

Wilbarger WWTP Expansion to 1.5 MGD

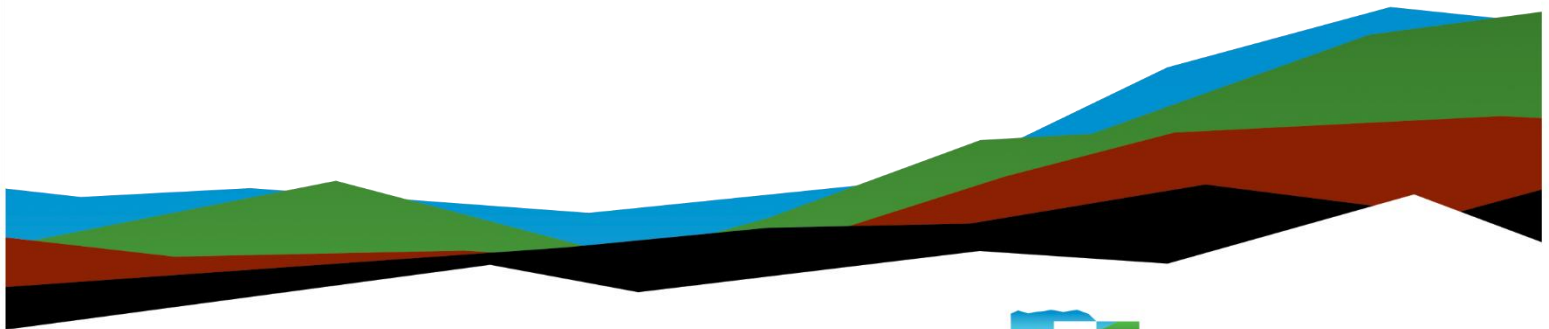
Geotechnical Engineering Report

Manor, TX

November 21, 2025 | Terracon Project No. 96255135

Prepared for:

Quiddity Engineering, LLC
2967 Oak Run Parkway Suite 215
New Braunfels, Texas, 78132



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November 21, 2025

Quiddity Engineering, LLC
2967 Oak Run Parkway Suite 215
New Braunfels, Texas, 78132

Attn: Shawn Schorn
P: 210-546-0068
E: sschorn@quiddity.com

Re: Geotechnical Engineering Report
Wilbarger WWTP Expansion to 1.5 MGD
12211 Old Hwy 20
Manor, TX
Terracon Project No. 96255135

Dear Mr. Schorn:

We have completed the scope of Geotechnical Engineering services for the above referenced project in general accordance with Terracon Proposal No. P96255135.REV2 dated August 15, 2025. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork, foundations, and pavements for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,

Terracon Consultants, Inc.
TBPELS Firm Registration TX-F3272

A handwritten signature in blue ink, appearing to read 'R. Scullion'.

Robert S. Scullion, P.E.
Senior Project Manager



12/16/2025

Edward Jaimes

Edward E. Jaimes, P.E.
Authorized Project Reviewer (APR), Geotechnical Services

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Note: This report was also delivered in a web-based format. **Blue Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the  Terracon logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

Refer to each individual Attachment for a listing of contents.

Introduction

This report presents the results of our subsurface exploration and Geotechnical Engineering services performed for the proposed Wilbarger wastewater treatment plant (WWTP) expansion to be located at 12211 Old Hwy 20 in Manor, TX. The purpose of these services was to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Seismic site classification per IBC
- Site preparation and earthwork
- Foundations
- Lateral earth pressure
- Pavements

The geotechnical engineering Scope of Services for this project included the advancement of ten (10) test borings, laboratory testing, engineering analysis, and preparation of this report.

Drawings showing the site and boring locations are shown on the [Site Location](#) and [Exploration Plan](#), respectively. The results of the laboratory testing performed on soil samples obtained from the site during our field exploration are included on the boring logs and as separate graphs in the [Exploration and Laboratory Results](#).

Project Description

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

Item	Description
Information Provided	An email request for proposal was provided by Shawn Schorn with Quiddity on July 7, 2025. The request included a Parcel Map, aerial imagery of the current wastewater treatment plant (WWTP) site, and a conceptual plan drawing showing the proposed expansion and proposed boring locations with depths. Additional information was provided by Jordan Zylberberg, P.E. with Quiddity on July 22, 2025. The additional information included an updated geotechnical request letter with proposed boring locations and depths specified.
Proposed Structure	Structures associated with the wastewater treatment plant (WWTP) expansion project include the following: ■ Peak Shaving Basin (Structure 04): FFE-500.5 ft ■ Aeration Basins (Structure 08): FFE-500.5 ft ■ Clarifiers (Structure 10): FFE-500.5 ft ■ Dewatering Building (Structure 11): FFE-505.5 ft ■ Chemical Storage Area (Structure 14): FFE-506.5 ft ■ Miscellaneous pads (Blowers, Equipment pads) ■ Associated Pavements/Access Roads
Building Construction	We anticipate that the structures will be constructed using either shallow or deep foundation construction techniques. The miscellaneous pad will be slab-on-grade foundations.
Grading/Slopes	We assume that relatively minimal grading will be required to achieve the FFE's listed above.
Below-Grade Structures	We understand the peak shaving basin, aeration basin and clarifiers are below-grade structures and expected to be approximately 6 feet below grade.
Free-Standing Retaining Walls	None anticipated.
Pavements	We understand that concrete pavement is the preferred pavement surfacing for the project. For concrete pavements (PCC), we assumed traffic would consist of the following American Concrete Institute (ACI) categories: ■ Category A: Car parking areas and access lanes ■ Category B: Entrance and truck service lanes ■ Category E: Garbage or maintenance lanes A pavement analysis period of 20 years was used.
Building Code	2021 IBC

Terracon should be notified if any of the above information is inconsistent with the planned construction, especially the grading limits, as modifications to our recommendations may be necessary.

Site Conditions

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project site is located at 12211 Old Hwy 20 in Manor, TX. See Site Location
Existing Improvements	Existing WWTP facility.
Current Ground Cover	Earthen (soils and grass), lightly vegetated with trees and brush surrounding the site, and concrete pavements.
Existing Topography	Actual elevations are unknown, however based on our site visit, it appears to be relatively level.

Geotechnical Characterization

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of the site. Conditions observed at each exploration point are indicated on the individual logs. The individual logs can be found in the [Exploration and Laboratory Results](#) and the GeoModel can be found in the [Figures](#) attachment of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel. Throughout this report, the terms GeoModel Layer and Stratum are synonymous and used interchangeably.

Model Layer	Layer Name	General Description
1	Fill Materials	Brown fat clay (CH), clayey sand (SC), and clayey gravel (GC).
2	Shallow Clays	Dark brown fat clay (CH) with various amounts of sand, gravel and organics.
3	Deeper Clays	Brown, light brown and gray fat clay (CH) and lean clay (CL) with various amounts of sand and gravel.
4	Shaley Fat Clays	Dark gray shaley fat clay (CH).

Groundwater

The borings were advanced using solid-stem augers that allow short-term groundwater observations to be made while drilling and at completion of drilling. Groundwater seepage was not encountered at the date/time of our field exploration.

Although not encountered, groundwater seepage is possible at this site, particularly in the form of seepage traveling along pervious seams/fissures in the soil and/or along soil stratum interfaces. Due to the low permeability of the soils encountered in the borings, a relatively long period may be necessary for a groundwater level to develop and stabilize in a borehole. Long term observations (which were outside the scope of services for this project) in piezometers sealed from the influence of surface water are often required to define groundwater levels in materials of this type. Please contact us if this is desired. Groundwater conditions should be evaluated immediately prior to construction.

Groundwater conditions may change because of seasonal variations in rainfall, construction activities, and other conditions not apparent at the time of drilling, therefore groundwater conditions may be different at the time of construction. The possibility of groundwater should be considered when developing the design and construction plans for the project.

Seismic Site Class

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC). Based on the soil properties observed at the site and as described on the exploration logs and results, our professional opinion

is that a **Seismic Site Classification** of **D** should be considered for the project. Subsurface explorations at this site were extended to a maximum depth of 50 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

Geotechnical Overview

The site appears suitable for the proposed construction based upon geotechnical conditions encountered in the test borings, provided that the recommendations provided in this report are implemented in the design and construction phases of this project.

The subsurface materials generally consisted primarily of fat clay soils with varying amounts of lean clay, sand and gravel extending to the maximum depth of the borings. Groundwater was not encountered within the maximum depths of exploration during and/or at the completion of drilling.

The near-surface soils could become problematic with typical earthwork and construction traffic, especially after precipitation events. The effective drainage should be completed early in the construction sequence and maintained after construction to avoid potential issues. Additional site preparation recommendations, including subgrade improvement and fill placement, are provided in the **Earthwork** section.

Based on our test borings, highly to very highly expansive soils that exhibit a potential for volumetric change during moisture variations are present at this site. These subgrade soils may experience expansion and contraction during the life of the structure. Based on existing grades, the soils at this site could exhibit a Potential Vertical Rise (PVR) of up to about 4¾ inches, as estimated by the TxDOT Method 124-E.

This report provides recommendations to help mitigate the effects of soil shrinkage and expansion. However, even if these procedures are followed, some movement and (at least minor) cracking in the structure should be anticipated. The severity of cracking and other damage such as uneven floor slabs will probably increase if modification of the site results in excessive wetting or drying of the expansive soils. Eliminating the risk of movement and distress may not be feasible, but it may be possible to further reduce the risk of movement if significantly more expensive measures are used during construction.

The **Shallow Foundations** section addresses support of the structures on footings or monolithic slab-on-grade directly bearing on select fill. Grading for the proposed foundations should incorporate the limits of the foundations plus a lateral distance of at least 5 feet beyond the outside edge of footings, where space is available. The

Earthwork section addresses support of the structures using overexcavation techniques.

Our opinion of pavement section thicknesses has been developed based on our understanding of the intended use, assumed traffic, and subgrade preparation recommended herein and adjusted with consideration to local practice. The **Pavements** section includes minimum pavement component thicknesses.

Support of pavements on or above existing fill materials is discussed in this report. However, even with the recommended construction procedures, an inherent risk remains for the owner that compressible fill or unsuitable material, within or buried by the fill, will not be discovered. This risk of unforeseen conditions cannot be eliminated without completely removing the existing fill but can be reduced by following the recommendations contained in this report.

The recommendations contained in this report are based upon the results of field and laboratory testing (presented in the **Exploration and Laboratory Results**), engineering analyses, and our current understanding of the proposed project. The **General Comments** section provides an understanding of the report limitations.

Earthwork

Earthwork is anticipated to include selective demolition, clearing and grubbing, excavations, and engineered fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria, as necessary, to render the site in the state considered in our geotechnical engineering evaluation for construction of foundations, pavements, and general site improvements.

Demolition

We recommend existing foundations, slabs, and utilities be removed from all areas within the expansion structures footprint to a depth of at least 2 feet below finished grades and at least 5 feet beyond the outer edge of foundations. If utilities are planned to be abandoned in place as an alternative to removal, the utility piping should be filled with flowable fill (TxDOT Item No. 401) and plugged such that it does not become a conduit for water flow or a potential voided area.

Existing Fill

As noted in **Geotechnical Characterization**, borings B-3 and P-1 through P-3 encountered previously placed fill to depths of about 2 feet. We have no records to

indicate the degree of control, and consequently, the fill is considered unreliable for support of foundation loads. Support of pavements on or above existing fill soils is discussed in this report. However, even with the recommended construction procedures, inherent risk exists for the owner that compressible fill or unsuitable material, within or buried by the fill will, not be discovered. This risk of unforeseen conditions associated with the existing fill cannot be eliminated without completely removing the existing fill but the risk can be reduced by following the recommendations contained in this report.

If the owner elects to construct pavements on the existing fill, the following protocol should be followed. Once the planned grading has been completed, the area should be undercut 18 inches within the pavement areas. Once materials have been removed, the entire pavement area should be proofrolled. Areas of soft or otherwise unsuitable material should be undercut and replaced with suitable paving fill. Refer to [Pavements](#) in this report for more details.

Site Preparation

Prior to placing fill, existing vegetation, topsoil, loose soil, fill soils, and root mats should be removed. Complete stripping of these materials should be performed in the proposed structure and pavement areas.

Although no evidence of underground facilities (such as septic tanks, cesspools, basements, and utilities) were observed during the exploration and site reconnaissance, such features could be encountered during construction. If unexpected underground facilities are encountered, such features should be removed, and the excavation thoroughly cleaned prior to backfill placement and/or construction.

Excavation

We anticipate that excavations for the proposed construction can be accomplished with conventional earthmoving equipment. The bottom of excavations should be thoroughly cleaned of loose soils and disturbed materials prior to backfill placement and/or construction.

Proofrolling

The exposed final subgrade (including the excavation required for the structural pads) in all construction areas (can be omitted in landscaping areas) should be proof rolled with an adequately loaded vehicle such as a 20-ton pneumatic roller, a fully loaded tandem-axle dump truck or similar vehicle. The proof rolling should be performed under the observation of the Geotechnical Engineer or representative. Areas excessively deflecting under the proof roll should be delineated and subsequently addressed. Excessively wet or dry material should either be removed, or moisture conditioned and recompacted.

After proofrolling and just prior to placement of fill, the exposed subgrade in all construction areas (may be omitted in landscaping areas) should be evaluated for moisture and density through field density testing. If the moisture and/or density testing results do not meet the moisture and density requirements below, the subgrade should be scarified to a minimum depth of 6 inches, moisture conditioned and compacted as per the fill compaction requirements in **Fill Placement and Compaction Requirements**.

Compacted select fill and pavement fill soils should then be placed to the proposed design grade and the moisture content and compaction of subgrade soils should be maintained until foundation, slabs, and/or pavement construction.

Based upon the subsurface conditions determined from the geotechnical exploration, subgrade soils exposed during construction are anticipated to be relatively workable; however, the workability of the subgrade may be affected by precipitation, repetitive construction traffic or other factors. If unworkable conditions develop, workability may be improved by scarifying and drying.

Subgrade Preparation

One option to minimize the potential for foundation distress resulting from volumetric changes would be to suspend the structures above the subgrade on drilled pier foundations with a crawl space or void boxes under the slab and beams. We understand a deep foundation system is not desired for this project and a shallow foundation system is desired instead. The following discussion provides recommendations for a grade-supported system.

While a grade-supported floor slab option is not as effective as a structurally suspended floor slab in reducing slab movements, it does represent a compromise between economics and risk of slab distress. If a grade-supported floor slab is utilized, we recommend that the soils immediately below the lowest-level slab be prepared as stated below to reduce the potential for foundation movements associated with volumetric changes of the underlying clay soils due to moisture variation.

A select fill pad overlying a moisture-conditioned subgrade may be implemented in order to reduce post-construction shrink/swell movements to approximately 1-inch. A select fill only building pad is the preferred option to reduce the PVR risk associated with highly expansive clay soils, however a combination of select fill and moisture conditioned subgrade is a common alternative to reduce PVR while considering the economic feasibility for the project. Although a select fill pad overlying a moisture conditioned subgrade as recommended below should reduce PVR to about 1-inch, the risk of PVR exceeding 1-inch for these options is greater than select fill building pad only options due to the Stratum 2 clays remaining in place. Should the Client be willing to accept this risk, the options presented below can be considered.

The sections below provide various preparation options for each structure depending on the amount of risk the Owner is willing to accept as the risk of PVR exceeding 1-inch in floor slab and surrounding flatwork areas increases as the select fill thickness decreases and the moisture conditioned clay thickness increases. The Owner should select the desired subgrade preparation option and provide that decision to the Design/Construction Team.

Peak Shaving Basin

We understand the Peak Shaving Basin foundation will be approximately 6 feet below existing grade. Recommended subgrade preparation options are provided below. If this information is incorrect, Terracon should be notified to review and modify or verify recommendations in writing.

Peak Shaving Basin			
Preparation Option	Select Fill Thickness (feet)	Moisture Conditioned Clay Thickness (below select fill; feet)	Total Building Pad Thickness (feet) ¹
S-1	5	0.5	5.5
S-2	4	2	6
S-3	3	4	7

1. As an example, if Option S-3 is selected, we recommend the on-site clay soils be excavated to a depth of 7 feet below the bottom of the slab. At least 4 feet of the excavated soils should be moisture conditioned and compacted as outlined in this report. The moisture conditioned clay soils should not be allowed to dry out prior to subsequent lift placements. Select fill should be placed above the moisture conditioned clay as outlined in this report in order to provide a select fill pad of at least 3 feet below the slab.

Aeration Basins

We understand the Aeration Basins foundation will be approximately 6 feet below existing grade. Recommended subgrade preparation options are provided below. If this information is incorrect, Terracon should be notified to review and modify or verify recommendations in writing.

Aeration Basin			
Preparation Option	Select Fill Thickness (feet)	Moisture Conditioned Clay Thickness (below select fill; feet)	Total Building Pad Thickness (feet) ¹
A-1	3	0.5	3.5
A-2	2	2	4

1. As an example, if Option A-2 is selected, we recommend the on-site clay soils be excavated to a depth of 4 feet below the bottom of the slab. At least 2 feet of the excavated soils should be moisture conditioned and compacted as outlined in this report. The moisture conditioned clay soils should not be allowed to dry out prior to subsequent lift placements. Select fill should be placed above the moisture conditioned clay as outlined in this report in order to provide a select fill pad of at least 2 feet below the slab.

Clarifiers

We understand the Clarifiers foundation will be approximately 6 feet below existing grade. Recommended subgrade preparation options are provided below. If this information is incorrect, Terracon should be notified to review and modify or verify recommendations in writing.

Clarifiers			
Preparation Option	Select Fill Thickness (feet)	Moisture Conditioned Clay Thickness (below select fill; feet)	Total Building Pad Thickness (feet) ¹
C-1	5	0.5	5.5
C-2	4	2	6
C-3	3	4	7

1. As an example, if Option C-3 is selected, we recommend the on-site clay soils be excavated to a depth of 7 feet below the bottom of the slab. At least 4 feet of the excavated soils should be moisture conditioned and compacted as outlined in this report. The moisture conditioned clay soils should not be allowed to dry out prior to subsequent lift placements. Select fill should be placed above the moisture conditioned clay as outlined in this report in order to provide a select fill pad of at least 3 feet below the slab.

Dewatering Building

We anticipate the Dewatering Building foundation is planned to be within 2 feet of existing grades. Recommended subgrade preparation options are provided below. If this

information is incorrect, Terracon should be notified to review and modify or verify recommendations in writing.

Dewatering Building			
Preparation Option	Select Fill Thickness (feet)	Moisture Conditioned Clay Thickness (below select fill; feet)	Total Building Pad Thickness (feet) ¹
D-1	6	0.5	6.5
D-2	5	2	7
D-3	4	4	8

1. As an example, if Option D-3 is selected, we recommend the on-site clay soils be excavated to a depth of 8 feet below the bottom of the slab. At least 4 feet of the excavated soils should be moisture conditioned and compacted as outlined in this report. The moisture conditioned clay soils should not be allowed to dry out prior to subsequent lift placements. Select fill should be placed above the moisture conditioned clay as outlined in this report in order to provide a select fill pad of at least 4 feet below the slab.

Chemical Storage Area

We anticipate the Chemical Storage Area foundation is planned to be within 2 feet of existing grades. Recommended subgrade preparation options are provided below. If this information is incorrect, Terracon should be notified to review and modify or verify recommendations in writing.

Chemical Storage Area			
Preparation Option	Select Fill Thickness (feet)	Moisture Conditioned Clay Thickness (below select fill; feet)	Total Building Pad Thickness (feet) ¹
H-1	8	0.5	8.5
H-2	7	2	9
H-3	6	4	10

1. As an example, if Option H-3 is selected, we recommend the on-site clay soils be excavated to a depth of 10 feet below the bottom of the slab. At least 4 feet of the excavated soils should be moisture conditioned and compacted as outlined in this report. The moisture conditioned clay soils should not be allowed to dry out prior to subsequent lift placements. Select fill should be placed above the moisture conditioned clay as outlined in this report in order to provide a select fill pad of at least 6 feet below the slab.

General Comments for Structural Areas

The above subgrade preparation recommendations should be applied to an area extending a minimum of 5 feet outside of at-grade structural areas including attached walkways and any other architectural members. We suggest the use of crushed limestone base in the upper 6 inches of the select fill pad from a standpoint of construction access during wet weather, as well as from a standpoint of slab support.

For any movement-sensitive flatwork (sidewalk, ramps, etc.) outside of the structural areas, subgrade preparation as discussed above should be considered to reduce differential movements between the flatwork and the adjacent structures. If subgrade preparation as given above for structural areas is not implemented in the exterior flatwork areas, those areas may be susceptible to post-construction movements in excess of that given above.

The potential movement values indicated are based upon moisture variations in the subgrade due to circumstances such as moisture increases due to rainfall and loss of evapotranspiration. In circumstances where significant water infiltration beneath the slab occurs (such as a leaking utility line or water seepage from outside the structures resulting from poor drainage), movements in isolated floor slab areas could potentially be in excess of those indicated in this report.

The post-construction performance of the foundation will likely be influenced more by post-construction volumetric changes of the subgrade due to in-situ moisture variations than upon settlement due to foundation loads. Settlement response of select fill supported slabs will be influenced as much by the quality of construction and fill placements as by soil-structure interaction. Therefore, it is essential that the recommendations for foundation construction be strictly followed during the construction phases of the building pad and foundation.

Considerations Related to Structural Pad Design and Performance

Long-term performance and maintenance risks increase when pad preparation involves reduced select fill and increased re-use of on-site clay. Shrink-swell movements in clay soils do not occur uniformly across individual structural footprints nor overall sites. Some of the increased performance and maintenance risks are as follows:

- Increased frequency and magnitude of interior slab and exterior flatwork cracking
- Uneven/sloping floor slabs and adjacent flatwork
- Leaks in domestic water/wastewater utility lines, roof drains, etc., as well as movements/distress to other underground utilities
- Differential movements and cracking between prepared slab/flatwork areas and adjacent flatwork and pavements beyond the pad overbuild limits.

The Client and Design/Construction Team should consider the above items when deciding on design changes. In addition, the Architect, Structural Engineer, Civil Engineer, and others may desire to review and modify their design elements.

Some items are listed below that the Design and Construction Team, as well as long-term maintenance team, could focus on to reduce risks. All of the following items should be regularly inspected and maintained/repared as issues arise.

- Positive slopes around all structures to promote surface drainage downhill and away so that ponding water does not occur near structures
- Proper discharge of roof drain runoff downhill and away from structures
- Installation of irrigation lines only where needed with irrigation cycles set to water only the volumes needed to promote healthy vegetative growth and to avoid overwatering
- Transitioning the upper select fill portion of the overbuild into a benched (or sloped) 1(Horizontal):1(Vertical) pattern, rather than an abrupt vertical transition.
- Installation of doweled expansion joints at the transition between prepared slab/flatwork areas and adjacent flatwork and pavements beyond the pad overbuild limits

Cuts Adjacent to Existing Building

All excavations should be performed in accordance with OSHA guidelines. To reduce the potential of undermining existing slabs and/or beams, we recommend that the existing soils immediately adjacent to the existing structures be excavated vertically to the bottom of the perimeter grade beam. From that depth downwards, remaining excavations should be cut and exposed in a benched pattern. The benched pattern should exhibit an overall slope of approximately 1(H):1(V) or flatter down to the bottom of the structural pad. From the bottom of the grade beams, there should be a horizontal bench of one foot wide, then a vertical cut of one foot deep. This process should be repeated until the bottom of the structural pad has been reached. Once the bottom elevation of the pad has been reached, imported select fill should be placed and compacted in maximum 6-inch-thick lifts as per **Fill Placement and Compaction Requirements**.

Please be aware that, since the structural pad will be benched at varying thicknesses, the entire structural area will not exhibit the same post-construction PVR of 1-inch. Based on the existing soils observed in the borings, the benched zone post-construction PVR estimates vary from 1-inch up to 3-inches, assuming perimeter beam depths of about 24 inches. A select fill pad overbuild thickness was not identified within the prior geotechnical report produced by a separate company. However, based on aerial images from Google Earth, it appears the existing structural pad for the existing structures

included a select fill overbuild width. If this select fill overbuild width is within the benched zone next to the existing structure, post-construction PVR is estimated to be less than the 3-inches mentioned above.

We also recommend the flatwork above the bench zone between the proposed and existing structure be covered in concrete to divert precipitation away from the structure and to limit the amount of surface water that can infiltrate between the structures into the subgrade.

Temporary Groundwater Control

Although not encountered during our drilling operations, groundwater seepage could be encountered during construction, especially after periods of wet weather. The volume of groundwater seeping/flowing into the excavation will vary based on rainfall patterns before and during construction. Temporary groundwater control during construction would typically consist of perimeter gravel-packed drains sloping toward common sump areas for groundwater collection and removal. Placement of drain laterals within the excavation could be required to remediate isolated water pockets.

Fill Material Types

Engineered fill required to achieve design grade should be classified as select fill or paving/general fill depending on its application. Select fill is material used below or within 5 feet of structures. Paving/general fill is material used to achieve grade in paving, non-reinforced earthen slopes, landscaping, or other general (non-structural) areas.

Fill Type ¹	Typical USCS Classification	Acceptable Specifications
Select Fill ^{2,3,4}	CL, SC, GM, GC	■ TxDOT Item 247, Type A, Grade 3 or better, OR ■ Crushed concrete (TxDOT Item 247, Type D, Grade 3 or better), OR ■ Soils with $7 \leq PI \leq 20$, $\leq 40\%$ retained on No. 4 sieve, and rocks ≤ 4 inches in maximum dimension
Paving/General Fill ⁵	CH, CL, GM, GC, SC	■ On-site soils; Rocks ≤ 4 inches in maximum dimension ■ Imported soils; $PI \leq 40$; and rocks ≤ 4 inches in maximum dimension

1. Select/structural and paving/general fill should consist of approved materials free of organic matter, debris, and other deleterious materials. A sample of

Fill Type ¹	Typical USCS Classification	Acceptable Specifications
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each material type should be submitted to the Geotechnical Engineer for evaluation prior to use on this site.

- As an alternative to the Acceptable Specifications above, a low plasticity granular material which does not meet the specifications above may be used only if approved by Terracon.
- Based on the laboratory testing performed during this exploration, the excavated on-site soils are not suitable for re-use as select fill. We do not recommend these soils be considered for re-use as select fill when planning budgets.
- The on-site soils exhibit high to very high shrink/swell potential. For economic reasons, expansive soils are often used in pavement and/or flatwork areas. The owner should be made aware that the risk exists for future movements of the subgrade soils which may result in movement and/or cracking of pavement and/or flatwork.

Fill Placement and Compaction Requirements

Engineered fill should meet the following compaction requirements.

Material Type		Maximum Lift Thickness	Minimum Compaction Requirements (%) ¹	Water Content Range (%) ¹
Select/Structural Fill		≤ 8 inches in loose thickness when heavy, self-propelled compaction equipment is used	95 ²	±3
Moisture Conditioned Building Subgrade	PI ≤ 25		95	±3
	PI > 25		92	+2 to +6
Paving Fill, Paving Subgrade, and General Fill	PI ≤ 25		95	±3
	PI > 25	≤ 6 inches in loose thickness when hand-guided equipment (i.e., jumping jack or plate compactor) is used	95	Optimum to +4
Crushed Limestone Base (beneath pavements) ³			100 ³	±3 ³

Material Type	Maximum Lift Thickness	Minimum Compaction Requirements (%) ¹	Water Content Range (%) ¹
Granular Wall Backfill (SP, SW, GP, GW)	12 inches	See Note Below ⁴	See Note Below ⁴

1. Maximum dry unit weight and optimum water content as determined by the standard Proctor test (ASTM D 698).
2. **For fills thicker than 5 feet, if any, the compaction should be increased to at least 100 percent of the ASTM D 698 maximum dry unit weight.**
3. Per TEX-113-E.
4. For below-grade-walls, granular backfill can be considered. If a free draining granular material is placed, the granular material should be compacted using hand guided equipment. A visual indicator should be placed on the adjacent wall corresponding to the loose lift height. The backfill must then be compacted until no further compaction/densification of the backfill is visually observed. Subsequent lifts can continue thereafter.

Cut Slopes

The table below provides the recommended slope inclinations for both permanent cut slopes and temporary cut slopes. In our opinion, cut slopes at the inclinations discussed below should be stable against a large-scale slide, however the potential for sloughing of loose soils zones exists.

Slope Type	Maximum Slope Inclination
Temporary	Per OSHA guidelines and standards
Permanent ^{1,2}	3(H):1(V) in on-site soils or imported compacted soil fill

1. If steeper slopes in cuts or embankments (natural soils or fill soils) are planned for final grading, then additional services will be required by Terracon to perform detail slope stability analyses.
2. For slopes to be used by mowers or other maintenance equipment, 4H:1V slopes or flatter are generally preferable.

Exposed cut slopes will also be susceptible to further erosion due to the nature of the on-site soils. Installation of erosion control measures in such areas would be beneficial in reducing the potential slope stability which could result from excessive erosion. In addition to initial erosion control measures, the cut slopes should be periodically checked for erosion (particularly after heavy rainfall events) and maintenance performed on areas exhibiting erosion.

Regarding worker safety, Occupation Safety and Health Administration (OSHA) Safety and Health Standards require the protection of workers adjacent to excavations. The OSHA guidelines and directives should be adhered by the Contractor during construction to provide a safe working environment.

Buffer Zones Adjacent to Cut Slopes

Excavation methods could result in decreased slope stability. To allow for some sloughing to occur, we recommend that a “buffer zone” at least 5 feet wide adjacent to pavement and other general areas be provided between the proposed construction areas and the permanent cut slopes (both at the toe and the crest). If structures are planned near these areas, the buffer zones should be increased to at least 10 feet. This should help reduce the possibility of sloughing soils from contacting the adjacent improvements on the downhill side and from undermining the improvements on the uphill side.

Embankment Fill Slopes

The table below provides the recommended slope inclinations for embankment fill slopes which are constructed in association with the pavement, and/or general site improvements.

Slope Type	Maximum Slope Inclination
Embankment Fill Slopes ^{1,2}	3(H):1(V) in on-site soils or imported compacted soil fill ³

1. For slopes to be used by mowers or other maintenance equipment, 4H:1V slopes or flatter are generally preferable.
2. Fill placement for the embankments should proceed as outlined in [Earthwork](#).
3. If steeper slopes in cuts or embankments (natural soils or fill soils) are planned for final grading, then additional services will be required by Terracon to perform detail slope stability analyses.

The embankment slopes should be properly protected from erosion. The use of rock rip-rap, erosion control fabrics, and/or vegetation is common. In addition to initial erosion control measures, the embankments should be periodically checked for erosion (particularly after heavy rainfall events) and maintenance performed on areas exhibiting erosion.

Embankments which are constructed on natural subgrade sloping steeper than 5(H):1(V) should be “keyed” into the subgrade at the toe of the embankment. The keyed-in toe should consist of a 12-foot-wide section which is excavated into the subgrade such that a horizontal working surface is attained for compaction of the first embankment lift.

Successive lifts should remain horizontal and should not tend to follow the slope of the natural subgrade.

The edges of fill embankments are often undercompacted in the field due to loose material being pushed off the edges as the embankment lifts are compacted. To reduce the possibility of this impacting the stability of the embankment fill, the embankments should be overbuilt and compacted as outlined in **Earthwork**. Then the embankment should be cut back to the slopes recommended above.

Utility Trench Backfill

Any soft or unsuitable materials encountered at the bottom of utility trench excavations should be removed and replaced with select fill (in building/structural areas), general fill (in non-building/structural areas), or bedding material in accordance with public works specifications for the utility to be supported. This recommendation is particularly applicable to utility work requiring grade control and/or in areas where subsequent grade raising could cause settlement in the subgrade supporting the utility. Trench excavation should not be conducted below a downward 1(H):1(V) projection from foundations without engineering review of shoring requirements and geotechnical observation during construction.

On-site materials are considered suitable for backfill of utility and pipe trenches in non-building/structural areas from 1 foot above the top of the pipe to the final ground surface, provided the material is free of organic matter and deleterious substances.

Trench backfill should be mechanically placed and compacted as discussed earlier in this report. Compaction of initial lifts should be accomplished with hand-operated tampers or other lightweight compactors. Where trenches are placed in building/structural areas, the backfill should satisfy the engineered select fill requirements discussed in this report. Flooding or jetting for placement and compaction of backfill is not recommended.

For low permeability subgrades, utility trenches are a common source of water infiltration and migration. Utility trenches penetrating beneath the building should be effectively sealed to restrict water intrusion and flow through the trenches, which could migrate below the building. The trench should provide an effective trench plug that extends at least 5 feet from the face of the building exterior. The plug material should consist of cementitious flowable fill or low permeability clay. The trench plug material should be placed to surround the utility line. If used, the clay trench plug material should be placed and compacted to comply with the water content and compaction recommendations for general fill stated previously in this report. If flowable fill is used, it should be in accordance with TxDOT Item 401.

Grading and Drainage

The performance of the proposed structures will not only be dependent upon the quality of construction, but also upon the stability of the moisture content of the near surface soils. Therefore, we highly recommend that site drainage be developed so that ponding of surface runoff near the structures does not occur. Accumulation of water near the structures may cause significant moisture variations in soils adjacent to the structures, thus increasing the potential for structural distress.

All grades must provide effective drainage away from the structures during and after construction and should be maintained throughout the life of the structures. Water retained next to the structures can result in soil movements greater than those discussed in this report. Greater movements can result in unacceptable differential floor slab and/or foundation movements, cracked slabs and walls, and roof leaks. A concrete apron (i.e., concrete sidewalks/pavements directly abutting the building) around the exterior perimeter of the structures for at least 6 feet (1 foot wider than the select fill overbuild) should be provided. The concrete should be sloped to provide drainage away from the structures and all joints should be sealed. In lieu of concrete aprons, or if sloping unpaved ground is planned around the structures, the select fill overbuild should be excavated to a depth of at least 2 feet below final grades, removed and replaced with a minimum of 2 feet of moisture-conditioned and compacted fat clay soils (USCS CH classification). The fat clay soils should be moisture-conditioned and compacted as per the compaction requirements in this report. We would be glad to discuss other measures (e.g. horizontal or vertical barriers) to reduce moisture infiltration in unpaved areas, if desired. The roof should have gutters/drains with downspouts that discharge onto splash blocks at a distance of at least 10 feet from the building or discharged on to positively sloped pavements.

Sprinkler mains and spray heads should preferably be located at least 5 feet away from the structures such that they cannot become a potential source of water directly adjacent to the structures. Placing large bushes and trees adjacent to the structures may cause significant moisture variations in the soils underlying the structures. Tree roots can adversely influence the subsurface soil moisture content. Watering of vegetation should be performed in a timely and controlled manner such that overwatering is avoided. Landscaped irrigation adjacent to the foundation units should be minimized or eliminated. Special care should be taken such that underground utilities do not develop leaks with time.

Exposed ground should be sloped and maintained at a minimum 5% away from the structures for at least 10 feet beyond the perimeter of the structures. For buildings, flatter grades may be necessary to transition ADA access requirements for flatwork. After construction and landscaping have been completed, final grades should be verified to document effective drainage has been achieved. Grades around the structure should also be periodically inspected and adjusted, as necessary, as part of the structure's

maintenance program. Where paving or flatwork abuts the structure, a maintenance program should be established to effectively seal and maintain joints and prevent surface water infiltration.

Earthwork Construction Considerations

Shallow excavations for the proposed structures are anticipated to be accomplished with conventional construction equipment. Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of grade-supported improvements such as floor slabs and pavements. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to floor slab construction.

Surface runoff could affect overexcavation efforts, especially for overexcavation and replacement of soils. A temporary dewatering system consisting of sumps with pumps may be necessary to achieve the recommended depth of overexcavation depending on precipitation conditions at the time of construction. Sump pits should preferably be excavated just outside the select fill pad limits.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, "Excavations" and its appendices, and in accordance with any applicable local and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety or the contractor's activities; such responsibility shall neither be implied nor inferred.

Excavations or other activities resulting in ground disturbance have the potential to affect adjoining properties and structures. Our scope of services does not include review of available final grading information or consider potential temporary grading performed by the contractor for potential effects such as ground movement beyond the project limits. A preconstruction/ precondition survey should be conducted to document nearby property/infrastructure prior to any site development activity. Excavation or ground disturbance activities adjacent or near property lines should be monitored or instrumented for potential ground movements that could negatively affect adjoining property and/or structures.

Construction Observation and Testing

The earthwork efforts should be observed by the Geotechnical Engineer (or others under their direction). Observation should include documentation of adequate removal of surficial materials (vegetation, topsoil, and pavements), as well as proofrolling and mitigation of unsuitable areas delineated by the proofroll.

Each lift of compacted fill should be tested, evaluated, and reworked as necessary, as recommended by the Geotechnical Engineer prior to placement of additional lifts. Each lift of fill should be tested for density and water content at a frequency of at least one test for every 2,500 square feet of compacted fill in the structural areas (minimum three (3) tests per lift) and 5,000 square feet in pavement areas. Where not specified by local ordinance, one density and water content test should be performed for every 100 linear feet of compacted utility trench backfill and a minimum of one test performed for every 12 vertical inches of compacted backfill.

In areas of foundation excavations, the bearing subgrade should be evaluated by the Geotechnical Engineer (or others under their direction). If unanticipated conditions are observed, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the opportunity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.

Shallow Foundations

Footings

Principal column and wall loads for the proposed structures may be supported on isolated (spread) and/or continuous (strip) footings bearing on compacted select fill. If the site has been prepared in accordance with the requirements noted in [Earthwork](#), the following design parameters are applicable for shallow foundations.

Design Parameters – Compressive Loads

Item	Description
Maximum Net Allowable Bearing Pressure^{1, 2}	2,500 psf – foundations bearing upon select fill
Required Bearing Stratum³	Select Fill

Item	Description
Minimum Foundation Dimensions	Per IBC 1809.7
Ultimate Passive Resistance⁴ (equivalent fluid pressures)	360 pcf – select fill
Ultimate Sliding Resistance⁵	0.35 coefficient of friction – select fill
Minimum Embedment below Finished Grade⁶	24 inches
Estimated Total Settlement from Structural Loads^{2,7}	About 1-inch
Estimated Differential Settlement^{2,7,8}	About ½ to ¾ of total settlement

1. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. Values assume that exterior grades are no steeper than 20% within 10 feet of structure.
2. Values provided are for maximum loads noted in [Project Description](#). Additional geotechnical consultation will be necessary if higher loads are anticipated.
3. Unsuitable or soft soils should be overexcavated and replaced per the recommendations presented in [Earthwork](#).
4. Use of passive earth pressures require the sides of the excavation for the spread footing foundation to be nearly vertical and the concrete placed neat against these vertical faces or that the footing forms be removed and compacted structural fill be placed against the vertical footing face. Assumes no hydrostatic pressure. Passive resistance should be neglected in the first 12 inches below finished grades. Ultimate values should be reduced by an appropriate factor of safety to compute allowable values.
5. Can be used to compute sliding resistance where foundations are placed on suitable soil/materials. Ultimate values should be reduced by an appropriate factor of safety to compute allowable values. For select fill we recommend the allowable sliding resistance be limited to 500 psf.
6. Embedment necessary to minimize the effects of seasonal water content variations and potential future disturbance around the perimeter. For sloping ground, maintain depth below the lowest adjacent exterior grade within 5 horizontal feet of the structure.
7. The estimated post-construction settlement of the shallow footings is assuming proper construction practices are followed. The settlement response of the

Item	Description
	footings will be more dependent upon the quality of construction than upon the response of the subgrade to the foundation loads.
8.	Differential settlements are noted for equivalent-loaded foundations and bearing elevation as measured over a span of 50 feet. Differential settlements may result from variances in subsurface conditions, loading conditions, and construction procedures.

Design Parameters – Overturning and Uplift Loads

Shallow foundations subjected to overturning loads should be proportioned such that the resultant eccentricity is maintained in the center-third of the foundation (e.g., $e < b/6$, where b is the foundation width). This requirement is intended to keep the entire foundation area in compression during the extreme lateral/overturning load event. Foundation oversizing may be required to satisfy this condition.

Uplift resistance of spread footings can be developed from the effective weight of the footing and the overlying soils with consideration to the IBC basic load combinations.

Item	Description
Soil Total Unit Weight¹	120 pcf
Soil weight included in uplift resistance	Soil included within the prism extending up from the top perimeter of the footing at an angle of 20 degrees from vertical to ground surface

1. The nominal values should be reduced by an appropriate factor of safety to compute allowable values. Soil weight should be ignored in potential zones of disturbance and in areas where erosion control measures are not used, or soil might otherwise be removed.

Slab on Grade Foundations

A slab on grade beam foundation may be considered to support the structures at this site. Parameters commonly used to design this type of foundation are provided on the table below. The slab foundation design parameters presented are based on the criteria published by the Building Research Advisory Board (BRAB), the Prestressed Concrete Institute (PCI), and the Wire Reinforcement Institute (WRI). These are essentially empirical design methods and the recommended design parameters are based on our understanding of the proposed project, our interpretation of the information and data collected as a part of this study, our area experience, and the criteria published in the BRAB, PCI, and WRI, design manuals.

Conventional Method Parameters	Value
Net Allowable Bearing Pressures ¹	2,500 psf
Bearing Stratum	Select Fill
Minimum Embedment of Grade Beams below Final Grade ²	24 inches
Subgrade Modulus (k)	100 pci
Potential Vertical Rise (PVR)	1 inch ^{5,6}
BRAB/WRI/PCI Method Parameters	
Effective Plasticity Index (PI) ³	38
Climatic Rating (Cw) ⁴	17
BRAB Support Index (C)	0.75

1. The net allowable bearing pressure provided above includes a Factor of Safety (FS) of at least 3. Based on building pad preparation recommended in this report.
2. Embedment is to reduce surface water migration below the foundation elements and to develop proper end bearing and is not based on structural considerations. The grade beam width and depth should be properly evaluated by the structural engineer. Grade beams may be thickened and widened at interior column locations to serve as spread footings at these concentrated load areas.
3. The BRAB effective PI is equal to the near surface PI if that PI is greater than the PI values in the upper 15 feet. The WRI/PCI effective PI is the weighted average of the PI values in the upper 15 feet of the soil profile. The upper 5 feet has a weight factor of 3; the depth range from 5 to 10 feet has a weight factor of 2; the depth range of 10 to 15 feet has a weight factor of 1.
4. The moisture beneath a shallow foundation will change in response to wetting and drying conditions around the foundation perimeter. The moisture condition has a significant effect on slab behavior and is highly variable with time, seasonal changes, annual climate conditions, drainage patterns, ground cover, and vegetation (e.g., trees and shrubs).
5. This value may be used provided subgrade preparation is implemented following one of the additional options presented above in this revised report.
6. Differential movements may result from variances in subsurface conditions, loading conditions, and construction procedures. We recommend that measures be taken whenever practical to increase the tolerance of the building to post-construction foundation movements. An example of such measures would be to provide frequent control joints for exterior masonry veneers and interior sheetrock walls (particularly near doors and windows) to control cracking across such walls and concentrate movement along the joints.

For a slab on grade foundation system designed and constructed as recommended in this report, post construction consolidation settlements should be less than 1 inch. Settlement response of a slab on grade foundation is influenced more by the quality of construction than by soil-structure interaction. Therefore, it is essential that the recommendations for foundation construction be strictly followed during the construction phases of the pad and foundation.

The use of a vapor retarder should be considered beneath concrete slabs-on-grade that will be covered with wood, tile, carpet or other moisture sensitive or impervious coverings, or when the slabs will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer and slab contractor should refer to ACI 302 for procedures and cautions about the use and placement of a vapor retarder.

Construction Adjacent to Existing Structures

Differential settlement between the additions and the existing structures is expected to approach the magnitude of the total settlement of the addition. Expansion joints should be provided between the existing structures and the proposed addition to accommodate differential movements between the two structures. Underground piping between the two structures should be designed with flexible couplings and utility knockouts in foundation walls should be oversized so minor deflections in alignment do not result in breakage or distress. Care should be taken during excavation adjacent to existing foundations to avoid disturbing existing foundation bearing soils.

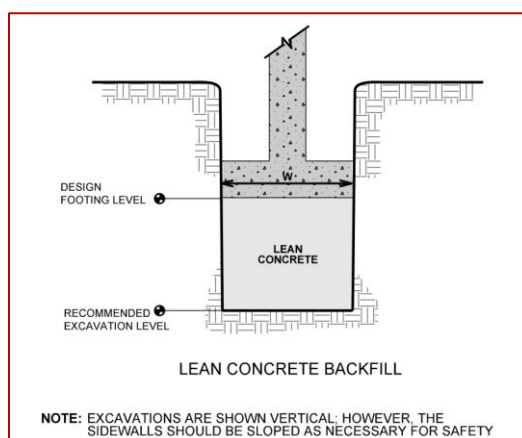
New footings should bear at or near the bearing elevation of immediately adjacent existing foundations. Depending upon their locations and current loads on the existing footings, footings for the new addition could cause settlement of adjacent walls. To reduce this concern and risk, clear distances at least equal to the new footing widths should be maintained between the addition's footings and footings supporting the existing structures.

Shallow Foundation Construction Considerations

Footings/Grade beams should be neat excavated, if possible. If neat excavation is not possible, the foundation should be properly formed. If a toothed bucket is used, excavation with this bucket should be stopped approximately 6 inches above final grade of the foundation and the foundation excavation be completed with a smooth-mouthed bucket or by hand labor. As noted in [Earthwork](#), the foundation excavations should be evaluated under the observation of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction.

Excessively wet or dry material or any loose/disturbed material in the bottom of the foundation excavations should be removed/reconditioned before foundation concrete is placed.

If unsuitable bearing soils are observed at the base of the planned foundation excavation, the excavation should be extended deeper to suitable soils, and the foundation could bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. The lean concrete replacement zone is illustrated on the sketch below.



Deep Foundations

Drilled Pier Design Parameters

Soil design parameters are provided below in the **Drilled Pier Design Summary** table for the design of drilled pier foundations.

Drilled Pier Design Summary ¹

Item	Design Parameter
Bearing Stratum	Stratum 3 or 4 Soils ²
Minimum Concreted Pier Length ³	20 feet
Minimum Pier Shaft Diameter	18 inches
Minimum Pier Spacing ⁴	3 diameters center-to-center
Allowable End Bearing Pressure ⁵	Net dead plus sustained live load – 6,700 psf Net total load – 10,000 psf
Allowable Side Friction ⁶	650 psf

Drilled Pier Design Summary ¹

Item	Design Parameter
Estimated Uplift Force ^{7,8,9}	30*D for prepared subgrade areas 70*D for unprepared subgrade areas
Minimum Percentage of Steel ^{7,8,9}	1 percent
Approximate Total Settlement ^{10,11}	1-inch
Estimated Differential Settlement ^{10,11}	½ to ¾ of total settlement

1. Design values are dependent upon the method of installation and quality control parameters.
2. See Subsurface Profile in [Geotechnical Characterization](#) for more details on stratigraphy.
3. The minimum concreted pier length refers to the concreted and reinforced pier section that is below the ground surface.
4. Drilled piers should have a minimum (center-to-center) spacing of three diameters. Closer spacing may require a reduction in axial load capacity. Axial capacity reduction can be determined by comparing the allowable axial capacity determined from the sum of individual piers in a group versus the capacity calculated using the perimeter and base of the pier group acting as a unit. The lesser of the two capacities should be used in design.
5. Whichever condition yields a larger bearing area.
6. Applicable for compressive loading only. Reduce to 2/3 of values shown for uplift loading. The effective weight of the shaft can be added to uplift load resistance to the extent permitted by IBC. Side friction should be neglected in the upper 10 feet of the pier. Permanently cased pier sections, if any, may not be accounted towards the side friction capacity.
7. The amount of reinforcing steel required can be computed by assuming the dead load of the structure surcharges the pier, the above estimated force acts vertically on the shaft, and the minimum pier length and embedment is sufficient in withstanding the uplift on the pier itself. The amount of required steel, as calculated by the structural engineer, should extend the entire pier length and in no case should the percentage of steel be less than 1 percent.
8. Uplift force (in kips) is used to calculate pier reinforcing steel. The term "D" is the pier diameter in feet. The equation for uplift force does not include a factor of safety. Piers should be adequately reinforced as designed by the Structural Engineer for both tension and shear to sufficient depths. Buoyant unit weights of the soil and concrete should be used in the calculations below the highest anticipated groundwater elevation.
9. The recommended minimum embedment depth of the piers below FFE should be sufficient in withstanding soil-related uplift forces. Please note the uplift force equation given above is intended for calculating the required reinforcing

Drilled Pier Design Summary ¹

Item	Design Parameter
	steel and is not intended for calculating pier embedment to overcome soil uplift forces. Additional reinforcing steel may be needed to resist external structural uplift forces.
10.	Provided proper construction practices are followed.
11.	Will result from variances in the subsurface conditions, loading conditions, and construction procedures, such as cleanliness of the bearing area or flowing water in the shaft.

Drilled Pier/Shaft Lateral Loading

The following table lists input values for use in LPILE analyses. Modern versions of LPILE provide estimated default values of k_h and E_{50} based on strength and are recommended for the project. Since deflection or a service limit criterion will most likely control lateral capacity design, no safety/resistance factor is included with the parameters.

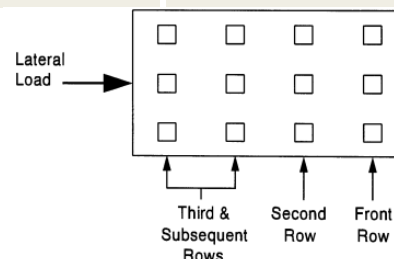
Stratigraphy ¹	L-Pile Soil Model	S_u (psf) ²	ϕ ²	γ' (pcf) ²	E_{50}	K (pci)	
						Static	Cyclic
Stratum 2	Stiff Clay w/o Free Water	1,500	---	125	Use Default Value		
Stratum 3	Stiff Clay w/o Free Water	2,000	---	120	Use Default Value		
Stratum 4	Stiff Clay w/o Free Water	2,000	---	125	Use Default Value		

- See Subsurface Profile in [Geotechnical Characterization](#) for more details on Stratigraphy.
- Definition of Terms:
 S_u : Undrained shear strength
 ϕ : Internal friction angle
 γ' : Effective unit weight
- For modeling lateral resistance, we recommend the upper 2 feet of the pier be ignored due to possible disturbance during construction, installation of utility trenches, installation of landscaping around the perimeter, and to possible changes to the site over time (e.g., future additions/expansions)

When piers are used in groups, the lateral capacities of the piers in the second, third, and subsequent rows of the group should be reduced as compared to the capacity of a single, independent pier. Guidance for applying p-multiplier factors to the p values in the p-y curves for each row of pile foundations within a pile group are as follows:

Center to Center Pier Spacing ^{1,2}	P-Multiplier, P_m ³		
	Front Row	Second Row	Third and Subsequent Rows
3D	0.8	0.4	0.3
4D	0.9	0.65	0.5
5D	1.0	0.85	0.7
6D	1.0	1.0	1.0

1. Spacing in the direction of loading. D = pier diameter
2. For the case of a single row of piers supporting a laterally loaded grade beam, group action for lateral resistance of piers would need be considered when spacing is less than three pier diameters (measured center-to-center).



3. See adjacent figure for definition of front, second and third rows.

For laterally loaded piers, spacing closer than 3D (where D is the diameter of the pier) is not recommended without additional geotechnical consultation due to potential for the installation of a new shaft disturbing an adjacent installed shaft likely resulting in axial capacity reduction.

Grade Beams between Drilled Piers

If a structurally suspended floor slab is used, grade beams spanning between drilled piers should be protected from the expansive soil. A minimum 10-inch void provided below the grade beams should allow the expansive clay to swell without causing distress in the grade beams. The sides of the void should be protected with permanent rigid soil retainers so that soil will not slough beneath the grade beams and fill the void. The above also applies to any individual isolated piers, if any, outside of the building footprint. If these isolated piers are overlain by larger pier caps or grade beams, then those caps/beams should also be protected from the clay by using void forms.

If a grade supported floor slab is used with subgrade preparation to reduce post-construction soil-related movements, grade beams spanning between drilled piers may be cast at-grade provided the subgrade in the beam areas is prepared as outlined in **Floor Slabs**. Grade beams should be designed to span across the drilled pier foundations without subgrade support, due to stress/strain incompatibility between different bearing materials at varying depths.

We recommend that clayey soils (such as the on-site soils) be used for backfill adjacent to grade beams at the exterior surface of the structure (to reduce potential infiltration of surface water into the subgrade areas). The exterior backfill should be compacted as outlined in **Earthwork**. On the interior sides of the perimeter grade beams, backfill should consist of properly compacted select fill or flowable fill (TxDOT Item 401), not sand or gravel. Compaction of select fill on the interior sides of beams should be performed by the Earthwork Contractor's personnel and equipment, not by concrete or utility contractors inexperienced with proper soil placements and compaction.

Drilled Pier Construction Considerations

The drilling contractor should be experienced in the subsurface conditions observed at the site, and the excavations should be performed with equipment capable of providing a clean bearing surface. The drilled pier foundation system should be installed in general accordance with the procedures presented in "Standard Specification for the Construction of Drilled Piers", ACI Publication No. 336.1-01.

The contractor is generally expected to use conventional "dry" techniques for installation of the drilled pier. Subsurface water was not encountered in boring during the drilling activities. Subsurface water levels are influenced by seasonal and climatic conditions, which result in fluctuations in subsurface water elevations. Additionally, it is common for water to be present after periods of significant rainfall.

Care should be taken to not disturb the sides and bottom of the excavation during construction. The bottom of the shaft excavation should be free of loose material before concrete placement. Concrete should be placed as soon as possible after the foundation excavation is completed, to reduce potential disturbance of the bearing surface.

The drilling contractor should remove all soft and disturbed soils from the base of the drilled pier prior to placing concrete. The drilled pier installation process should be performed under the observation of the Geotechnical Engineer or their representative. The Geotechnical Engineer or their representative should document the pier installation process including soil and groundwater conditions observed, consistency with expected conditions, and details of the installed pier.

Lateral Earth Pressures

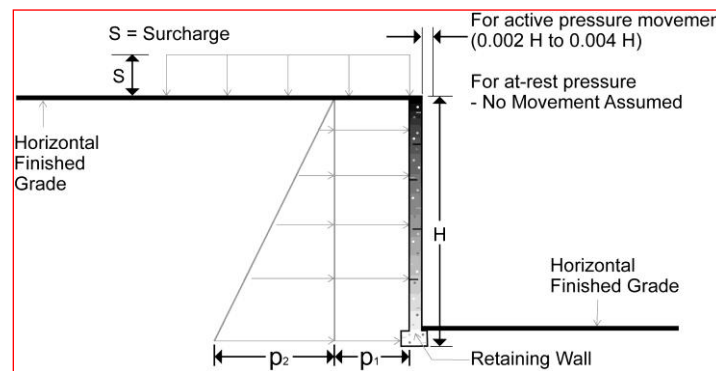
Design Parameters

Structures with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to values indicated in the following table. Earth pressures will be

influenced by structural design of the walls, conditions of wall restraint, methods of construction, and/or compaction and the strength of the materials being restrained.

Two wall restraint conditions are shown in the diagram below. For the below grade structures, the "at-rest" condition, which assumes no wall movement, should be implemented without any resistance from passive earth pressures. For conventional site retaining walls, if planned, active earth pressure, which assumes some wall movements, is commonly used for design. For site retaining walls, passive resistance from backfilled soils on the toe side of the wall may be considered.

The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls (unless stated). The following values are intended for walls installed in open cut conditions with backfill (e.g., double formed walls). If temporary retention systems and single-formed walls will be used, please contact us for revised earth pressures.



Lateral Earth Pressure Design Parameters				
Backfill Type	Estimated Total Unit Weight, pcf ¹	Lateral Earth Pressure Coefficients ²		
		At Rest, K _o	Active, K _A	Passive, K _P
Crushed Limestone	135	0.45	0.3	3.5
Clean Sand	120	0.5	0.35	3.0
Clean Gravel	120	0.45	0.3	3.5

1. Compaction should be maintained between 95 and 100 percent of Standard Proctor (ASTM D 698) maximum dry density. Overcompaction can produce lateral earth pressure coefficients in excess of those provided.
2. Coefficients represent nominal (unfactored) values. Appropriate safety factors should be applied.

The above values do not include a hydrostatic or ground-level surcharge component. To prevent hydrostatic pressure build-up, retaining walls should incorporate functional drainage (via free-draining aggregate or manufactured drainage mats) within the backfill zone. The effect of surcharge loads, where applicable, should be incorporated into wall pressure diagrams by adding a uniform horizontal pressure component equal to the applicable lateral earth pressure coefficient times the surcharge load, applied to the full height of the wall.

Backfill placed against structures should consist of granular soils or low plasticity cohesive soils. For the granular values to be valid, the granular backfill must extend out and up from the base of the wall at an angle of at least 45 degrees from vertical for the active case.

Footings or other loads bearing on backfill behind walls may have a significant influence on the lateral earth pressure. Placing footings within wall backfill and in the zone of active soil influence on the wall should be avoided unless structural analyses indicate the wall can safely withstand the increased pressure.

All retaining walls should be checked against failure due to overturning, sliding and overall slope stability. Such an analysis can only be performed once the dimensions of the wall and cut/fill scenarios are known. For retaining wall bearing capacity design, we recommend the following parameters be applied for footings bearing at least 2 feet below final grade.

Retaining Wall Footing Parameters

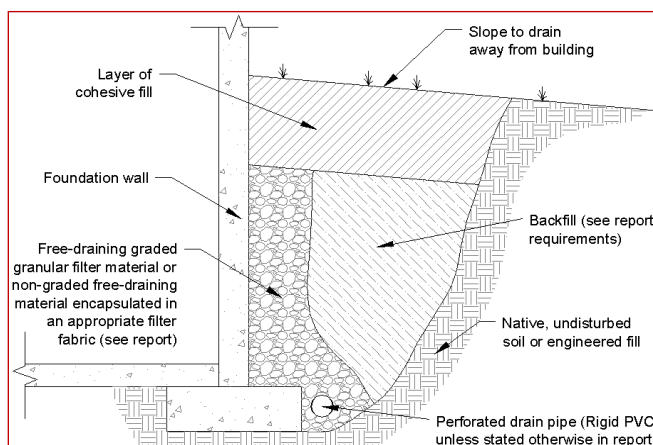
Bearing Material ¹	Sliding Resistance	Maximum Allowable Sliding Resistance (psf)	Maximum Footing Bearing Capacity (psf) ⁴
On-site soils ²	0.3	300	2,000
Select Fill ³	As per Shallow Foundations		

1. There exists a higher movement potential for any retaining walls bearing on the native on-site soils (up to 4¾ inches). If lower movement potential is desired, please contact us so that we may provide additional recommendations.
2. Frequent joints should be provided throughout the length of the retaining wall to reduce cracking due to differential movements caused by the shrink/swell movement of the fat clay subgrade.
3. If the subgrade is prepared as recommended in [Earthwork](#), the value for Select Fill may be considered.
4. Wall areas are often prepared for construction by specialty subcontractors, not the primary Earthwork Contractor. Regardless, the subgrade and fills within wall footing areas should be prepared as recommended in this report. If the areas are prepared weeks to months in advance of wall construction, the final subgrade needs to be evaluated prior to wall footing construction.

The lateral earth pressure recommendations given in this section are applicable to the design of rigid retaining walls subject to slight rotation, such as cantilever, or gravity type concrete walls. These recommendations are not applicable to the design of modular block - geogrid reinforced backfill walls (also termed MSE walls). Recommendations covering these types of wall systems are beyond the scope of services for this assignment. However, we would be pleased to develop a proposal for evaluation and design of such wall systems upon request.

Subsurface Drainage for Below-Grade Walls

A perforated rigid plastic drain line installed behind the base of walls and extends below adjacent grade is recommended to prevent hydrostatic loading on the walls. The invert of a drain line around a below-grade building area or exterior retaining wall should be placed near foundation bearing level. The drain line should be sloped to provide positive gravity drainage to daylight or to a sump pit and pump. The drain line should be surrounded by clean, free-draining granular material having less than 5% passing the No. 200 sieve, such as No. 57 aggregate. The free-draining aggregate should be encapsulated in a filter fabric. The granular fill should extend to within 2 feet of final grade, where it should be capped with compacted cohesive fill to reduce infiltration of surface water into the drain system.



As an alternative to free-draining granular fill, a prefabricated drainage structure may be used. A prefabricated drainage structure is a plastic drainage core or mesh which is covered with filter fabric to prevent soil intrusion and is fastened to the wall prior to placing backfill.

Comments on Excavation and/or Trench Safety

The following subsections present comments pertaining to the subsurface conditions encountered in the test borings drilled at the site and the effects these conditions may

have upon excavation and/or trench safety. Our comments are based on the data obtained from the field and laboratory test programs, geologic conditions, and our experience with similar projects. We are providing general comments for the most common methods of excavation and/or trench safety, including sloping, benching, shoring, bracing, and trench shields. The client, design engineer, and/or contractor should decide which is the most feasible system for this site depending items such as space limitations, construction budget, and construction schedule.

General

OSHA Safety and Health Standards (29 CFR Part 1926) require that all trenches in excess of 5 feet deep be shored or appropriately sloped unless the sidewalls are comprised of “stable” rock. State of Texas legislation requires detailed plans and specifications for retention systems that meet OSHA standards for a safe construction environment during utilities installation. The following sections provide general information to aid in designing an excavation retention system for this project based on the subsurface conditions observed at our test boring locations. These comments are intended for use in conjunction with OSHA safety regulations and not in lieu of those regulations. Prior to utility line construction, an excavation/trench safety plan, which is designed by a registered Professional Engineer, should be completed.

Construction

As stated above, OSHA requires all trenches in excess of 5 feet in depth to be shored or appropriately sloped. Currently available and practiced methods for achieving slope and/or sidewall stability includes sloping, benching, combinations of sloping and benching, and installation of shoring systems (hydraulic, timber, etc.). Trench shields may also be considered for use. However, trench shields only provide protection to workers; they are not means for providing slope or sidewall stability.

Sloping and Benching

If right-of-way is available, sloping, benching, or a combination thereof could be considered. The slope angle and/or vertical height of the bench section will be dependent on the subsurface conditions. In general, temporary excavations may be cut at the slopes indicated previously in [Earthwork](#). We recommend that all sloping/benching be performed as directed by OSHA in 29 CFR, Part 1926.

During excavation, slopes or benches should be observed for possible signs of failure such as bulging of the vertical face of the bench, tension cracks at the slope crest and/or raveling of material down the slope. Surcharge loading from spoil piles, traffic, or equipment loading closer than 6 feet from the crest of the slope, which might alter the

stability of the slope, should be avoided. If such conditions are observed, workers should not be permitted in the excavation until the conditions noted are corrected by the contractor. If such conditions cannot be avoided, further flattening of the slope may be required. Flattening of the slope may also be necessary if excess amounts of groundwater influx are observed.

Surface water runoff which flows down the slopes or benches and ponds at the toe or crest of an excavation may be detrimental to stability. The excavation slopes should be thoroughly evaluated following a rainfall event and prior to workers entering the excavation.

Shoring

If desired, shoring may be utilized for excavation safety. Earth pressures for design of shoring should be based on a "worst case" condition from an earth pressure standpoint. The appropriate earth pressures to be utilized should be evaluated by the excavation safety system designer. Each strut or brace should be proportioned as if it would be subjected to the maximum lateral load.

Excavation safety systems may be subjected to surcharge loads in the form of construction equipment and/or spoil piles. Surcharge loads from soil surcharge should be considered when calculating earth pressures for the shoring systems. Equipment such as backhoes, front-end loaders, etc., should not operate within a distance of 6 feet from the excavation sidewall (and no vibrating equipment should be used) while workers are in the excavation. The excavation safety system designer should review the surcharge loads imposed on the excavation safety system.

Trench Shields

If sloping, benching, or shoring is not selected, trench shields may be considered to protect the workers from slope instability. As for shoring, the design of the trench shields should be based on a "worst case" earth pressure standpoint, with the appropriate earth pressures properly evaluated by the excavation safety system designer. We should note that trench shields only serve as a means for worker protection; they are not a means of excavation retention. Potential effects of sidewall caving and corresponding damage to adjacent property and personnel should be considered when considering the use of trench shields. As stated above for shoring, hydrostatic pressures and effects of spoil, equipment, and other surcharge loading should be considered.

Alternate Sidewall Protection Methods

Other equivalent methods of slope protection or shoring may be considered for this project. However, any excavation safety system to be utilized should fully comply with OSHA regulations.

Inspection of Excavation Safety System

Inspections of the excavations should be performed by a competent person to perform the following:

- Confirm that actual conditions are as anticipated from analysis of the borings
- To examine for the presence of faults or other geologic features that might be an indication of sidewall instability
- Observe the presence of spoil piles or equipment which could cause surcharge loading
- To help ensure that the excavation safety system design is properly interpreted and incorporated into construction.

The construction sequence should be planned so that an adequate inspection can be performed prior to personnel entering the excavation.

In addition, OSHA regulations require that inspections be made daily by a competent person for situations which could result in a possible cave-in, indications of failure of the protective systems, hazardous atmospheres, or other hazardous conditions. Workers should not be permitted in the excavation until these conditions have been reviewed by a competent person on a daily basis. A competent person is defined within the OSHA Safety and Health Standards and Interpretations Part 1926 of 29 CFR, amended 1989, Subpart P - Excavations, as one who is capable of identifying existing and predictable hazards in the surrounding or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Pavements

General Pavement Comments

Recommended minimum pavement thicknesses are provided for the traffic conditions and pavement life conditions as noted in [Project Description](#) and in the following sections of this report. A critical aspect of pavement performance is site preparation. Recommended minimum pavement thicknesses noted in this section must be applied to the site which has been prepared as recommended in the [Earthwork](#) section.

Recommended minimum pavement thicknesses are intended to provide structural sections with adequate thickness over a particular subgrade such that wheel loads are reduced to a level the subgrade can support. Support characteristics of subgrade for pavement design do not account for shrink/swell movements of an expansive clay subgrade, such as the on-site soils observed on this project. Thus, the pavement may be adequate from a structural standpoint, yet still experience cracking and deformation due to shrink/swell related movement of the subgrade. It is therefore important to minimize moisture changes in the subgrade to reduce shrink/swell movements. Proper site perimeter drainage should be provided so that infiltration of surface water from unpaved areas surrounding the pavement is minimized.

Lime treatment of the on-site fat clay subgrade is suggested to enhance the workability and support characteristics of the subgrade as well to provide a barrier to reduce moisture infiltration in the underlying clay subgrade. The lime treatment also helps to reduce the shrink/swell potential of the lime-treated layer. If lime-treatment is planned, we recommend the subgrade soils be investigated for the presence of sulfates during construction. Based on numerous research studies performed by educational institutions, regulatory agencies, and both public and private entities, soils that contain significant amounts of soluble sulfates are not optimal candidates for lime treatment and may result in excessive heave of the subgrade and subsequent distress to the pavements. Soluble sulfate levels of up to 3,000 parts per million (ppm) are generally considered to be acceptable for lime treatment. Soluble sulfate levels between 3,000 ppm and 10,000 ppm in clay soils are generally considered to be moderate to high and pose a greater risk to successful lime treatment. Excessive concentrations of sulfates in the soils can result in poor performance of lime-treated subgrade.

Pavement Section Thicknesses

The following table provides our opinion of minimum thickness of reinforced PCC pavements.

Portland Cement Reinforced Concrete

Layer ²	Thickness (inches) ¹					
	Traffic Category A		Traffic Category B		Traffic Category E	
Reinforced PCC	5.0		6.0	5.5	7.0 ⁴	6.5
Lime-Treated Subgrade ³	---	8.0	---	8.0	---	8.0
Moisture Conditioned Subgrade ⁵	18.0	10.0	18.0	10.0	18.0	10.0

1. See [Project Description](#) for more specifics regarding traffic classifications.
2. All materials should meet the current specifications as outlined in **Pavement Materials** below.
3. If the fat clay pavement subgrade is to be lime-treated, sulfate testing should be performed on the actual final pavement subgrade soils prior to any lime treatment.
4. For fire lanes to withstand the occasional HS-20 loading of 32,000 pounds per axle and up to 90,000-pound gross truck weight, use Traffic Category E pavements or thicker.
5. Due to the potential of encountering Stratum 1 fill soils in the pavement areas, we recommend either the subgrade be moisture conditioned to a depth of 18 inches below the concrete pavements if a moisture conditioned subgrade only section is considered, or the subgrade be moisture conditioned to 10 inches with 8 inches of lime treated subgrade. In addition, we recommend the exposed subgrade be fully proofrolled prior to placement of the moisture conditioned subgrade.

Areas for parking of heavy vehicles, concentrated turn areas, and start/stop maneuvers could require thicker pavement sections. Edge restraints (e.g., concrete curbs or aggregate shoulders) should be planned along curves and areas of maneuvering vehicles.

Although not required for structural support, a minimum 4-inch-thick base course layer is recommended to help reduce potential for slab curl, shrinkage cracking, and subgrade pumping through joints. Proper joint spacing will also be required to prevent excessive slab curling and shrinkage cracking. Joints should be sealed to prevent entry of foreign material and doweled where necessary for load transfer. PCC pavement details for joint spacing, joint reinforcement, and joint sealing should be prepared in accordance with ACI 330 and ACI 325.

Where practical, we recommend early-entry cutting of crack-control joints in PCC pavements. Cutting of the concrete in its “green” state typically reduces the potential for micro-cracking of the pavements prior to the crack control joints being formed, compared to cutting the joints after the concrete has fully set. Micro-cracking of pavements may lead to crack formation in locations other than the sawed joints, and/or reduction of fatigue life of the pavement.

Pavement Materials

Presented below are our recommended material requirements for the various pavement sections.

Item	Value
Portland Cement Concrete (PCC)	28-day compressive strength $\geq$ 3,500 psi
Crushed Limestone Base ¹	TxDOT Item 247, Type A, Grade 1-2 compacted as outlined in Earthwork .
Lime Treated Subgrade ^{2,3}	If soil subgrade consists of high PI (≥ 30) with $\leq$ 15% gravel, lime treatment as per TxDOT Item 260 is applicable either through dry placement or slurry placement.
Moisture Conditioned Subgrade ⁴	As outlined in Earthwork .

1. Each lift of base should be thoroughly proof-rolled just prior to placement of subsequent lifts and/or asphalt. Particular attention should be paid to areas along curbs, above utility trenches, and adjacent to landscape islands, manholes, and storm drain inlets. Preparation of the base material should extend at least 24 inches behind curbs.
2. We anticipate that approximately 6 to 10 percent hydrated lime will be required to treat the subgrade soils. We suggest 8% lime be used for bidding purposes with add/deduct line items for 1 to 2% above or below the base bid items. Prior to the application of lime to the subgrade, the optimum percentage of lime to be added should be determined based on Plasticity Index (TEX-112-E) and/or pH (ASTM D 6276) laboratory tests conducted on mixtures of the subgrade soils with lime. Subgrade soil samples should be obtained from the pavement areas as the proposed final subgrade elevation. Please note these tests require up to 5 business days to complete.
3. The lime should initially be blended with a mixing device such as a Pulvermixer, sufficient water added, and allowed to cure for at least 48 hours. After curing, mixing should continue until gradation requirements of TxDOT Item 260.4.4 are achieved. The mixture should be moisture adjusted and compacted as outlined in [Earthwork](#). Preparation of the lime-treated subgrade should extend at least 24 inches behind curbs.

Item	Value
4.	Subgrade should not dry out or become saturated prior to pavement construction. The pavement subgrade should be thoroughly proof-rolled as outlined in Earthwork . Particular attention should be paid to areas along curbs, above utility trenches, and adjacent to landscape islands, manholes, and storm drain inlets. Preparation of the moisture conditioned subgrade should extend at least 24 inches behind curbs.

Presented below are our recommendations for the construction of the reinforced concrete pavements.

Item	Value
Reinforcing Steel	Category A and B: #3 bars spaced at 18 inches on center in both directions. Category E: #4 bars spaced at 18 inches (or #3 bars spaced at 12 inches) on center in both directions. Rebar should be placed at midpoint of concrete section and supported on chairs prior to concrete placement.
Control (i.e., Contraction) Joint Spacing	In accordance with ACI 330, control joints should be spaced no greater than 12.5 feet for 5-inch-thick concrete and 15 feet for 6-inch-thick or greater concrete. If sawcut, control joints should be cut within 6 to 12 hours of concrete placement. Sawcut joint should be at least $\frac{1}{4}$ of the slab thickness.
Expansion (i.e., Isolation) Joint Spacing	ACI 330 indicates that regularly spaced expansion joints may be deleted from concrete pavements, except adjacent to structures, manholes, inlets, light poles, etc. Therefore, the installation of expansion joints is optional and should be evaluated by the design/construction team. Expansion joints, if not sealed and maintained can allow infiltration of surface water into the subgrade.
Dowels at Expansion Joints	$\frac{3}{4}$ -inch smooth bars, 18 inches in length, with one end treated to slip, spaced at 12 inches on centers at each joint, and placed level at midpoint of concrete section.

Pavement Drainage

On most projects, rough site grading is accomplished relatively early in the construction phase. Fills are placed and compacted in a uniform manner. However, as construction proceeds, excavations are made into these areas, dry weather may desiccate some areas, rainfall and surface water saturates some areas, heavy traffic from concrete and

other delivery vehicles disturbs the subgrade, and many surface irregularities are filled in with loose soils to temporarily improve subgrade conditions. As a result, the pavement subgrade should be carefully evaluated as the time for pavement construction approaches. This is particularly important in and around utility trench cuts. All pavement areas should be moisture conditioned and properly compacted to the recommendations in this report immediately prior to paving. Thorough proof-rolling of pavement areas should be performed no more than 36 hours prior to surface paving. Proof-rolling should be repeated if the site received rainfall prior to paving. Any problematic areas should be reworked and compacted at that time.

Openings in pavements, such as landscaped islands, are sources for water infiltration into surrounding pavement systems. Water can collect in the islands and migrate into the surrounding subgrade soils thereby degrading support of the pavement. Islands with raised concrete curbs, irrigated foliage, and low permeability near-surface soils are particular areas of concern. The civil design for the pavements with these conditions should include features to restrict or to collect and discharge excess water from the islands. Examples of features are self-contained planters, edge drains connected to the storm water collection system, longitudinal subdrains, or other suitable outlet, and impermeable barriers preventing lateral migration of water such as a cutoff wall installed to a depth below the pavement structure.

Pavements should be sloped to provide rapid drainage of surface water. Water allowed to pond on or adjacent to the pavements could saturate the subgrade and contribute to premature pavement deterioration. In addition, the pavement subgrade should be graded to provide positive drainage within the granular base section.

Pavement Maintenance

The pavement sections represent minimum recommended thicknesses and, as such, periodic upkeep should be anticipated. Preventive maintenance should be planned and provided for through an on-going pavement management program. Maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Pavement care consists of both localized (e.g., crack and joint sealing and patching) and global maintenance (e.g., surface sealing). Additional engineering consultation is recommended to determine the type and extent of a cost-effective program. Even with periodic maintenance, some movements and related cracking may still occur, and repairs may be required.

Pavement performance is affected by its surroundings. In addition to providing preventive maintenance, the civil engineer should consider the following recommendations in the design and layout of pavements:

- Final grade adjacent to paved areas should slope down from the edges at a minimum 2%.

- Subgrade and pavement surfaces should have a minimum 2% slope to promote proper surface drainage.
- Install pavement drainage systems (e.g., French drains) surrounding areas anticipated for frequent wetting.
- Install joint sealant and seal cracks immediately.
- Seal all landscaped areas in or adjacent to pavements to reduce moisture migration to subgrade soils.
- Place compacted, low permeability backfill against the exterior side of curb and gutter.
- Construct curb, gutter and/or sidewalk directly on subgrade soils rather than on unbound granular base course materials.

General Comments

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly affect excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety and cost estimating including excavation support and dewatering requirements/design are the responsibility of others. Construction and site development have the potential to affect adjacent properties. Such impacts can include damages due to vibration, modification of groundwater/surface water flow during construction, foundation movement due to undermining or subsidence from excavation, as well as noise or air quality concerns. Evaluation of these items on nearby properties are commonly associated with contractor means and methods and are not addressed in this report. The owner and contractor should consider a preconstruction/precondition survey of surrounding development. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

Geotechnical Engineering Report

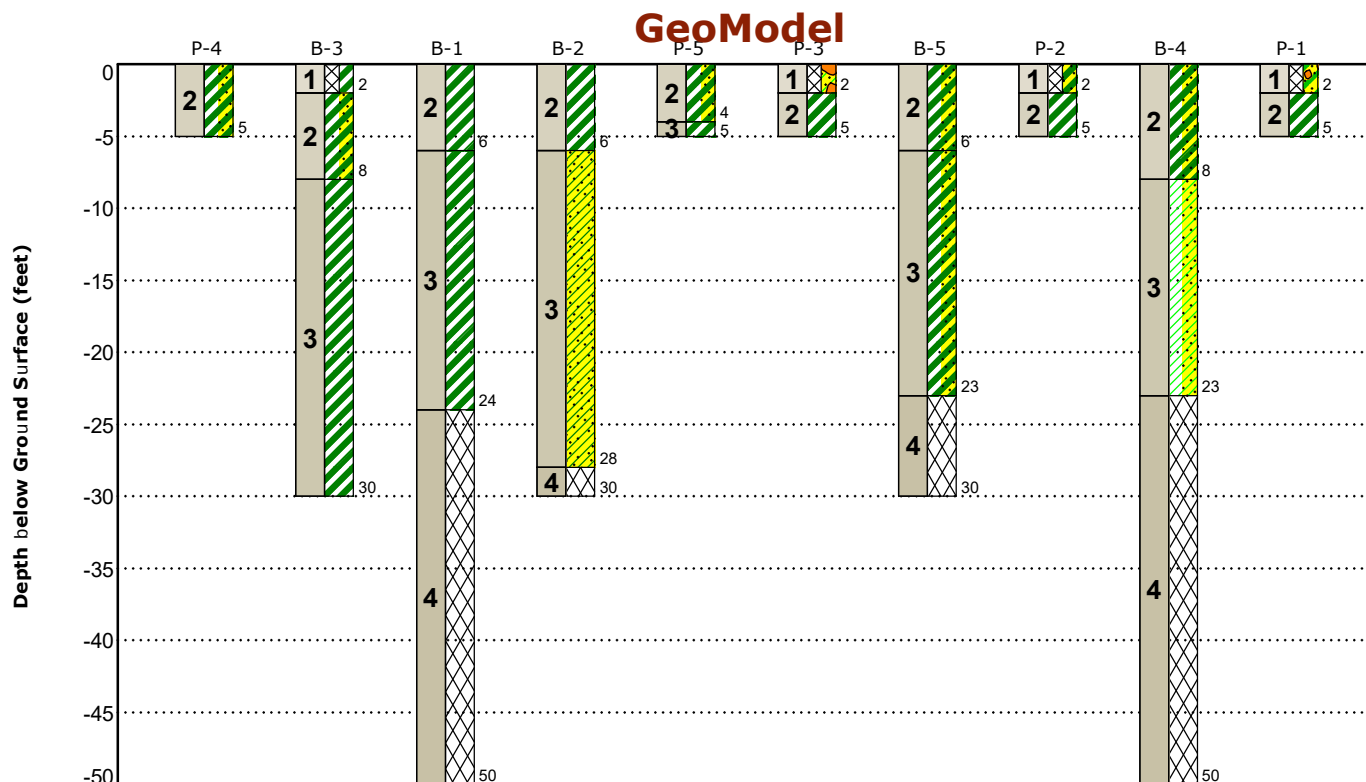
Wilbarger WWTP Expansion to 1.5 MGD | Manor, TX
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Figures

Contents:

GeoModel



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

Model Layer	Layer Name	General Description	Legend
1	Fill Materials	Brown fat clay (CH), clayey sand (SC) and clayey gravel (GC).	Fat Clay Highly Weathered Shale
2	Shallow Clays	Dark brown fat clay (CH) with various amounts of sand, gravel and organics.	Sandy Lean Clay Fat Clay with Sand
3	Deeper Clays	Brown, light brown and gray fat clay (CH) and lean clay (CL) with various amounts of sand and gravel.	Lean Clay with Sand Clayey Sand with Gravel
4	Shaley Fat Clays	Dark gray shaley fat clay	Sandy Fat Clay Clayey Gravel with Sand

NOTES:

Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project.

Numbers adjacent to soil column indicate depth below ground surface.

Geotechnical Engineering Report

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Attachments

Exploration and Testing Procedures

Field Exploration

Number of Borings	Approximate Boring Depth (feet)	Location
1 (B-1)	50	Clarifier Tank Area
1 (B-2)	30	Aeration Basin Area
1 (B-3)	30	Chemical Storage Area
1 (B-4)	50	Dewatering Building Area
1 (B-5)	30	Peak Shaving Basin Area
5 (P-1 through P-5)	5	Pavement areas

Boring Layout and Elevations: Terracon personnel provided the boring layout using handheld GPS equipment (estimated horizontal accuracy of about ±10 feet) and referencing existing site features. If elevations and a more precise boring layout are desired, we recommend borings be surveyed.

Subsurface Exploration Procedures: Our drilling subcontractor advanced the borings with a truck-mounted rotary drill rig using solid stem augers. Samples were obtained at approximately two-foot intervals in the upper 10 feet of each boring and at intervals of 5 feet thereafter. Soil sampling was performed using shelly tube samplers and/or split-barrel sampling procedures. The split-barrel samplers were driven in accordance with the standard test method for standard penetration test (SPT) and split-barrel sampling of soils. For safety purposes, all borings were backfilled with auger cuttings after their completion.

Our drilling subcontractor observed and recorded for possible groundwater levels during drilling and sampling. Groundwater was not observed during our field investigation.

The sampling depths, penetration distances, and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials observed during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests. The laboratory testing program included the following types of tests:

- Moisture Content
- Dry Unit Weight
- Grain Size Distribution
- Atterberg Limits
- Unconfined Compression

The laboratory testing program included examination of soil samples by an engineer. Based on the results of our field and laboratory programs, we described and classified the soil samples in accordance with the Unified Soil Classification System.

Site Location and Exploration Plans

Contents:

Site Location Plan
Exploration Plan (2 pages)

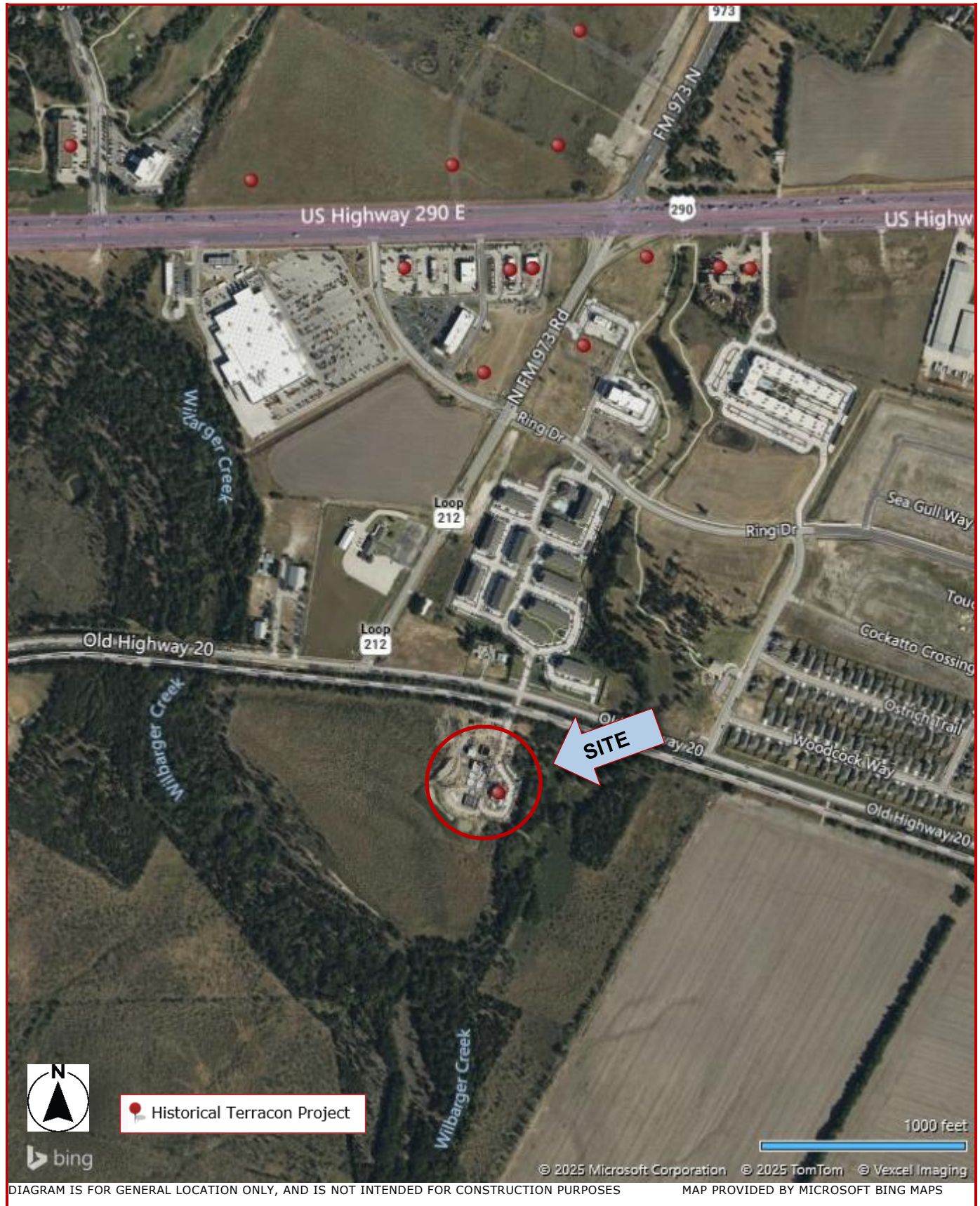
Note: All attachments are one page unless noted above.

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Site Location



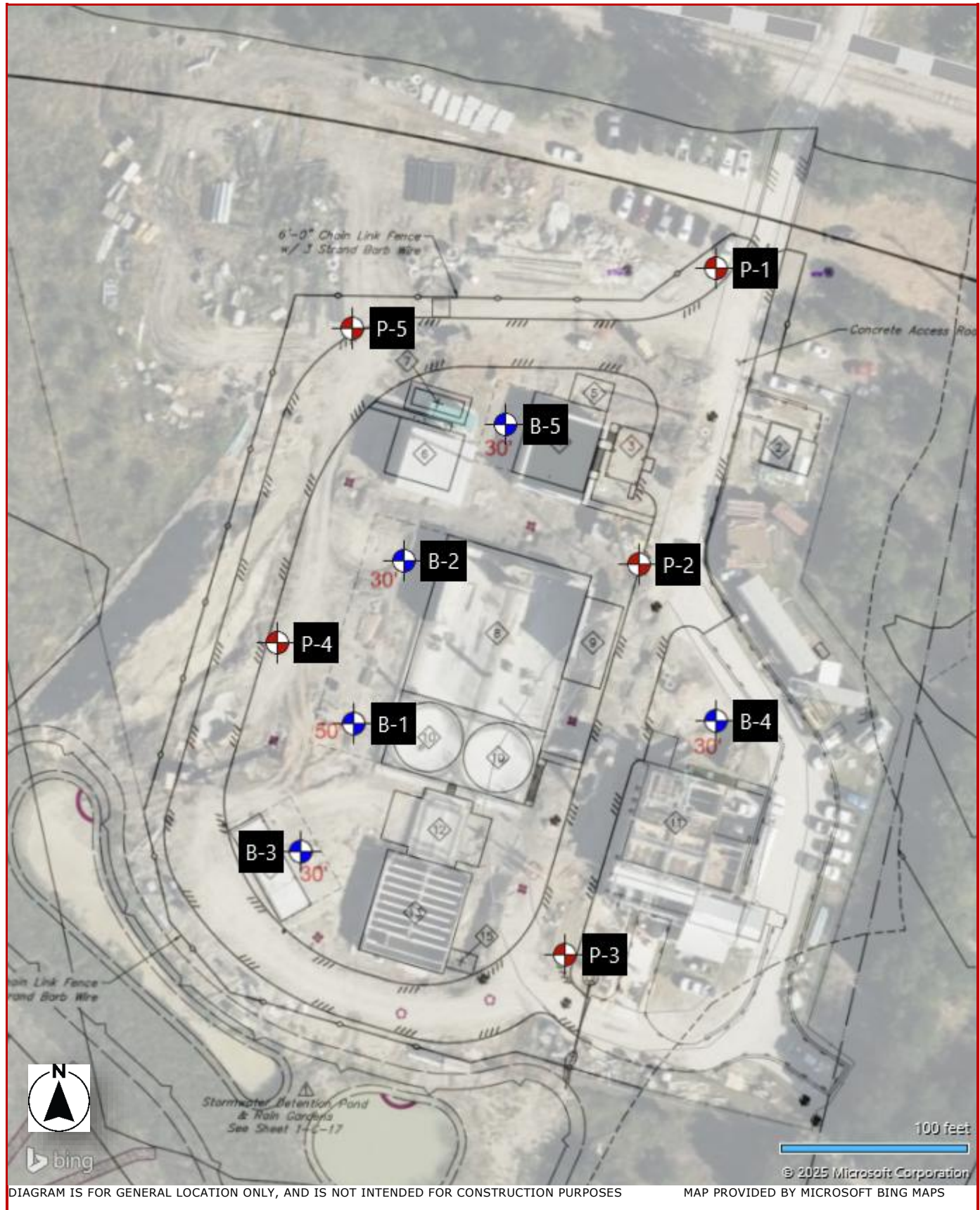
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Exploration Plan (with Site Plan)

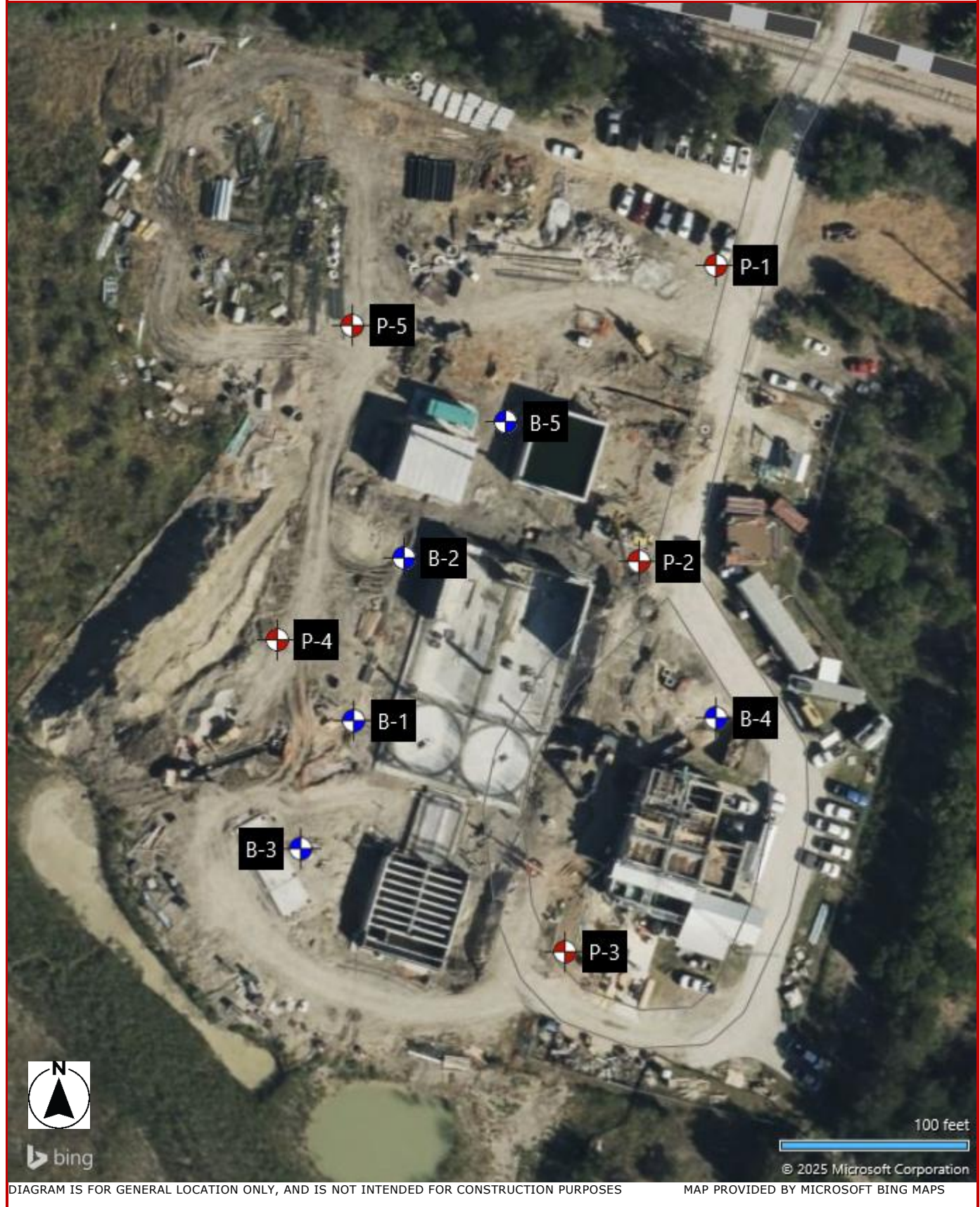


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Exploration Plan (without Site Plan)



Exploration and Laboratory Results

Contents:

Boring Logs (B-1 through B-5 and P-1 through P-5)

Atterberg Limits (2 pages)

Grain Size Distribution (4 pages)

Note: All attachments are one page unless noted above.

Boring Log No. B-1

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3418° Longitude: -97.5410° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits		
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	Percent Fines	
2		FAT CLAY (CH) , dark brown, hard, with scattered gravel - organics to about 4 feet	5			4.5 tsf (HP)				15.5		55-19-36	85.9	
						4.5 tsf (HP)				16.4				
						4.5 tsf (HP)				16.1				
3		FAT CLAY (CH) , brown and gray, very stiff to hard	10			4.5 tsf (HP)	UC	5.63	11.4	17.1	112	86-19-67	94.1	
						4.5 tsf (HP)				28.1				
			15			4.5 tsf (HP)				31.6	79-21-58	95.3		
			20			4.5 tsf (HP)	UC	2.20	2.5	29.4	93			
			25			4.5 tsf (HP)								
30	4.5 tsf (HP)	UC		0.51	11.9	30.3	91							
4		SHALEY FAT CLAY (CH) , dark gray, hard	35			24-28-36 N=64								
			40			15-28-20 N=48								
			45			22-32-24 N=56								
50	23-32-21 N=53													
		Boring Terminated at 50 Feet	50											

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).
See [Supporting Information](#) for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig
CME 55
Hammer Type
Automatic
Driller
Texas Geo Bore

Notes

Advancement Method
Solid stem augers.

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
Texas Geo Bore
Boring Started
09-24-2025
Boring Completed
09-24-2025

Boring Log No. B-2

[illegible]

See **Exploration and Testing Procedures** for a description of field and laboratory procedures used and additional data (if any).

See **Supporting Information** for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Notes

Water Level Observations

No free water observed

Drill Rig

CME 55

Hammer Type

Automatic

Driller

Texas Geo Bore

Logged by

Texas Geo Bore

Boring Started

09-24-2025

Boring Completed

09-24-2025

Advancement Method

Solid stem augers.

Abandonment Method

Boring backfilled with auger cuttings upon completion.

Boring Log No. B-3

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3416° Longitude: -97.5411° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	Percent Fines
1		FILL - FAT CLAY (CH) , brown, hard, with scattered gravel	2.0			4.5 tsf (HP)				10.1			
2		FAT CLAY WITH SAND (CH) , dark brown, hard, with calcareous deposits	8.0			4.5 tsf (HP)				13.4		54-18-36	75.8
						4.5 tsf (HP)				13.2			
						7-13-27 N=40				13.9			
3		FAT CLAY (CH) , light brown and gray, very stiff to hard	30.0			4.5 tsf (HP)	UC	5.49	3.9	23.5	101		
						4.5 tsf (HP)				31.5		76-19-57	97.7
						4.5 tsf (HP)	UC	2.08	4.1	28.8	94		
						4.5 tsf (HP)							
						4.5 tsf (HP)	UC	5.21	2.2	24.7	100		
		Boring Terminated at 30 Feet	30										

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).
See [Supporting Information](#) for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig
CME 55
Hammer Type
Automatic
Driller
Texas Geo Bore

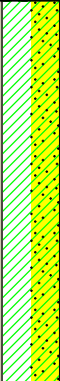
Notes

Advancement Method
Solid stem augers.

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
Texas Geo Bore
Boring Started
09-24-2025
Boring Completed
09-24-2025

Boring Log No. B-4

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3418° Longitude: -97.5404° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	Percent Fines
2		FAT CLAY WITH SAND (CH) , dark brown, hard, with scattered gravel - with organics to about 4 feet	5			4.5 tsf (HP)				9.4		54-18-36	82.7
						4.5 tsf (HP)							
						4.5 tsf (HP)							
						4.5 tsf (HP)							
3		LEAN CLAY WITH SAND (CL) , light brown, very stiff to hard, varies to fat clay (CH) - with scattered gravel to about 10 feet	10			12-20-18 N=38				13.5		39-17-22	76.9
			15			4.0 tsf (HP)	UC	3.11	4.8	28.1	93		
			20			3.5 tsf (HP)							
4		SHALEY FAT CLAY (CH) , dark gray, very stiff to hard	25			4.5 tsf (HP)	UC	2.88	6.4	31.4	89		
			30			7-12-15 N=27							
			35			18-25-27 N=52							
			40			21-27-29 N=56							
45			20-23-33 N=56										
			27-50/6"										
		Boring Terminated at 50 Feet	50										

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).
See [Supporting Information](#) for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig
B-57
Hammer Type
Automatic
Driller
Texas Geo Bore

Notes

Advancement Method
Solid stem augers.

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
Texas Geo Bore
Boring Started
09-25-2025
Boring Completed
09-25-2025

Boring Log No. B-5

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3422° Longitude: -97.5407° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	Percent Fines
2		FAT CLAY WITH SAND (CH) , dark brown, stiff to very stiff, with scattered gravel	5			2.0 tsf (HP)				25.4		58-20-38	77.0
						2.0 tsf (HP)				23.5			
3		FAT CLAY WITH SAND (CH) , light brown and gray, very stiff to hard	10			2.0 tsf (HP)	UC	1.93	8.6	20.5	105	63-19-44	76.5
						3.0 tsf (HP)				25.8			
			3.0 tsf (HP)			22.1							
			15			4.5 tsf (HP)				26.9			
			20			4.5 tsf (HP)				UC			
25	4.5 tsf (HP)												
30	4.5 tsf (HP)	UC	6.68	7.9	21.9	99							
Boring Terminated at 30 Feet			30										

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).
See [Supporting Information](#) for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig
B-57
Hammer Type
Automatic
Driller
Texas Geo Bore

Notes

Advancement Method
Solid stem augers.

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
Texas Geo Bore
Boring Started
09-25-2025
Boring Completed
09-25-2025

Boring Log No. P-1

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3424° Longitude: -97.5403° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	Percent Fines
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	
1		FILL - CLAYEY SAND WITH GRAVEL (SC) , brown, medium dense, with scattered gravel 2.0	5			6-5-5 N=10				17.9		46-17-29	27.0
2		FAT CLAY (CH) , dark brown, hard, with scattered gravel 5.0				4.5 tsf (HP)				19.0			
		Boring Terminated at 5 Feet				4.5 tsf (HP)				19.0		61-18-43	89.3

Notes	See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).	Water Level Observations No free water observed	Drill Rig CME 55
	See Supporting Information for explanation of symbols and abbreviations.		
	Elevation Reference: Elevations were not determined.		
Notes		Hammer Type Automatic	Driller Texas Geo Bore
Notes		Advancement Method Solid stem augers.	Logged by Texas Geo Bore
Notes		Abandonment Method Boring backfilled with auger cuttings upon completion.	Boring Started 09-24-2025
Notes			Boring Completed 09-24-2025

Boring Log No. P-2

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3420° Longitude: -97.5404° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	Percent Fines
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	
1		FILL - SANDY FAT CLAY (CH) , tan, hard	5			4.5 tsf (HP)				10.0		52-18-34	66.0
2		FAT CLAY (CH) , dark brown, hard, with calcareous deposits				4.5 tsf (HP)				15.1			
						4.5 tsf (HP)				14.5		59-19-40	87.0
Boring Terminated at 5 Feet													

See **Exploration and Testing Procedures** for a description of field and laboratory procedures used and additional data (if any).

See **Supporting Information** for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Notes

Water Level Observations
No free water observed

Advancement Method

Advancement Model
Solid stem augers.

Abandonment Method

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Drill Rig B-57

Hammer Type Automatic

Driller
Texas Geo Bore

Logged by
Texas Geo Bore

Boring Started
09-25-2025

Boring Completed
09-25-2025

Boring Log No. P-3

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3414° Longitude: -97.5407° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	Percent Fines
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	
1		FILL - CLAYEY GRAVEL WITH SAND (GC) , tan, medium dense 2.0			X	18-8-7 N=15				4.2		43-18-25	31.9
2		FAT CLAY (CH) , dark brown, very stiff to hard 5.0	5			4.5 tsf (HP)				20.3			
		Boring Terminated at 5 Feet				3.5 tsf (HP)				21.8		52-18-34	

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).
See [Supporting Information](#) for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig
B-57
Hammer Type
Automatic
Driller
Texas Geo Bore

Notes

Advancement Method
Solid stem augers.

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
Texas Geo Bore
Boring Started
09-25-2025
Boring Completed
09-25-2025

Boring Log No. P-4

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 30.3419° Longitude: -97.5412° Depth (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test			Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	Percent Fines
							Test Type	Compressive Strength (tsf)	Strain (%)			LL-PL-PI	
2		FAT CLAY WITH SAND (CH) , dark brown, very stiff to hard, with calcareous deposits 5.0	5			4.5 tsf (HP)				8.3			
						12-12-16 N=28				11.5		53-19-34	81.3
						4.5 tsf (HP)				13.0			
						15-13-15 N=28				8.7		52-18-34	83.7
		Boring Terminated at 5 Feet											

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).
See [Supporting Information](#) for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig
CME 55

Hammer Type
Automatic

Driller
Texas Geo Bore

Notes

Advancement Method
Solid stem augers.

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
Texas Geo Bore

Boring Started
09-24-2025

Boring Completed
09-24-2025

Boring Log No. P-5

[illegible]

See **Exploration and Testing Procedures** for a description of field and laboratory procedures used and additional data (If any).

See **Supporting Information** for explanation of symbols and abbreviations.
Elevation Reference: Elevations were not determined.

Water Level Observations
No free water observed

Drill Rig B-57

Hammer Type Automatic

Driller
Texas Geo Bore

Logged by
Texas Geo Bore

Boring Started
09-26-2025

Boring Completed
09-26-2025

Notes

Advancement Method

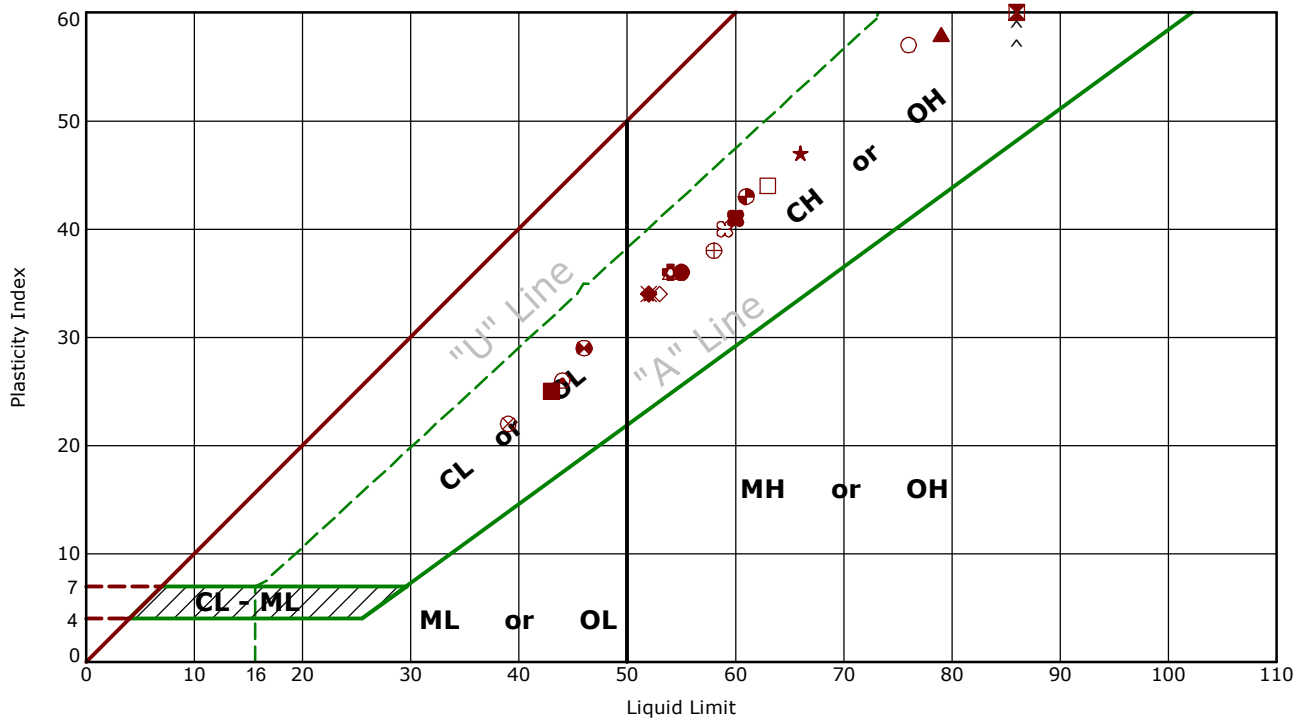
Solid stem augers.

Abandonment Method

Boring backfilled with auger cuttings upon completion.

Atterberg Limit Results

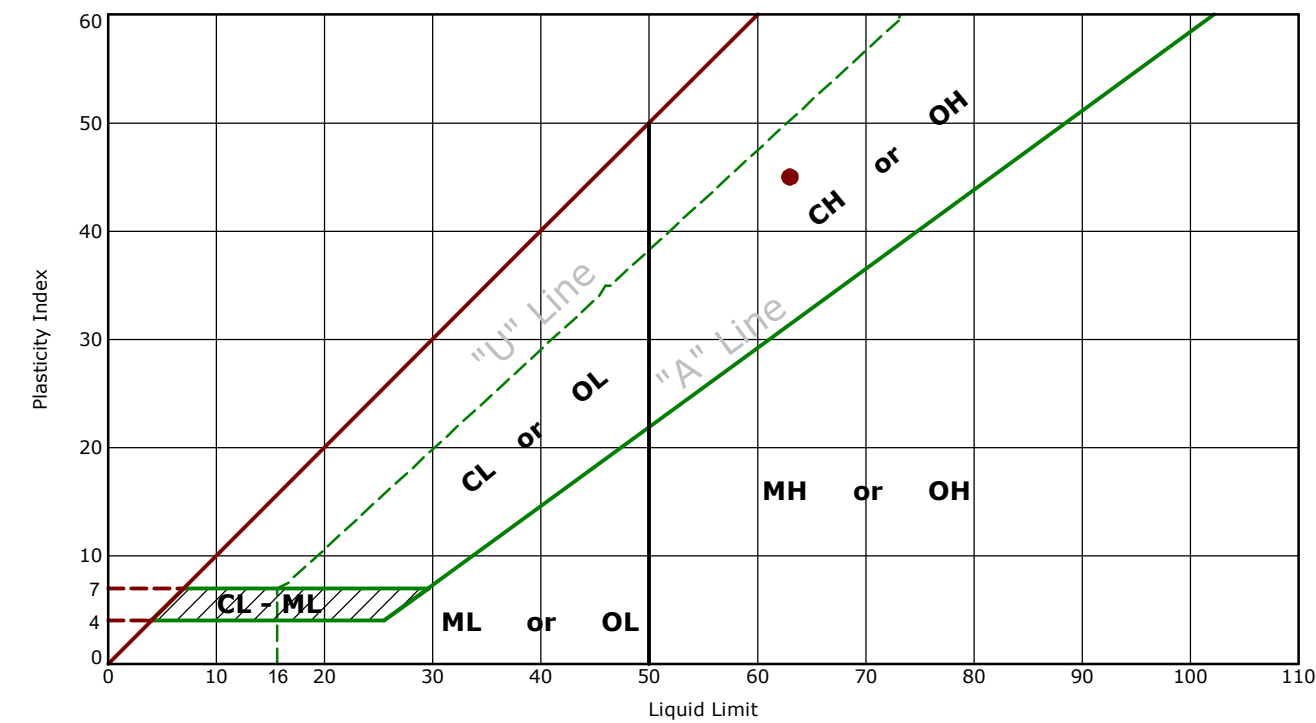
ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	B-1	2 - 4	55	19	36	85.9	CH	FAT CLAY
⊠	B-1	8 - 10	86	19	67	94.1	CH	FAT CLAY
▲	B-1	13 - 15	79	21	58	95.3	CH	FAT CLAY
★	B-2	4 - 6	66	19	47	85.8	CH	FAT CLAY
⊙	B-2	8 - 10	44	18	26	58.2	CL	SANDY LEAN CLAY
⊕	B-3	2 - 4	54	18	36	75.8	CH	FAT CLAY with SAND
○	B-3	13 - 15	76	19	57	97.7	CH	FAT CLAY
△	B-4	4 - 6	54	18	36	82.7	CH	FAT CLAY with SAND
⊗	B-4	8.5 - 10	39	17	22	76.9	CL	LEAN CLAY with SAND
⊕	B-5	2 - 4	58	20	38	77.0	CH	FAT CLAY with SAND
□	B-5	8 - 10	63	19	44	76.5	CH	FAT CLAY with SAND
⊕	P-1	0 - 1.5	46	17	29	27.0	SC	CLAYEY SAND with GRAVEL
⊕	P-1	4 - 5	61	18	43	89.3	CH	FAT CLAY
★	P-2	0 - 2	52	18	34	66.0	CH	SANDY FAT CLAY
⊗	P-2	4 - 5	59	19	40	87.0	CH	FAT CLAY
■	P-3	0 - 1.5	43	18	25	31.9	GC	CLAYEY GRAVEL with SAND
◆	P-3	4 - 5	52	18	34			
◇	P-4	0 - 0.5	53	19	34	81.3	CH	FAT CLAY with SAND
⊗	P-4	3.5 - 5	52	18	34	83.7	CH	FAT CLAY with SAND
⊕	P-5	0 - 2	60	19	41	79.6	CH	FAT CLAY with SAND

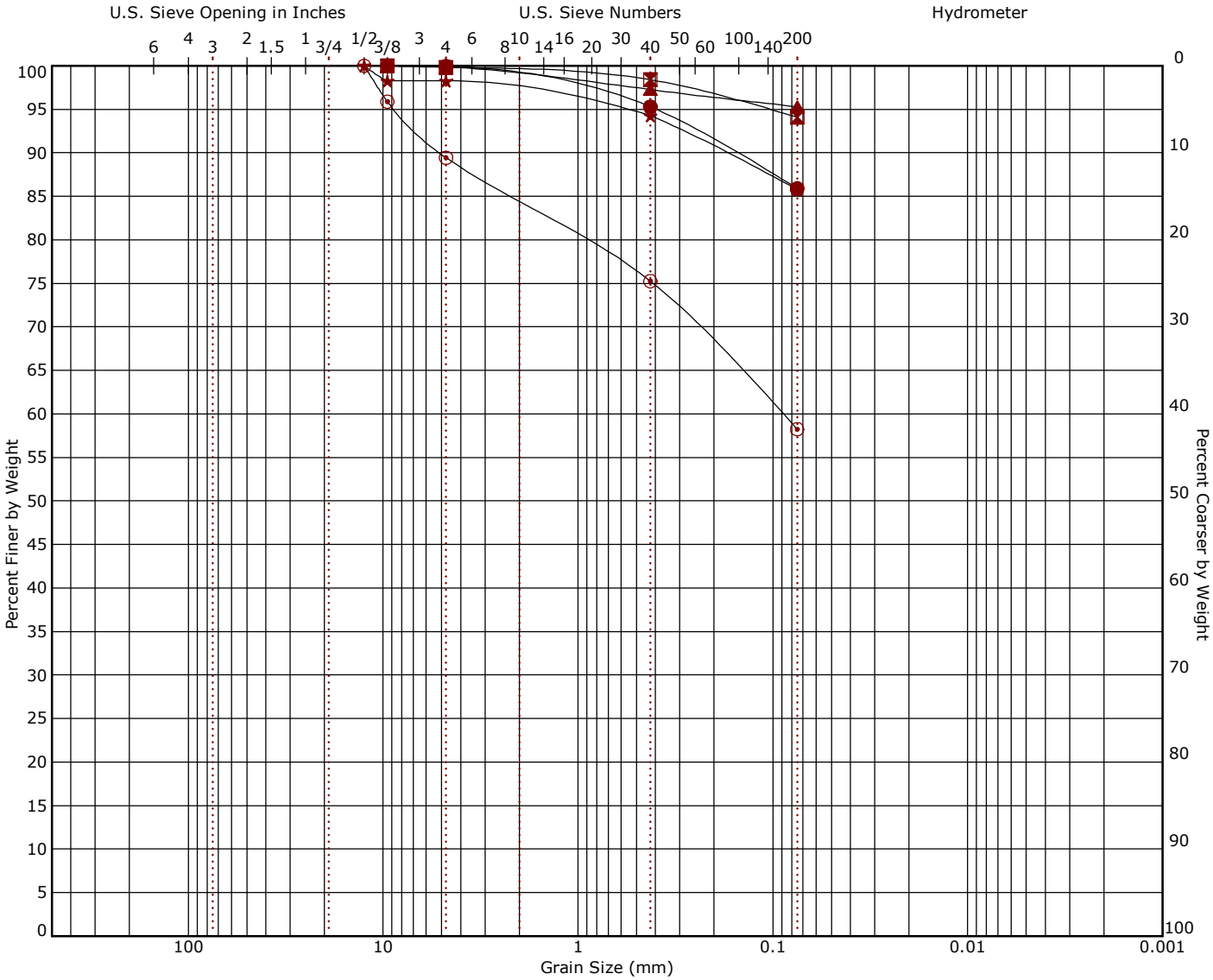
Atterberg Limit Results

ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	P-5	4 - 5	63	18	45	85.3	CH	FAT CLAY

Grain Size Distribution
ASTM D422 / ASTM C136 / AASHTO T27



Cobbles		Gravel		Sand			Silt or Clay						
		coarse	fine	coarse	medium	fine							
Boring ID		Depth (Ft)	Description						LL	PL	PI	Cc	Cu
●	B-1	2 - 4	FAT CLAY						55	19	36		
⊠	B-1	8 - 10	FAT CLAY						86	19	67		
▲	B-1	13 - 15	FAT CLAY						79	21	58		
★	B-2	4 - 6	FAT CLAY						66	19	47		
⊙	B-2	8 - 10	SANDY LEAN CLAY						44	18	26		
Boring ID		Depth (Ft)	D ₁₀₀	D ₆₀	D ₃₀	D ₁₀	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay	
●	B-1	2 - 4	9.5				0.0	0.1	14.1	85.9			
⊠	B-1	8 - 10	9.5				0.0	0.2	5.7	94.1			
▲	B-1	13 - 15	9.5				0.0	0.1	4.6	95.3			
★	B-2	4 - 6	12.5				0.0	1.7	12.5	85.8			
⊙	B-2	8 - 10	12.5	0.09			0.0	10.6	31.2	58.2			

U.S. Sieve Opening in Inches

U.S. Sieve Numbers

Hydrometer

Percent Finer by Weight

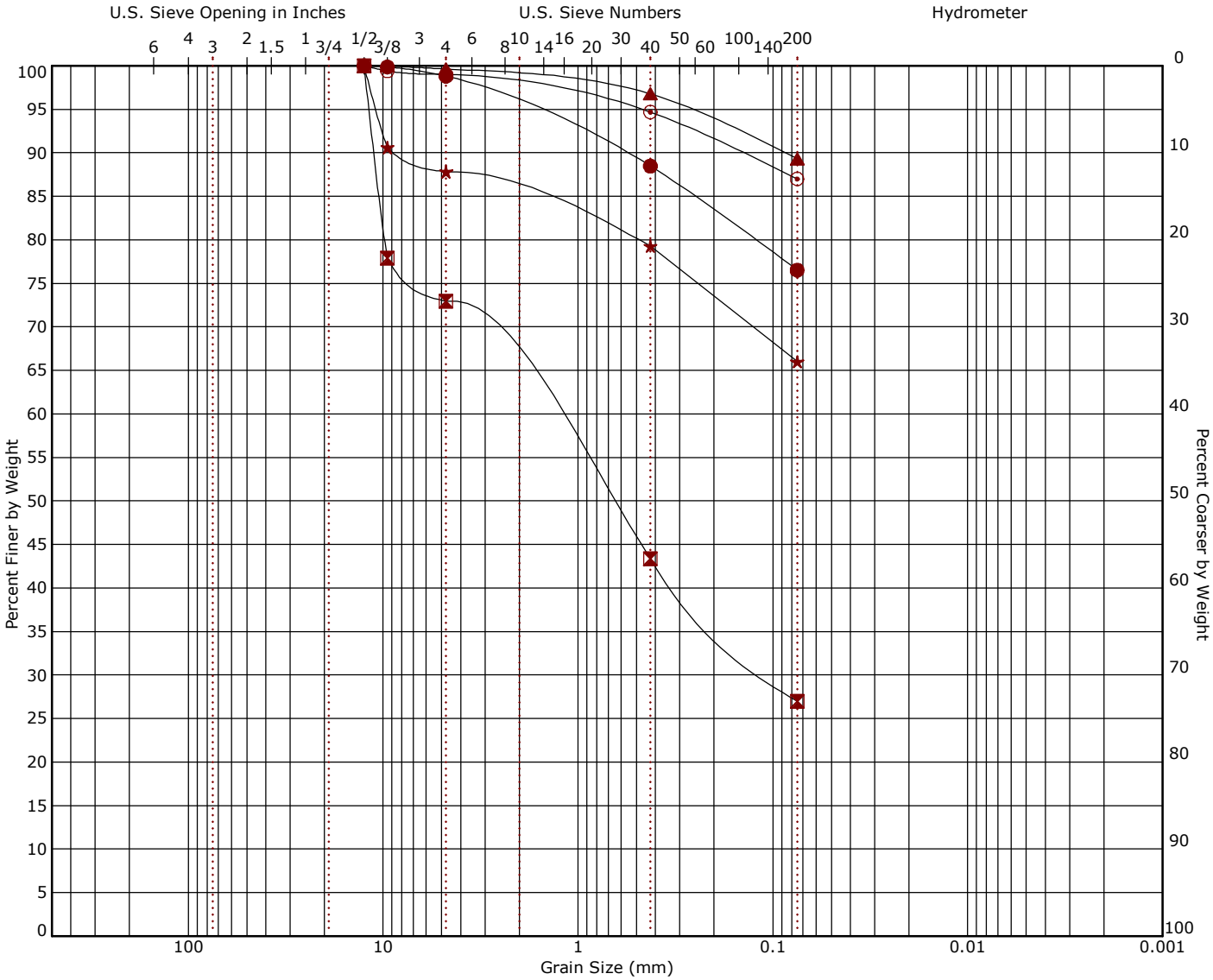
Grain Size (mm)

Percent Coarser by Weight

Grain Size (mm)	Percent Finer (%) - Sample 1 (x)	Percent Finer (%) - Sample 2 (Δ)	Percent Finer (%) - Sample 3 (○)
100	100	100	100
75	100	100	100
60	100	100	100
47.5	100	100	100
37.5	100	100	100
30	100	100	100
25	100	100	100
20	100	100	100
15	100	100	100
12.5	100	100	100
10	100	100	100
7.5	100	100	100
6	100	100	100
4.75	100	100	100
4	100	100	100
3.75	100	100	100
3	100	100	100
2.5	100	100	100
2	100	100	100
1.75	100	100	100
1.5	100	100	100
1.25	100	100	100
1	100	100	100
0.75	100	100	100
0.6	100	100	100
0.5	100	100	100
0.425	100	100	100
0.375	100	100	100
0.3	100	100	100
0.25	100	100	100
0.2	100	100	100
0.175	100	100	100
0.15	100	100	100
0.125	100	100	100
0.106	100	100	100
0.075	100	100	100
0.06	100	100	100
0.05	100	100	100
0.0425	100	100	100
0.0375	100	100	100
0.03	100	100	100
0.025	100	100	100
0.02	100	100	100
0.0175	100	100	100
0.015	100	100	100
0.0125	100	100	100
0.0106	100	100	100
0.0075	100	100	100
0.006	100	100	100
0.005	100	100	100
0.00425	100	100	100
0.00375	100	100	100
0.003	100	100	100
0.0025	100	100	100
0.002	100	100	100
0.00175	100	100	100
0.0015	100	100	100
0.00125	100	100	100
0.00106	100	100	100
0.00075	100	100	100
0.0006	100	100	100
0.0005	100	100	100
0.000425	100	100	100
0.000375	100	100	100
0.0003	100	100	100
0.00025	100	100	100
0.0002	100	100	100
0.000175	100	100	100
0.00015	100	100	100
0.000125	100	100	100
0.000106	100	100	100
0.000075	100	100	100
0.00006	100	100	100
0.00005	100	100	100
0.0000425	100	100	100
0.0000375	100	100	100
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0.000025	100	100	100
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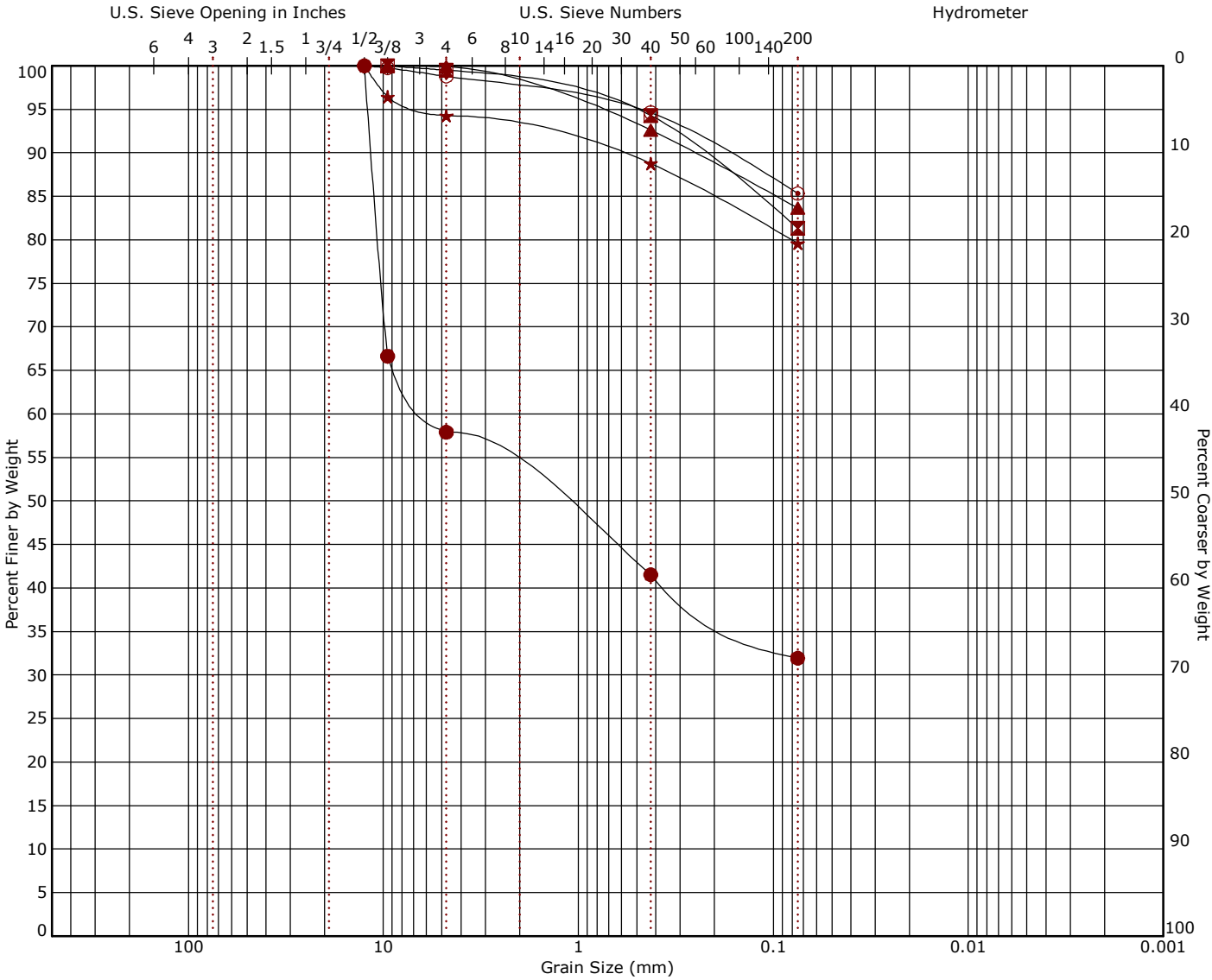
Facilities | Environmental | **Geotechnical** | Materials

Grain Size Distribution
ASTM D422 / ASTM C136 / AASHTO T27



Cobbles		Gravel		Sand			Silt or Clay						
		coarse	fine	coarse	medium	fine							
Boring ID		Depth (Ft)	Description						LL	PL	PI	Cc	Cu
●	B-5	8 - 10	FAT CLAY with SAND						63	19	44		
⊠	P-1	0 - 1.5	CLAYEY SAND with GRAVEL						46	17	29		
▲	P-1	4 - 5	FAT CLAY						61	18	43		
★	P-2	0 - 2	SANDY FAT CLAY						52	18	34		
⊙	P-2	4 - 5	FAT CLAY						59	19	40		
Boring ID		Depth (Ft)	D ₁₀₀	D ₆₀	D ₃₀	D ₁₀	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay	
●	B-5	8 - 10	12.5				0.0	1.2	22.3	76.5			
⊠	P-1	0 - 1.5	12.5	1.651	0.103		0.0	27.1	46.0	27.0			
▲	P-1	4 - 5	9.5				0.0	0.4	10.3	89.3			
★	P-2	0 - 2	12.5				0.0	12.2	21.8	66.0			
⊙	P-2	4 - 5	12.5				0.0	1.0	12.0	87.0			

Grain Size Distribution
ASTM D422 / ASTM C136 / AASHTO T27



Supporting Information

Contents:

General Notes

Unified Soil Classification System

Note: All attachments are one page unless noted above.

General Notes

Sampling	Water Level	Field Tests
 Shelby Tube  Standard Penetration Test	 Water Initially Encountered  Water Level After a Specified Period of Time  Water Level After a Specified Period of Time  Cave In Encountered Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.	N Standard Penetration Test Resistance (Blows/Ft.) (HP) Hand Penetrometer (T) Torvane (DCP) Dynamic Cone Penetrometer UC Unconfined Compressive Strength (PID) Photo-Ionization Detector (OVA) Organic Vapor Analyzer

Descriptive Soil Classification

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

Location And Elevation Notes

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See Exploration and Testing Procedures in the report for the methods used to locate the exploration points for this project. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

Strength Terms

Relative Density of Coarse-Grained Soils (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		Consistency of Fine-Grained Soils (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Relative Density	Standard Penetration or N-Value (Blows/Ft.)	Consistency	Unconfined Compressive Strength Qu (tsf)	Standard Penetration or N-Value (Blows/Ft.)
Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
Medium Dense	10 - 29	Medium Stiff	0.50 to 1.00	5 - 8
Dense	30 - 50	Stiff	1.00 to 2.00	9 - 15
Very Dense	> 50	Very Stiff	2.00 to 4.00	16 - 30
		Hard	> 4.00	> 30

Relevance of Exploration and Laboratory Test Results

Exploration/field results and/or laboratory test data contained within this document are intended for application to the project as described in this document. Use of such exploration/field results and/or laboratory test data should not be used independently of this document.

Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^A				Soil Classification	
				Group Symbol	Group Name ^B
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	Gravels: More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels: Less than 5% fines ^C	$Cu \geq 4$ and $1 \leq Cc \leq 3$ ^E	GW	Well-graded gravel ^F
		Gravels with Fines: More than 12% fines ^C	$Cu < 4$ and/or $[Cc < 1 \text{ or } Cc > 3.0]$ ^E	GP	Poorly graded gravel ^F
			Fines classify as ML or MH	GM	Silty gravel ^{F, G, H}
			Fines classify as CL or CH	GC	Clayey gravel ^{F, G, H}
	Sands: 50% or more of coarse fraction passes No. 4 sieve	Clean Sands: Less than 5% fines ^D	$Cu \geq 6$ and $1 \leq Cc \leq 3$ ^E	SW	Well-graded sand ^I
		Sands with Fines: More than 12% fines ^D	$Cu < 6$ and/or $[Cc < 1 \text{ or } Cc > 3.0]$ ^E	SP	Poorly graded sand ^I
			Fines classify as ML or MH	SM	Silty sand ^{G, H, I}
			Fines classify as CL or CH	SC	Clayey sand ^{G, H, I}
Fine-Grained Soils: 50% or more passes the No. 200 sieve	Silts and Clays: Liquid limit less than 50	Inorganic:	$PI > 7$ and plots above "A" line ^J	CL	Lean clay ^{K, L, M}
			$PI < 4$ or plots below "A" line ^J	ML	Silt ^{K, L, M}
	Silts and Clays: Liquid limit 50 or more	Organic:	$\frac{LL \text{ oven dried}}{LL \text{ not dried}} < 0.75$	OL	Organic clay ^{K, L, M, N}
					Organic silt ^{K, L, M, O}
		Inorganic:	PI plots on or above "A" line	CH	Fat clay ^{K, L, M}
			PI plots below "A" line	MH	Elastic silt ^{K, L, M}
		Organic:	$\frac{LL \text{ oven dried}}{LL \text{ not dried}} < 0.75$	OH	Organic clay ^{K, L, M, P}
					Organic silt ^{K, L, M, Q}
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

^A Based on the material passing the 3-inch (75-mm) sieve.

^B If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

^C Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

^D Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.

$$E \quad Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

^F If soil contains $\geq 15\%$ sand, add "with sand" to group name.

^G If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

^H If fines are organic, add "with organic fines" to group name.

^I If soil contains $\geq 15\%$ gravel, add "with gravel" to group name.

^J If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

^K If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

^L If soil contains $\geq 30\%$ plus No. 200 predominantly sand, add "sandy" to group name.

^M If soil contains $\geq 30\%$ plus No. 200, predominantly gravel, add "gravelly" to group name.

^N $PI \geq 4$ and plots on or above "A" line.

^O $PI < 4$ or plots below "A" line.

^P PI plots on or above "A" line.

^Q PI plots below "A" line.

