

Geotechnical Engineering Report

Stone Hill Town Center Tract 12B

Limestone Commercial Drive

Pflugerville, Texas

December 18, 2017

Terracon Project No. 96175391



Prepared for:

NewQuest Properties

Houston, Texas

Prepared by:

Terracon Consultants, Inc.

Austin, Texas

terracon.com

Terracon

Environmental



Facilities



Geotechnical



Materials

December 18, 2017



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Re: Geotechnical Engineering Report
Stone Hill Town Center Tract 12B
Limestone Commercial Drive
Pflugerville, Texas
Terracon Project No. 96175391

Dear Mr. Pitts:

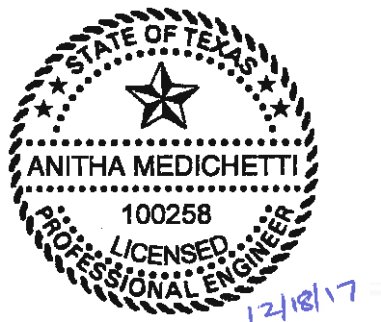
Terracon Consultants, Inc. (Terracon) is pleased to submit our Geotechnical Engineering Report for the proposed construction of retail buildings at Tract 12B of the Stone Hill Town Center in Pflugerville, Texas. We trust that this report is responsive to your project needs. Please contact us if you have any questions or if we can be of further assistance.

We appreciate the opportunity to work with you on this project and look forward to providing additional Geotechnical Engineering and Construction Materials Testing services in the future.

Sincerely,
Terracon Consultants, Inc.
(TBPE Firm Registration: TX F3272)

M. Anitha
Anitha Medichetti, P.E.
Project Engineer

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EXECUTIVE SUMMARY

A geotechnical investigation has been performed for the proposed construction of retail buildings at Tract 12B of the Stone Hill Town Center in Pflugerville, Texas. Two borings, designated B-1 and B-2, were performed to depths of approximately 20 feet below existing grades for the site.

Based on the information obtained from our subsurface exploration, the site can be developed for the proposed project. The following geotechnical considerations were identified:

- Stripping should include existing pavements, surface vegetation, loose topsoil, or other unsuitable materials, as well as the over-excavation required in the building area.
- Proofrolling should be performed to detect weak areas. Weak areas should be removed and replaced with select fill or soils exhibiting similar characteristics as the adjacent in-situ soils.
- A monolithic slab-on-grade foundation system would also be appropriate to support the proposed buildings. Recommendations have been provided in **Section 4.3.1**.
- Building pad subgrade preparation recommendations are provided in **Section 4.4**.
- Pavements in parking areas should be designed with 5 inches of reinforced concrete over moisture conditioned.
- Pavements in light duty to medium duty driveways should be designed with 6 inches of reinforced concrete over moisture conditioned subgrade.

This summary should be used in conjunction with the entire report for design purposes. It should be recognized that details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein. The section titled **GENERAL COMMENTS** should be read for an understanding of the report limitations.

**GEOTECHNICAL ENGINEERING REPORT
STONE HILL TOWN CENTER TRACT 12B
LIMESTONE COMMERCIAL DRIVE
PFLUGERVILLE, TEXAS**

Project No. 96175391

December 18, 2017

1.0 INTRODUCTION

Terracon is pleased to submit our Geotechnical Engineering Report for the proposed construction of retail buildings at Tract 12B of the Stone Hill Town Center in Pflugerville, Texas. This project was authorized by Mr. Corey Pitts with NewQuest Properties, through signature of "Terracon Proposal No. P96175391 dated November 20, 2017" on November 21, 2017.

The purpose of this report is to describe the subsurface conditions observed at the two borings drilled for this study, analyze and evaluate the test data, and provide recommendations with respect to:

- Foundation design and construction for the buildings;
- Seismic site classification according to IBC 2015;
- Pavement design and construction; and
- Site, subgrade, and fill preparation.

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Exhibit A-2, Boring Location Plan, in Appendix A.
Proposed Improvements	The project is planned to include the construction of two single story retail buildings with footprints of about 2,475 square feet and 2,625 square feet. Some adjacent paving may also be planned.
Building construction	Unknown at this time.
Finished floor elevation (FFE)	Unknown at this time but assumed to be within 1 to 2 feet of existing grades.
Maximum loads	Unknown at this time.
Grading	Unknown at this time but assumed to have cuts/fills of less than 2 feet.
Cut and fill slopes	None anticipated.

Item	Description
Free-standing retaining walls	None anticipated.
Below-grade areas	None anticipated.

2.2 Site Location and Description

Item	Description
Location	The project site is located on an existing parking lot along Limestone Commercial Drive within the Stone Hill Town Center development at the southwest quadrant of the intersection of State Highway 130 and Stone Hill Drive in Pflugerville, Texas. (See Exhibit A-1).
Existing improvements	Existing pavements.
Current ground cover	Pavements and landscaped grass.
Existing topography	A topographic plan was not available at the time of this report; however, based on visual observations and Google Earth® software, the site appears to be relatively level. If a professional topographic survey is available, please provide such information to Terracon, along with planned FFE.

3.0 SUBSURFACE CONDITIONS

3.1 Geology

Based on our review of available geological informationⁱ and the recovered samples, the site generally lies within an outcrop of the Austin Group of Upper Cretaceous Age. The Austin Group is generally comprised of tan to gray chalky limestone and marls, and is commonly overlain by a variable thickness of low to high plasticity clayey soils.

3.2 Typical Profile

The borings were drilled through the existing pavements which consisted of about 5½ to 6½ inches of concrete. Based on the results of the borings, subsurface conditions on the project site can be generalized as below.

ⁱ Garner, L.E. and Young, K.P., "Environmental Geology of the Austin Area: An Aid to Urban Planning", Bureau of Economic Geology, the University of Texas at Austin, 1976.

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Description	Approximate Depth Range of Stratum (feet)	Material Encountered	Consistency/Density	Range of Plasticity Indices (PI's) (Average PI)
Stratum I	0.5 to 5	<u>Fill – Tan to Light Gray</u> Lean Clay (CL) to Lean Clay with Gravel (CL)	Stiff to Hard	21 to 28 (25)
Stratum II	4 to 8.5	<u>Dark Brown to Brown</u> Fat Clay (CH)	Very Stiff to Hard	40
Stratum III	6 to 20	Limestone (Austin Group)	-	-

Conditions encountered at each boring location are indicated on the individual boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil types; in-situ, the transition between materials may be gradual. Details for each of the borings can be found on the boring logs in Appendix A.

3.3 Groundwater

The borings were dry augered to depths of about 6.5 to 10 feet below existing grades, then drilled to the completion depths of 20 feet using air rotary drilling techniques to facilitate rock coring. Groundwater was not encountered in any of the borings during dry augering.

Although not observed in our geotechnical field program, groundwater at the site may be observed in the form of seepage traveling along pervious seams/fissures in the soil, along the soil/limestone interface, and/or in fissures/fractures in the limestone. During periods of wet weather, zones of seepage may appear and isolated zones of “perched water” may become trapped (or confined) by zones possessing a low permeability. Groundwater conditions at the site could fluctuate as a result of seasonal and climatic variations. Please note that it often takes several hours/days for water to accumulate in a borehole, and geotechnical borings are relatively fast, short-term boreholes that are backfilled the same day. Long-term groundwater readings can more accurately be achieved using monitoring wells. Please contact us if this is desired. Groundwater conditions should be evaluated immediately prior to construction.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

The following recommendations are based upon the data obtained in our field and laboratory programs, project information provided to us, and on our experience with similar subsurface and site conditions.

4.1 Geotechnical Considerations

Based on our test borings, moderately to moderately highly expansive soils that exhibit a potential for volumetric change during moisture variations are present near the ground surface. The subgrade soils at this site may experience significant expansion and contraction due to changes in moisture content. The soils exhibit a Potential Vertical Rise (PVR) of up to about 2¼ inches, as estimated by the Texas Department of Transportation (TxDOT) Method TEX-124-E.

4.2 Earthwork

Construction areas should be stripped of existing pavements, utilities, and other unsuitable material. Any utilities leading into the planned excavation area should be completely removed. If this is not feasible, then the abandoned utility piping should be filled with flowable backfill and plugged such that it does not become a conduit for water flow towards the excavation.

Once final subgrade elevations have been achieved (including the over-excavation required for building pad), the exposed subgrade should be carefully proofrolled with a 20-ton pneumatic roller or a fully-loaded dump truck to detect weak zones in the subgrade. Weak areas detected during proofrolling, as well as zones containing debris or organics and voids resulting from removal of boulders, etc. should be removed and replaced with soils exhibiting similar classification, moisture content, and density as the adjacent in-situ soils. Proper site drainage should be maintained during construction so that ponding of surface runoff does not occur and causes construction delays and/or inhibit site access.

Subsequent to proofrolling, and just prior to placement of fill, the exposed subgrade within the construction areas should be evaluated for moisture and density. If the moisture and/or density requirements do not meet the criteria described in the table below, the subgrade should be scarified to a minimum depth of 6 inches, moisture adjusted and compacted as per **Section 4.2.1**. Select fill and on-site soils should meet the following criteria.

Fill Type ¹	USCS Classification	Acceptable Location For Placement
Imported Select Fill ^{2,3}	CL, SC, and/or GC (5≤PI≤20)	Select fill material should be used for all grade adjustments within the building limits.
General Fill ⁴	CH, CL	General fill is for use within other non-structural areas of the site. If imported, paving fill should exhibit a maximum PI of 30 or less.

^{1.} Prior to any filling operations, samples of proposed borrow and/or on-site materials should be obtained for laboratory testing. The tests will provide a basis for evaluation of fill compaction by in-place density testing. A qualified soil technician should perform sufficient in-place density tests during the filling operations to evaluate that proper levels of compaction, including dry unit weight and moisture content, are being attained.

2. Imported select fill should consist of crushed limestone base material meeting the requirements of the Texas Department of Transportation (TxDOT) Standard Specifications Item 247, Type A, Grade 3, or a low-plasticity clayey soil with a plasticity index between 5 and 20 percent, a maximum gravel content (percentage retained on No. 4 sieve) of 40 percent, and rocks no larger than 4 inches in their largest dimension. As an alternative, a low-plasticity granular fill material which does not meet these specifications may be utilized only if approved by Terracon.
3. Based on the laboratory testing performed during this exploration, the 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. Select fill will need to be imported.
4. Excavated on-site soils, if free of organics, debris, and rocks larger than 4 inches, may be considered for use as fill in pavement, landscape, ponds, or other general areas. If paving fills are imported from another location, the maximum PI allowed for paving fill is 30.

4.2.1 Compaction Requirements

Item	Description
Fill Lift Thickness	The fill soils should be placed on prepared surfaces in lifts not to exceed 8 inches loose measure, with compacted thickness not to exceed 6 inches.
Moisture/Density Control	Fills should be placed in uniform lifts compacted to at least 95 percent of the Standard Proctor (ASTM D 698) maximum dry density. Stratum I soils with $PI's \geq 25$ and Stratum II dark brown to brown soils should be moisture conditioned to between 0 and +4 of optimum moisture content. Select fill and Stratum I soils with $PI's < 25$ should be moisture conditioned to between -3 and +3 of optimum moisture content.

4.2.2 Grading and Drainage

The performance of the foundation system for 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 building foundations may cause significant moisture variations in the soils adjacent to the foundations, thus increasing the potential for structural distress.

Positive drainage away from the structures must be provided during construction and maintained through the life of the proposed project. Infiltration of water into excavations should be prevented during construction. It is important that foundation soils are not allowed to become wetted. All grades must provide effective drainage away from the buildings during and after construction. Exposed (unpaved) ground should be sloped at a minimum 5 percent away from the buildings for at least 10 feet beyond the perimeter of the buildings. Water permitted to pond next to the buildings can result in greater soil movements than those discussed in this report. Estimated movements described in this report are based on effective drainage for the life of the structures and cannot be relied upon if effective drainage is not maintained.

Roof runoff and surface drainage should be collected and discharged away from the structures to prevent wetting of the foundation soils. Roof gutters should be installed and connected to downspouts and pipes directing roof runoff at least 10 feet away from the buildings, or discharged on to positively sloped pavements. Sprinkler mains and spray heads should be located at least 5 feet away from the buildings such that they cannot become a potential point source of water directly adjacent to the buildings. In addition, the owner and/or builder should be made aware that placing large bushes and trees adjacent to the structures may cause significant moisture variations in the soils underlying the structures. Watering of vegetation should be performed in a timely and controlled manner and prolonged watering should be 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.

4.2.3 Temporary Groundwater Control

Although not observed during our drilling operations, the presence of groundwater should be anticipated during construction, especially after periods of wet weather. 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.

4.3 Foundation System

Based upon the subsurface conditions observed during this exploration and anticipated loading, a monolithic slab-on-grade foundation system would be appropriate to support the proposed buildings. Recommendations for this type of foundation systems are presented below.

4.3.1 Design Recommendations – Monolithic Slab-On-Grade

A monolithic slab-on-grade foundation system (either conventionally reinforced or post-tensioned) would be appropriate to support the proposed buildings provided subgrade preparation as described in **Section 4.4 – Building Pad Preparation** is followed. The slab foundation design parameters presented in the tables below are based on the criteria published by the Building Research Advisory Board (BRAB), the Prestressed Concrete Institute (PCI), the Wire Reinforcement Institute (WRI), and the Post-Tensioning Institute (PTI) 3rd Edition. 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, WRI, and PTI design manuals.

Conventional Slab and Beam System Parameters	
Minimum embedment of grade beams below final grade¹	18 inches
Bearing Pressures (allowable)²	Net dead plus sustained live load – 1,700 psf

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	Net total load – 2,500 psf
Subgrade Modulus (k) ³	150 pci
Approximate Potential Vertical Rise (PVR)	2¼ inches (About 1 inch) ^{4,5}

1. 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.
2. Grade beams should bear on compacted select fill soils.
3. Several design methods use the modulus of subgrade reaction, k, to account for soil properties in design of flat, floor slabs. The modulus of subgrade reaction is a spring constant that depends on the kind of soil, the degree of compaction, and the moisture content. Based on our recommendations provided in **Section 4.4**, the above indicated subgrade modulus can be used for design of a flat, grade-supported floor slab.
4. 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.
5. The building subgrade should be properly prepared as described in **Section 4.4** below.

BRAB/WRI/PCI Parameters			
Design Plasticity Index (PI) ¹	BRAB/ WRI/PCI	Unprepared Subgrade	31
		Prepared Subgrade (as in Section 4.4)	22
Climatic Rating (C _w)			19
Unconfined Compressive Strength			1.0 tsf
Soil Support Index (C) for BRAB	Unprepared Subgrade		0.83
	Prepared Subgrade (as in Section 4.4)		0.93

1. The BRAB effective PI is equal to the near surface PI if that PI is greater than all of the PI values in the upper 15 feet. If the near-surface PI is not highest (i.e., after the building pad is prepared), then the effective PI is the weighted average of the upper 15 feet. The WRI/PCI effective PI is always the weighted average of the PI values in the upper 15 feet.

Post Tensioning Institute (PTI) Parameters¹	
Depth of Seasonal Moisture Change²	Up to 8.5 feet (or shallower at top of limestone)
Plasticity Index ³	Select Fill – 20
	Stratum I Soils – 21 to 28 (average ~ 25)
	Stratum II Soils – 40
Percent Finer than 2 Microns ³	Select Fill – 25 (estimated)
	Stratum I Soils – 35 (estimated)
	Stratum II Soils – 57 (measured)
Soil Fabric Factor	1.0

Approximate Thornthwaite Moisture Index		-12
Estimated Constant Soil Suction		3.5 pF
Range of Soil Suction		3.0 to 4.5 pF
Edge Moisture Variation Distance, e_m ^{4, 5}	Center Lift	7.5 feet (8.5 feet) ⁶
	Edge Lift	4 feet (4.4 feet) ⁶
Differential Soil Movement, y_m (Center Lift) ⁵	Center Lift	1.4 inches (1 inch) ⁶
	Edge Lift	2.1 inches (1.2 inches) ⁶

1. Based on our analysis of the field and laboratory data, design parameters were computed using the Addendum to the 2004 Post-Tensioning Institute (PTI) methodⁱⁱ for slab-on-grade design and the subsequent Errata to the Addendum approved by the PTI Slab-on-Grade Committee on February 7, 2008.
2. 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, changing seasonally, with annual climate conditions, drainage patterns, ground cover, and vegetation (trees and shrubs).
3. The plasticity index and the clay mineral percentage are values of the soil that can be estimated by laboratory tests, and, although variable from location to location, remain relatively constant with time.
4. The maximum moisture variation distance is termed the edge moisture variation distance, e_m , and is an important factor governing the design of post-tensioned floor slabs. The e_m is related to percent fine clay and climatic conditions as well as other parameters, such as soil fabric factor and unsaturated diffusion coefficient.
5. The differential movements, y_m , and edge moisture variation distances, e_m , were calculated by modeling soil profiles using the commercial software program VOLFLO as recommended by the PTI manual.
6. Values in parentheses may be used provided subgrade preparation is implemented as described in **Section 4.4** below.

When considering a grade-supported floor slab, the design of the floor slab involves the interaction of the floor slab and the soil support system to resist moments and shears induced by the applied structural loads. Floor slabs can be thickened, or stiffening beams can be added, to aid in resisting moments and shears. The Stratum II fat clay soils can be a concern at this site. We recommend that the potential effects of these soils be reduced by following the recommendations presented in **Section 4.4 – Building Pad Preparation**. Joints should be constructed at regular intervals as recommended by the American Concrete Institute (ACI) to help control the location of any cracking.

For a slab foundation system designed and constructed as recommended in this report, post construction settlements should be less than 1 inch. Settlement response of a select fill supported slab is influenced more by the quality of construction than by soil-structure

ii. Post-Tensioning Institute, "Addendum No. 1 to the 3rd Edition of the Design of Post-Tensioned Slabs-on-Ground", Post-Tensioning Institute, Phoenix, AZ, May 2007.

interaction. Therefore, it is essential that the recommendations for foundation construction be strictly followed during the construction phases of the building 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.

4.3.2 Foundation Construction Considerations

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 and the grade beam excavation completed with a smooth-mouthed bucket or by hand labor. Debris in the bottom of the excavation should be removed prior to steel placement. The foundation excavation should be sloped sufficiently to create internal sumps for runoff collection and removal. If surface runoff water or groundwater seepage in excess of one inch accumulates at the bottom of the foundation excavation, it should be collected, removed, and not allowed to adversely affect the quality of the bearing surface.

If utilized, the post-tensioned slab-on-grade construction technique should be carefully monitored by qualified personnel. The sophistication of this construction procedure requires careful attention to details such as concrete integrity and anchorages, along with tendon spacing, support, covering, and stressing. Poor construction could result in a non-functional slab foundation system.

4.3.2.1 Foundation Construction Monitoring

The performance of the foundation system for the proposed structures will be highly dependent upon the quality of construction. Thus, we recommend that the foundation installation be monitored by Terracon to identify the proper bearing strata and depths and to help evaluate foundation construction. We would be pleased to develop a plan for foundation monitoring to be incorporated in the overall quality control program.

4.4 Building Pad Preparation

Information about existing and proposed grades and FFE for the proposed buildings has not been provided to Terracon at this time. However, we assume that the planned FFE will be within 2 to 3 feet of the existing grades. If this assumption is incorrect, Terracon should be notified to review and modify and/or verify recommendations in writing.

For the proposed buildings, the on-site Stratum I/II soils should be excavated and removed to a depth of at least 3½ feet below existing grades and replaced with properly compacted select fill material. The above subgrade preparation recommendations should reduce movements to approximately 1 inch.

Prior to placement and compaction of select fill, the soil subgrade should be thoroughly proofrolled with a 20-ton roller to detect weak zones in the existing fill subgrade as discussed in **Section 4.2 – Earthwork** section of this report. The above subgrade preparation recommendations should be applied to an area extending a minimum of 5 feet outside of building and canopy areas, including attached walkways and any other architectural members. Material and placement requirements for select fill, as well as other subgrade preparation recommendations, are presented in **Section 4.2 – Earthwork** subsection. We suggest the use of crushed limestone base as the select fill material within the upper 6 inches of the fill pad from a standpoint of construction access during wet weather, as well as from a standpoint of floor slab support.

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

We should also note that 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 floor slab occurs (such as a leaking utility line or water seepage from outside the building resulting from poor drainage), movements in isolated floor slab areas could potentially be in excess of those indicated in this report.

4.5 Seismic Design Information

Code Used	Seismic Design Category	Site Class Designation
2015 International Building Code (IBC)	A ¹	B ²

1 Per IBC 2015 Section 1613.3.1.

Per IBC 2015, $S_s=0.064$; $S_1=0.035$; $S_{M1}=0.064$; $S_{M1}=0.035$; $S_{D5}=0.043$; $S_{D1}=0.023$

2 Per IBC 2015 Section 1613.3.2. The IBC requires a site soil profile determination extending a depth of 100 feet for seismic site classification. The current scope does not include the required 100 foot soil profile determination. Borings extended to a maximum depth of approximately 20 feet and this seismic site class definition assumes materials with similar characteristics are below the maximum depth of the subsurface exploration. Additional exploration to deeper depths would be required to confirm the conditions below the current depth of exploration. Alternatively, a geophysical exploration could be utilized in order to attempt to justify a higher seismic class.

4.6 Pavements

Detailed traffic loads and frequencies were not available for the pavements. However, we anticipate that traffic will consist primarily of passenger vehicles in the parking areas (assumed as the light duty pavements) and passenger vehicles combined with occasional garbage and delivery trucks in driveways (assumed as light-medium duty pavements). If heavier traffic loading is expected or other traffic information is available, Terracon should be provided with the information and allowed to review the pavement sections provided herein. Tabulated below are the assumed traffic frequencies and loads used to design pavement sections for this project.

Pavement Type	Traffic Design Index	Description
Parking Areas (Passenger Vehicles Only):	DI-1	Light traffic – Few vehicles heavier than passenger cars, panel, and pick-up trucks; no regular use by heavily loaded two-axle trucks or lightly loaded larger vehicles. (EAL ¹ < 5)
Driveways (Light-Medium Duty), Fire Lanes ² and Dumpster Enclosures:	DI-2	Light to medium traffic – Similar to DI-1, including not over 50 heavily loaded two-axle trucks or lightly loaded larger vehicles per day. No regular use by heavily loaded trucks with three or more axles. (EAL = 6 – 20)

1. Equivalent daily 18-kip single axle load applications.
2. For Fire Lanes to withstand the occasional HS-20 loading of 32,000 pounds per axle and 80,000-pound gross truck weight, use DI-2 pavements or thicker.

Listed below are pavement component thicknesses which may be used as a guide for pavement systems at the site assuming that the Stratum I soils will generally act as the pavement subgrade, and that the pavement subgrade is prepared as outlined in the “Moisture Conditioned Subgrade” portions of this section and in accordance with our general recommendations for site preparation in **Section 4.2 – Earthwork**. We should note that these systems were derived based on general characterization of the subgrade. No specific testing (such as CBR, resilient modulus tests, etc.) was performed for this project to evaluate the support characteristics of the subgrade.

RIGID PAVEMENT SYSTEM

Component	Material Thickness (Inches)	
	DI-1	DI-2
Reinforced Concrete	5.0	6.0
Moisture Conditioned Subgrade	6.0	6.0

Reinforcing Steel: #3 bars spaced at 18 inches on centers in both directions.

Control Joint Spacing: In accordance with ACI 330R-08, control joints should be spaced no greater than 12.5 feet for 5-inch thick concrete and no greater than 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 joints should be at least $\frac{1}{4}$ of the slab thickness.

Expansion Joint Spacing: ACI-330R-8 indicates that regularly spaced expansion joints are not needed when control joints are properly spaced. Their use should be limited to isolating fixed objects (such as light poles, landscape islands, and buildings) within or abutting the pavement. Therefore, the installation of expansion joints for routine use 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. At a minimum, an expansion joint (used as a construction joint) should be placed at the termination of each day's concrete placement. These joints should be fully sealed.

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.

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

Reinforced Portland Cement Concrete (PCC) – Concrete should be designed to exhibit a minimum 28-day compressive strength of 3,500 psi.

Moisture Conditioned Subgrade – The soil subgrade should be scarified to a depth of 6 inches, moisture conditioned, and recompacted to at least 95 percent of the maximum dry density as determined by ASTM D 698. On-site soils should be moisture conditioned and compacted as detailed in **Section 4.2.1 – Compaction Requirements**. Care should be taken such that the subgrade does not dry out or become saturated prior to pavement construction. The pavement subgrade should be thoroughly proofrolled with a rubber-tired vehicle (fully loaded water or dump truck) immediately prior placement of base material. Particular attention should be paid to areas along curbs, above utility trenches, and adjacent to landscape islands, manholes, and storm drain inlets. Placement of the moisture conditioned subgrade should extend at least 18 inches behind curbs or pavement edges.

Pavement design methods 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. The support characteristics of the subgrade for pavement design do not account for shrink/swell movements of an expansive clay subgrade such as the Stratum II fat clay soils

encountered 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 perimeter drainage should be provided so that infiltration of surface water from unpaved areas surrounding the pavement is minimized.

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 proofrolling of pavement areas using a fully-loaded water truck or dump truck (rubber-wheeled vehicle that can impart point wheel loads) should be performed no more than 36 hours prior to surface paving. Any problematic areas should be reworked and compacted at that time.

Long-term pavement performance will be dependent upon several factors, including maintaining subgrade moisture levels and providing for preventive maintenance. The following recommendations should be considered at a minimum:

- Adjacent site grading at a minimum 2% grade away from the pavements;
- A minimum $\frac{1}{4}$ inch per foot slope on the pavement surface to promote proper surface drainage;
- Install joint sealant and seal cracks immediately;
- Placing compacted, low permeability clay backfill against the exterior side of curb and gutter; and,
- Placing curb and gutters through any base material and directly on subgrade soils.

Preventive maintenance should be planned and provided for through an on-going pavement management program. These activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Preventive maintenance consists of both localized maintenance (e.g. crack and joint sealing and patching) and global maintenance. This is usually the first priority when implementing a planned pavement maintenance program and provides the highest return on investment for pavements. Prior to implementing any maintenance, additional engineering observation is recommended to determine the type and extent of preventive maintenance.

5.0 GENERAL COMMENTS

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon also should be retained to provide testing and observation during excavation, grading, foundation installation, and other construction phases of the project.

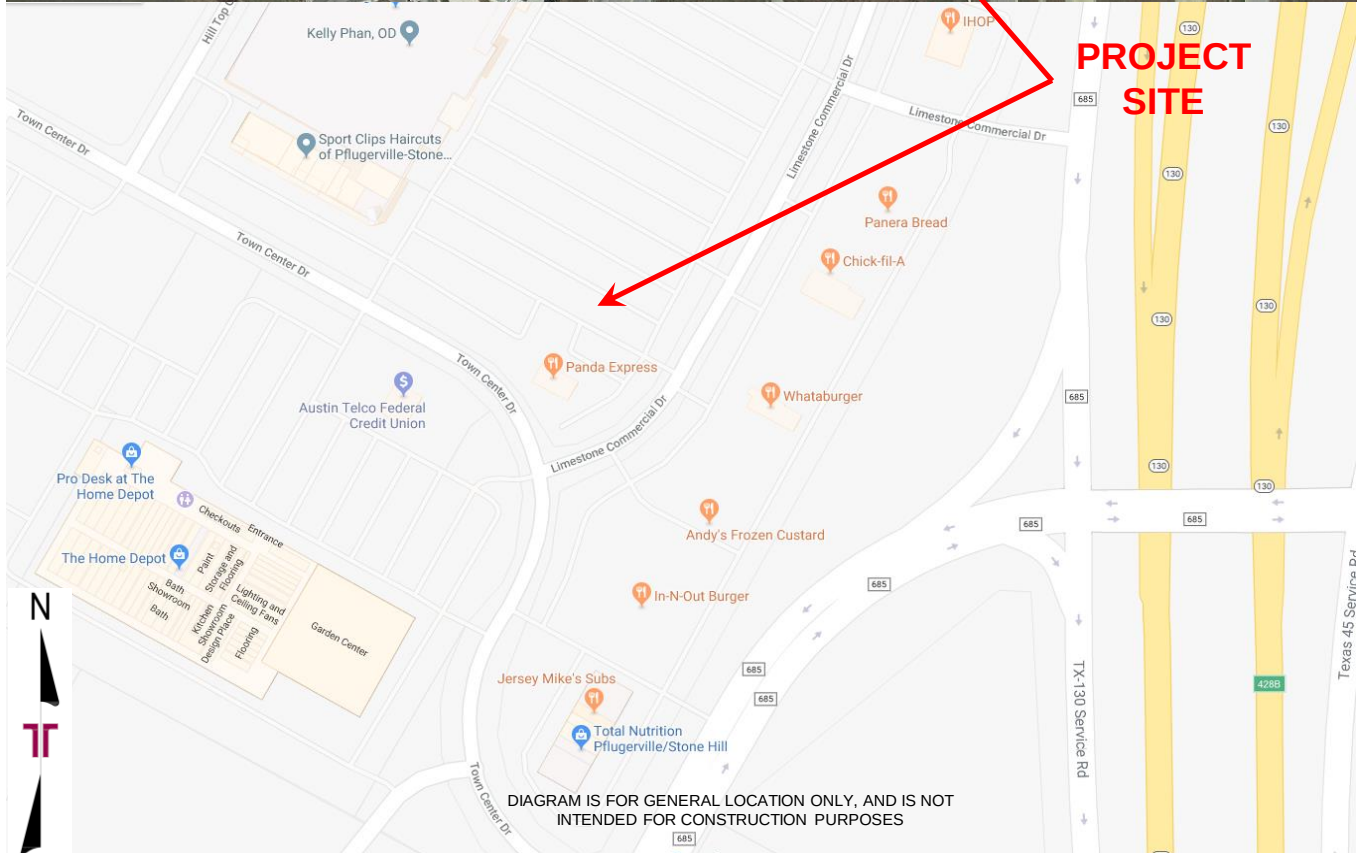
The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project 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.

For any excavation construction activities at this site, all Occupational Safety and Health Administration (OSHA) guidelines and directives should be followed by the Contractor during construction to provide a safe working environment. In regards to worker safety, OSHA Safety and Health Standards require the protection of workers from excavation instability in trench situations.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION



Project Mgr:	AM
Drawn By:	AM
Checked By:	BSM
Approved By:	BSM
Project No.	96175391
Scale:	N.T.S
File Name:	SITE PLAN
Date:	12/14/2017

Terracon
Consulting Engineers & Scientists
5307 Industrial Oaks Blvd, Suite 160, Austin, Texas 78735
PH. (512) 442-1122 FAX. (512) 442-1181

SITE AERIAL AND LOCATION PLAN

Stone Hill Town Center Tract 12B
Limestone Commercial Drive
Pflugerville, Texas

EXHIBIT

A-1



DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT
INTENDED FOR CONSTRUCTION PURPOSES



Boring Locations

Project Mgr:	AM
Drawn By:	AM
Checked By:	BSM
Approved By:	BSM
Project No.	96175391
Scale:	N.T.S
File Name:	SITE PLAN
Date:	12/14/2017

Terracon
Consulting Engineers & Scientists
5307 Industrial Oaks Blvd, Suite 160, Austin, Texas 78735
PH. (512) 442-1122 FAX. (512) 442-1181

BORING LOCATION PLAN
Stone Hill Town Center Tract 12B
Limestone Commercial Drive
Pflugerville, Texas

EXHIBIT
A-2

Geotechnical Engineering Report

Stone Hill Town Center Tract 12B ■ Pflugerville, Texas

December 18, 2017 ■ Terracon Project No. 96175391



Field Exploration Description

Subsurface conditions were evaluated by drilling two borings (B-1 and B-2) to depths of about 20 feet across the site. The borings were drilled with truck-mounted rotary drilling equipment at the approximate locations shown on Exhibit A-2 of Appendix A. Boring depths were measured from the existing ground surface at the time of our field activities. The boring coordinates were located in the field through the use of a Garmin handheld GPS unit. The coordinates are presented on the top of the boring logs. Elevations were approximated based on Google Earth® software. These estimated surface elevations should be updated once the Client or Civil Engineer has a professional topographic site survey. Please provide such information to Terracon for boring log revisions.

The boring logs, which include the subsurface descriptions, types of sampling used, and additional field data for this study, are presented on Exhibits A-4 and A-5 of Appendix A. Criteria defining terms, abbreviations and descriptions used on the boring logs are presented in Appendix C.

Soil samples were recovered using thin-walled, open-tube sampler (Shelby tubes). A pocket penetrometer test was performed on the samples of cohesive soils in the field to serve as a general measure of consistency.

Soils and upper portion of the limestone was sampled by means of the Standard Penetration Test (SPT). This test consists of measuring the number of blows required for a 140-pound hammer free falling 30 inches to drive a standard split-spoon sampler 12 inches into the subsurface material after being seated 6 inches. This blow count or SPT "N" value is used to estimate the engineering properties of the stratum. For this project, a CME automatic SPT hammer was used to advance the split-barrel sampler in the borings. A greater efficiency is achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. Published correlations between SPT value and soil properties are based on the lower efficiency cathead and rope method. This higher efficiency affects the standard penetration resistance blow count (N) value by increasing the penetration per hammer blow in comparison to the N-value that would be expected using the cathead and rope method.

Once competent rock was encountered, the borings were advanced with Nx coring equipment. Visual classifications of all of the samples were performed in the field and percentages of Recovery and Rock Quality Designation (RQD) were calculated from recovered rock cores. Recovery is defined as the percentage of core recovered as a function of the length of core run drilled. The RQD is a modified measurement of core recovery which indirectly takes into account fractures and/or softening in the rock mass by summing up only pieces of sound core which are 4 inches or greater in length as a percentage of the total core run.

Samples were removed from the samplers in the field, visually classified, and appropriately sealed in sample containers to preserve the in-situ moisture contents. Samples were then placed in core boxes for transportation to our laboratory in Austin, Texas.

BORING LOG NO. B-1

Page 1 of 1

PROJECT: Stone Hill Town Center Tract 12B

CLIENT: NewQuest Properties
Houston, TX

SITE: Limestone Commercial Drive
Pflugerville, TX

GRAPHIC LOG	LOCATION See Exhibit A-2 Latitude: 30.4657° Longitude: -97.5976° Approximate Surface Elev: 743 (Ft.) +/-	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	RECOVERY (%) RQD (%)	STRENGTH TEST			WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
							TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)				
	PAVEMENT 6.5" Concrete	0.5											
	FILL, LEAN CLAY WITH GRAVEL (CL) Very stiff to hard, tan to light gray, with limestone fragments	4.0			4.5 tsf (HP)					16	106	37-16-21	84
	FAT CLAY (CH) Very stiff to hard, dark brown to brown, with limestone fragments	8.5			2.25 tsf (HP)		UC	2.36	10.9	19	108	60-20-40	92
					4.5 tsf (HP)								
	LIMESTONE (Austin Group) Tan, with clay seams -weathered to 10 feet -moderately fractured, weak rock 10 to 20 feet -gray below 15 feet	20.0			50/6"								
						88 45	UC	289.50		9	125		
						100 67							
	Boring Terminated at 20 Feet	20											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 10 feet; Air Rotary 10 to 20 feet

See Exhibit A-3 for description of field procedures.

Notes:

Abandonment Method:
Boring backfilled with bentonite
Surface capped with concrete

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
5307 Industrial Oaks Blvd Ste 160
Austin, TX

Boring Started: 11-30-2017

Boring Completed: 11-30-2017

Drill Rig: CME 45

Driller: Austin Geo-Logic

Project No.: 96175391

Exhibit: A-4

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 96175391 STONE HILL TOWN C.G.P.J. TERRACON DATATEMPLATE.GDT 12/18/17

BORING LOG NO. B-2

Page 1 of 1

PROJECT: Stone Hill Town Center Tract 12B

CLIENT: NewQuest Properties
Houston, TX

SITE: Limestone Commercial Drive
Pflugerville, TX

GRAPHIC LOG	LOCATION See Exhibit A-2 Latitude: 30.4661° Longitude: -97.5976° Approximate Surface Elev. 744 (Ft.) +/-	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	RECOVERY (%) RQD (%)	STRENGTH TEST			WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
							TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)				
	DEPTH ELEVATION (Ft.)												
	0.5 PAVEMENT 743.5+/-												
	5.5" Concrete				9-11-12 N=23					16		43-17-26	94
	FILL, LEAN CLAY (CL)				2.25 tsf (HP)								
	Stiff to very stiff, tan to light gray, with limestone fragments				1.25 tsf (HP)					13	95	45-17-28	
	6.0 LIMESTONE (Austin Group) 738+/-				50/6"								
	Gray, weak rock					93 79	UC	273.64		8	129		
	-weathered, with clay seams to 6.5 feet					100 100							
						100 83	UC	269.02		11	130		
	20.0 Boring Terminated at 20 Feet 724+/-	20											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 6.5 feet; Air Rotary 6.5 to 20 feet

See Exhibit A-3 for description of field procedures.

Notes:

Abandonment Method:
Boring backfilled with bentonite
Surface capped with concrete

See Appendix B for description of laboratory
procedures and additional data (if any).

See Appendix C for explanation of symbols and
abbreviations.

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
5307 Industrial Oaks Blvd Ste 160
Austin, TX

Boring Started: 11-30-2017

Boring Completed: 11-30-2017

Drill Rig: CME 45

Driller: Austin Geo-Logic

Project No.: 96175391

Exhibit: A-5

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 96175391 STONE HILL TOWN C.G.P.J. TERRACON DATATEMPLATE.GDT 12/18/17

APPENDIX B

LABORATORY TESTING

Geotechnical Engineering Report

Stone Hill Town Center Tract 12B ■ Pflugerville, Texas
December 18, 2017 ■ Terracon Project No. 96175391



Laboratory Testing

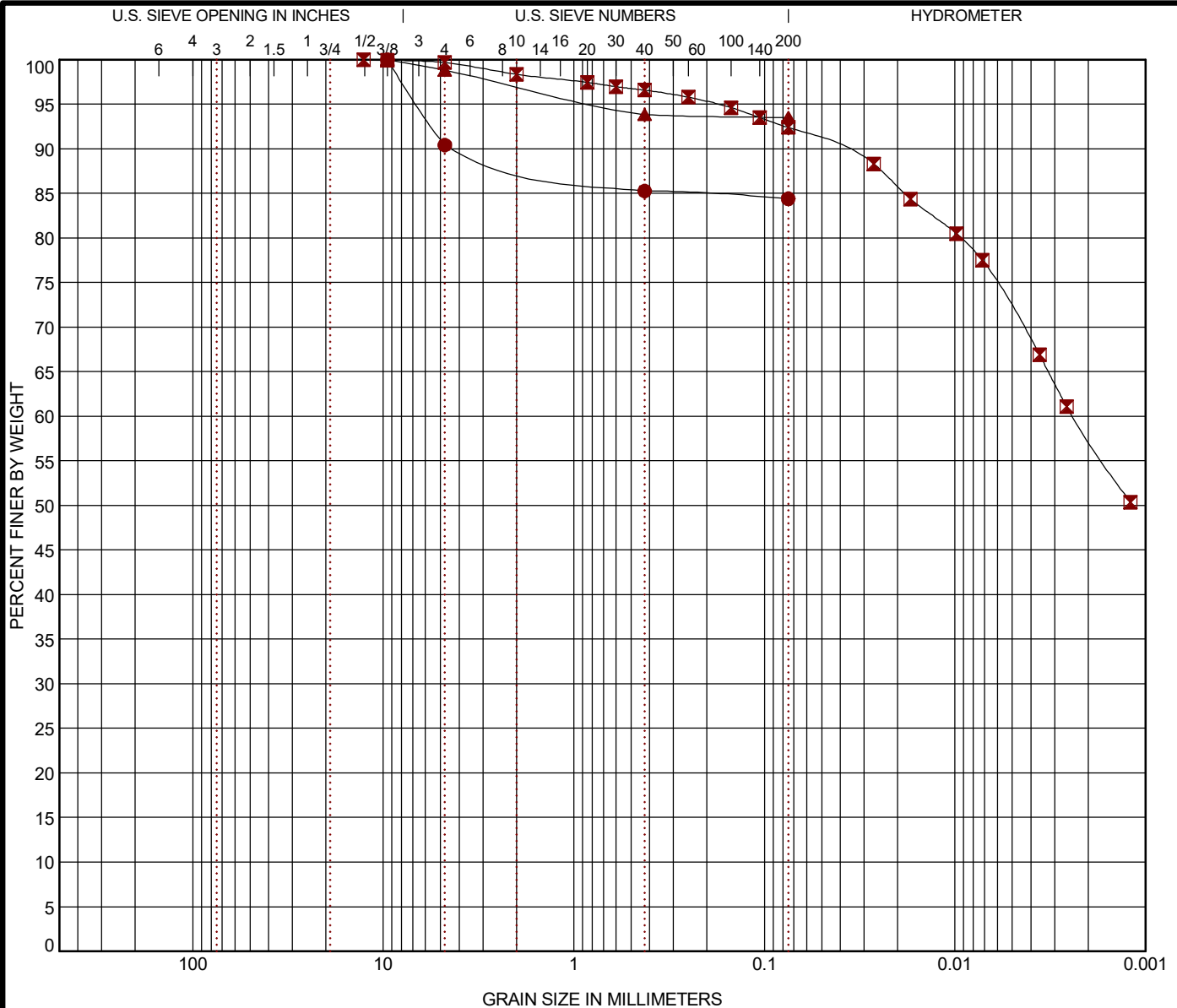
Samples obtained during the field program were visually classified in the laboratory by a geotechnical engineer. A testing program was conducted on selected samples, as directed by the geotechnical engineer, to aid in classification and evaluation of engineering properties required for analyses.

Results of the laboratory tests are presented on the boring logs, located in Appendix A, Appendix B, and/or are discussed in **Section 3.0 – Subsurface Conditions** of the report. Laboratory test results were used to classify the soils encountered as generally outlined by the Unified Soil Classification System.

Samples not tested in the laboratory will be stored for a period of 30 days subsequent to submittal of this report and will be discarded after this period, unless we are notified otherwise.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



APPENDIX C
SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING	 Auger Cuttings	 Rock Core	WATER LEVEL	 Water Initially Encountered	FIELD TESTS	N	Standard Penetration Test Resistance (Blows/Ft.)
	 Shelby Tube	 Split Spoon		 Water Level After a Specified Period of Time		(HP)	Hand Penetrometer
				 Water Level After a Specified Period of Time		(T)	Torvane
						(DCP)	Dynamic Cone Penetrometer
					(PID)	Photo-Ionization Detector	
					(OVA)	Organic Vapor Analyzer	

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.

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. 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		
	Descriptive Term (Density)	Standard Penetration or N-Value Blows/Ft.	Descriptive Term (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	4 - 8
	Dense	30 - 50	Stiff	1.00 to 2.00	8 - 15
	Very Dense	> 50	Very Stiff	2.00 to 4.00	15 - 30
			Hard	> 4.00	> 30

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 - 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1 - 10
Medium	11 - 30
High	> 30

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 ≥ 4 and 1 ≤ Cc ≤ 3 ^E		GW	Well-graded gravel ^F
			Cu < 4 and/or 1 > Cc > 3 ^E		GP	Poorly graded gravel ^F
		Gravels with Fines: More than 12% fines ^C	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 ≥ 6 and 1 ≤ Cc ≤ 3 ^E		SW	Well-graded sand ^I
			Cu < 6 and/or 1 > Cc > 3 ^E		SP	Poorly graded sand ^I
		Sands with Fines: More than 12% fines ^D	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 on or above “A” line ^J		CL	Lean clay ^{K,L,M}
			PI < 4 or plots below “A” line ^J		ML	Silt ^{K,L,M}
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay ^{K,L,M,N}
			Liquid limit - not dried			Organic silt ^{K,L,M,O}
	Silts and Clays: Liquid limit 50 or more	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:	Liquid limit - oven dried	< 0.75	OH	Organic clay ^{K,L,M,P}
			Liquid limit - not dried			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 and/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

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

^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.

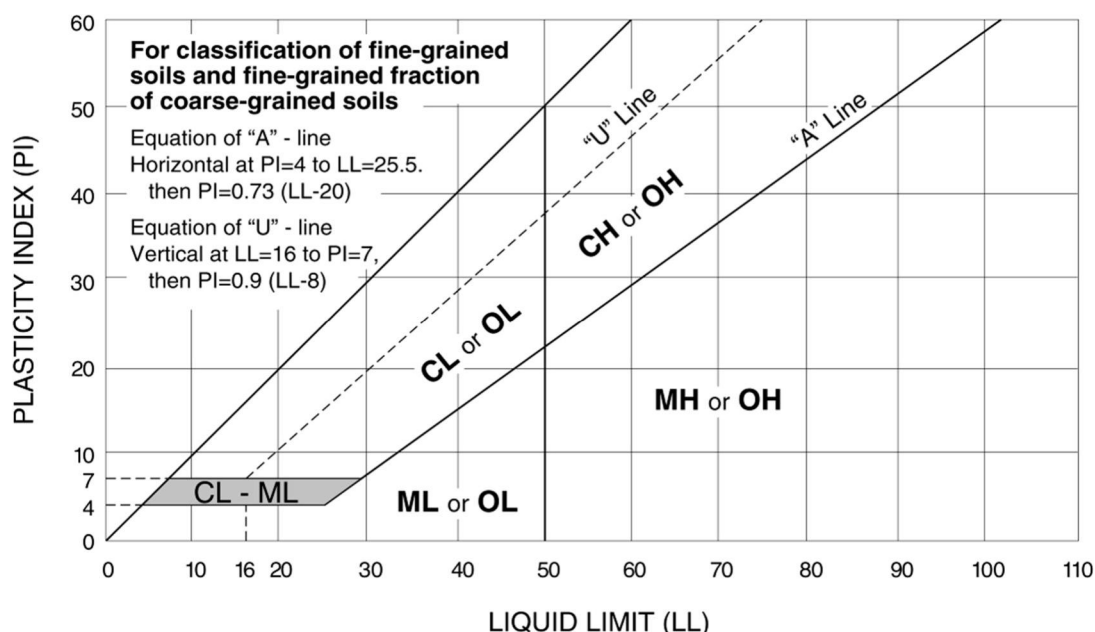
^M If soil contains $\geq 30\%$ plus No. 200, predominantly gravel, add "gravelly" to group name.

^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.



DESCRIPTION OF ROCK PROPERTIES

WEATHERING

Term	Description
Unweathered	No visible sign of rock material weathering, perhaps slight discoloration on major discontinuity surfaces.
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

STRENGTH OR HARDNESS

Description	Field Identification	Uniaxial Compressive Strength, PSI (TSF)
Extremely weak	Indented by thumbnail	40-150 (2.9 – 10.8)
Very weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	150-700 (10.8 – 50.4)
Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	700-4,000 (50.4 – 288)
Medium strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	4,000-7,000 (288 – 504)
Strong rock	Specimen requires more than one blow of geological hammer to fracture it	7,000-15,000 (504 – 1,080)
Very strong	Specimen requires many blows of geological hammer to fracture it	15,000-36,000 (1,080 – 2,592)
Extremely strong	Specimen can only be chipped with geological hammer	> 36,000 (> 2,592)

DISCONTINUITY DESCRIPTION

Fracture Spacing (Joints, Faults, Other Fractures)		Bedding Spacing (May Include Foliation or Banding)	
Description	Spacing	Description	Spacing
Extremely close	< ¾ in (< 19 mm)	Laminated	< ½ in (< 12 mm)
Very close	¾ in – 2½ in (19 – 60 mm)	Very thin	½ in – 2 in (12 – 50 mm)
Close	2½ in – 8 in (60 – 200 mm)	Thin	2 in – 1 ft (50 – 300 mm)
Moderate	8 in – 2 ft (200 – 600 mm)	Medium	1 ft – 3 ft (300 – 900 mm)
Wide	2 ft – 6 ft (600 mm – 2 m)	Thick	3 ft – 10 ft (900 mm – 3 m)
Very Wide	6 ft – 20 ft (2 – 6 m)	Massive	> 10 ft (3 m)

Discontinuity Orientation (Angle): Measure the angle of discontinuity relative to a plane perpendicular to the longitudinal axis of the core. (For most cases, the core axis is vertical; therefore, the plane perpendicular to the core axis is horizontal.) For example, a horizontal bedding plane would have a 0 degree angle.

ROCK QUALITY DESIGNATION (RQD*)

Description	RQD Value (%)
Very Poor	0 – 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 – 100

*The combined length of all sound and intact core segments equal to or greater than 4 inches in length, expressed as a percentage of the total core run length.

Reference: U.S. Department of Transportation, Federal Highway Administration, Publication No FHWA-NHI-10-034, December 2009
Technical Manual for Design and Construction of Road Tunnels – Civil Elements