeled:

Case 1 – Active face with 10 feet of exposed waste; 3 years
Case 2 – Daily cover with over 25 feet of waste; 5 years
Case 3 – Intermediate cover over 50 feet of waste; 10 years
Case 4 – Intermediate cover over 200 feet of waste; 10 years
Case 5 – Final cover over 400 feet of waste; 30 years

INPUT PARAMETERS

The HELP model input parameters for each case are summarized on page D6B.4. The selection of each parameter is briefly described below.

Evapotranspiration Data

Default evapotranspiration data for the Whitesboro,Texas area were used in the model. The minimum evaporative zone depth selected for Cases 1 and 2 and the medium evaporative zone depth was selected for Cases 3, 4 and 5.

Climate Data

The climate data used for the HELP model was synthetically generated using climate coefficients for the Whitesboro,Texas area.

Runoff Curve Number

Default curve numbers were chosen based on the soil data, ground cover, surface slope, and slope length of the selected case.

Erosion Layer

The erosion layer consists of a 24-inch-thick layer of soils that are capable of sustaining vegetation. Geotechnical information provided in Attachment D5 indicates that CH and CL soils will be available for use as erosion layer.

Drainage Layer

The drainage layer will consist of geotextile on topslopes; a geocomposite will be used on sideslopes. Since the sideslopes will not yield as much infiltration into the cover as the topslopes, the model reflects the topslope configuration.

Flexible Membrane Cover

The flexible membrane cover consists of a 40-mil LLDPE geomembrane. The cover will be installed and tested in accordance with the requirements of Attachment D8 – Final Cover Quality Control Plan; therefore, the cover was modeled for good installation quality, one defect per acre, and a pinhole density of one-half hole per acre.

Infiltration Layer

The infiltration layer consists of an 18-inch-thick layer of compacted clay with hydraulic conductivity of 1×10^{-5} cm/sec or less.

Intermediate Cover

The intermediate cover consists of a total 12-inch-thick layer of on-site soils. Geotechnical information provided in Attachment D5 indicates that CH and CL soils will be available for use as daily and intermediate cover.

Waste Layers

Waste layers of 10, 25, 50, 200, and 400 feet were used to represent the stages of landfill development. The bottom two feet of solid waste was modeled as a lateral drainage layer to account for leachate movement across the top of the protective cover layer.

Protective Cover

The protective cover consists of a 24-inch-thick layer of on-site soils. Geotechnical information provided in Attachment D5 indicates that CH and CL soils will be available for use as protective cover. The top two inches of protective cover was modeled as a barrier soil layer to force the model to calculate leachate volume running across the top of protective cover into the leachate chimneys.

Leachate Collection Layer

The leachate collection layer will consist of a double-sided geocomposite on side slopes and a single-sided geocomposite on the floor. The thickness and hydraulic conductivity values are calculated in Attachment D6, Appendix D6A. The critical slope and drainage distance for the leachate collection system were determined from details included in Attachment D3.

Flexible Membrane Liner

The flexible membrane liner consists of a 60-mil HDPE geomembrane. The liner will be installed and tested in accordance with the requirements of Attachment D7 – Liner Quality Control Plan; therefore, the liner was modeled for excellent installation quality, one defect per acre, and a pinhole density of one-half hole per acre.

Compacted Soil Liner

The compacted soil layer consists of a 24-inch-thick layer of compacted soil with a hydraulic conductivity of 1 x 10^{-7} cm/sec or less.

HELP MODEL OUTPUT

Output files for the HELP model are provided on pages D6B.5 through D6B.34. The output for each case is summarized on page D6B.4.

TASWA DRF
HELP SUMMARY

Case No.	1	2	3	4	5
Cover	None	Daily	Intermediate	Intermediate	Final Cover
Top	Sideslope	Sideslope	Sideslope	Topslope	Topslope
Bottom	Floor	Sidewall	Floor	Floor	Floor
Waste Thickness (ft)	10	25	50	200	400
Years	3	5	10	10	30
Vegetative Cover	N/A	Bare	Bare	Bare	Good
Model Area (acre)	1	1	1	1	1
Runoff Area (%)	0	100	100	100	100
Maximum Leaf Area Index	0	0	0	0	4.5
Evaporative Zone Depth (in)	10	10	22	22	22
Erosion Layer					
Layer No.					1
Type					vertical percolation
Thickness (ft)					2.0
Geomembrane					
Layer No.					2
Type					geomembrane
Thickness (in)					0.04
Installation Quality					excellent
Defects per acre					1
Pinholes per acre					0.5
Infiltration Laye					
Layer No.					3
Type					barrier soil
Thickness (ft)					1.5
Interim/Daily Cove					
Layer No.		1	1	1	4
Type		vertical percolation	vertical percolation	vertical percolation	vertical percolation
Thickness (ft)		0.5	1.0	1.0	1.0
Solid Waste					
Layer No.	1	2	2	2	5
Type	vertical percolation	vertical percolation	vertical percolation	vertical percolation	vertical percolation
Thickness (ft)	8.0	23.0	48.0	198.0	398.0
Solid Wast					
Layer No.	2	3	3	3	6
Type	lateral drainage	lateral drainage	lateral drainage	lateral drainage	lateral drainage
Thickness (ft)	2.0	2.0	2.0	2.0	2.0
Slope (%)	2.0	25.0	2.0	2.0	2.0
Flow Distance (ft)	200	200	200	200	200
Protective Cove					
Layer No.	3	4	4	4	7
Type	barrier soil	barrier soil	barrier soil	barrier soil	barrier soil
Thickness (ft)	0.16	0.16	0.16	0.16	0.16
Protective Cover					
Layer No.	4	5	5	5	8
Type	vertical percolation	vertical percolation	vertical percolation	vertical percolation	vertical percolation
Thickness (ft)	1.84	1.84	1.84	1.84	1.84
LCS					
Layer No.	5	6	6	6	9
Type	lateral drainage	lateral drainage	lateral drainage	lateral drainage	lateral drainage
Thickness (in)	0.20	0.20	0.20	0.20	0.20
Slope (%)	2.0	25.0	2.0	2.0	2.0
Flow Distance (ft)	200	200	200	200	200
Hydraulic Conductivity (cm/sec)	20.01	0.32	3.31	2.43	1.81
Geomembrane					
Layer No.	6	7	7	7	10
Type	geomembrane	geomembrane	geomembrane	geomembrane	geomembrane
Thickness (in)	0.06	0.06	0.06	0.06	0.06
Installation Quality	excellent	excellent	excellent	excellent	excellent
Defects per acre	1	1	1	1	1
Pinholes per acre	0.5	0.5	0.5	0.5	0.5
Clay Line					
Layer No.	7	8	8	8	11
Type	barrier soil	barrier soil	barrier soil	barrier soil	barrier soil
Thickness (ft)	2.0	2.0	2.0	2.0	2.0
Average Lateral Drainage (cf/yr)	22,405	9,913	10,006	10,006	137
Peak Lateral Drainage (cf/day)	467	450	445	444	0.98
Average Daily Head on Liner(in)	0.02	0.06	0.07	0.09	0.00

CASE 1 - Active Face with 10' Waste

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: TASWA Active Face w/10' Waste **Simulated On:** 8/8/2022 15:26

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
Municipal Solid Waste (MSW) (900 pcy)
Material Texture Number 18

Thickness	=	96 inches
Porosity	=	0.671 vol/vol
Field Capacity	=	0.292 vol/vol
Wilting Point	=	0.077 vol/vol
Initial Soil Water Content	=	0.2891 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03 cm/sec

Layer 2

Type 2 - Lateral Drainage Layer
Btm 2' Waste
Material Texture Number 43

Thickness	=	24 inches
Porosity	=	0.671 vol/vol
Field Capacity	=	0.292 vol/vol
Wilting Point	=	0.077 vol/vol
Initial Soil Water Content	=	0.2923 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 3

Type 3 - Barrier Soil Liner
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	2 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.437 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

CASE 1 - Active Face with 10' Waste

Layer 4
Type 1 - Vertical Percolation Layer
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	22 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.3733 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 5
Type 2 - Lateral Drainage Layer
LCS
Material Texture Number 123

Thickness	=	0.2 inches
Porosity	=	0.85 vol/vol
Field Capacity	=	0.01 vol/vol
Wilting Point	=	0.005 vol/vol
Initial Soil Water Content	=	0.01 vol/vol
Effective Sat. Hyd. Conductivity	=	2.00E+01 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 6
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06 inches
Effective Sat. Hyd. Conductivity	=	2.00E-13 cm/sec
FML Pinhole Density	=	0.5 Holes/Acre
FML Installation Defects	=	1 Holes/Acre
FML Placement Quality	=	2 Excellent

Layer 7
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	24 inches
Porosity	=	0.427 vol/vol
Field Capacity	=	0.418 vol/vol
Wilting Point	=	0.367 vol/vol
Initial Soil Water Content	=	0.427 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07 cm/sec

CASE 1 - Active Face with 10' Waste

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	80.3
Fraction of Area Allowing Runoff	=	0 %
Area projected on a horizontal plane	=	1 acres
Evaporative Zone Depth	=	10 inches
Initial Water in Evaporative Zone	=	2.639 inches
Upper Limit of Evaporative Storage	=	6.71 inches
Lower Limit of Evaporative Storage	=	0.77 inches
Initial Snow Water	=	0 inches
Initial Water in Layer Materials	=	54.103 inches
Total Initial Water	=	54.103 inches
Total Subsurface Inflow	=	0 inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	33.74 Degrees
Maximum Leaf Area Index	=	0
Start of Growing Season (Julian Date)	=	85 days
End of Growing Season (Julian Date)	=	319 days
Average Wind Speed	=	3.12 mph
Average 1st Quarter Relative Humidity	=	80 %
Average 2nd Quarter Relative Humidity	=	78 %
Average 3rd Quarter Relative Humidity	=	70 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for Whitesboro, Texas

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	Mav/Nov	Jun/Dec
1.6498	2.891636	3.947355	3.787942	3.026906	2.650465
0.9624	1.878638	3.636671	3.531476	2.639797	3.692893

Note: Precipitation was simulated based on HELP V4 weather simulation for: Lat/Long: 33.74/-96.94

CASE 1 - Active Face with 10' Waste

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
50.4	69.6	56	71.9	82.9	83.3
102.1	91.5	82.2	69.6	59.5	40.1

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

CASE 1 - Active Face with 10' Waste

Average Annual Totals Summary

Title: TASWA Active Face w/10' Waste
Simulated on: 8/8/2022 15:26

	Average Annual Totals for Years 1 - 3*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	34.30	[2.89]	124,494.4	100.00
Runoff	0.000	[0]	0.0000	0.00
Evapotranspiration	26.603	[1.595]	96,569.1	77.57
Subprofile1				
Lateral drainage collected from Layer 2	0.0028	[0.0007]	10.3	0.01
Percolation/leakage through Layer 3	6.536683	[0.972209]	23,728.2	19.06
Average Head on Top of Layer 3	0.0144	[0.0031]	---	---
Subprofile2				
Lateral drainage collected from Layer 5	6.1693	[0.3486]	22,394.5	17.99
Percolation/leakage through Layer 7	0.000001	[0]	0.0024	0.00
Average Head on Top of Layer 6	0.0025	[0.0001]	---	---
Water storage				
Change in water storage	1.5208	[1.3214]	5,520.5	4.43

* Note: Average inches are converted to volume based on the user-specified area.

CASE 1 - Active Face with 10' Waste

Peak Values Summary

Title: TASWA Active Face w/10' Waste
Simulated on: 8/8/2022 15:26

	Peak Values for Years 1 - 3*	
	(inches)	(cubic feet)
Precipitation	3.12	11,326.1
Runoff	0.000	0.0000
Subprofile1		
Drainage collected from Layer 2	0.0003	0.9643
Percolation/leakage through Layer 3	0.151156	548.7
Average head on Layer 3	0.4688	---
Maximum head on Layer 3	0.8823	---
Location of maximum head in Layer 2	11.71	(feet from drain)
Subprofile2		
Drainage collected from Layer 5	0.1284	466.0
Percolation/leakage through Layer 7	0.000000	0.0000
Average head on Layer 6	0.0182	---
Maximum head on Layer 6	0.0226	---
Location of maximum head in Layer 5	0.55	(feet from drain)
Other Parameters		
Snow water	2.9846	10,834.0
Maximum vegetation soil water	0.5024	(vol/vol)
Minimum vegetation soil water	0.0845	(vol/vol)

CASE 2 - Daily Cover with 25' Waste

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: TASWA Daily Cover w/25' Waste **Simulated On:** 8/8/2022 15:38

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	6	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.2782	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer (Waste)
Municipal Solid Waste (MSW) (900 pcy)
Material Texture Number 18

Thickness	=	276	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.2928	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
Btm 2' Solid Waste
Material Texture Number 43

Thickness	=	24	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.2975	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec
Slope	=	25	%
Drainage Length	=	200	ft

CASE 2 - Daily Cover with 25' Waste

Layer 4
Type 3 - Barrier Soil Liner
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	2 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.437 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 5
Type 1 - Vertical Percolation Layer
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	22 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.4023 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 6
Type 2 - Lateral Drainage Layer
LCS
Material Texture Number 123

Thickness	=	0.24 inches
Porosity	=	0.85 vol/vol
Field Capacity	=	0.01 vol/vol
Wilting Point	=	0.005 vol/vol
Initial Soil Water Content	=	0.0303 vol/vol
Effective Sat. Hyd. Conductivity	=	3.20E-01 cm/sec
Slope	=	25 %
Drainage Length	=	200 ft

Layer 7
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06 inches
Effective Sat. Hyd. Conductivity	=	2.00E-13 cm/sec
FML Pinhole Density	=	0.5 Holes/Acre
FML Installation Defects	=	1 Holes/Acre
FML Placement Quality	=	2 Excellent

CASE 2 - Daily Cover with 25' Waste

Layer 8

Type 3 - Barrier Soil Liner

Liner Soil (High)

Material Texture Number 16

Thickness	=	24 inches
Porosity	=	0.427 vol/vol
Field Capacity	=	0.418 vol/vol
Wilting Point	=	0.367 vol/vol
Initial Soil Water Content	=	0.427 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07 cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	94.9
Fraction of Area Allowing Runoff	=	100 %
Area projected on a horizontal plane	=	1 acres
Evaporative Zone Depth	=	10 inches
Initial Water in Evaporative Zone	=	2.747 inches
Upper Limit of Evaporative Storage	=	5.468 inches
Lower Limit of Evaporative Storage	=	1.43 inches
Initial Snow Water	=	0 inches
Initial Water in Layer Materials	=	109.598 inches
Total Initial Water	=	109.598 inches
Total Subsurface Inflow	=	0 inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	33.74 Degrees
Maximum Leaf Area Index	=	0
Start of Growing Season (Julian Date)	=	85 days
End of Growing Season (Julian Date)	=	319 days
Average Wind Speed	=	3.12 mph
Average 1st Quarter Relative Humidity	=	80 %
Average 2nd Quarter Relative Humidity	=	78 %
Average 3rd Quarter Relative Humidity	=	70 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for Whitesboro, Texas

CASE 2 - Daily Cover with 25' Waste

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.277393	3.079896	2.747615	2.407115	6.090154	4.259626
2.304377	2.285939	1.993561	2.510634	2.489127	3.281812

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
53.3	54.4	58.2	73	77	86.4
96.2	94.4	82.7	77.6	67.7	51.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

CASE 2 - Daily Cover with 25' Waste

Average Annual Totals Summary

Title: TASWA Daily Cover w/25' Waste
Simulated on: 8/8/2022 15:39

	Average Annual Totals for Years 1 - 5*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.73	[4.89]	129,689.9	100.00
Runoff	7.390	[1.947]	26,824.6	20.68
Evapotranspiration	25.366	[1.87]	92,076.8	71.00
Subprofile1				
Lateral drainage collected from Layer 3	0.0068	[0.0038]	24.6	0.02
Percolation/leakage through Layer 4	2.719796	[1.066164]	9,872.9	7.61
Average Head on Top of Layer 4	0.0034	[0.0017]	---	---
Subprofile2				
Lateral drainage collected from Layer 6	2.7239	[1.0085]	9,887.9	7.62
Percolation/leakage through Layer 8	0.000002	[0]	0.0057	0.00
Average Head on Top of Layer 7	0.0035	[0.0013]	---	---
Water storage				
Change in water storage	0.2413	[1.2046]	875.9	0.68

* Note: Average inches are converted to volume based on the user-specified area.

CASE 2 - Daily Cover with 25' Waste

Peak Values Summary

Title: TASWA Daily Cover w/25' Waste
Simulated on: 8/8/2022 15:39

	Peak Values for Years 1 - 5*		
	(inches)		(cubic feet)
Precipitation	2.69		9,780.8
Runoff	1.628		5,911.3
Subprofile1			
Drainage collected from Layer 3	0.0016		5.6469
Percolation/leakage through Layer 4	0.136735		496.3
Average head on Layer 4	0.2332		---
Maximum head on Layer 4	0.4643		---
Location of maximum head in Layer 3	0.00	(feet from drain)	
Subprofile2			
Drainage collected from Layer 6	0.1224		444.4
Percolation/leakage through Layer 8	0.000000		0.0000
Average head on Layer 7	0.0574		---
Maximum head on Layer 7	0.1146		---
Location of maximum head in Layer 6	0.00	(feet from drain)	
Other Parameters			
Snow water	1.7947		6,514.6
Maximum vegetation soil water	0.3607	(vol/vol)	
Minimum vegetation soil water	0.1430	(vol/vol)	

CASE 3 - Intermediate Cover with 50' Waste

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title:	TASWA Int Cover w/50' Waste	**Simulated On:**	8/9/2022 14:30

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	12	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.3114	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer (Waste)
Municipal Solid Waste (MSW) (900 pcy)
Material Texture Number 18

Thickness	=	576	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.2908	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
Btm 2' Solid Waste
Material Texture Number 43

Thickness	=	24	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.292	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec
Slope	=	2	%
Drainage Length	=	200	ft

CASE 3 - Intermediate Cover with 50' Waste

Layer 4

Type 3 - Barrier Soil Liner
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	2 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.437 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 5

Type 1 - Vertical Percolation Layer
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	22 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.373 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 6

Type 2 - Lateral Drainage Layer
LCS
Material Texture Number 123

Thickness	=	0.23 inches
Porosity	=	0.85 vol/vol
Field Capacity	=	0.01 vol/vol
Wilting Point	=	0.005 vol/vol
Initial Soil Water Content	=	0.0193 vol/vol
Effective Sat. Hyd. Conductivity	=	3.31E+00 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 7

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06 inches
Effective Sat. Hyd. Conductivity	=	2.00E-13 cm/sec
FML Pinhole Density	=	0.5 Holes/Acre
FML Installation Defects	=	1 Holes/Acre
FML Placement Quality	=	2 Excellent

CASE 3 - Intermediate Cover with 50' Waste

Layer 8

Type 3 - Barrier Soil Liner

Liner Soil (High)

Material Texture Number 16

Thickness	=	24 inches
Porosity	=	0.427 vol/vol
Field Capacity	=	0.418 vol/vol
Wilting Point	=	0.367 vol/vol
Initial Soil Water Content	=	0.427 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07 cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	94.6
Fraction of Area Allowing Runoff	=	100 %
Area projected on a horizontal plane	=	1 acres
Evaporative Zone Depth	=	22 inches
Initial Water in Evaporative Zone	=	5.973 inches
Upper Limit of Evaporative Storage	=	12.278 inches
Lower Limit of Evaporative Storage	=	3.014 inches
Initial Snow Water	=	0 inches
Initial Water in Layer Materials	=	197.587 inches
Total Initial Water	=	197.587 inches
Total Subsurface Inflow	=	0 inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	33.74 Degrees
Maximum Leaf Area Index	=	0
Start of Growing Season (Julian Date)	=	85 days
End of Growing Season (Julian Date)	=	319 days
Average Wind Speed	=	3.12 mph
Average 1st Quarter Relative Humidity	=	80 %
Average 2nd Quarter Relative Humidity	=	78 %
Average 3rd Quarter Relative Humidity	=	70 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for Whitesboro, Texas

CASE 3 - Intermediate Cover with 50' Waste

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.917535	2.366924	4.184818	2.989739	3.134919	2.58253
2.245574	1.878252	3.199888	3.518067	2.953201	3.002938

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
53.9	46.5	59.2	72.7	80.7	92.6
93.8	93.7	83	70.5	58	59

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

CASE 3 - Intermediate Cover with 50' Waste

Average Annual Totals Summary

Title: TASWA Int Cover w/50' Waste
Simulated on: 8/9/2022 14:30

	Average Annual Totals for Years 1 - 10*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	34.97	[5.24]	126,957.0	100.00
Runoff	7.408	[2.05]	26,892.7	21.18
Evapotranspiration	24.853	[2.525]	90,215.6	71.06
Subprofile1				
Lateral drainage collected from Layer 3	0.0005	[0.0004]	1.7569	0.00
Percolation/leakage through Layer 4	2.755923	[1.82567]	10,004.0	7.88
Average Head on Top of Layer 4	0.0031	[0.0019]	---	---
Subprofile2				
Lateral drainage collected from Layer 6	2.7559	[1.7681]	10,004.0	7.88
Percolation/leakage through Layer 8	0.000002	[0]	0.0071	0.00
Average Head on Top of Layer 7	0.0040	[0.0026]	---	---
Water storage				
Change in water storage	-0.0433	[1.8591]	-157.0	-0.12

* Note: Average inches are converted to volume based on the user-specified area.

CASE 3 - Intermediate Cover with 50' Waste

Peak Values Summary

Title: TASWA Int Cover w/50' Waste
Simulated on: 8/9/2022 14:30

	Peak Values for Years 1 - 10*	
	(inches)	(cubic feet)
Precipitation	2.78	10,087.4
Runoff	1.587	5,760.5
Subprofile1		
Drainage collected from Layer 3	0.0001	0.4683
Percolation/leakage through Layer 4	0.136394	495.1
Average head on Layer 4	0.2277	---
Maximum head on Layer 4	0.4394	---
Location of maximum head in Layer 3	6.93	(feet from drain)
Subprofile2		
Drainage collected from Layer 6	0.1224	444.5
Percolation/leakage through Layer 8	0.000000	0.0001
Average head on Layer 7	0.0653	---
Maximum head on Layer 7	0.1288	---
Location of maximum head in Layer 6	2.59	(feet from drain)
Other Parameters		
Snow water	2.7592	10,016.0
Maximum vegetation soil water	0.3720	(vol/vol)
Minimum vegetation soil water	0.1958	(vol/vol)

CASE 4 - Intermediate Cover with 200' Waste

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: TASWA Int Cvr w/200' Waste **Simulated On:** 8/9/2022 15:26

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	12	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.3114	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer (Waste)
Municipal Solid Waste (MSW) (900 pcy)
Material Texture Number 18

Thickness	=	2376	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.2917	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
Btm 2' Solid Waste
Material Texture Number 43

Thickness	=	24	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.292	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec
Slope	=	2	%
Drainage Length	=	200	ft

CASE 4 - Intermediate Cover with 200' Waste

Layer 4
Type 3 - Barrier Soil Liner
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	2 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.437 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 5
Type 1 - Vertical Percolation Layer
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	22 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.373 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 6
Type 2 - Lateral Drainage Layer
LCS
Material Texture Number 123

Thickness	=	0.19 inches
Porosity	=	0.85 vol/vol
Field Capacity	=	0.01 vol/vol
Wilting Point	=	0.005 vol/vol
Initial Soil Water Content	=	0.0239 vol/vol
Effective Sat. Hyd. Conductivity	=	2.43E+00 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 7
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06 inches
Effective Sat. Hyd. Conductivity	=	2.00E-13 cm/sec
FML Pinhole Density	=	0.5 Holes/Acre
FML Installation Defects	=	1 Holes/Acre
FML Placement Quality	=	2 Excellent

CASE 4 - Intermediate Cover with 200' Waste

Layer 8

Type 3 - Barrier Soil Liner

Liner Soil (High)

Material Texture Number 16

Thickness	=	24 inches
Porosity	=	0.427 vol/vol
Field Capacity	=	0.418 vol/vol
Wilting Point	=	0.367 vol/vol
Initial Soil Water Content	=	0.427 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07 cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	94.6
Fraction of Area Allowing Runoff	=	100 %
Area projected on a horizontal plane	=	1 acres
Evaporative Zone Depth	=	22 inches
Initial Water in Evaporative Zone	=	5.973 inches
Upper Limit of Evaporative Storage	=	12.278 inches
Lower Limit of Evaporative Storage	=	3.014 inches
Initial Snow Water	=	0 inches
Initial Water in Layer Materials	=	723.187 inches
Total Initial Water	=	723.187 inches
Total Subsurface Inflow	=	0 inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	33.74 Degrees
Maximum Leaf Area Index	=	0
Start of Growing Season (Julian Date)	=	85 days
End of Growing Season (Julian Date)	=	319 days
Average Wind Speed	=	3.12 mph
Average 1st Quarter Relative Humidity	=	80 %
Average 2nd Quarter Relative Humidity	=	78 %
Average 3rd Quarter Relative Humidity	=	70 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for Whitesboro, Texas

CASE 4 - Intermediate Cover with 200' Waste

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.917535	2.366924	4.184818	2.989739	3.134919	2.58253
2.245574	1.878252	3.199888	3.518067	2.953201	3.002938

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
53.9	46.5	59.2	72.7	80.7	92.6
93.8	93.7	83	70.5	58	59

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

CASE 4 - Intermediate Cover with 200' Waste

Average Annual Totals Summary

Title: TASWA Int Cvr w/200' Waste
Simulated on: 8/9/2022 15:27

	Average Annual Totals for Years 1 - 10*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	34.97	[5.24]	126,957.0	100.00
Runoff	7.408	[2.05]	26,892.7	21.18
Evapotranspiration	24.853	[2.525]	90,215.6	71.06
Subprofile1				
Lateral drainage collected from Layer 3	0.0005	[0.0004]	1.7943	0.00
Percolation/leakage through Layer 4	2.755913	[1.827371]	10,004.0	7.88
Average Head on Top of Layer 4	0.0032	[0.002]	---	---
Subprofile2				
Lateral drainage collected from Layer 6	2.7560	[1.7668]	10,004.1	7.88
Percolation/leakage through Layer 8	0.000002	[0]	0.0079	0.00
Average Head on Top of Layer 7	0.0055	[0.0035]	---	---
Water storage				
Change in water storage	-0.0433	[1.8598]	-157.2	-0.12

* Note: Average inches are converted to volume based on the user-specified area.

CASE 4 - Intermediate Cover with 200' Waste

Peak Values Summary

Title: TASWA Int Cvr w/200' Waste
Simulated on: 8/9/2022 15:27

	Peak Values for Years 1 - 10*	
	(inches)	(cubic feet)
Precipitation	2.78	10,087.4
Runoff	1.587	5,760.5
Subprofile1		
Drainage collected from Layer 3	0.0001	0.4393
Percolation/leakage through Layer 4	0.135529	492.0
Average head on Layer 4	0.2135	---
Maximum head on Layer 4	0.4128	---
Location of maximum head in Layer 3	6.61 (feet from drain)	
Subprofile2		
Drainage collected from Layer 6	0.1223	443.9
Percolation/leakage through Layer 8	0.000000	0.0001
Average head on Layer 7	0.0888	---
Maximum head on Layer 7	0.1746	---
Location of maximum head in Layer 6	3.33 (feet from drain)	
Other Parameters		
Snow water	2.7592	10,016.0
Maximum vegetation soil water	0.3720 (vol/vol)	
Minimum vegetation soil water	0.1958 (vol/vol)	

CASE 5 - Final Cover with 400' Waste

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: TASWA Int Cvr w/200' Waste **Simulated On:** 8/9/2022 10:37

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	24 inches
Porosity	=	0.464 vol/vol
Field Capacity	=	0.31 vol/vol
Wilting Point	=	0.187 vol/vol
Initial Soil Water Content	=	0.42 vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05 cm/sec

Layer 2
Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04 inches
Effective Sat. Hyd. Conductivity	=	4.00E-13 cm/sec
FML Pinhole Density	=	0.5 Holes/Acre
FML Installation Defects	=	1 Holes/Acre
FML Placement Quality	=	2 Excellent

Layer 3
Type 3 - Barrier Soil Liner
C - Clay (Low Density)
Material Texture Number 15

Thickness	=	18 inches
Porosity	=	0.475 vol/vol
Field Capacity	=	0.378 vol/vol
Wilting Point	=	0.265 vol/vol
Initial Soil Water Content	=	0.475 vol/vol
Effective Sat. Hyd. Conductivity	=	1.70E-05 cm/sec

CASE 5 - Final Cover with 400' Waste

Layer 4

Type 1 - Vertical Percolation Layer

CL - Clay Loam

Material Texture Number 11

Thickness	=	12 inches
Porosity	=	0.464 vol/vol
Field Capacity	=	0.31 vol/vol
Wilting Point	=	0.187 vol/vol
Initial Soil Water Content	=	0.31 vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05 cm/sec

Layer 5

Type 1 - Vertical Percolation Layer (Waste)

Municipal Solid Waste (MSW) (900 pcy)

Material Texture Number 18

Thickness	=	4776 inches
Porosity	=	0.671 vol/vol
Field Capacity	=	0.292 vol/vol
Wilting Point	=	0.077 vol/vol
Initial Soil Water Content	=	0.292 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03 cm/sec

Layer 6

Type 2 - Lateral Drainage Layer

Btm 2' Solid Waste

Material Texture Number 43

Thickness	=	24 inches
Porosity	=	0.671 vol/vol
Field Capacity	=	0.292 vol/vol
Wilting Point	=	0.077 vol/vol
Initial Soil Water Content	=	0.292 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 7

Type 3 - Barrier Soil Liner

CL - Clay Loam (Moderate)

Material Texture Number 25

Thickness	=	2 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.437 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

CASE 5 - Final Cover with 400' Waste

Layer 8
Type 1 - Vertical Percolation Layer
CL - Clay Loam (Moderate)
Material Texture Number 25

Thickness	=	22 inches
Porosity	=	0.437 vol/vol
Field Capacity	=	0.373 vol/vol
Wilting Point	=	0.266 vol/vol
Initial Soil Water Content	=	0.373 vol/vol
Effective Sat. Hyd. Conductivity	=	3.60E-06 cm/sec

Layer 9
Type 2 - Lateral Drainage Layer
LCS
Material Texture Number 123

Thickness	=	0.14 inches
Porosity	=	0.85 vol/vol
Field Capacity	=	0.01 vol/vol
Wilting Point	=	0.005 vol/vol
Initial Soil Water Content	=	0.0112 vol/vol
Effective Sat. Hyd. Conductivity	=	1.81E+00 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 10
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06 inches
Effective Sat. Hyd. Conductivity	=	2.00E-13 cm/sec
FML Pinhole Density	=	0.5 Holes/Acre
FML Installation Defects	=	1 Holes/Acre
FML Placement Quality	=	2 Excellent

Layer 11
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	24 inches
Porosity	=	0.427 vol/vol
Field Capacity	=	0.418 vol/vol
Wilting Point	=	0.367 vol/vol
Initial Soil Water Content	=	0.427 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07 cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

CASE 5 - Final Cover with 400' Waste

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	82.2
Fraction of Area Allowing Runoff	=	100 %
Area projected on a horizontal plane	=	1 acres
Evaporative Zone Depth	=	22 inches
Initial Water in Evaporative Zone	=	9.153 inches
Upper Limit of Evaporative Storage	=	10.208 inches
Lower Limit of Evaporative Storage	=	4.114 inches
Initial Snow Water	=	0 inches
Initial Water in Layer Materials	=	1443.28 inches
Total Initial Water	=	1443.28 inches
Total Subsurface Inflow	=	0 inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	33.74 Degrees
Maximum Leaf Area Index	=	4
Start of Growing Season (Julian Date)	=	85 days
End of Growing Season (Julian Date)	=	319 days
Average Wind Speed	=	3.12 mph
Average 1st Quarter Relative Humidity	=	80 %
Average 2nd Quarter Relative Humidity	=	78 %
Average 3rd Quarter Relative Humidity	=	70 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for Whitesboro, Texas

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.754034	1.993557	3.211899	3.464894	4.71725	3.92418
2.940024	2.227022	3.66323	3.961307	3.082641	2.839882

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
55.8	58	63.6	71.2	80.2	91.8
93	91.7	83.5	73.1	66.6	56.2

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 33.74/-96.94

CASE 5 - Final Cover with 400' Waste

Average Annual Totals Summary

Title: TASWA Int Cvr w/200' Waste
Simulated on: 8/9/2022 10:38

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	37.78	[5.64]	137,141.1	100.00
Runoff	3.835	[3.05]	13,920.2	10.15
Evapotranspiration	33.959	[3.389]	123,270.5	89.89
Subprofile1				
Percolation/leakage through Layer 3	0.037821	[0.011244]	137.3	0.10
Average Head on Top of Layer 2	9.5592	[2.7446]	---	---
Subprofile2				
Lateral drainage collected from Layer 6	0.0000	[0]	0.0001	0.00
Percolation/leakage through Layer 7	0.037821	[0.011244]	137.3	0.10
Average Head on Top of Layer 7	0.0000	[0]	---	---
Subprofile3				
Lateral drainage collected from Layer 9	0.0378	[0.0113]	137.3	0.10
Percolation/leakage through Layer 11	0.000002	[0]	0.0090	0.00
Average Head on Top of Layer 10	0.0001	[0]	---	---
Water storage				
Change in water storage	-0.0515	[2.1714]	-186.8	-0.14

* Note: Average inches are converted to volume based on the user-specified area.

CASE 5 - Final Cover with 400' Waste

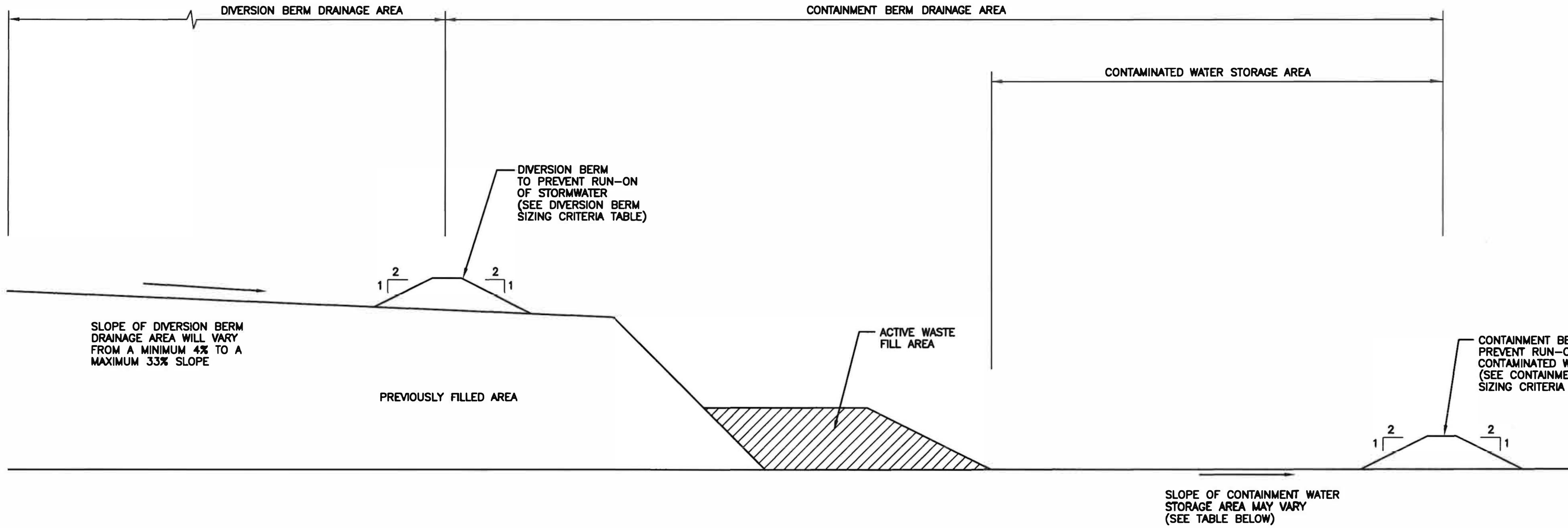
Peak Values Summary

Title: TASWA Int Cvr w/200' Waste
Simulated on: 8/9/2022 10:38

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	3.58	12,987.1
Runoff	2.908	10,556.8
Subprofile1		
Percolation/leakage through Layer 3	0.000270	0.9790
Average head on Layer 2	23.9998	
Subprofile2		
Drainage collected from Layer 6	0.0000	0.0000
Percolation/leakage through Layer 7	0.000270	0.9790
Average head on Layer 7	0.0001	---
Maximum head on Layer 7	0.0000	---
Location of maximum head in Layer 6	1.71 (feet from drain)	
Subprofile3		
Drainage collected from Layer 9	0.0003	0.9789
Percolation/leakage through Layer 11	0.000000	0.0000
Average head on Layer 10	0.0003	---
Maximum head on Layer 10	0.0005	---
Location of maximum head in Layer 9	0.00 (feet from drain)	
Other Parameters		
Snow water	3.0062	10,912.6
Maximum vegetation soil water	0.4640 (vol/vol)	
Minimum vegetation soil water	0.1870 (vol/vol)	

APPENDIX D6C
CONTAINMENT/DIVERSION BERM DESIGN

STATE OF TEXAS
DAVID L. CLARK
81905
LICENSED
PROFESSIONAL ENGINEER
2-28-25
Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256



DIVERSION BERM SIZING CRITERIA

DIVERSION BERM DRAINAGE AREA (ACRES)	4%			33%		
	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)
0.5	4.7	0.5	1.5	4.0	0.9	1.9
1.0	7.6	0.6	1.6	6.8	1.1	2.1
1.5	11.5	0.7	1.7	10.6	1.3	2.3

NOTE: DIVERSION BERMS WILL BE SIZED TO DIVERT STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT WITH A FREEBOARD OF 1 FT.

CONTAINMENT BERM SIZING CRITERIA

CONTAINMENT BERM DRAINAGE AREA (ACRES)	CONTAINMENT WATER STORAGE AREA (ACRES)	FLOOR SLOPE OF CONTAMINATED WATER STORAGE AREA	REQUIRED MINIMUM HEIGHT OF CONTAINMENT BERM (FT)
0.5	0.35 0.25 0.20	1 % 2 % 4 %	1.5 2.2 3.5
1.0	0.50 0.35 0.25	1 % 2 % 4 %	2.2 3.0 4.4
1.5	0.60 0.40 0.30	1 % 2 % 4 %	2.6 3.5 5.2

NOTE: CONTAINMENT BERMS WILL BE SIZED TO CONTAIN STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. THE CRITERIA ARE BASED ON A MINIMUM DOWNSLOPE CONTAINMENT BERM LENGTH OF 100 FEET WITH A FREEBOARD OF 0.5 FT.

STATE OF TEXAS
DAVID L. CLARK
81905
PROFESSIONAL ENGINEER
2-28-25

CONTAMINATED WATER RUNON/RUNOFF DETAILS

TEXOMA AREA SOLID WASTE AUTHORITY
TASWA DRF
PERMIT AMENDMENT

BME

BIGGS & MATHEWS ENVIRONMENTAL
1700 ROBERT ROAD, STE. 100
MANSFIELD, TEXAS 76063
817-563-1144

TBPE FIRM NO. F-256
TBPG FIRM NO. 50222

DRAWING
D6-C1

ISSUED FOR PERMITTING PURPOSES ONLY

O:\TASWA\P\Drawings\ATT D\D6-C1.dwg Layout: Layout1 User: dclark

Containment Berm Design

Required: Determine the necessary dimensions of the diversion berms.

Method:

1. Determine the flow using the Rational Method.
2. Calculate flow capacity using Manning's Method.

References:

1. Dodson's and Associates, Inc., *Hands-On HEC-1,* June 1997.
2. Ponce, Victor M., *Engineering Hydrology Principles and Practices,* 1989.
3. Texas Department of Transportation, Hydraulic Design Manual, Revised October 2011.
4. NOAA Atlas 14 Point Precipitation Frequency Estimates: Sherman, TX

Solution: Diversion berms will be designed to pass the 25-year storm event.
The Rational Method (Q=CiA) was used to determine the runoff.

25-Year Rainfall Depth (Pd) =	1.3	(Ref. 4, 25 yr, 10 min. duration)
Time of Concentration (tc) =	10.0 min	(conservative minimum value)
Rainfall Intensity (I) =	7.9 in/hr	(Ref. 3, I = Pd/tc)
Runoff Coefficient (C) =	0.7	
Time of Concentration (tc) =	10 min	
Running berm slope =	0.5 %	
Manning's n =	0.03	
Right side slope =	2 :1	

Drainage Area (ac)	0.5		1.0		1.5	
Peak Flow (cfs)	2.8		5.5		8.3	
Berm Evaluation						
Left Side Slope	3:1	25:1	3:1	25:1	3:1	25:1
Flow Depth (ft)	0.9	0.5	1.1	0.6	1.3	0.7
Flow Area (sf)	2.0	3.4	3.0	4.9	4.2	6.6
Wetted Perimeter (ft)	4.9	13.6	5.9	16.4	7.0	19.1
Velocity (fps)	2.0	1.4	2.2	1.6	2.5	1.7
Berm Capacity (cfs)	4.0	4.7	6.8	7.6	10.6	11.5

Containment Berm Design

Required: Size containment berms to contain contaminated water around the working face.

References:
1) Texas Department of Transportation, Hydraulic Design Manual, Revised October 2011.
2) NOAA Atlas 14 Point Precipitation Frequency Estimates: Sherman, TX

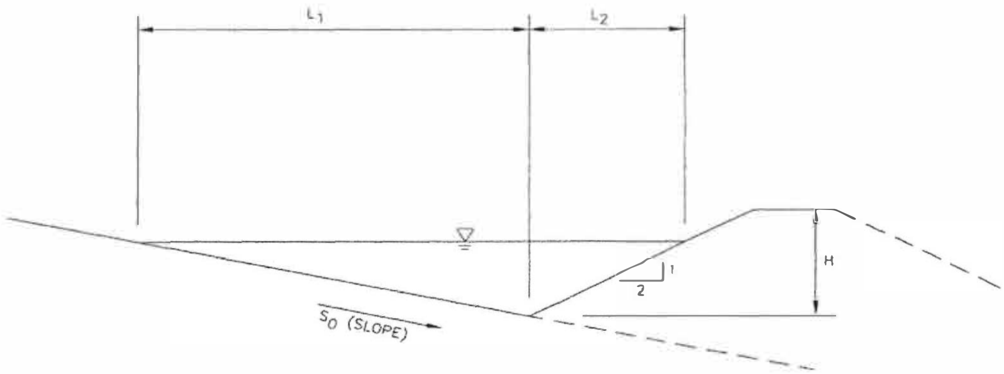
Solution:

Determine the storage volume required for the 25-year rainfall for Grayson County.

$V_R = CAR$

where: V_R = required storage volume (cf)
C = runoff coeffecient = 0.7
A = drainage area (acres)
R = 25-year rainfall = 8 in (24 hr)

Size the storage area from the following figure:



$A_s = (L_1 + L_2)H/2$ Storage Area = $W(L_1 + L_2)$

where: A_s = cross section area (sf) W = storage width (ft)
$L_1 = H/S_o$
$L_2 = 2H$

Drainage area ac	Required Volume cf	W ft	Storage Area ac	S_o ft/ft	L_1 ft	L_2 ft	H ft	As sf	Vs cf
0.5	10,164	100	0.35	0.01	152	3.0	1.5	118.5	11,854
0.5	10,164	100	0.25	0.02	109	4.4	2.2	123.3	12,334
0.5	10,164	100	0.20	0.04	87	7.0	3.5	163.9	16,394
1	20,328	100	0.50	0.01	218	4.4	2.2	241.9	24,193
1	20,328	100	0.35	0.02	152	6.1	3.0	241.7	24,174
1	20,328	100	0.25	0.04	109	8.7	4.4	256.2	25,616
1.5	30,492	100	0.60	0.01	261	5.2	2.6	348.4	34,838
1.5	30,492	100	0.40	0.02	174	7.0	3.5	315.7	31,574
1.5	30,492	100	0.30	0.04	131	10.5	5.2	368.9	36,887

APPENDIX D6D
SECONDARY CONTAINMENT VOLUME CALCULATIONS

STATE OF TEXAS
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2-28-25
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SECONDARY CONTAINMENT CALCULATION

Required: 1. Verify that the secondary containment area will contain a worst-case release from dual 25,000-gallon storage tanks, and precipitation from the 25-year, 24-hour rainfall event.

References: 1. NOAA ATLAS 14 Point Precipitation Frequency Estimates, Sherman TX

Solution: a) ***Provided Volume***

Calculate the provided secondary containment volume.

Length of containment area =	L =	78.5	ft
Width of containment area =	W =	78.5	ft
Containment area =	A =	6,162	sf
Containment wall height =	hw=	4.5	ft
Storage height with 6" of freeboard =	h=	4.0	ft

$$V_{PROVIDED} = A \times h$$

$$\mathbf{V_{PROVIDED} = 24{,}649 \text{ cf}}$$

b) ***Required Volume***

Calculate the required secondary containment volume. The requried volume is the sum of rainfall volume and tank volume.

Rainfall Volume

Calculate the rainfall volume that will collect in the containment area during the 25 year, 24-hour rainfall event.

From Reference 1, the 25-year, 24-hour rainfall event for Sherman, Texas is 7.5 inches.

Rainfall depth =	D =	7.5	in.	(Ref. 1)
Containment area =	A =	6,162	sf	

$$V_{RAINFALL} = D \times A$$

$$V_{RAINFALL} = 3{,}862 \text{ cf}$$

Storage Tank Volume

Tank volume =	V_{TANK} =	50,000	gal
	V_{TANK} =	6,684	cf

Required Secondary Containment Volume

$$V_{REQUIRED} = V_{RAINFALL} + V_{TANK}$$

$$\mathbf{V_{REQUIRED} = 10{,}546 \text{ cf}}$$

c) ***Conclusion***

$$\mathbf{V_{PROVIDED} = 24{,}649 \text{ cf}}$$

$$\mathbf{V_{REQUIRED} = 10{,}546 \text{ cf}}$$

Therefore, the provided secondary containment area will contain the required worst-case release from the storage tank and precipitation from the 25-year, 24-hour rainfall event.

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT APPLICATION NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT D7
LINER QUALITY CONTROL PLAN

Prepared for

Texoma Area Solid Waste Authority

February 2025

STATE OF TEXAS
DAVID L. CLARK
81905
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CONTENTS

30 TAC §§330.63(d)(4)(G), 330.331, 330.337, 330.339, 330.341

1 INTRODUCTION

30 TAC §330.339

1.1 Purpose

This Liner Quality Control Plan (LQCP) has been prepared in accordance with 30 TAC §330.339 to establish procedures for the design, construction, testing, and documentation of the liner and leachate collection system.

1.2 Definitions

Specific terms and acronyms that are used in this LQCP are defined below.

ASTM – American Society for Testing and Material

BER – Ballast Evaluation Report

Construction Quality Assurance (CQA) – CQA is a planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design. CQA includes the observations, evaluations, and testing necessary to assess and document the quality of the constructed facility. CQA includes measures taken by the CQA organization to assess whether the work is in compliance with the plans, specifications, and permit requirements for a project.

GLER – Geomembrane Liner Evaluation Report

Geotechnical Professional (GP) – The GP is the authorized representative of the operator who is responsible for all CQA activities for the project. The GP must be registered as a Professional Engineer in Texas. Experience and education should include geotechnical engineering, engineering geology, soil mechanics, geotechnical laboratory testing, construction quality assurance and quality control testing, and hydrogeology. The GP must also have competency and experience in certifying similar projects.

The GP may also be known in applicable regulations and guidelines as the CQA engineer, resident project representative, geotechnical quality control/quality assurance professional (GQCP), or professional of record (POR).

CQA Monitors – CQA monitors are representatives of the GP who work under direct supervision of the GP. The CQA monitor is responsible for quality assurance monitoring and performing on-site tests and observations. The CQA monitor must be NICET-certified at Level 2 for soils and geosynthetics, an engineering technician with a minimum of four years directly related experience, or a graduate engineer or geologist with one year of directly related experience.

Quality Assurance – Quality assurance is a planned program that is designed to assure that the work meets the requirements of the plans, specifications, and permit for a project. Quality assurance includes procedures, quality control activities, and documentation that are performed by the GP and CQA monitor.

Quality Control – Quality control includes the activities that implement the quality assurance program. The GP, CQA monitor, and contractor will perform quality control.

Seasonal High Water Table – The seasonal high water table is the highest measured water level within the construction area.

SLER – Soil Liner Evaluation Report

1.3 Sequence of Construction Activities

Construction of lined areas at the TASWA DRF will generally proceed in the following sequence of activities:

- The area will be excavated to the proposed subgrade elevations.
- A temporary dewatering system, if required, will be installed as described in Section 3.3.
- The subgrade elevations will be verified.
- The compacted soil liner will be constructed, tested, and verified in accordance with Section 4.
- The geomembrane liner will be constructed, tested, and verified in accordance with Section 5.
- The leachate collection system will be constructed and verified in accordance with Section 6. All soil testing and evaluation of constructed soil liners will be complete prior to installing the leachate collection system.
- The protective cover will be constructed and verified in accordance with Section 7.
- The Soils and Liner Evaluation Report will be submitted to the TCEQ.
- The Geomembrane Liner Evaluation Report will be submitted to the TCEQ.

2 LINER SYSTEM

30 TAC §330.331

2.1 Composite Liner and Leachate Collection Systems

The components of the composite liner system are listed from top to bottom in the table below. Details of the composite liner system are provided in Attachment D3.

Components of the Composite Liner System

Liner System Component	Description	Thickness
Protective Cover	General earthfill	24 inches
Leachate Collection Layer	Single-sided geocomposite on floor Double-sided geocomposite on side slopes	0.2 inches nominal
Geomembrane Liner	Smooth HDPE geomembrane on floor Textured HDPE geomembrane on side slopes	60 mil
Compacted Soil Liner	Compacted soil with a coefficient of permeability less than or equal to 1×10^{-7} cm/sec	24 inches

The leachate collection layer will be graded to drain to a collection trench along the centerline of each cell. The leachate collection trench will consist of perforated HDPE pipe encased in aggregate. The leachate collection trench will convey leachate to a sump located along the toe of the side slope. A description of the leachate collection system is provided in Attachment D6, and details of the leachate collection system are provided in Attachment D3.

2.2 Construction Monitoring

Continuous on-site monitoring is necessary to confirm that the components of the liner system are constructed in accordance with this LQCP. In accordance with 30 TAC §330.339(a)(2), the CQA monitor shall provide continuous on-site observation and field sampling and testing as required during the following construction activities:

- Temporary dewatering system installation
- Subgrade preparation
- Compacted soil liner placement, processing, compaction, and testing
- Geomembrane liner deployment, trial welds, seaming, testing, and repairing

- Leachate collection layer deployment and seaming
- Anchor trench backfill
- Protective cover layer placement
- Any work that could damage the installed components of the liner system

The GP will document and certify that the liner system was constructed in accordance with this LQCP. The GP shall make sufficient site visits to observe critical construction activities and to verify that the construction and quality assurance activities are performed in accordance with this LQCP.

3 EARTHWORK

30 TAC §§330.337, 330.339

3.1 General

The grading plan for the remaining cells to be constructed at the TASWA DRF provides for the landfill floor to slope at 1 percent to the perimeter sidewalls, which will slope at 4H:1V. The fill area will be divided into cells, each of which has a 2 percent cross slope to a leachate collection trench along the centerline of the cell. Collection trenches will slope to sumps located along the perimeter of the landfill. Earthwork activities and testing will be documented in the SLER in accordance with Section 9.2.

3.2 Materials

The following material classifications will be encountered in excavations or will be required for landfill construction.

General Fill

General fill consists of soil that is free from debris, rubbish, solid waste, organic matter, and particles larger than 4 inches in diameter.

Compacted Soil Liner

Compacted soil liner materials consist of soil that is free from debris, rubbish, solid waste, organic matter, and meets the requirements of Section 4.2.

Protective Cover

Protective cover materials consist of soil that is free from debris, rubbish, solid waste, organic matter, and meets the requirements of Section 7.2.

Leachate Aggregate

Drainage aggregate consists of natural or manufactured granular material that meets the requirements of Section 6.2.4.

Anchor Trench Backfill

Anchor trench backfill consists of general fill that is free of particles larger than 1 inch in diameter.

Daily and Intermediate Cover

Daily and intermediate cover materials consist of soil that has not been previously mixed with solid waste.

Topsoil

Topsoil consists of soil that is capable of sustaining vegetation and is free of debris, rubbish, and solid waste.

Unsuitable Materials

Unsuitable materials consist of any material that is determined by the GP to not be suitable for use as classified above.

3.3 Construction Below Groundwater

3.3.1 Highest Measured Water Elevations

The highest measured water elevations in the upper (Layer II) zone and lower (Layer V) zone will be used as the design groundwater elevations. The most recent groundwater elevations must be reviewed before the construction of each cell and, if necessary, the highest measured water elevations will be adjusted upward.

3.3.2 Temporary Dewatering

Groundwater is potentially contained in Layer II sand and sandstone and the Layer V sandstone/shaly sand shale with sand. If present, groundwater found in the upper part of Layer III is apparently in direct communication with groundwater in Layer II and acts as one hydrogeologic unit. Layer IV acts as a lower confining unit for groundwater in Layer II and III and as an upper confining unit to groundwater in Layer V.

If groundwater is encountered during excavation, lined areas will be dewatered during and after construction by a temporary dewatering system. The temporary dewatering system will consist of a network of underdrains consisting of HDPE panel-shaped pipe wrapped in geotextile encased in sand-filled trenches or perforated pipe encased in an aggregate trench wrapped in geotextile. The underdrains will discharge into open sumps beyond the lined areas or into closed sumps beneath the lined areas. The groundwater will be pumped from the sumps into the perimeter drainage system. Automated submersible pumps will be installed in closed sumps. The temporary dewatering system will be operated until sufficient ballast has been placed to offset the hydrostatic forces and the ballast has been documented in the BER.

The design procedures and typical details of the temporary dewatering system are provided in Appendix D7B – Temporary Dewatering System. Design and installation of the temporary dewatering system will be documented in the SLER in accordance with Section 9.2. The facility will submit a BER to the TCEQ once it is determined that ballasting or dewatering is no longer necessary.

3.4 Excavation

A description of the materials that will be encountered in the excavations is provided in Attachment D5.

The slope stability analyses are provided in Attachment D5. The slope stability analyses are only valid for the conditions that were analyzed. Any changes to the excavation plan, dewatering system, ballast system, liner system, final cover system, or landfill completion plan will necessitate that the slope stability analyses be revised to reflect the actual conditions.

4 COMPACTED SOIL LINER

30 TAC §330.339

4.1 General

The compacted soil liner component of the composite liner system consists of a 24-inch-thick layer of compacted, relatively homogeneous, cohesive material. The CQA monitor shall provide continuous on-site observation during compacted soil liner placement, compaction, and testing in accordance with 30 TAC §330.339(a)(2). The GP shall make sufficient site visits during compacted soil liner construction to document the construction activities, testing, and thickness verification in the SLER, in accordance with Section 9.2.

4.2 Materials

Compacted soil liner material shall consist of soil that is free from debris, rubbish, frozen materials, foreign objects, and organic material. The required compacted soil liner material properties are summarized below.

Compacted Soil Liner Material Properties

Test	Standard	Required Property
Plasticity Index	ASTM D 4318	15 or greater
Liquid Limit	ASTM D 4318	30 or greater
Percent Passing No. 200 Mesh Sieve	ASTM D 1140	30 or greater
Percent Passing 1-inch Sieve*	ASTM D 422	100
Coefficient of Permeability	ASTM D 5084 or COE EM 1110-2-1906 Appendix VII	1 x 10^{-7} cm/sec or less

* Can be visually verified. Onsite material used for soil liner is clay without aggregate.

Preconstruction testing procedures and frequencies for compacted soil liner materials are listed in Section 4.8.1.

4.3 Subgrade Preparation

Prior to placing soil liner material, the subgrade should be proof-rolled with heavy, rubber-tired construction equipment to detect soft areas. The GP or CQA monitor must observe the proof-rolling operation. Soft areas should be undercut to firm material, then backfilled with compacted general fill. The GP will observe the subgrade for signs of groundwater seepage and take appropriate actions, if necessary.

The subgrade elevations shall be verified in accordance with the requirements of Section 4.8.3 prior to the placement of compacted soil liner.

4.4 Placement and Processing

The compacted soil subgrade and surface of each lift should be roughened prior to placement of the next lift of compacted soil liner. The soil liner material should be placed in maximum 8-inch loose lifts to produce compacted lift thickness of approximately 6 inches. The material should be processed to a maximum particle size of 1 inch or less before water is added. Rocks and clods less than 1 inch in diameter should not total more than 10 percent by weight. The surface of the top lift shall contain no material larger than 3/8 inch.

If additional water is necessary to adjust the moisture content, it should be applied after initial processing, but prior to compaction. Water should be applied evenly across the lift and worked into the material. Water used for the soil liner compaction must not be contaminated by waste or any objectionable material.

4.5 Compaction

The soil liner shall be compacted with a pad/tamping-foot or prong-foot roller. Soil liner shall not be compacted with a bulldozer, rubber-tired roller, flat-wheel roller, scraper, truck, or any track equipment unless it is used to pull a footed roller. The compactor should weigh at least 40,000 pounds. The lift thickness shall be controlled to achieve penetration into the top of the previously compacted lift; therefore, the lift thickness should not be greater than the pad or prong length. Cleaning devices on the roller must be in place and maintained to prevent the prongs or pad feet from becoming clogged to the point that they cannot achieve full penetration.

The compactor should make approximately four passes across the area being compacted. The material should be compacted to a minimum of 95 percent of the maximum dry density determined by standard Proctor (ASTM D 698) at a moisture content at or above optimum moisture. Areas with failing tests shall be reworked, recompacted, and retested, and passing tests must be achieved before another lift is added.

After a lift is compacted, it must be watered to prevent drying and desiccation until the next lift can be placed. If desiccation occurs, the GP must determine if the lift can be rehydrated by surface application of water or if the lift must be scarified, watered, and recompacted. Following compaction and fine grading of the final lift, the surface of the compacted soil liner shall be smooth drum rolled.

4.6 Protection

The compacted soil liner must be protected from drying, desiccation, rutting, erosion, and ponded water until the geomembrane is installed. Areas that undergo excessive desiccation or damage shall be reworked, recompacted, and retested as directed by the GP.

4.7 Tie-in to Existing Liners

The edge of existing compacted soil liners shall be cut back on either a slope or steps to prevent the formation of a vertical joint. Details of the existing liner tie-in are shown in Attachment D3.

4.8 Testing and Verification

4.8.1 Preconstruction Testing

The table below lists the minimum testing required for material proposed for use as compacted soil liner.

Compacted Soil Liner Material Preconstruction Tests

Test	Standard	Frequency
Plasticity Index	ASTM D 4318	1 per material type
Liquid Limit	ASTM D 4318	1 per material type
Percent Passing No. 200 Mesh Sieve	ASTM D 1140	1 per material type
Percent Passing 1-inch Sieve*	ASTM D 422	1 per material type (if needed)
Standard Proctor Test	ASTM D 698	1 per material type
Coefficient of Permeability	ASTM D 5084 or COE EM 1110-2-1906 Appendix VII	1 per material type

* Can be visually verified.

After the moisture density relationship has been determined for a material type, a soil sample should be remolded to about 95 percent of the maximum dry density at the optimum moisture content. This sample will be tested to determine if the soil can be compacted to achieve the required coefficient of permeability. Either falling head or constant head laboratory permeability tests may be performed to determine the coefficient of permeability. The permeant fluid for testing must be tap water or 0.05N calcium sulfate solution. Distilled or deionized water shall not be used as the permeant fluid.

4.8.2 Construction Testing

The table below lists the minimum testing required for material used as compacted soil liner.

Compacted Soil Liner Material Construction Tests

Test	Standard	Frequency
Field Density	ASTM D 2922	1/8,000 sf per 6-inch lift
Plasticity Index	ASTM D 4318	1/100,000 sf per 6-inch lift
Liquid Limit	ASTM D 4318	1/100,000 sf per 6-inch lift
Percent Passing 1-inch (if needed*) and No. 200 Sieve	ASTM D 1140 ASTM D 422	1/100,000 sf per 6-inch lift
Standard Proctor Test	ASTM D 698	1 per material type
Coefficient of Permeability	ASTM D 5084 or COE EM 1110-2-1906 Appendix VII	1/100,000 sf per 6-inch lift

* Can be visually verified. Onsite material used for soil liner is clay without aggregate.

Permeability testing will be performed on undisturbed samples from the compacted soil liner as described in Section 4.8.1 and all test data will be reported.

4.8.3 Thickness Verification

The as-built thickness of the compacted soil liner shall be determined by standard survey methods. Prior to the placement of liner material, the subgrade elevations will be determined at a minimum rate of 1 survey point per 5,000 sf of lined area. After the compacted soil liner is completed, the top of the liner elevations will be determined at the same locations as the subgrade elevations.

5 GEOMEMBRANE LINER

30 TAC §§330.331, 330.339

5.1 General

The geomembrane liner (GM) component of the composite liner system consists of a 60-mil-thick HDPE geomembrane placed over the compacted soil liner. Smooth or textured GM will be placed on the floor liner and textured GM will be placed over the sidewall liner. The CQA monitor shall provide continuous on-site observation during GM deployment, trial welds, seaming, testing, and repairing in accordance with 30 TAC §330.339(a)(2). The GP shall make sufficient site visits during the GM installation to document the installation and testing in the GLER, in accordance with Section 9.3.

5.2 Materials

5.2.1 Properties

GM shall consist of smooth and textured high-density polyethylene (HDPE) geomembrane produced from virgin raw materials. Recycled materials are not acceptable. The GM shall not be manufactured from resin from differing suppliers. The GM shall meet the requirements in the most current revision of the Geosynthetics Research Institute (GRI) Standard GM13. A copy of GRI-GM13 is included in Attachment D7.

Manufacturer quality control testing procedures and frequencies for GM are listed in Section 5.5.1. Third party conformance testing procedures and frequencies for GM are listed in Section 5.5.2.

5.2.2 Delivery and Storage

GM shall be shipped in rolls labeled with the manufacturer's name, roll number, and lot or batch number. The CQA monitor shall inspect the rolls for shipping damage and confirm that the materials delivered to the site meet project specifications.

Upon delivery of the geomembrane, the CQA monitor will observe that:

- Equipment used to unload and store the rolls or pallets does not damage the geomembrane.
- The geomembrane is stored in an acceptable location and not stacked more than five rolls high.

- The geomembrane is protected from puncture, dirt, grease, water, moisture, and excessive heat, or other damage.
- All manufacturing documentation required by the specifications has been received and reviewed for compliance with the specifications.

Damaged geomembrane may be rejected and removed from the site or stored at a location separate from accepted geomembrane.

5.3 Preparation

The surface of the compacted soil liner shall be protected in accordance with Section 4.6 until the GM is installed. Prior to installation of the GM, the compacted soil liner shall be tested and verified in accordance with Section 4.8, and the GP or CQA monitor and geosynthetics installer shall inspect the surface of the soil liner to verify that:

- The soil liner surface has been smooth drum rolled.
- The soil liner surface is free of irregularities, soft areas, or loose soil.
- The soil liner surface is free of stones, protrusions, or objects that could damage the GM.

The geosynthetics installer must accept the condition of the compacted soil liner and sign a subgrade acceptance form prior to the installation of the GM.

5.4 Installation

5.4.1 Deployment and Placement

The following activities must take place prior to GM deployment:

- The manufacturer's quality control and third-party conformance tests should be completed and approved by the GP in accordance with the requirements of Section 5.5.
- The GP or CQA monitor and geosynthetics installer shall approve the subgrade in accordance with the requirements of Section 5.3.
- The geosynthetics installer shall sign the subgrade acceptance form.

GM shall be deployed by equipment that will unroll the GM without damaging, crimping, or stretching it and deployment equipment must not damage the underlying compacted soil liner. GM must not be deployed during periods of rain or high winds and shall not be deployed on top of frozen subgrade. The installer must only deploy the amount of GM that can be seamed on the same day. The GM shall be installed in direct and uniform contact with the compacted soil liner.

Upon deployment, each panel shall be assigned a unique identification number. All panels must be anchored with adequate ballast to prevent uplift from wind. Smoking and wearing shoes that could damage the GM shall not be permitted on the GM, and only low-ground pressure supporting equipment shall be allowed on the GM. Textured GM shall be placed on side slopes and shall extend to a minimum of 5 feet beyond the toe of the slope.

During GM placement, the CQA monitor must:

- Provide full-time observation.
- Observe the condition of the subgrade and note any deficiencies. All deficiencies shall be repaired and approved by the CQA monitor.
- Observe the condition of the GM and note any defects. All defects must be repaired in accordance with the requirements of Section 5.4.4.
- Observe that people working on the GM do not smoke, wear shoes that could damage the GM, or engage in activities that could damage the GM.
- Observe that the deployment method minimizes wrinkles and that the GM is anchored to prevent movement from wind.
- Observe that no more panels are deployed than can be seamed on the same day.
- Observe that there are no horizontal seams on side slopes and that the textured material extends a minimum of 5 feet past the toe of the slope. For slopes longer than typical manufacturer membrane lengths, seams on the side slope are to be made at an approximate 45-degree angle.

Any panels that are not deployed in accordance with this section shall be marked by the CQA monitor and be repaired in accordance with Section 5.4.4 or be removed and replaced by the installer.

5.4.2 Seaming

Each seam shall be assigned a unique number, which is preferably consistent with the panel numbering system. Sidewall seams shall be oriented downslope. Prior to welding, the proper panel overlap shall be provided; dirt, grease, and free moisture shall be cleaned from the panel contact area; and wrinkles shall be removed as much as practical. For extrusion welds, oxidation shall be ground from the seam area within one hour of the welding operation and the extrudate shall be purged from the extrusion welding apparatus. Seaming operations shall not be allowed when the ambient temperature is below 40°F or above 104°F unless trial welds have demonstrated that adequate welds can be achieved outside these limits. Geomembrane seaming shall be performed in strict accordance with the methods approved or recommended by the geomembrane manufacturer.

During GM seaming operations, the CQA monitor must:

- Provide full time observation.
- Observe that only approved welding apparatus and operators are allowed to weld seams.
- Observe the condition of the seams and note any defects. All defects must be repaired in accordance with the requirements of Section 5.4.4.
- Observe that people working on the GM do not smoke, wear shoes that could damage the GM, or engage in activities that could damage the GM.
- Observe that the seams are free of grease, dirt, moisture, and wrinkles.
- Observe that welding operations take place within the approved ambient temperature range.
- Observe that seam grinding has been completed less than one hour before extrusion welding and the extrudate has been purged from extrusion welders.
- Observe that there are no horizontal seams on side slopes and that the textured material extends a minimum of 5 feet past the toe of the slope. For slopes longer than typical manufacturer membrane lengths, seams on the side slope are to be made at an approximate 45-degree angle.

5.4.3 Anchor Trenches

The GM anchor trench shall be left open until the seaming is completed. Expansion and contraction of the GM should be accounted for during deployment. The bottom of the anchor trench shall be dry, stable and free of loose particles and rocks. Anchor trenches shall be backfilled with compacted general fill in a manner that does not damage or induce stress to the GM.

5.4.4 Repairs

Geomembrane repairs shall be performed in accordance with the methods approved or recommended by the geomembrane manufacturer. Defects in the GM, defects in seams, failing destructive tests, failing nondestructive tests, holes from nondestructive tests, and destructive test sample locations shall be repaired by one of the following repair techniques:

- Patching - used to repair large holes, tears, large GM defects, and destructive test locations.
- Extrusion - used to repair small GM defects, cuts, holes from nondestructive tests, and seam defects less than ½-inch long.

- Capping - used to repair failed seams or seams where nondestructive tests cannot be performed.
- Removal - used to replace areas with large defects where other repair techniques are not appropriate.

Repair procedures include the following:

- Abrade geomembrane surfaces to be repaired (extrusion welds only) no more than one hour prior to the repair.
- Clean and dry all surfaces at the time of repair.
- Extend patches or caps at least 6 inches beyond the edge of the defect, and round all corners of material to be patched and the patches to a radius of at least 3 inches. Bevel the top edges of patches prior to extrusion welding.

Destructive and non-destructive testing will be performed on all repairs in accordance with Section 5.5.4.

5.5 Testing and Verification

5.5.1 Manufacturer's Quality Control Testing

The GM manufacturer shall test the geomembrane and raw materials in accordance with GRI Standard GM13 to assure the quality of the GM. Resin shall be tested at a frequency of 1 test per 200,000 lbs. and every resin lot for density and melt flow index. See Appendix D7E for testing methods.

5.5.2 Conformance Testing

Conformance samples of the GM shall be cut across the full width of selected rolls in accordance with the test frequency specified in the table below. Conformance samples may be taken at the manufacturing plant or at the project site and forwarded to a third-party laboratory for testing. Material property requirements are provided in Section 5.2.1. Minimum conformance testing requirements are provided in the table below.

GM Conformance Tests

Test	Standard	Frequency
Sheet Thickness	ASTM D 5199, 1593, or 5994	1 per 100,000 sf and every resin lot
Specific Gravity	ASTM D 1505	1 per 100,000 sf and every resin lot
Carbon Black Content	ASTM D 1603	1 per 100,000 sf and every resin lot
Carbon Black Dispersion	ASTM D 3015 or 5596	1 per 100,000 sf and every resin lot
Tensile Properties	ASTM D 638	1 per 100,000 sf and every resin lot

5.5.3 Trial Welds

Each operator and welding apparatus must be tested to verify that seam welds that meet the specifications can be achieved under the site conditions. Trial welds must be performed at the beginning and midpoint of each day for each operator and apparatus used that day.

The trial weld samples shall be 3 feet long and 12 inches wide, with the seam centered lengthwise. At least four 1-inch-wide coupons will be cut from each trial weld sample. Two coupons from each sample will be tested for shear and two samples will be tested for peel. Peel test coupons for dual-track welds shall be tested on both sides of the air channel. Each coupon must meet the minimum strength requirements. If the trial weld fails, two more trial seams must be welded and tested. This process will continue until passing trial welds are achieved.

5.5.4 Construction Testing

Nondestructive Tests

Nondestructive seam tests include vacuum testing and air pressure testing. Nondestructive testing shall be performed for the entire length of each seam by the GM installer.

Vacuum testing shall be used to test extrusion-welded seams and fusion-welded seams that cannot be tested by air pressure methods. The vacuum box shall be placed over a seam section that has been thoroughly saturated with a soapy water solution. The rubber gasket on the bottom of the vacuum box must seal against the GM to prevent leaks. The vacuum box shall pull a vacuum of 4 to 8 psi with a dwell time of at least 10 seconds. Soap bubbles will indicate the presence of holes or non-bonded seams.

Air pressure testing shall be used to test fusion-welded seams that have an air channel. Both ends of the air channel shall be sealed and air shall be pumped into the channel to at least 30 psi or ½ psi per mil of thickness, whichever is greater. The air channel must sustain the pressure for at least five minutes, without more than a 4-psi pressure drop. Following a passing pressure test, the pressure shall be released from the end of the seam that is opposite of the pressure gauge. The pressure gauge must return to zero; if it does not, the seam is probably blocked. After the blockage has been located, the seam shall be pressure tested on both sides of the blockage. All penetration holes shall be sealed after the air pressure testing is completed.

During the nondestructive testing, the CQA monitor must:

- Observe that equipment and operators perform the tests properly.
- Observe that the entire length of each seam is tested and record the results of the test.
- Identify failed seams and inform the installer of any required repairs.
- Record all completed and tested repairs on the repair log.

Destructive Tests

Destructive testing shall be performed at a frequency of one test location per 500 linear feet of seam. Repairs over 10 feet long shall be included in the total seam length. Destructive test samples should be 45 inches long by 12 inches wide with the seam centered along the length of the sample.

Two coupons should be cut from each end of the sample and the installer must test these coupons with a tensiometer capable of measuring the seam strength. The installer shall test two coupons in shear and two coupons in peel. For double wedge-welded seams, both sides of the air channel shall be tested in peel. The minimum requirements for destructive testing are provided in the table below. If one of the coupons fails in either peel or shear, the installer shall reconstruct the entire seam between passed test locations or take additional samples 10 feet in both directions of the failed test. If the additional tests pass, the contractor shall reconstruct or cap the seam between the passing test locations. If the additional tests fail, the sampling and testing procedure shall be repeated until the length of the faulty seam is established.

If the field test results are satisfactory, the remaining sample shall be divided into three parts: one-third for the installer, one-third for independent laboratory testing, and one-third for archive in case retesting is necessary. The laboratory shall test five coupons from each sample in shear and test five coupons from each sample in peel (10 when testing both inner and outer welds of dual-track fusion welds). The minimum requirements for destructive testing are provided in the table below. If the laboratory test fails in either peel or shear, the installer shall reconstruct the entire seam between passed test locations or take additional samples 10 feet in both directions of the failed test. If the additional tests pass, the contractor shall reconstruct or cap the seam between the passing test locations. If the additional tests fail, the sampling and testing procedure shall be repeated until the length of the faulty seam is established. All seams shall be bracketed by passing laboratory tests.

GM Seam Properties

Test	Standard	Frequency	Minimum Criteria
Shear	ASTM D 4437	1 sample per 500 feet of seam	Each of the five specimens from each sample must have a shear strength greater than or equal to 120 ppi.
Peel	ASTM D 4437	1 sample per 500 feet of seam	Hot wedge Seams: Each of the five specimens from each sample must have a peel strength greater than or equal to 91 ppi and no more than 25% peel separation. Both sides of dual track seams shall meet the minimum criteria. Each track is considered a separate sample. Locus-of-break pattern shall not be AD or AD-Brk>25%. Extrusion Fillet Seams: Each of the five specimens from each sample must have a peel strength greater than or equal to 78 ppi and no more than 25% peel separation. Locus-of-break pattern shall not be AD1, AD2 or AD-WLD.

During destructive seam testing, the CQA monitor must:

- Select sample locations.
- Assign sample numbers and label samples.
- Record sample locations, sample number, and lab test results.

6 LEACHATE COLLECTION SYSTEM

30 TAC §330.333

6.1 General

The leachate collection system consists of the collection layer, collection trenches, piping, and sumps. Details of the leachate collection system design are provided in Attachment D3. The design capacity calculations are provided in Attachment D6. Material properties are described in Section 6.2. The CQA monitor shall provide on-site observation during leachate collection layer and piping installation in accordance with 30 TAC §330.339(a)(2). The GP shall make sufficient site visits during the leachate collection system installation to document the installation in the GLER, in accordance with Section 9.3.

6.2 Materials

6.2.1 Geocomposite

The leachate collection layer consists of geocomposite drainage net installed above the GM. Single-sided geocomposite (nonwoven geotextile bonded to the top of HDPE drainage net) will be installed on the floor, and double-sided geocomposite (nonwoven geotextile bonded to the top and bottom of HDPE drainage net) will be installed on the sidewalls. The geocomposite shall have the minimum properties listed below.

Geocomposite Properties

Material	Test	Standard	Required Property
Geotextile	Material		Nonwoven polypropylene or polyester
	Apparent Opening Size	ASTM D 4751	70 sieve maximum
	Unit Weight	ASTM D 5261	8 oz/yd^2
	Grab Strength	ASTM D 4632	150 lb
	Puncture Strength	ASTM D 6241	500 lb
HDPE Drainage Net	Specific Gravity	ASTM D 1505	0.93 g/cm^3
	Thickness	ASTM D 5199	200 mil
	Carbon Black	ASTM D 1603	Minimum 2%, maximum 3%
	Tensile Strength	ASTM D 7179	40 lb/in
Floor Geocomposite	Transmissivity	ASTM D 4716	5 x 10^{-4} m^2/sec
Sidewall Geocomposite	Transmissivity	ASTM D 4716	3 x 10^{-5} m^2/sec

Manufacturer quality control testing procedures and frequencies for geocomposite are listed in Section 6.5.1.

6.2.2 Geotextile

The leachate aggregate that is placed in the collection trenches and sumps shall be wrapped in a geotextile filter fabric. The geotextile shall have the minimum properties listed in the table below.

Geotextile Properties

Test	Standard	Required Property
Material		Nonwoven polypropylene or polyester
Apparent Opening Size	ASTM D 4751	70 sieve maximum
Unit Weight	ASTM D 5261	8 oz/yd^2
Grab Strength	ASTM D 4632	150 lb
Tear Strength	ASTM D 4533	60 lb
Puncture Strength	ASTM D 6241	500 lb

Manufacturer quality control testing procedures and frequencies for geotextile are listed in Section 6.5.1.

6.2.3 Leachate Pipe

The leachate piping includes perforated collection trench pipes and solid sidewall riser pipes. The leachate piping shall meet the cell classification PE345434C in accordance with ASTM D 3350. The pipe shall have the minimum SDR rating and perforation schedule shown on the plans and specifications.

6.2.4 Leachate Aggregate

Leachate aggregate will be placed in the collection trenches and in the sumps. The aggregate shall consist of manufactured or natural materials having the properties listed in the table below. Alternate gradations may be approved by the GP.

Leachate Aggregate Properties

Test	Standard	Required Property	
Gradation	ASTM D 422	Sieve 1.5" 1/2" 3/8"	% Passing 90-100 20-50 0-15
Hydraulic Conductivity	ASTM D 2434	$\geq 1 \times 10^{-2}$ cm/sec	
Carbonate Content	JLT-S-105-89 or ASTM D 3042[a]	Maximum 15% loss	

[a] Use an HCL solution having a pH of 5 or lower.

Conformance testing procedures and frequencies for leachate aggregate are listed in Section 6.5.2.

6.2.5 Delivery and Storage

Geocomposite and geotextile shall be shipped in rolls labeled with the manufacturer's name, roll number, and lot or batch number. The CQA monitor shall inspect the rolls for shipping damage and complete a geosynthetics receipt log for all materials delivered to the site. Damaged rolls shall be rejected. Pipe shall be shipped in bundles labeled with the manufacturer's name and cell classification number.

The geocomposite, geotextile, and pipe shall be unloaded and handled with equipment that does not cause damage. Rolls should not be pushed, slid, or dragged to the storage location. The geocomposite and geotextile must not be stored on wet, soft, or rocky subgrade but must be stored on a stable subgrade. Geocomposite and geotextile must not be stacked more than five rolls high to avoid crushing the roll cores. The stored geocomposite, geotextile, and pipe must be protected from puncture, grease, dirt, excessive heat, or other damage.

6.3 Preparation

Prior to installation of the leachate collection layer the soil liner and GM shall be tested and verified in accordance with Sections 4.8 and 5.5. The CQA monitor shall observe that the surface to receive the geocomposite is free of debris, stones, and dirt and verify that the geocomposite conformance documentation has been submitted and approved.

6.4 Installation

6.4.1 Geocomposite

Double-sided geocomposite shall be installed on sidewalls and single or double-sided geocomposite shall be installed on the floor. Geocomposite shall be deployed by equipment that will unroll the geocomposite without damaging, crimping, or stretching it and deployment equipment must not damage the underlying GM. All panels must be anchored with adequate ballast to prevent uplift from wind. Smoking and wearing shoes that could damage the geocomposite or GM shall not be permitted on the geocomposite and only low-ground pressure supporting equipment shall be allowed on the geocomposite or GM. Adjacent rolls of geocomposite shall be securely tied through the drainage net with plastic fasteners every 5 feet along the length of the panel and every 6 inches along the ends of the panels. The top geotextile of adjacent rolls shall be overlapped and be sewn or heat bonded together. Additional geotextile will be used at end seams to cover holes made by installation of the plastic fasteners. This material shall be sewn or heat bonded to the geotextile on the geocomposite. The installer shall take precautions to prevent burning holes in the geotextile when using heat bonding techniques.

During geocomposite placement, the CQA monitor must:

- Provide full time observation.
- Record weather conditions.
- Observe the condition of the geocomposite and note any defects. All defects must be repaired or replaced.
- Observe that people working on the geocomposite or GM do not smoke, wear shoes that could damage the geocomposite or GM, or engage in activities that could damage the geocomposite or GM.
- Observe that the deployment method minimizes wrinkles in the geocomposite and GM.
- Observe that the geocomposite panels have been properly tied and seamed.

Any panels that are not installed in accordance with this section shall be marked by the CQA monitor and be repaired or removed and replaced by the installer.

6.4.2 Geotextile

Geotextile shall be placed around the leachate aggregate in the collection trenches and the sumps in accordance with the plans. Geotextile shall be deployed by equipment that will unroll the geocomposite without damaging or stretching it, and deployment equipment must not damage the underlying geosynthetics. Smoking and wearing shoes that could damage the geotextile, geocomposite, or GM shall not be permitted on the geotextile and only low-ground pressure supporting equipment shall be allowed on the geotextile, geocomposite, or GM. Adjacent rolls shall be overlapped and sewn or heat bonded together. The installer shall take precautions to prevent burning holes in the geotextile when using heat bonding techniques.

During geotextile placement, the CQA monitor must:

- Provide full time observation.
- Observe the condition of the geotextile and note any defects. All defects must be repaired or replaced.
- Observe that people working on the geotextile, geocomposite, or GM do not smoke, wear shoes that could damage the geotextile, geocomposite, or GM, or engage in activities that could damage the geotextile, geocomposite, or GM.
- Observe that the deployment method minimizes wrinkles in the geotextile, geocomposite, and GM.
- Observe that the geotextile panels have been properly seamed.

Any panels that are not installed in accordance with this section shall be marked by the CQA monitor and be repaired or removed and replaced by the installer.

6.4.3 Pipe

Leachate pipe shall be placed to the lines and grades shown on the plans. The pipe shall be joined in accordance with the manufacturer's recommendations and the project specifications.

Construction equipment shall not be allowed to travel directly over the leachate pipes to prevent crushing or excessive deflection until aggregates and protective cover have been placed. Minimum equipment separation distances listed in Section 7.4 shall be observed.

During leachate pipe placement, the CQA monitor must:

- Provide full time observation.
- Observe the condition of the pipes and note any defects. All defective pipes must be replaced.
- Observe that people working on the geotextile, geocomposite, or GM do not smoke, wear shoes that could damage the geotextile, geocomposite, or GM, or engage in activities that could damage the geotextile, geocomposite, or GM.
- Observe that construction equipment does not damage pipes, geotextile, geocomposite, or GM.
- Observe that the perforations and pipe orientation are in accordance with the plans and specifications.
- Observe that the pipes and fittings are joined in accordance with the project specifications and the manufacturer's recommendations.

Any pipes that are not installed in accordance with this section shall be marked by the CQA monitor and be repaired or removed and replaced by the installer.

6.4.4 Leachate Aggregate

Leachate aggregate shall be placed in the collection trenches and sumps to the lines and grades shown on the plans. During leachate aggregate placement, the CQA monitor must:

- Observe that leachate aggregate is placed in accordance with the plans and specifications.
- Observe that the leachate aggregate is consistent with the conformance test samples.
- Observe that leachate aggregate placement activities do not dislodge or damage leachate pipes or underlying geosynthetics.

6.5 Testing and Verification

6.5.1 Manufacturer's Testing

The geocomposite manufacturer shall test the geocomposite to assure the quality of the geocomposite. Material property requirements are provided in Section 6.2.1. Minimum manufacturer's testing requirements are provided in the table below. The manufacturer's testing shall be conducted at a minimum frequency of 1 test per 100,000 sf of material.

Geocomposite Manufacturer's Tests

Material	Test	Standard
Geotextile	Weight	ASTM D 5261
	Apparent Opening Size	ASTM D 4751
	Grab Strength	ASTM D 4632
	Puncture Strength	ASTM D 6241
HDPE Drainage Net	Specific Gravity	ASTM D 1505
	Thickness	ASTM D 5199
	Carbon Black	ASTM D 4218
Geocomposite	Transmissivity[1]	ASTM D 4716

[1]Transmissivity testing to be conducted under the conditions specified by the GP according to the design conditions

The geotextile manufacturer shall test the geotextile to assure the quality of the geotextile. Material property requirements are provided in Section 6.2.2. Minimum manufacturer's testing requirements are provided in the table below. The manufacturer's testing shall be conducted at a minimum frequency of 1 test per 100,000 sf of material.

Geotextile Manufacturer's Tests

Test	Standard
Weight	ASTM D 5261
Apparent Opening Size	ASTM D 4751
Grab Strength	ASTM D 4632
Tear Strength	ASTM D 4533
Puncture Strength	ASTM D 6241

The leachate piping manufacturer shall provide a certification that the pipe meets the cell classification PE345434C in accordance with ASTM D 3350, and the minimum SDR rating and perforation schedule shown on the plans and specifications.

6.5.2 Construction Testing

The leachate aggregate shall be tested to assure that the aggregate meets the specifications. Material property requirements are provided in Section 6.2.4. Minimum construction testing requirements are provided in the table below.

Leachate Aggregate Construction Tests

Test	Standard	Frequency
Gradation	ASTM D 422	1 per source/project
Hydraulic Conductivity	ASTM D 2434	1 per source/project
Carbonate Content	JLT-S-105-89 or ASTM D 3042[a]	1 per source/project

[a] Use an HCL solution having a pH of 5 or lower.

6.5.3 Verification

The as-built location of the leachate piping shall be determined and reported in the GLER. All components of the leachate collection system shall be verified and documented in the GLER in accordance with Section 9.3.

7 PROTECTIVE COVER

30 TAC §330.339

7.1 General

The protective cover component of the composite liner system consists of a 24-inch-thick layer of soil placed over the leachate collection layer. The drainage aggregate around the leachate collection pipes will extend through the protective cover to form a chimney drain for the leachate collection system. The CQA monitor shall provide continuous on-site observation during protective cover placement to assure that protective cover placement does not damage underlying geosynthetics (geomembrane liner and geocomposite leachate collection layer) in accordance with 30 TAC §330.339(a)(2). The GP shall make sufficient site visits during protective cover placement to document the construction activities, testing, and thickness verification in the GLER in accordance with Section 9.3.

7.2 Materials

Protective cover material shall consist of soil that is free from debris, rubbish, frozen materials, foreign objects, and organic material, or any material that could damage the underlying geosynthetics. Since drainage aggregate chimneys will be provided above the LCS trenches, there are no permeability requirements for protective cover materials.

7.3 Preparation

Prior to placing the protective cover material, the top of compacted soil liner elevations shall be verified in accordance with the requirements of Section 4.8.3 and all testing on the underlying geosynthetics shall be completed.

7.4 Placement

The protective cover shall be placed in a manner that minimizes the potential to damage the underlying geosynthetics. Hauling equipment shall be restricted to haul roads of sufficient thickness to protect the underlying geosynthetics. The protective cover shall be dumped from the haul road and spread by low ground pressure equipment in a manner that minimizes wrinkles and stress in the geosynthetics. On sidewalls, protective cover shall be placed from the bottom to the top, not across or down. The minimum separation distances between construction equipment and geosynthetics are listed in the table below.

Minimum Separation Distance

Equipment Ground Pressure (psi)	Minimum Separation Distance (in)
< 4	12
4 - 8	18
8 - 16	24
> 16	36

Any geosynthetic material that, in the opinion of the CQA monitor, has been damaged by the protective cover placement must be repaired and retested in accordance with Sections 5.4 and 6.4.

7.5 Testing and Verification

7.5.1 Testing

If the protective cover is counted as ballast against hydrostatic forces, the field density of the in-place protective cover may be determined at a rate of 1 test per 10,000 sf. The in-place field density will be determined for information only, and there is no minimum compaction requirement for protective cover.

7.5.2 Thickness Verification

The as-built thickness of the protective cover shall be determined by standard survey methods. Prior to the placement of protective cover, the top of compacted soil liner elevations will be determined at a minimum rate of 1 survey point per 5,000 sf of lined area. After the protective cover is completed, the top of the protective cover elevations will be determined at the same locations as the top of compacted soil liner elevations.

8 BALLAST

30 TAC §330.337

8.1 General

The highest measured water elevations in the upper (Layer II) zone and the lower (Layer V) zone are presented in Attachment D7 and represent the highest groundwater elevations that have been encountered at the site. The highest measured water elevations will be used as the design groundwater elevations. The most recent groundwater elevations for both zones must be reviewed before the construction of each cell and, if necessary, the highest measured water elevations must be adjusted upward. Lined areas will be dewatered during and after construction using a temporary dewatering system as described in Section 3.3.2.

Long-term hydrostatic uplift pressures will be resisted by the weight of the materials placed above the geomembrane liner in accordance with §330.337. Ballast includes the weight of the leachate collection system, protective cover, and compacted waste. The ballast will be documented in the BER in accordance with Section 9.4.

8.2 Ballast Geometry

For each new lined area, the GP will prepare calculations to determine the geometry of the ballast that is required to prevent hydrostatic uplift of the liner system with a minimum factor of safety of 1.5. Procedures for calculating the height of compacted waste or additional protective cover soil above the liner system needed to ballast hydrostatic pressure are provided in Attachment D7, along with example calculations.

8.3 Ballast Materials

Ballast will consist of protective cover, leachate aggregate, infiltration layer, erosion layer, and solid waste. Material properties for protective cover are listed in Section 7.2 and material properties for leachate aggregate are listed in Section 6.2.4. Solid waste ballast will consist of waste accepted at the site in accordance with Part IV. Large, bulky items must be excluded from the initial 5 feet of waste ballast.

8.4 Ballast Placement

Landfill personnel will verify and document that the initial 5 feet of waste does not contain large, bulky items which could damage the liner system, or which cannot be compacted to the required density. Waste ballast must be compacted to a density of not less than 1,200 lb/cy or 44 pcf. The site manager will document that the waste used for ballast has been compacted with multiple passes of a wheeled compactor that weighs more than 40,000 pounds. The form to be used by the landfill manager is included in Attachment D7. This documentation will be placed in the site operating record and attached to the BER.

8.5 Testing and Verification

Where protective cover is used as ballast, it may be tested in accordance with Section 7.5.1 and test results will be used to calculate the required ballast thickness. Where protective cover is not tested, the protective cover will be assumed to have a density of 90 percent of the maximum dry density of the material. Waste ballast compaction will be verified by the site manager and documented on the Waste-for-Ballast Placement Record. The GP will verify that the temporary dewatering system prevented uplift forces on the liner during construction of the liner. The verification will include observations of water levels in the dewatering sumps or survey data as deemed appropriate by the GP. The site manager will document that the dewatering system remained operational until ballast was placed. The documentation will be placed in the site operating record.

Once the calculated height of compacted waste has been achieved for each cell area, the temporary dewatering system no longer needs to remain operational, and the groundwater can be allowed to rebound against the bottom of the liner system. Before submittal of the BER, the GP will review compaction information and density of material used as ballast, and the thickness of all materials used in Ballast Calculations. A BER must be submitted to the TCEQ in accordance with Section 9.4 to document that adequate ballast height has been achieved and to request that the temporary dewatering system operations be discontinued.

9 DOCUMENTATION

30 TAC §330.341

9.1 Reports

Each report shall be submitted to the TCEQ and shall be prepared in accordance with the methods and procedures contained in this LQCP. The evaluated area should not be used for the receipt of solid waste until acceptance is received from the executive director. The executive director may respond to the permittee either verbally or in writing within 14 days from the date on which the SLER document is received by the TCEQ. Verbal acceptance may be obtained from the executive director, which will be followed by written concurrence. If no response, either written or verbal, is received within 14 days, the SLER or GLER shall be considered accepted, and the owner or operator may continue facility construction or operations. Each report must be signed and, where applicable, sealed by the individual performing the evaluation and countersigned by the site operator or his authorized representative.

Markers will be placed to identify all disposal areas for which a SLER has been submitted and accepted by the executive director. These markers shall be located so that they are not destroyed during operations.

The surface of a liner should be covered with a layer of solid waste within a period of six months to mitigate the effects of surface erosion and rutting due to traffic. Liner surfaces not covered with waste within six months shall be checked by the SLER evaluator, who shall then submit a letter report on his findings to the executive director. Any required repairs shall be performed properly. A new SLER shall be submitted on the new construction for all liners that need repair due to damage.

9.2 Soils and Liner Evaluation Report

After construction of the compacted soil liner, the GP will submit a SLER to the TCEQ on behalf of the owner. Preparation and submission of the SLER shall be in accordance with TCEQ MSWR. The purpose of the SLER is to document that the construction methods and test procedures are consistent with this LQCP, the TCEQ MSWR, and the project specifications.

At a minimum, the SLER will contain the properly completed TCEQ SLER form and necessary documents to supplement the form including:

- A summary of construction activities
- A summary of laboratory and field test results

- Sampling and testing location drawings
- Record drawings
- A statement of compliance with the LQCP
- An updated seasonal high water table map
- A description of the temporary dewatering system
- The seal and signature of the GP and assistant GP, if applicable, in accordance with the Texas Engineering Practice Act

9.3 Geomembrane Liner Evaluation Report

After construction of the geosynthetics portion of the liner, the GP will submit a GLER to the TCEQ on behalf of the owner. Preparation and submission of the GLER shall be in accordance with TCEQ MSWR. The purpose of the GLER is to document that the construction methods and test procedures are consistent with this LQCP, the TCEQ MSWR, and the project specifications.

At a minimum, the GLER will contain the properly completed TCEQ GLER form and necessary documents to supplement the form including the following:

- A summary of construction activities
- A summary of laboratory and field testing
- Sampling and testing locations
- Record drawings
- A statement of compliance with the LQCP
- An updated seasonal high water table map
- A brief description of the temporary dewatering system (if required)
- Calculations for the required ballast thickness (if required)
- The seal and signature of the GP and assistant GP, if applicable, in accordance with the Texas Engineering Practice Act

9.4 Ballast Evaluation Report

For areas where waste is used for ballast, a BER will be completed and submitted to the TCEQ. The purpose of the BER is to document that sufficient ballast has been placed to offset the potential long-term hydrostatic uplift forces that may exist below the liner system. The BER will provide documentation that the temporary groundwater control system is no longer required. The BER shall include the following information:

- Names and phone numbers of contact persons.
- Evaluation by the GP documenting that detrimental uplift has not occurred within the liner system. The evaluation shall include survey data as deemed pertinent by the GP.
- Certification from the owner of the type of waste placed in the lower 5 feet and documentation of the compaction from the Site Operating Record (see form in Attachment D7).
- Survey of the top of waste to document that the required thickness has been placed.
- Documentation that any dewatering system used to lower the groundwater level during liner construction was in effect throughout the completion of the ballast placement.
- Documentation that the seasonal high-water elevation has not increased from that presented in Attachment D7, or that additional ballast has been provided to compensate for upward changes in the high water table during ballast placement.
- The signature and seal of the registered professional engineer performing the evaluation and the signature of the owner's authorized representative.

If adequate ballast is placed on a liner as part of the construction process it will be documented in the GLER. If it is documented in the GLER that adequate ballast is present to counteract any hydrostatic uplift, a separate BER will not be required or submitted for that particular liner installation.

APPENDIX D7A
HIGHEST MEASURED WATER LEVELS

STATE OF TEXAS
DAVID L. CLARK
81905
LICENSED
PROFESSIONAL ENGINEER
2-28-25
Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

HISTORIC WATER LEVEL MEASUREMENTS
PIEZOMETERS AND MONITORING WELLS

Layer II/III Groundwater Levels		
Location	Date of Highest Measured Level	Highest Measured Water Level
L35S	Apr-01	757.71
P20S	Mar-01	746.32
U30S	Jun-00	743.47
EE35S	Mar-01	736.11
JJ10S	Apr-00	745.41
TT20S	Apr-00	734.80
TT30S	Apr-00	732.73
MW1	Mar-16	763.67
MW2	Mar-20	758.32
MW3	Mar-20	747.02
MW4	Mar-20	737.84
MW5	Mar-20	729.05
MW6	Mar-20	732.32
MW7	Feb-23	729.88
MW12	Mar-20	760.37
BME1s	Jul-24	764.08
BME6s	Jan-23	750.06
BME8s	May-22	725.98
BME10s	May-22	721.71
BME12s	May-22	729.64
BME13s	Apr-22	726.12

Layer V Groundwater Levels		
Location	Date of Highest Measured Level	Highest Measured Water Level
LL35D	Apr-00	680.55
P10D	May-00	675.87
P20D	Apr-00	681.42
Z20D	May-00	667.77
EE15D	Apr-00	664.03
EE25D	Apr-00	664.54
EE35D	Mar-01	658.22
JJ10D	May-00	665.98
OO15D	May-00	655.80
TT10D	May-00	655.54
YY25D	Mar-01	655.31
YY35D	Mar-01	655.26
MW13	Mar-22	657.40
MW14	Mar-22	657.00
MW15	Mar-24	656.31
MW16	Aug -24	655.44
MW17	Aug -24	655.28
MW18	Aug -24	655.48
MW19	Aug-24	655.42
MW26	Aug-21	690.94
BME1d	Mar-22	665.42
BME4d	Mar-22	663.86
BME6d	Mar-22	655.54
BME7d	Mar-22	655.80
BME8d	Mar-22	654.19
BME10d	Mar-22	654.05
BME12d	Mar-22	654.02
BME13d	Mar-22	653.73

APPENDIX D7B
TEMPORARY DEWATERING SYSTEM

STATE OF TEXAS
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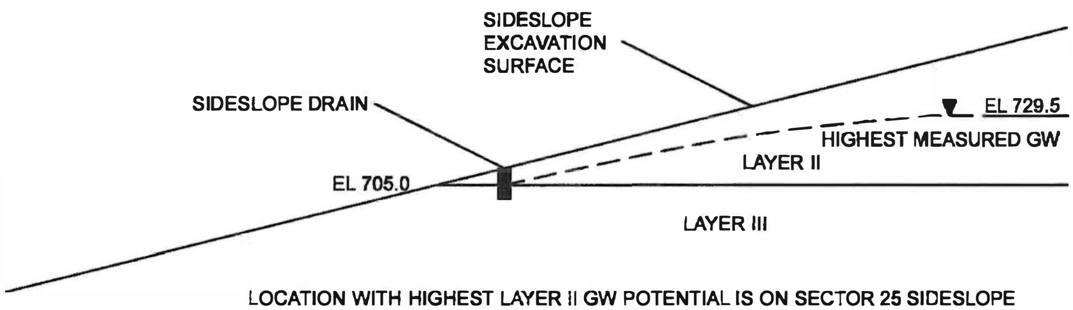
Temporary Dewatering Inflow Rate
Layer IV Groundwater

Required: Determine the inflow rate to the sideslope drain of the temporary dewatering system:

References: *Dewatering and Groundwater Control*, UFC 3-220-05, January 2004 (replaces TM 5-818-5).

Assumptions: The temporary dewatering system will be designed for the highest recorded water levels (see Drawing D7A-1).
The dewatering system plan and details are included in Attachment D3.
The groundwater elevation in Layer IV rises to intersect the excavation subgrade at the lowest subgrade location."

Solution: ***Floor Drain***



LOCATION WITH HIGHEST LAYER II GW POTENTIAL IS ON SECTOR 25 SIDESLOPE
(NTS)

H_1 = design water height =	24.5	ft
H_2 = sideslope drain height =	3	ft
H = saturated layer thickness ($H_1 - H_2$) =	21.5	ft
L = length of sideslope drain	1300	ft (longest drainage length)

Use Darcy's equation to estimate the inflow into the drain.

$Q = KiA$

where: Q = design flowrate

K = hydraulic conductivity of GWBU =	24	ft/year
i = average hydraulic gradient (see Appendix E6) =	0.0625	ft/ft
(based on March 2022 potentiometric surface average)		
A = flow area (H x L) =	27950	sf

Q = 1.33E-03 cfs

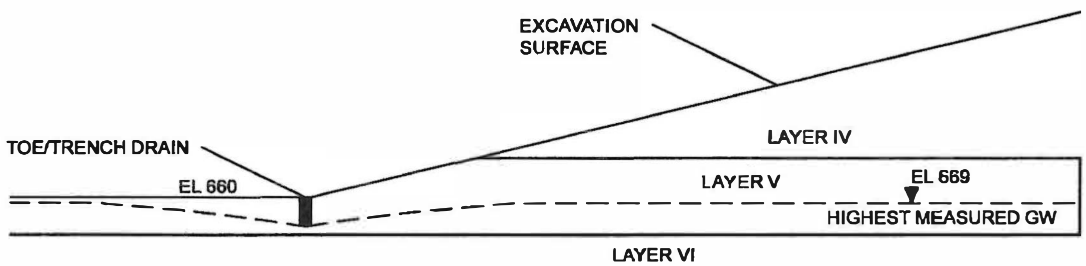
Temporary Dewatering Inflow Rate
Layer V Groundwater

Required: Determine the inflow rate to the sideslope drain of the temporary dewatering system:

References: *Dewatering and Groundwater Control*, UFC 3-220-05, January 2004 (replaces TM 5-818-5).

Assumptions: The temporary dewatering system will be designed for the highest recorded water levels (see Drawing D7A-1).
The dewatering system plan and details are included in Attachment D3.
The boundary of the uppermost ground water bearing unit (GWBU) is at the top of Layer VI.

Solution: ***Sideslope Drain***
The sidewall drain is located at the interface of the GWBU (Layer II) and Layer III. The sidewall drain consists of either a prefabricated composite drain backfilled with sand or a trench backfilled with drainage aggregate and pipe to convey groundwater to a collection and removal sump. The critical sidewall drain is located in sidewall of Sector 25. The critical sidewall drain section is shown below.



LOCATION WITH HIGHEST LAYERV GW POTENTIAL IS AT LOW END OF SECTOR 5
(NTS)

H_1 = design water height =	9	ft
H_2 = toe/trench drain height =	3	ft
H = saturated layer thickness ($H_1 - H_2$) =	6	ft
L = length of sideslope drain	1550	ft (longest drainage length)

Use Darcy's equation to estimate the inflow into the drain.

$Q = KiA$

where: Q = design flowrate

K = hydraulic conductivity of GWBU =	14	ft/year
i = average hydraulic gradient (see Appendix E6) =	0.0625	ft/ft
(based on March 2022 potentiometric surface average)		
A = flow area (H x L) =	9300	sf

Q = 2.58E-04 cfs

Temporary Dewatering System

Temporary Dewatering System

Required: Size the following elements of the temporary dewatering system:
1) Composite Drains
2) Pump

References:
1) *AdvanEDGE Pipe (L-1074) Literature referencing KTC-97-5, SPR-92-143, "Performance and Cost Effectiveness of Pavement Edge Drains",* L. John Fleckenstein, Kentucky Transportation Center, 1997.

Assumptions:
1) The dewatering system plan and details are shown on Drawings D3.7 And D3.8.
2) The largest flow in a composite drain will be the sideslope drain in Sector 25.
3) Flow rates are from the inflow rate calculations.

Solution
1) Maximum flowrate is inflow rate calculated for critical section with highest measured groundwater level.

Q = maximum flowrate = 1.33E-03 cfs
= 5.97E-01 gpm

Flow capacity of 12" ADS Composite Drain = 39.0 gpm (Ref 1)

2) Use the maximum flowrate to the sump to size the pump with a

Q_p = pumping rate = 8.95E-01 gpm

Temporary Dewatering Geosynthetic Design

Required: Determine the minimum geosynthetic properties for temporary dewatering system:
1) Geotextile for the composite drain.

References: 1) *Designing with Geosynthetics,* Fourth Edition; Robert M. Koerner.

Assumptions: 1) The adjacent soils will have at least 50% finer than the No. 200 sieve.

Solution: 1) *Geotextile*

Calculate the required permittivity from the equation:

$$\Psi_{req} = q / \Delta hA$$

where:

Ψ_{req} = permittivity		
q = peak inflow rate =	1.33E-03	cfs
Δh = maximum allowable head =	3.0	ft
L = trench length =	1300	ft
H = drain height =	3.0	ft
A = inflow area = L x 2H =	7800.0	sf

Substitute and solve for required permittivity = 5.6813E-08 sec^{-1}

Calculate the allowabe permittivity from Reference 1, Equation 2.25.

$$\Psi_{req} = \Psi_{all} \, (1 / RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC})$$

where:

RF_{SCB} = soil clogging/binding reduction factor =	7.0	(Ref. 1, Table 2.12)
RF_{CR} = creep reduction factor =	1.5	(Ref. 1, Table 2.12)
RF_{IN} = intrusion reduction factor =	1.2	(Ref. 1, Table 2.12)
RF_{CC} = chemical clogging reduction factor =	1.0	(Ref. 1, Table 2.12)
RF_{BC} = biological clogging reduction factor =	1.0	(Ref. 1, Table 2.12)

Substitute and solve for allowable permittivity = 7.2E-07 sec^{-1}

Determine the appropriate soil retention criteria from Reference 1, Figure 2.4.

For fine-grained, non-dispersive soils the AOS must be less than 0.21mm.

Temporary Dewatering Drawdown Curve

Required: Determine the drawdown curve when the dewatering system is active.

References: *Dewatering and Groundwater Control*, UFC 3-220-05, January 2004 (supercedes TM 5-818-5).

Assumptions: The temporary dewatering system will be designed for the highest recorded water levels.
The dewatering system plan and details are in provided in Attachment D3.
The boundary of the ground water bearing unit (GWBU) is at the top of Layer VI as demonstrated in Attachment E.
Groundwater inflow to the dewatering trench as calculated in Appendix D7-B.
Insitu hydraulic conductivity of Stratum I material as demonstrated in Att. E.

Solution: Use equations for gravity flow and drawdown from Ref 1, Fig 4-1 "Flow and Head for fully penetrating line slot"

Using known values for flow rate and hydraulic conductivity, solve for drawdown length.

$$Q = \left(\frac{kx}{2L}\right)(H^2 - h_o^2)$$

Where:

Q =	Inflow Rate =	2.58E-04	cfs
k =	hydraulic conductivity =	4.44E-07	fps
x =	length of dewatering trench=	1550	ft
H =	design water height =	9	ft
h_o =	toe/trench drain height =	3	ft

Solve for drawdown length: L

$$L = \left(\frac{kx}{2Q}\right)(H^2 - h_o^2)$$

L =	96 ft

APPENDIX D7C
BALLAST CALCULATIONS

STATE OF TEXAS
DAVID L. CLARK
81905
LICENSED
PROFESSIONAL ENGINEER
2-28-25

Biggs & Mathews Environmental, inc.
Firm Registration No. F-256

LINER BALLAST CALCULATIONS

The required ballast thickness shall be calculated by the GP and included in the GLER. The ballast calculation shall be based on the as-built conditions and the updated highest groundwater elevations. The required ballast thickness shall be calculated as follows:

A. Review and update, as necessary, the water level elevations (see Attachment D7, Appendix D7-A – Highest Measured Water Levels). Adjust the seasonal high-water table upward, if necessary, across the area being lined using the current highest measured water levels. Determine the design water level for the area being analyzed. The lined area may be subdivided into more than one area as appropriate.

B. Determine the hydrostatic uplift pressure on the base of the bottom and sidewall liner system including normal, vertical, and horizontal components of the uplift pressure as follows:

1. Bottom Liner: Determine the maximum hydrostatic uplift pressures acting normal to the base of the bottom liner system using the unit weight of water, γ_W, times the vertical distance from the geomembrane (GM) to the design water level, H.

$$P_N = \gamma_W H$$

2. Sidewall Liner: Determine the maximum hydrostatic uplift pressures acting normal, vertical, and horizontal to the base of the sidewall liner system using the following steps.

(a) Determine the maximum normal uplift pressure on the sidewall liner using the unit weight of water times the vertical distance from the GM to the design water level, H.

$$P_N = \gamma_W H$$

(b) Determine the maximum vertical uplift pressure on the sidewall liner using the normal uplift pressure times the cosine of the slope angle.

$$P_V = P_N \cos \beta$$

(c) Determine the maximum horizontal uplift pressure on the sidewall liner using the normal uplift pressure times the sine of the slope angle.

$$P_H = P_N \sin \beta$$

C. Determine the resisting pressure of the protective cover soil against uplift of the bottom and sidewall liner system including normal, vertical, and horizontal components of the resisting pressures as follows:

1. Bottom Liner: Determine the normal resisting pressure at the GM using the unit weight of the protective cover times the thickness of the protective cover.

$$R_N = (\gamma_{pc} T_{pc})$$

Where: γ_{pc} = Wet unit weight of the protective cover
T_{pc} = Thickness of the protective cover

The unit weight of the protective cover shall be determined from field measured unit weights or assumed to equal 100 pcf (~90% of dry density).

2. Sidewall Liner:

(a) Determine the vertical resisting pressure of the sidewall liner using the unit weight of the protective cover material times the vertical thickness of the protective cover layer. This is equal to the normal resisting pressure divided by the cosine of the slope angle.

$$R_v = R_N / \cos \beta$$

(b) Determine the horizontal resisting pressure of the sidewall liner using the coefficient of at-rest earth pressure of the liner system components times the vertical resisting pressure.

$$R_H = K_O R_V$$

The coefficient of at-rest earth pressure, K_O, is based on the assumed angle of internal friction, ϕ, of the material resisting hydrostatic pressures (compacted soil).

(c) Determine the normal resisting pressure of the sidewall liner system using the normal components of the horizontal and vertical resisting pressures calculated in steps (a) and (b) above.

$$R_N = R_H \sin \beta + R_V \cos \beta$$

D. Evaluate the factor of safety against uplift of the bottom and sidewall liner system due to hydrostatic pressures.

1. Bottom Liner: Determine the factor of safety against uplift of the bottom liner system due to hydrostatic forces acting normal to the base of the bottom liner system.

$$FS = R_N / P_N$$

If the factor of safety is greater than or equal to 1.2, the protective cover provides sufficient ballast to offset the hydrostatic uplift forces.

If the factor of safety is less than 1.2, additional ballast in the form of solid waste or additional soil will be necessary to offset the hydrostatic forces. See Step E for determining the geometry of solid waste or additional ballast.

2. Sidewall Liner:

Determine the factor of safety against uplift of the sidewall liner system due to hydrostatic pressures acting normal, vertical, and horizontal to the sidewall liner system.

(a) $FS_N = R_N / P_N$

(b) $FS_V = R_V / P_V$

(c) $FS_H = R_H / P_H$

If the factors of safety are greater than or equal to 1.2, the protective cover provides sufficient ballast to offset the hydrostatic forces.

If the factor of safety is less than 1.2 for any of the components (normal, vertical, or horizontal), additional ballast in the form of solid waste or additional soil will be necessary to offset the hydrostatic forces. See Step E for determining the geometry of solid waste or additional soil ballast.

E. Use a factor of safety of 1.5 against uplift of the liner and ballast system for solid waste ballast.

Assume a unit weight of 44 pcf for solid waste and a unit weight of 100 pcf for soil if field measurements are not available, or if conditions indicate the field measurements are no longer applicable.

1. Bottom Liner

The factor of safety against uplift of the liner and ballast system is calculated as follows:

$$FS = (R_N + B_N) / P_N$$

Where R_N = Normal protective cover pressure
B_N = Normal ballast pressure
B_N = $H_{sw} * \gamma_{sw}$ (Height and unit weight of solid waste ballast)
FS = 1.5 for waste

Solving the above equation for the height of ballast:

$$H = (FS\ P_N - R_N) / \gamma$$

2. Sidewall Liner

The factor of safety against uplift of the liner and ballast system is calculated as follows:

(a) $FS = (R_V + B_V) / P_V$ (Vertical Components)

Where R_V = Vertical protective cover pressure
B_V = Vertical ballast pressure
B_V = $H * \gamma$
FS = 1.5 for waste

Solving the above equation for the height of ballast:

$$H = (FS\ P_V - R_V) / \gamma$$

(b) $FS = (R_H + B_H) / P_H$ (Horizontal Components)

Where R_H = Horizontal protective cover pressure
B_H = Horizontal ballast pressure
B_H = $B_V * K_0$
B_H = $H * \gamma * 0.7$
FS = 1.5 for waste, 1.2 for soil

Solving the above equation for the height of ballast:

$$H = (FS\ P_H - R_H) / \gamma * k_0$$

(c) $FS = ((R_v+B_v)cosB + (R_h+B_h)sinB) / P_n$ (Normal Components)

Example calculations are provided on pages D7C.6 through D7C.9.

Temporary Dewatering Drawdown Curve

Required: Determine the drawdown curve when the dewatering system is active.

References: *Dewatering and Groundwater Control*, UFC 3-220-05, January 2004 (supercedes TM 5-818-5).

Assumptions: The temporary dewatering system will be designed for the highest recorded water levels.
The dewatering system plan and details are in provided in Attachment D3.
The boundary of the ground water bearing unit (GWBU) is at the top of Layer VI as demonstrated in Attachment E.
Groundwater inflow to the dewatering trench as calculated in Appendix D7-B.
Insitu hydraulic conductivity of Stratum I material as demonstrated in Att. E.

Solution: Use equations for gravity flow and drawdown from Ref 1, Fig 4-1 "Flow and Head for fully penetrating line slot"

Using known values for flow rate and hydraulic conductivity, solve for drawdown length.

$$Q = \left(\frac{kx}{2L}\right)(H^2 - h_o^2)$$

Where:

Q =	Inflow Rate =	2.58E-04	cfs
k =	hydraulic conductivity =	4.44E-07	fps
x =	length of dewatering trench=	1550	ft
H =	design water height =	9	ft
h_o =	toe/trench drain height =	3	ft

Solve for drawdown length: L

$$L = \left(\frac{kx}{2Q}\right)(H^2 - h_o^2)$$

L = 96 ft

Example Ballast Calculation
Layer II Groundwater

Required: Example calculation to evaluate the long-term hydrostatic uplift pressures on the liner system and determine the ballast requirements.

Assumptions:
1) The design water elevations are shown on Drawing D7A-1.
2) All cells must be re-evaluated based on updated groundwater data prior to construction.
3) Assume normal and vertical forces to be the same in the bottom, and design for normal forces.
4) Uplift is evaluated at the clay liner geomembrane interface.
5) Groundwater is present in Layer II and upper Layer III but is not connected to Layer V as demonstrated in Attachment E.

References: Equations used are basic vector, soil and fluid mechanics equations found in all vector, soil and fluid mechanics textbooks.

Solution: Calculations are shown for the sideslope of Sector 25 where Layer II has the highest groundwater potential.

The forces acting upon the liner system are:

P_N = normal pressure	R_N = normal resistance
P_V = vertical pressure	R_V = vertical resistance
P_H = horizontal pressure	R_H = horizontal resistance

Section B

1) Determine the uplift pressure upon the FML at the bottom of Layer II.

γ_w = unit weight of water =	62.4	pcf
Groundwater elevation =	729.5	ft-msl
Liner elevation =	705	ft-msl
H = design water level above liner =	24.5	ft
β = sidewall slope =	14.0	deg

Equation B1	***Bottom***	$P_N = H\gamma_w =$	1528.8 psf	(No groundwater pressure acts at toe/bottom calculation provided only for future reference)
Equation B2(a)	***Slope***	$P_N = H\gamma_w =$	1528.8 psf	
Equation B2(b)		$P_V = P_N \cos\beta =$	1483.1 psf	
Equation B2(c)		$P_H = P_N \sin\beta =$	370.9 psf	

Section C

2) Determine the resistance pressure of protective cover at the bottom and on the slope.

Protective cover:

γ = density (92% std proctor or field data) =	115.0	pcf
T_N = normal thickness =	2.0	ft
T_V = vertical thickness =	2.06	ft
ϕ = angle of internal friction =	14.0	deg

Equation C1	***Bottom***	$R_N = \gamma_{pc} T_N =$	230.0 psf	(No groundwater pressure acts at toe/bottom calculation provided only for future reference)
Equation C2(a)	***Slope***	$R_V = R_N / \cos\beta$	237.0 psf	
Equation C2(b)		$R_H = k_o R_V =$	118.5 psf	(k_0 assumed as 0.5)
Equation C2(c)		$R_N = R_H \sin\beta + R_V \cos\beta =$	258.7 psf	

Section D

3) Determine the factors of safety against uplift and evaluate the need for additional ballast.

Equation D1	***Bottom***	$FS_N = R_N / P_N =$	0.2	(No groundwater pressure acts at toe/bottom - calculation provided only for future reference)
Equation D2(a)	***Slope***	$FS_N = R_N / P_N =$	0.2	
Equation D2(b)		$FS_V = R_V / P_V =$	0.2	
Equation D2(c)		$FS_H = R_H / P_H =$	0.3	

Example Ballast Calculation
Layer II Groundwater

The factor of safety for protective cover providing ballast against hydrostatic uplift is less than 1.2. Evaluate the height of waste ballast required to provide a factor of safety of at least 1.5.

γ_{sw} = unit weight of solid waste = 44.0 pcf

Section E

Equation E1 — **Bottom** — $FS = (R_N + B_N) / P_N$ (No groundwater pressure acts at toe/bottom - calculation provided only for future reference)

Equation E2(a) — **Slope** — $FS = (R_v + B_v) / P_v$

For FS = 1.5 $H = (FS * P_v - R_v) / \gamma_{sw}$

H = 45.2 ft

Equation E2(b) — $FS = (R_H + B_H) / P_H$

For FS = 1.5 $H = (FS * P_H - R_H) / (\gamma_{sw} * k_0)$

H = 19.9 ft

Using waste height calculated for vertical forces, check FS with normal forces:

For H_{sw} = 45.2 ft

Equation E2(c) — $FS = ((R_v + B_v)cosB + (R_h + B_h)sinB) / P_n$

FS = 1.8 Factor of safety is greater than 1.5 so vertical forces control

This example calculation was performed at the location in Sector 25 that has the largest hydrostatic force at the site based on the highest measured groundwater map included in Appendix D7-A .

The GP will evaluate the highest measured water levels to determine where the largest hydrostatic force is located and perform these calculations to determine how much ballast is required when preparing the Ballast Evaluation Report for submittal to the TCEQ prior to decommissioning any dewatering system.

Example Ballast Calculation
Layer V Groundwater

Required: Example calculation to evaluate the long-term hydrostatic uplift pressures on the liner system and determine the ballast requirements.

Assumptions:
1) The design water elevations are shown on Drawing D7A-2.
2) All cells must be re-evaluated based on updated groundwater data prior to construction.
3) Assume normal and vertical forces to be the same in the bottom, and design for normal forces.
4) Uplift is evaluated at the clay liner geomembrane interface.
5) Groundwater is present in Layer V and not in Layer VI as demonstrated in Attachment E.

References: Equations used are basic vector, soil and fluid mechanics equations found in all vector, soil and fluid mechanics textbooks.

Solution: Calculations are shown for the lower end of Sector 9 where Layer V has the highest groundwater potential relative to the design liner elevation.

PLOT

P_N = normal pressure	R_N = normal resistance
P_V = vertical pressure	R_V = vertical resistance
P_H = horizontal pressure	R_H = horizontal resistance

Section B — 1) Determine the uplift pressure upon the FML at the critical location on the bottom liner.

γ_w = unit weight of water =	62.4 pcf
Groundwater elevation =	669 ft-msl
Liner elevation =	662 ft-msl
H = design water level above liner =	7 ft
β = sidewall slope =	14.0 deg

Equation B1	**Bottom**	$P_N = H\gamma_w =$	436.8 psf
Equation B2(a)	**Slope**	$P_N = H\gamma_w =$	436.8 psf
Equation B2(b)		$P_V = P_N \cos\beta =$	423.8 psf
Equation B2(c)		$P_H = P_N \sin\beta =$	106.0 psf

Section C — 2) Determine the resistance pressure of protective cover at the bottom and on the slope.

Protective cover:

γ = density (92% std proctor or field data) =	115.0 pcf
T_N = normal thickness =	2.0 ft
T_V = vertical thickness =	2.06 ft
ϕ = angle of internal friction =	14.0 deg

Equation C1	**Bottom**	$R_N = \gamma_{pc} T_N =$	230.0 psf
Equation C2(a)	**Slope**	$R_V = R_N / \cos\beta$	237.0 psf
Equation C2(b)		$R_H = k_o R_V =$	118.5 psf (k_0 assumed as 0.5)
Equation C2(c)		$R_N = R_H \sin\beta + R_V \cos\beta =$	258.7 psf

Section D — 3) Determine the factors of safety against uplift and evaluate the need for additional ballast.

Equation D1	**Bottom**	$FS_N = R_N / P_N =$	0.5 (No groundwater pressure acts at toe/bottom - calculation provided only for future reference)
Equation D2(a)	**Slope**	$FS_N = R_N / P_N =$	0.6
Equation D2(b)		$FS_V = R_V / P_V =$	0.6
Equation D2(c)		$FS_H = R_H / P_H =$	1.1

Example Ballast Calculation
Layer V Groundwater

The factor of safety for protective cover providing ballast against hydrostatic uplift is less than 1.2. Evaluate the height of waste ballast required to provide a factor of safety of at least 1.5.

γ_{sw} = unit weight of solid waste = 44.0 pcf

Section E

Equation E1 — **Bottom** $FS = (R_N + B_N) / P_N$

Equation E2(a) — **Slope** $FS = (R_v + B_v) / P_v$

For FS = 1.5 $H = (FS * P_v - R_v) / \gamma_{sw}$

$H =$ 9.1 ft

Equation E2(b) $FS = (R_H + B_H) / P_H$

For FS = 1.5 $H = (FS*P_H - R_H) / (\gamma_{sw}*k_0)$

$H =$ 1.8 ft

Using waste height calculated for vertical forces, check FS with normal forces:

For H_{sw} = 9.1 ft

Equation E2(c) $FS = ((R_v + B_v)cosB + (R_h + B_h)sinB) / P_n$

FS = 1.9 Factor of safety is greater than 1.5 so vertical forces control

This example calculation was performed at the location in Sector 9 that has the largest hydrostatic force at the site based on the highest measured groundwater map included in Appendix D7-A .

The GP will evaluate the highest measured water levels to determine where the largest hydrostatic force is located and perform these calculations to determine how much ballast is required when preparing the Ballast Evaluation Report for submittal to the TCEQ prior to decommissioning any dewatering system.

APPENDIX D7D
WASTE-FOR-BALLAST PLACEMENT RECORD

WASTE-FOR-BALLAST PLACEMENT RECORD

This form is to be completed by the landfill manager for all landfilled areas requiring waste-for-ballast. One form will be developed for each area as addressed in a Soil and Liner Evaluation Report (SLER). The Professional of Record (POR) may reference this form to certify that the placement of ballast is in compliance with the LQCP.

GENERAL INFORMATION

Area documented by this record (provide site grid coordinates of each corner):

____

____

____

____

SLER approval date for this area: ________________

Date of initial waste placement: ________________

Date of completion of first 5 feet of waste in place over entire area: ________________

Total required waste-for-ballast thickness for this area:
(Note: Calculations for determining the required thickness of waste-as-ballast will be included with the SLER for this area.) ________________

Date when minimum required thickness of waste was achieved: ________________

Actual waste-for-ballast thickness demonstrated by this record: ________________

WASTE EQUIPMENT USED

☐ 40,000-pound minimum gross weight wheeled compactor.
Specify equipment used:________________________________

FIRST LIFT CONSIDERATIONS

☐ No brush, large, bulky, elongated or other waste items which could damage the underlying liner system have been placed within the first 5 feet of waste above the top of the protective cover.

☐ A 5-foot lift of loose waste (acceptable waste defined above) has been maintained between the waste compaction equipment and the top of the liner protective cover in all fill areas to allow uniform compaction of the waste material.

☐ Describe type(s) of waste placed in the first 5 feet of waste over the top of the liner protective cover.

____

____

WASTE COMPACTION METHODS FOR THE TOTAL WASTE-FOR-BALLAST THICKNESS

☐ Loose waste layer thickness was less than 2-feet-thick prior to compaction to allow uniform compaction of the acceptable waste material (i.e., no brush, large bulky items).

☐ Compaction was achieved over the entire area evaluated using a minimum of three passes of at least one track for each loose waste layer.

☐ The slope of the compacted waste layers was less than (flatter) 4 horizontal to 1 vertical.

SIGNATURE OF PERMITTEE

The waste overlying the area described in this record has been placed and compacted as described in this record and in accordance with the site Soils and Liner Quality Control Plan and Site Operating Plan.

Texoma Area Solid Waste Authority

____
Signature

____
Typed or Printed Name

____
Title

____
Date Signed

Note: This completed form will be placed in the Operating Record and will be available for TCEQ review.

APPENDIX D7E
GRI-GM13

Geosynthetic Institute
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Revision 16: March 17, 2021
Revision schedule on pg. 11

GRI - GM13 Standard Specification*

Standard Specification for

"Test Methods, Test Properties and Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes" SM

> This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute's Website <<geosynthetic-institute.org>>.

values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792	Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004	Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238	Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505	Test Method for Density of Plastics by the Density-Gradient Technique
D 1603	Test Method for Carbon Black in Olefin Plastics
D 4218	Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199	Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397	Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596	Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721	Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885	Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994	Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370	Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693	Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238	Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
D 7466	Test Method for Measuring the Asperity Height of Textured Geomembranes
D 8117	Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by Differential Scanning Calorimetry

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

Nominal - Representative value of a measurable property determined under a set of conditions, by which a product may be described. Abbreviated as nom. in Tables 1 and 2.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.) - mils • lowest individual of 10 values - %	D5199	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	per roll
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	200,000 lb
Tensile Properties *(1)* (min. ave.) • yield strength - lb/in. • break strength - lb/in. • yield elongation - % • break elongation - %	D 6693 Type IV	 63 114 12 700	 84 152 12 700	 105 190 12 700	 126 228 12 700	 168 304 12 700	 210 380 12 700	 252 456 12 700	20,000 lb
Tear Resistance (min. ave.) - lb	D 1004	21	28	35	42	56	70	84	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	54	72	90	108	144	180	216	45,000 lb
Stress Crack Resistance *(2)* - hr.	D5397 (App.)	500	500	500	500	500	500	500	per GRI-GM10
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 8117 D 5885	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC) UNITS

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - (min. ave.) - mm • lowest individual of 10 values - %	D5199	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	per roll
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	90,000 kg
Tensile Properties *(1)* (min. ave.) • yield strength - kN/m • break strength - kN/m • yield elongation - % • break elongation - %	D 6693 Type IV	 11 20 12 700	 15 27 12 700	 18 33 12 700	 22 40 12 700	 29 53 12 700	 37 67 12 700	 44 80 12 700	9,000 kg
Tear Resistance (min. ave.) - N	D 1004	93	125	156	187	249	311	374	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	240	320	400	480	640	800	960	20,000 kg
Stress Crack Resistance *(2)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM-10
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 8117 D 5885	 N. R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	 N.R. *(8)* 50	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) - mils • lowest individual for 8 out of 10 values - % • lowest individual for any of the 10 values - %	D 5994	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	per roll
Asperity Height mils (min. ave.) - mils	D 7466	16	16	16	16	16	16	16	every 2nd roll *(1)*
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	200,000 lb
Tensile Properties (min. ave.) *(2)* • yield strength - lb/in. • break strength - lb/in. • yield elongation - % • break elongation - %	D 6693 Type IV	 63 45 12 100	 84 60 12 100	 105 75 12 100	 126 90 12 100	 168 120 12 100	 210 150 12 100	 252 180 12 100	20,000 lb
Tear Resistance (min. ave.) - lb	D 1004	21	28	35	42	56	70	84	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	45	60	75	90	120	150	180	45,000 lb
Stress Crack Resistance *(3)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(4)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(6)*, *(7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 8117 D 5885	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(3) SP-NCTL per ASTM D5397 Appendix, is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness (min. ave.) - mm • lowest individual for 8 out of 10 values - % • lowest individual for any of the 10 values - %	D 5994	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	per roll
Asperity Height mils (min. ave.) - mm	D 7466	0.40	0.40	0.40	0.40	0.40	0.40	0.40	every 2nd roll *(1)*
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	90,000 kg
Tensile Properties (min. ave.) *(2)* • yield strength - kN/m • break strength - kN/m • yield elongation - % • break elongation - %	D 6693 Type IV	 11 8 12 100	 15 10 12 100	 18 13 12 100	 22 16 12 100	 29 21 12 100	 37 26 12 100	 44 32 12 100	9,000 kg
Tear Resistance (min. ave.) - N	D 1004	93	125	156	187	249	311	374	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	200	267	333	400	534	667	800	20,000 kg
Stress Crack Resistance *(3)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(4)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	9,000 kg
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(6)*, *(7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	 55 80	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 8117 D 5885	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	 N.R. *(9)* 50	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Adoption and Revision Schedule
for
HDPE Specification per GRI-GM13

"Test Methods, Test Properties, Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
Revision 7:	February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
Revision 8:	Removed recommended warranty from specification.
Revision 9:	June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
Revision 10	April 11, 2011: Added alternative carbon black content test methods
Revision 11	December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
Revision 12	November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 13	November 4, 2015: Removed Footnote (1) on asperity height from tables.
Revision 14	January 6, 2016: Removed Trouser Tear from Note 5.
Revision 15:	September 9, 2019: Editorial update to harmonize tables.
Revision 16:	March 17, 2021: Updated Standard OIT Test from ASTM D3895 to D8117

TASWA DISPOSAL AND RECYCLING FACILITY
GRAYSON COUNTY, TEXAS
TCEQ PERMIT APPLICATION NO. MSW 2290A

PERMIT AMENDMENT APPLICATION

PART III – FACILITY INVESTIGATION AND DESIGN
ATTACHMENT D8
FINAL COVER QUALITY CONTROL PLAN

Prepared for

Texoma Area Solid Waste Authority

February 2025

STATE OF TEXAS
DAVID L. CLARK
81905
LICENSED PROFESSIONAL ENGINEER
2-28-25
Biggs & Mathews Environmental, Inc.
Firm Registration No. F-256

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CONTENTS

30 TAC §330.457

1 INTRODUCTION

30 TAC §330.457

1.1 Purpose

This Final Cover Quality Control Plan (FCQCP) has been prepared in accordance with 30 TAC §330.457. This FCQCP establishes the procedures for the design, construction, testing, and documentation of the final cover system for the TASWA Disposal and Recycling Facility (TASWA DRF).

1.2 Definitions

Specific terms and acronyms that are used in this FCQCP are defined below.

ASTM – American Society for Testing and Material

Construction Quality Assurance (CQA) – CQA is a planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design. CQA includes the observations, evaluations, and testing necessary to assess and document the quality of the constructed facility. CQA includes measures taken by the CQA organization to assess whether the work is in compliance with the plans, specifications, and permit requirements for a project.

Geotechnical Professional (GP) – The GP is the authorized representative of the owner who is responsible for all CQA activities for the project. The GP must be registered as a Professional Engineer in Texas. Experience and education should include geotechnical engineering, engineering geology, soil mechanics, geotechnical laboratory testing, construction quality assurance and quality control testing, and hydrogeology. The GP must also have competency and experience in certifying similar projects.

The GP may also be known in applicable regulations and guidelines as the CQA engineer, resident project representative, geotechnical quality control/quality assurance professional (GQCP), or professional of record (POR).

CQA Monitors – CQA monitors are representatives of the GP who work under direct supervision of the GP. The CQA monitor is responsible for quality assurance monitoring and performing on-site tests and observations. The CQA monitor must be NICET-certified at Level 2 for soils and geosynthetics, an engineering technician with a minimum of four years directly related experience, or a graduate engineer or geologist with one year of directly related experience.

Owner's Representative – The owner's representative is an official representative of the owner responsible for planning, organizing, and controlling the design and construction activities.

Quality Assurance – Quality assurance is a planned program that is designed to assure that the work meets the requirements of the plans, specifications, and permit for a project. Quality assurance includes procedures, quality control activities, and documentation that are performed by the GP and CQA monitor.

Quality Control – Quality control includes the activities that implement the quality assurance program. The GP, CQA monitor, and contractor will perform quality control.

2 FINAL COVER SYSTEM

30 TAC §330.457

2.1 Final Cover System

The final cover system in the TASWA DRF will be a composite cover system consisting of an intermediate cover layer, an infiltration layer, a flexible membrane cover (FMC), a drainage layer, and an erosion layer.

The final cover plan is included in Attachment D3. Details of the final cover system are provided in Drawing D3.7. The components of the final cover system are listed from top to bottom in the table below.

Components of the Final Cover System

Cover System Component	Description	Minimum Thickness
TOPSLOPE		
Erosion Layer	Soil that is capable of sustaining plant growth	24 inches
Cushion Layer	Geotextile	8 oz nominal
Flexible Membrane Cover	Smooth or Textured LLDPE geomembrane	40 mil nominal
Infiltration Layer	Compacted soil with a coefficient of permeability less than or equal to 1×10^{-5} cm/sec	18 inches
SIDESLOPE		
Erosion Layer	Soil that is capable of sustaining plant growth	24 inches
Drainage Layer	Double-sided geocomposite	0.2 inches nominal
Flexible Membrane Cover	Textured LLDPE geomembrane	40 mil nominal
Infiltration Layer	Compacted soil with a coefficient of permeability less than or equal to 1×10^{-5} cm/sec	18 inches

Construction Monitoring

Continuous on-site monitoring is necessary to assure that the components of the final cover system are constructed in accordance with this FCQCP. The CQA monitor shall provide continuous on-site observation during the following construction activities:

- Infiltration layer placement, processing, compaction, and testing
- Flexible membrane cover deployment, trial welds, seaming, testing, and repairing
- Drainage layer deployment and seaming
- Erosion layer placement

- Any work that could damage the installed components of the final cover system

The GP will document and certify that the final cover system was constructed in accordance with this FCQCP. The GP shall make sufficient site visits to observe critical construction activities and to verify that the construction and quality assurance activities are performed in accordance with this FCQCP.

3 INTERMEDIATE COVER AND GRADING

§330.165(c)

3.1 General

The proposed landfill final cover plan for the TASWA DRF is provided in Attachment D3. The final lift of waste will be covered by at least 12 inches of intermediate cover that is placed in accordance with the Site Operating Plan.

3.2 Materials

Intermediate cover will consist of general fill that has not previously come into contact with waste.

3.3 Slopes

The slope stability analyses are provided in Attachment D5. The slope stability analyses are only valid for the conditions that were analyzed. Any changes to the final cover system or landfill completion plan will require that the slope stability analyses be revised to reflect the actual conditions. Temporary construction slopes shall not be steeper than the interim slopes and concentrated loadings, such as heavy equipment and soil stockpiles, and shall not be placed near the crest of slopes unless additional slope stability analyses are performed.

3.4 Testing and Verification

Intermediate cover placement and grading will be observed and documented by the landfill staff in accordance with the Site Operating Plan.

4 INFILTRATION LAYER

30 TAC §330.457

4.1 General

The infiltration layer consists of an 18-inch-thick layer of compacted, relatively homogeneous, cohesive material. The CQA monitor shall provide continuous on-site observation during infiltration layer placement, processing, compaction, and testing. The GP shall make sufficient site visits during infiltration layer construction to document the construction activities, testing, and thickness verification in the Final Cover System Report, in accordance with Section 8.

4.2 Materials

Infiltration layer material shall consist of soil that is free from debris, rubbish, frozen materials, foreign objects, and organic material. The required infiltration layer material properties are summarized in the table below.

Infiltration Material Properties

Test	Standard	Required Property
Plasticity Index	ASTM D 4318	15 or greater
Liquid Limit	ASTM D 4318	30 or greater
Percent Passing No. 200 Mesh Sieve	ASTM D 1140	30 or greater
Percent Passing 1-inch Sieve	ASTM D 422	100
Coefficient of Permeability	ASTM D 5084 or COE EM 1110-2-1906 Appendix VII	less than or equal to 1×10^{-5} cm/sec

Preconstruction testing procedures and frequencies for infiltration layer materials are listed in Section 4.8.1.

4.3 Subgrade Preparation

Prior to placing infiltration layer material, the intermediate cover should be proof rolled with heavy, rubber-tired construction equipment to detect soft areas. The GP or CQA monitor must observe the proof-rolling operation. Soft areas should be compacted and then be proof rolled again.

The top of intermediate cover elevations shall be verified in accordance with the requirements of Section 4.8.3 prior to the placement of infiltration layer.

4.4 Placement and Processing

The infiltration layer subgrade and surface of each lift should be scarified to a minimum depth of 6 inches prior to placement of the next lift of the infiltration layer. The infiltration layer material should be placed in maximum 8-inch loose lifts to produce a compacted lift thickness of approximately six inches. The material should be processed to a maximum particle size of 1 inch or less before water is added. Rocks and clods less than one inch in diameter should not total more than about 10 percent by weight. The surface of the top lift shall contain no material larger than 3/8 inch.

If additional water is necessary to adjust the moisture content, it should be applied after initial processing but prior to compaction. Water should be applied evenly across the lift and worked into the material. Waste or any objectionable material must not contaminate compaction water.

4.5 Compaction

The infiltration layer shall be compacted with a pad/tamping-foot or prong-foot roller. The infiltration layer shall not be compacted with a bulldozer, rubber-tired roller, flat-wheel roller, scrapers, or any track equipment unless it is used to pull a footed roller. The compactor should weigh at least 40,000 pounds. The lift thickness shall be controlled to achieve total penetration into the top of the previously compacted lift; therefore, the lift thickness must not be greater than the pad or prong length. Cleaning devices on the roller must be in place and maintained to prevent the prongs or pad feet from becoming clogged to the point that they cannot achieve full penetration.

The compactor shall make at least four passes across the area being compacted. A pass is defined as one pass of the compactor, front and rear drums. The material should be compacted to a minimum of 95 percent of the maximum dry density determined by standard Proctor (ASTM D 698) at a moisture content at or above optimum moisture. Areas with failing tests shall be reworked and recompacted, and then retested with passing tests before another lift is added.

After a lift is compacted, it must be watered to prevent drying and desiccation until the next lift can be placed. If desiccation occurs, the GP must determine if the lift can be rehydrated by surface application of water or if the lift must be scarified, watered, and then recompacted. Following compaction and fine grading of the final lift, the surface of the infiltration layer shall be smooth drum rolled.

4.6 Protection

The completed infiltration layer must be protected from drying, desiccation, rutting, erosion, and ponded water until the FMC is installed. Areas that undergo excessive desiccation or damage shall be reworked, recompacted, and retested as directed by the GP.

4.7 Tie In to Existing Covers

The edge of existing infiltration layers shall be cut back on either a slope or step to prevent the formation of a vertical joint. Details for the tie-in to existing cover are provided in Attachment D3.

4.8 Testing and Verification

4.8.1 Preconstruction Testing

The table below lists the minimum testing required for material proposed for use as the infiltration layer.

Infiltration Layer Material Preconstruction Tests

Test	Standard	Frequency
Unified Soil Classification	ASTM D 2487	1 per material type
Atterberg Limits	ASTM D 4318	1 per material type
Percent Passing No. 200 Mesh Sieve	ASTM D 1140	1 per material type
Percent Passing 1-inch Sieve*	ASTM D 422	1 per material type (if needed)
Standard Proctor Test	ASTM D 698	1 per material type
Coefficient of Permeability	ASTM D 5084 or COE EM 1110-2-1906 Appendix VII	1 per material type

* Can be visually verified.

After the moisture density relationship has been determined for a material type, a soil sample should be remolded to about 95 percent of the maximum dry density at the optimum moisture content. This sample will be tested to determine if the soil can be compacted to achieve a suitable coefficient of permeability. Either falling head or constant head laboratory permeability tests may be performed to determine the coefficient of permeability. The permeant fluid for testing must be as required by ASTM D 5084. Distilled or deionized water shall not be used as the permeant fluid.

4.8.2 Construction Testing

The table below lists the minimum testing required for material used as the infiltration layer.

Infiltration Layer Material Construction Tests

Test	Standard	Frequency[1]
Field Density	ASTM D 2922	1/8,000 sf per 6-inch lift
Standard Proctor Test	ASTM D 698	1 per material type
Coefficient of Permeability	ASTM D 5084 or COE EM 1110-2-1906 Appendix VII	1 per acre (evenly distributed through all lifts)

[1] A minimum of one test must be performed for each lift regardless of surface area.

Permeability testing will be performed on undisturbed samples from the infiltration layer as described in Section 4.8.1 and all test data will be reported.

4.8.3 Thickness Verification

The as-built thickness of the infiltration layer shall be determined by standard survey methods. Prior to the placement of infiltration layer material, the top of intermediate cover (subgrade) elevations will be determined at a minimum rate of one survey point per 5,000 square feet of lined area. After the infiltration layer is completed, the top of infiltration layer elevations will be determined at the same locations as the subgrade elevations.

5 FLEXIBLE MEMBRANE COVER

30 TAC §330.457

5.1 General

The flexible membrane cover (FMC) component of the final cover system consists of:

TOPSLOPE

- Smooth or textured 40-mil thick linear low-density polyethylene (LLDPE) geomembrane

SIDESLOPE

- Textured 40-mil thick LLDPE geomembrane

The CQA monitor shall provide continuous on-site observation of during FMC deployment, trial welds, seaming, testing, and repairing. The GP shall make sufficient site visits during the FMC installation to document the installation and testing in the Final Cover Evaluation Report, in accordance with Section 8.

5.2 Materials

5.2.1 Properties

FMC shall consist of smooth and textured LLDPE geomembrane produced from virgin raw materials. Recycled materials are not acceptable. The FMC shall not be manufactured from resin from differing suppliers. The FMC shall meet the requirements in the most current revisions of Geosynthetics Research Institute (GRI) Standard GM17 (LLDPE). Copies of GRI GM17 are included in Appendix D8A.

Manufacturer quality control testing procedures and frequencies for FMC are listed in Section 5.5.1. Third party conformance testing procedures and frequencies for FMC are listed in Section 5.5.2.

5.2.2 Delivery and Storage

FMC shall be shipped in rolls labeled with the manufacturer's name, roll number, and lot or batch number. The CQA monitor shall inspect the rolls for shipping damage and complete a geosynthetics receipt log for all materials delivered to the site. Damaged rolls shall be rejected.

The FMC shall be unloaded and handled with equipment that does not damage the rolls. Rolls should not be pushed, slid, or dragged to the storage location. The FMC must not be stored on wet, soft, or rocky subgrade, but must be stored on a stable subgrade. FMC must not be stacked more than five rolls high to avoid crushing the roll cores. The stored FMC must be protected from puncture, grease, dirt, excessive heat, or other damage.

5.3 Preparation

The surface of the infiltration layer shall be protected until the FMC is installed in accordance with Section 4.6. Prior to installation of the FMC the infiltration layer shall be tested and verified in accordance with Section 4.8, and the GP or CQA monitor and geosynthetics installer shall inspect the surface of the infiltration layer to verify that:

- The infiltration layer surface has been smooth drum rolled.
- The infiltration layer surface is free of irregularities, soft areas, or loose soil.
- The infiltration layer surface is free of stones, protrusions, or objects that could damage the FMC.

The geosynthetics installer must accept the condition of the infiltration layer and sign a subgrade acceptance form prior to the installation of the FMC.

5.4 Installation

5.4.1 Deployment and Placement

The following activities must take place prior to FMC deployment:

- The manufacturer's quality control and third party conformance tests should be completed and approved by the GP in accordance with the requirements of Section 5.5.
- The GP or CQA monitor and geosynthetics installer shall approve the subgrade in accordance with the requirements of Section 5.3.
- The geosynthetics installer shall sign the subgrade acceptance form.
- The geosynthetics installer shall submit a drawing showing the proposed panel layout.

FMC shall be deployed by equipment that will unroll the FMC without damaging, crimping, or stretching it and deployment equipment must not damage the underlying compacted infiltration layer. FMC must not be deployed during periods of rain or high winds and shall not be deployed on frozen subgrade. The installer must only deploy the amount of FMC that can be seamed on the same day.

Upon deployment, each panel shall be assigned a unique identification number. All panels must be anchored with adequate ballast to prevent uplift from wind. Smoking and damaging shoes shall not be permitted on the FMC and only low-ground pressure supporting equipment shall be allowed on the FMC. Textured FMC shall be placed on sideslopes and shall extend to a minimum of five feet above the crest of the slope. The number of field seams should be minimized as practical at corners and odd shaped geometric locations.

During FMC placement, the CQA monitor must:

- Provide full time observation.
- Record panel numbers, panel dimensions, and roll numbers on the panel layout drawing.
- Record weather conditions.
- Observe the condition of the subgrade and note any deficiencies. All deficiencies shall be repaired and approved by the CQA monitor.
- Observe the condition of the FMC and note any defects. All defects must be repaired in accordance with the requirements of Section 5.4.4.
- Observe that people working on the FMC do not smoke, wear shoes that could damage the FMC, or engage in activities that could damage the FMC.
- Observe that the deployment method minimizes wrinkles and that the FMC is anchored to prevent movement from wind.
- Observe that no more panels are deployed than can be seamed on the same day.
- Observe that there are no horizontal seams on sideslopes. For slopes longer than typical manufacturer membrane lengths, seams on the side slope are to be made at an approximate 45-degree angle.

Any panels that are not deployed in accordance with this section shall be marked by the CQA monitor and repaired in accordance with Section 5.4.4 or be removed and replaced by the installer.

5.4.2 Seaming

Only welding apparatus and operators that have completed approved trial welds, in accordance with Section 5.5.3, shall be allowed to weld panel seams. Each seam shall be assigned a unique number, which is preferably consistent with the panel numbering system. Prior to welding, dirt, grease, and free moisture shall be cleaned from the panel contact area; and wrinkles shall be removed as much as practical. Panels will be positioned with the overlap recommended by the manufacturer, but not less than three inches. The CQA monitor must visually inspect the placement and overlap of the panels to ensure that proper overlap is provided. For extrusion welds, oxidation shall be ground from the seam area within one hour of the welding operation and the extrudate shall be purged from the extrusion welding apparatus. Seaming operations shall not be allowed when the ambient temperature is below 40°F or above 104°F unless trial welds have demonstrated that adequate welds can be achieved outside these limits.

During FMC seaming operations, the CQA monitor must:

- Provide full time observation.
- Record seam numbers on the panel layout drawing.
- Record weather conditions.
- Observe that only approved welding apparatus and operators are allowed to weld seams.
- Observe the condition of the seams and note any defects. All defects must be repaired in accordance with the requirements of Section 5.4.4.
- Observe that people working on the FMC do not smoke, wear shoes that could damage the FMC, or engage in activities that could damage the FMC.
- Observe that the seams are free of grease, dirt, moisture, and wrinkles.
- Observe that welding operations take place within the approved ambient temperature range.
- Observe that seam grinding has been completed less than one hour before extrusion welding and the extrudate has been purged from extrusion welders.
- Observe that there are no horizontal seams on sideslopes. For slopes longer than typical manufacturer membrane lengths, seams on the side slope are to be made at an approximate 45-degree angle.

5.4.3 Anchor Trenches

The FMC anchor trench shall be left open until the seaming is completed. Expansion and contraction of the FMC should be accounted for during deployment. The top corner of the anchor trenches shall be rounded to prevent crimping the FMC. The bottom of the anchor trench shall be dry, stable, and free of loose particles and rocks. Anchor trenches shall be backfilled with compacted general fill that is free of particles larger than 1 inch in diameter. The anchor trenches shall be backfilled and compacted in a manner that does not damage or induce stress to the FMC.

5.4.4 Repairs

Defects in the FMC, defects in seams, failing destructive tests, failing nondestructive tests, holes from nondestructive tests, and destructive test sample locations shall be repaired by one of the following repair techniques:

- Patching - used to repair large holes, tears, large FMC defects, and destructive test locations.
- Extrusion - used to repair small FMC defects, cuts, holes from nondestructive tests, and seam defects less than 1/2-inch long.
- Capping - used to repair failed seams or seams where nondestructive tests cannot be performed.
- Removal - used to replace areas with large defects where other repair techniques are not appropriate.

Patches and caps should extend six inches beyond the edge of the defect and the repair surfaces shall be clean and dry. The area to be repaired shall be abraded to remove oxidation and the top edges of patches should be beveled.

5.5 Testing and Verification

5.5.1 Manufacturer's Quality Control Testing

The FMC manufacturer shall test the geomembrane and raw materials in accordance with GRI Standard GM17 to assure the quality of the FMC. Material property requirements are provided in Section 5.2.1. Minimum manufacturer's testing requirements are provided in the table below.

5.5.2 Conformance Testing

Conformance samples of the FMC shall be cut across the full width of selected rolls in accordance with the test frequency specified in Table 5. Conformance samples may be taken at the manufacturing plant or at the project site and forwarded to a third-party laboratory for testing. Material property requirements are provided in Section 5.2.1. Minimum conformance testing requirements are provided in Table 5.

FMC Conformance Tests

Test	Standard	Frequency
Sheet Thickness*	ASTM D 5199, 1593, or 5994	1 per 50,000 sf and every resin lot
Specific Gravity	ASTM D 1505	1 per 100,000 sf and every resin lot
Carbon Black Content	ASTM D 1603	1 per 100,000 sf and every resin lot
Carbon Black Dispersion	ASTM D 3015 or 5596	1 per 100,000 sf and every resin lot
Tensile Properties	ASTM D 638	1 per 100,000 sf and every resin lot

* Additional thickness testing at laboratory performed in lieu of field thickness testing.

5.5.3 Trial Welds

Each operator and welding apparatus must be tested to verify that seam welds that meet the specifications can be achieved under the site conditions. Trial welds must be performed at the beginning of each day and after each break longer than 30 minutes for each operator and apparatus used that day. Trial welds will also be required whenever the welding apparatus is turned off more than 30 minutes or when used to seam different materials (i.e., smooth to textured). Both the operator and the welding apparatus must be tested for each new trial seam when extrusion welding. Only the welding apparatus must be tested for each new trial seam when fusion welding. Each operator must make at least one test seam each day that they perform seaming.

The trial weld samples shall be three feet long and 12 inches wide, with the seam centered lengthwise. At least four one-inch-wide coupons will be cut from each trial weld sample. Two coupons from each sample will be tested for shear and two samples will be tested for peel. Peel test coupons for dual-track welds shall be tested on both sides of the air channel. Each coupon must meet the minimum strength requirements listed in Table 6 and exhibit a Film Tear Bond (FTB). If the trial weld fails, two more trial seams must be welded and tested. This process will continue until passing trial welds are achieved.

5.5.4 Construction Testing

Nondestructive Tests

Nondestructive seam tests include vacuum testing and air pressure testing. Nondestructive testing shall be performed for the entire length of each seam by the FMC installer.

Vacuum testing shall be used to test extrusion-welded seams and fusion-welded seams that cannot be tested by air pressure methods. The vacuum box shall be placed over a seam section, which has been thoroughly saturated with a soapy water solution. The rubber gasket on the bottom of the vacuum box must seal against the FMC to prevent leaks. The vacuum box pressure shall be reduced to about three to five inches of Hg. Soap bubbles will indicate the presence of holes or non-bonded seams. The vacuum box dwell time shall be at least 10 seconds.

Air pressure testing shall be used to test fusion-welded seams that have an air channel. Both ends of the air channel shall be sealed and air shall be pumped into the channel to at least 30 psi or 1/2 psi per mil of thickness, whichever is greater. The air channel must sustain the pressure for at least five minutes, without more than a 4-psi pressure drop. Following a passing pressure test, the pressure shall be released from the end of the seam that is opposite of the pressure gauge. The pressure gauge must return to zero; if it does not, the seam is probably blocked. After the blockage has been located, the seam shall be pressure tested on both sides of the blockage. All penetration holes shall be sealed after the air pressure testing is completed.

During the nondestructive testing, the CQA monitor must:

- Observe that equipment and operators perform the tests properly.
- Observe that the entire length of each seam is tested and record the results of the test.
- Identify failed seams and inform the installer of any required repairs.
- Record all completed and tested repairs.

Destructive Tests

Destructive testing shall be performed at a minimum frequency of one test location per 500 linear feet of seam. Additional destructive test samples may be taken if deemed necessary by the geotechnical professional or his representative. Destructive test samples should be 45 inches long by 12 inches wide with the seam centered along the length of the sample.

Two coupons should be cut from each end of the sample and the installer must test these coupons with a tensiometer capable of measuring the seam strength. The installer shall test two coupons in shear and two coupons in peel. For double wedge-welded seams, both sides of the air channel shall be tested in peel. The CQA monitor must observe the tests and record the results on the destructive testing log. The minimum requirements for destructive testing are provided in the table below. All coupons must pass in both peel and shear; otherwise, the installer shall reconstruct or cap all seams done by the welder/machine within the time period between passed test locations or trial welds, or test additional samples 10 feet in both directions of the failed test. If the additional tests pass, the contractor shall reconstruct or cap the seam between the passing test locations. If the additional tests fail, the sampling and testing procedure shall be repeated until the faulty seam is bracketed by passing destructive tests.

If the field test results are satisfactory, the remaining sample shall be divided into three parts: one-third for the installer, one-third for third party laboratory testing, and one-third for the owner to archive. The laboratory shall test five coupons from each sample in shear and test five coupons from each sample in peel (10 when testing both inner and outer welds of dual-track welds). The minimum requirements for destructive testing are provided in the table below. If the laboratory test fails in either peel or shear, the installer shall reconstruct or cap all seams done by the welder/machine within the time period between passed test locations or trial welds or take additional samples 10 feet in both directions of the failed test. If the additional tests pass, the contractor shall reconstruct or cap the seam between the passing test locations. If the additional tests fail, the sampling and testing procedure shall be repeated until the faulty seam is bracketed by passing laboratory tests; field test results shall not be used for final acceptance.

FMC Seam Properties

Test	Standard	Frequency	Minimum Criteria
Shear	ASTM D 4437	1 sample per 500 feet of seam	All field specimens and four of five laboratory specimens from each sample must have a shear strength greater than or equal to 95% of sheet strength but not less than 40 ppi (LLDPE). All field specimens and the average shear strength value of all laboratory specimens must be greater than or equal to 95% of sheet strength but not less than 40 ppi (LLDPE).
Peel	ASTM D 4437	1 sample per 500 feet of seam	All field specimens and four of five laboratory specimens from each sample must have a peel strength greater than or equal to 62% of sheet strength but not less than 36 ppi (LLDPE). All field specimens and the average peel strength value of all laboratory specimens must be greater than or equal to 62% of sheet strength but not less than 36 ppi (LLDPE). Both sides of dual track seams shall meet the minimum criteria. Each track is considered a separate sample. All specimens shall exhibit Film Tear Bond.

During destructive seam testing, the CQA monitor must:

- Select sample locations and observe sample cutting.
- Assign sample numbers and label samples.
- Observe installer-performed tests.
- Record sample locations, sample number, sample purpose, and field test results.

6 DRAINAGE LAYER

30 TAC §330.457

6.1 General

The drainage layer consists of a geocomposite over textured geomembrane on the sideslopes. A geotextile will be installed as a cushion fabric on topslopes. The CQA monitor shall provide on-site observation during geocomposite and geotextile installation. The GP shall make sufficient site visits during the geocomposite drainage layer and geotextile installation to document the installation in the Final Cover Evaluation Report.

6.2 Materials

6.2.1 Geocomposite

Double-sided geocomposite (nonwoven geotextile bonded to the top and bottom of HDPE drainage net) will be installed on the sideslopes over textured membrane. The geocomposite shall have the minimum properties listed in the table below.

Geocomposite Properties

Material	Test	Standard	Required Property
Geotextile	Material Apparent Opening Size	 ASTM D 4751	Nonwoven polypropylene or polyester 70 sieve
	Unit Weight	ASTM D 5261	8 oz/yd^2 (nomimal)
	Grab Strength	ASTM D 4632	150 lb
	Puncture Resistance	ASTM D 6241	300 lb
	Trapezoidal Tear Strength	ASTM D 4533	65 lb
	Permittivity	ASTM D 4491	0.1 sec^{-1}
	UV Resistance	ASTM D 4355	70%/500 hrs
HDPE Drainage Net	Density Thickness Carbon Black	ASTM D 1505 ASTM D 5199 ASTM D 4218	0.93 g/cm^3 0.2 inch Minimum 2%, maximum 3%
	Resin Melt Flow Index	ASTM D 1238	1 g/10 min
	Tensile Strength	ASTM D 5035 or 7179	40 lb/in
Geocomposite	Transmissivity	ASTM D 4716	2.7 x 10^{-4} m^2/sec
	Ply Adhesion	ASTM D 7005	0.5 lb/in

Manufacturer quality control testing procedures for geocomposite are listed in Section 6.5.

6.2.2 Geotextile

Nonwoven geotextile will be installed on the top slopes as a cushion layer. The geotextile shall have the minimum properties listed in the table below.

Geotextile Properties

Test	Standard	Required Property
Material Unit Weight	 ASTM D 5261	Nonwoven polypropylene or polyester 8 oz/yd^2

Manufacturer quality control testing procedures for geotextile are listed in Section 6.5.

6.2.3 Delivery and Storage

Geocomposite and geotextile shall be shipped in rolls with opaque wrappers labeled with the manufacturer's name, roll number, and lot or batch number. The CQA monitor shall inspect the rolls for shipping damage and complete a geosynthetics receipt log for all materials delivered to the site. Damaged rolls shall be rejected.

The geocomposite and geotextile shall be unloaded and handled with equipment that does not cause damage. Rolls should not be pushed, slid, or dragged to the storage location. The geocomposite and geotextile must not be stored on wet, soft, or rocky subgrade, but must be stored on a stable subgrade. Geocomposite and geotextile must not be stacked more than five rolls high to avoid crushing the roll cores. The stored geocomposite and geotextile must be protected from puncture, grease, dirt, excessive heat, or other damage.

6.3 Preparation

Prior to installation of the drainage layer, the FMC shall be tested and verified in accordance with Section 5.5. The CQA monitor shall observe that the surface to receive the geocomposite or geotextile is free of debris, stones, and dirt and verify that the conformance documentation has been submitted and approved.

6.4 Installation

Geocomposite and geotextile shall be deployed by equipment that will not damage, crimp, or stretch it nor damage the underlying FMC. All panels must be anchored with adequate ballast to prevent uplift from wind. Smoking and damaging shoes shall not be permitted on the geocomposite or geotextile and only low-ground pressure supporting equipment shall be allowed on the FMC. Adjacent rolls of geocomposite shall be securely tied through the drainage net with plastic fasteners every five feet along the length of the panel and every 6 inches along the ends of the panels. Adjacent rolls of geotextile shall be overlapped and sewn or heat bonded together.

During drainage layer placement, the CQA monitor must:

- Provide full time observation.
- Record weather conditions.
- Observe the condition of the geocomposite and geotextile and note any defects. All defects must be repaired or replaced.
- Observe that people working on the FMC do not smoke, wear shoes that could damage the FMC, or engage in activities that could damage the FMC.
- Observe that the deployment method minimizes wrinkles in the FMC and the geocomposite.
- Observe that the geocomposite and geotextile panels have been properly tied and seamed.

Any panels that are not installed in accordance with this section shall be marked by the CQA monitor and be repaired or removed and replaced by the installer.

6.5 Testing and Verification

The manufacturer shall test the geotextile and geocomposite to assure the quality of the drainage layer materials. Material property requirements are provided in Section 6.2. Minimum manufacturer's testing requirements are provided in the table below. Manufacturer's testing shall be performed at a minimum frequency of one test per 100,000 sf with a minimum of 1 test per resin lot, except ASTM D 4355 which shall be tested at a frequency of 1 per formulation.

Geocomposite and Geotextile Manufacturer's Tests

Material	Test	Standard
Geotextile	Unit Weight	ASTM D 5261
	Apparent Opening Size	ASTM D 4751
	Grab Strength	ASTM D 4632
	Trapezoidal Tear Strength	ASTM D 4533
	Puncture Strength	ASTM D 6241
	Permittivity	ASTM D 4491
	Deterioration	ASTM D 4355
HDPE Drainage Net	Density	ASTM D 1505
	Thickness	ASTM D 5199
	Carbon Black	ASTM D 4218
	Resin Melt Index	ASTM D 1238
	Tensile Strength	ASTM D 5035 or 7179
Geocomposite	Transmissivity	ASTM D 4716
	Ply Adhesion	ASTM D 7005

7 EROSION LAYER

30 TAC §330.457

7.1 General

The erosion layer consists of a 24-inch-thick layer of soil with the top six inches capable of sustaining plant growth. The CQA monitor shall provide continuous on-site observation during erosion layer placement to assure that erosion layer placement does not damage underlying geosynthetics. The GP shall make sufficient site visits during erosion layer placement to document the construction activities and thickness verification in the Final Cover Evaluation Report.

7.2 Materials

Erosion layer material shall consist of soil that is free from debris, rubbish, frozen materials, foreign objects, or any material that could damage the underlying geosynthetics.

7.3 Preparation

Prior to placing the erosion layer material, the top of infiltration layer elevations shall be verified in accordance with the requirements of Section 4.8.3 and all testing on the underlying geosynthetics shall be completed.

7.4 Placement

The erosion layer shall be placed in a manner that minimizes the potential to damage the underlying geosynthetics. Hauling equipment shall be restricted to haul roads of sufficient thickness to protect the underlying geosynthetics. The erosion layer shall be dumped from the haul road and spread by low ground pressure equipment in a manner that minimizes wrinkles and stress in the geosynthetics. On sideslopes, erosion layer shall be placed from the bottom to the top, not across or down. Erosion layer shall not be placed over geosynthetics that are stretched across the toes of slopes. The minimum separation distance between construction equipment and the geosynthetics are listed in the table below.

The erosion layer will be seeded or sodded immediately following the application of final cover to minimize erosion.

Minimum Separation Distance

Equipment Ground Pressure (psi)	Minimum Separation Distance (in)
< 4	12
4 - 8	18
8 - 16	24
> 16	36

Any geosynthetic material that, in the opinion of the CQA monitor, has been damaged by the erosion layer placement must be repaired and retested in accordance with Sections 5 and 6.

7.5 Testing and Verification

The as-built thickness of the erosion layer shall be determined by standard survey methods. Prior to the placement of erosion layer, the top of infiltration layer elevations will be determined at a minimum rate of one survey point per 5,000 square feet of lined area. After the erosion layer is completed, the top of the erosion layer elevations will be determined at the same locations as the top of infiltration layer elevations.

8 DOCUMENTATION

After construction of the final cover system, the GP will submit a Final Cover Evaluation Report to the TCEQ on behalf of the owner. The purpose of the Final Cover Evaluation Report is to document that the construction methods and test procedures are consistent with this FCQCP.

At a minimum, the Final Cover Evaluation Report will contain the following:

- A summary of construction activities
- A summary of laboratory and field test results
- Sampling and testing location drawings
- Record drawings
- A statement of compliance with the FCQCP
- The seal and signature of the GP and assistant GP, if applicable, in accordance with the Texas Engineering Practice Act

APPENDIX D8A
GRI GM17

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GRI - GM17 Standard Specification*

Standard Specification for

"Test Methods, Test Properties and Testing Frequency for
Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes" SM

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers linear low density polyethylene (LLDPE) geomembranes with a formulated sheet density of 0.939 g/ml, or lower, in the thickness range of 0.50 mm (20 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, maximum, or range of physical, mechanical and endurance properties that must be met, or exceeded by the geomembrane being manufactured.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

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*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute's Website <<geosynthetic-institute.org>>.

1.4 This standard specification is intended to ensure good uniform quality LLDPE geomembranes for use in general applications.

Note 2: Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application. In this situation, interactions with the manufacturers are required.

Note 3: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5323 Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5617 Test Method for Multi-Axial Tension Test for Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent Condensation Device
D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

D 8117 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by Differential Scanning Calorimetry

2.2 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Linear Low Density Polyethylene (LLDPE), n – A ethylene/α-olefin copolymer having a linear molecular structure. The comonomers used to produce the resin can include 1-butene, 1-hexene, 1-octene or 4-methyl-1-pentene. LLDPE resins have a natural density in the range of 0.915 to 0.926 g/ml (ref. Pate, T. J. Chapter 29 in Handbook of Plastic Materials and Technology, I.I. Rubin Ed., Wiley, 1990).

Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For linear low density polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

Nominal - Representative value of a measurable property determined under a set of conditions, by which a product may be described. Abbreviated as nom. in Tables 1 and 2.

4. Material Classification and Formulation

4.1 This specification covers linear low density polyethylene geomembranes with a formulated sheet density of 0.939 g/ml, or lower. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.926 g/ml or lower, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min. This refers to the natural, i.e., nonformulated, resin.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be of the same formulation (or other approved formulation) as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth LLDPE geomembranes and Table 2 is for single and double sided textured LLDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is "soft". It is to be understood that the tables refer to the latest revision of the referenced test methods and practices.

Note 4: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 5: There are several tests sometimes included in other LLDPE geomembrane specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693 and D 5397)
- Wide Width Tensile
- Water Vapor Transmission
- Solvent Vapor Transmission
- Water Absorption
- Ozone Resistance
- Hydrostatic Resistance
- Tensile Impact
- Small Scale Burst
- Various Toxicity Tests
- Field Seam Strength

Note 6: There are several tests which are included in this standard (that are not customarily required in other LLDPE geomembrane specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Tensile Properties, incl. 2% Secant Modulus
- Puncture Resistance
- Axi-Symmetric Break Resistance Strain
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

Note 8: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The various properties of the LLDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent, it must be followed in like manner.

Note 9: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively. Communication and interaction with the manufacturer is strongly suggested.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

9.2 Marking of the geomembrane rolls shall be done in accordance with the manufacturers accepted procedure as set forth in their quality manual.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

English Units

Table 1(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness - (min. ave.) - mils • lowest individual of 10 values - %	D5199	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	per roll
Formulated Density (max.) - g/cc	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,00 lb
Tensile Properties *(1)* (min. ave.) • break strength - lb/in. • break elongation - %	D 6693 Type IV	 76 800	 114 800	 152 800	 190 800	 228 800	 304 800	 380 800	 456 800	20,000 lb
2% Modulus (max.) - lb/in.	D 5323	1200	1800	2400	3000	3600	4800	6000	7200	per formulation
Tear Resistance (min. ave.) - lb	D 1004	11	16	22	27	33	44	55	66	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	28	42	56	70	84	112	140	168	45,000 lb
Axi-Symmetric Break Resistance Strain (min.) - %	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content (range) - %	D 4218 *(2)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb
Carbon Black Dispersion	D 5596	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(4)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(5)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulation
UV Resistance *(6)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(8)*	D 7238 D 8117 D 5885	 N. R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	per formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(2) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 1(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		0.50 mm	0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - (min. ave.) - mm • lowest individual of 10 values - %	D5199	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	nom. -10	per roll
Formulated Density (max.) - g/cc	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties *(1)* (min. ave.) • break strength - N/mm • break elongation - %	D 6693 Type IV	13 800	20 800	27 800	33 800	40 800	53 800	66 800	80 800	9,000 kg
2% Modulus (max.) - N/mm	D 5323	210	315	420	520	630	840	1050	1260	per formulation
Tear Resistance (min. ave.) - N	D 1004	50	70	100	120	150	200	250	300	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	120	190	250	310	370	500	620	750	20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(4)* (c) Standard OIT - min. — or — (d) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(5)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulation
UV Resistance *(6)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(8)*	D 7238 D 8117 D 5885	 N. R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	per formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(2) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

English Units

Table 2(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.) - mils • lowest individual for 8 out of 10 values - % • lowest individual for any of the 10 values - %	D 5994	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	per roll
Asperity Height (min. ave.) - mils	D 7466	16	16	16	16	16	16	16	16	Every 2nd roll *(1)*
Formulated Density (max.) - g/cc	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,000 lb
Tensile Properties *(2)* (min. ave.) • break strength - lb/in. • break elongation - %	D 6693 Type IV	30 250	45 250	60 250	75 250	90 250	120 250	150 250	180 250	20,000 lb
2% Modulus – lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200	per formulation
Tear Resistance (min. ave.) - lb	D 1004	11	16	22	27	33	44	55	66	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	22	33	44	55	66	88	110	132	45,000 lb
Axi-Symmetric Break Resistance Strain (min.) - %	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)* (e) Standard OIT - min. — or — (f) High Pressure OIT - min.	D 8117 D 5885	100 400	100 400	100 400	100 400	100 400	100 400	100 400	100 400	200,000 lb
Oven Aging at 85°C *(6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	35 60	35 60	35 60	35 60	35 60	35 60	35 60	35 60	per formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 8117 D 5885	N. R. *(8)* 35	N.R. *(8)* 35	N.R. *(8)* 35	N.R. *(8)* 35	N.R. *(8)* 35	N.R. *(8)* 35	N.R. *(8)* 35	N.R. *(8)* 35	per formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (Metric) Units

Table 2(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		0.50 mm	0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness (min. ave.) - mm • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. (5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	nom. -5% -10 -15	per roll
Asperity Height mm (min. ave.)	D 7466	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	Every 2nd roll *(1)*
Formulated Density (max.) - g/cc	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties *(2)* (min. ave.) • break strength - N/mm • break elongation - %	D 6693 Type IV	 5 250	 9 250	 11 250	 13 250	 16 250	 21 250	 26 250	 31 250	9,000 kg
2% Modulus (max.) - N/mm	D 5323	210	315	420	520	630	840	1050	1260	per formulation
Tear Resistance (min. ave.) - N	D 1004	50	70	100	120	150	200	250	300	20,000 kg
Puncture Resistance – (min. ave.) - N	D 4833	100	150	200	250	300	400	500	600	20,000 kg
Axi-Symmetric Break Resistance Strain (min.) - %	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (g) Standard OIT - min. — or — (h) High Pressure OIT - min.	 D 8117 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 8117 D 5885	 N. R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	per formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Adoption and Revision Schedule
for
GRI Test Method GM17

"Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes"

Adopted:	April 3, 2000
Revision 1:	June 28, 2000: added a new Section 5.2 that the numeric tables values are neither MARV nor MaxARV. They are to be interpreted per the designated test method. Also, corrected typographical error of textured sheet thickness test method designation from D5199 to D5994.
Revision 2:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 3:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 4.
Revision 4:	February 20, 2006: Added Note 9 on Asperity Height clarification with respect to shear strength.
Revision 5:	Removed recommended warranty from specification.
Revision 6:	June 1, 2009: Replaced GRI-GM12 test method for asperity height of textured geomembranes with ASTM D 7466.
Revision 7:	April 11, 2011: Added alternative carbon black test methods.
Revision 8:	October 3, 2011: Expanded types of comonomers in the definition of LLDPE.
Revision 9:	December 14, 2012: Replaced GRI-GM12 with the equivalent ASTM D7238.
Revision 10:	November 14, 2014: Increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 11:	April 13, 2015: Unit conversion error was corrected for 0.75 mm (30 mil) thickness for the property of 2% modulus. The test value was changed from 370 N/mm to 315 N/mm in the SI (Metric) units tables to agree with the English units tables.
Revision 12:	November 4, 2015: Removed Footnote (1) on asperity height from tables.
Revision 13:	September 9, 2019: Editorial update to harmonize tables.
Revision 14:	March 17, 2021: Updated Standard OIT Test from ASTM D3895 to D8117.

APPENDIX D8B
GEOCOMPOSITE TRANSMISSIVITY CALCULATION

Geocomposite Design

Required: Determine the minimum transmissivity for the final cover geocomposite.

References:

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

Assumptions:

1) The liquid supply to the geocomposite will be limited to the hydraulic conductivity of the overlying erosion layer since the rate of infiltrating stormwater cannot exceed the soil's hydraulic conductivity.

Solution:

1) Calculate the ultimate transmissivity value for the final cover geocomposite from Reference 1.

$$T_{ult} = q_h L / \sin\beta \quad \text{[Ref 1., Eq. 35]}$$

where:

q_h = rate of liquid supply
L = horizontal drainage layer distance
β = slope angle of drainage layer, measured from horizontal

q_h = hydraulic conductivity of overlying erosion layer
= 1.00E-05 cm/sec
= 0.014173228 in/hour

q_h in/hour	L ft	Sideslope %	β deg	T_{ult} m^2/sec
0.01417323	1000	25	14.0	1.3E-04