Geotechnical Engineering Report

Circle K – Pflugerville

SEC West Pecan Street and Sarah's Creek Drive

Pflugerville, Texas

October 25, 2013

Terracon Project No. 96135184

Prepared for:

Circle K Stores, Inc.
Tempe, Arizona

Prepared by:

Terracon Consultants, Inc.
Austin, Texas

October 25, 2013

Terracon

Circle K Stores, Inc.
1130 West Warner Road, Building B
Tempe, AZ 85284

Attention: Mr. Bill Bunch
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Re: Geotechnical Engineering Report
Circle K - Pflugerville
SEC West Pecan Street and Sarah's Creek Drive
Pflugerville, Texas
Terracon Project No. 96135184

Dear Mr. Bunch:

Terracon Consultants, Inc. (Terracon) is pleased to submit our Geotechnical Engineering Report for the proposed construction of a Circle K store 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 Geotechnical Engineer

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Bryan S. Moulin, P.E.
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EXECUTIVE SUMMARY

A geotechnical investigation has been performed for the proposed construction of a Circle K store in Pflugerville, Texas. Five borings, designated B-1 through B-5, were performed to depths of approximately 5 to 25 feet below the existing grade for the project. 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 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 be appropriate to support the proposed convenience store building. The foundation should be sized for a total load allowable bearing pressure of 2,500 psf or a net dead load allowable bearing pressure of 1,700 psf, if bearing in select fill/Stratum II tan to light brown soils. The foundation should be sized for a total load allowable bearing pressure of 4,000 psf or a net dead load allowable bearing pressure of 2,600 psf, if bearing in Stratum III limestone.
- Drilled piers placed to bear in the Stratum III tan to gray Austin Group limestone are appropriate to support the planned fuel canopy. Based on the subsurface data obtained during this exploration, we recommend the piers extend a minimum depth of 3 feet into the Stratum III tan to gray limestone and be sized using a maximum allowable total load bearing pressure of 40,000 psf. In addition, an allowable side friction of 4,000 psf may be used within the limestone for piers embedded beyond the minimum 3 foot embedment depth.
- As an alternative, a spread footing foundation system may be utilized to support the proposed fuel canopy and should be sized for a total load allowable bearing pressure of 2,500 psf if bearing in select fill/Stratum II tan to light brown soils or a total load allowable bearing pressure of 10,000 psf if bearing at least 12 inches into Stratum III limestone.
- To achieve a PVR of about 1 inch, the on-site Stratum I dark brown to brown clay soils (observed to depths of about 1 to 2 feet) should be excavated and completely removed from the building areas. The removed soils should be replaced with properly compacted select fill within all the building areas up to final grades. The removed soils should be replaced with properly compacted select fill within all the building areas up to final grades. More details are included in **Section 4.4**.
- Pavements in parking areas should be designed with at least 2 inches of asphalt over 8 inches of base material over moisture conditioned subgrade. As an alternative, 5 inches of reinforced concrete over moisture conditioned subgrade may be used.
- Pavements in light to medium duty traffic areas should be designed with at least 2.5 inches of asphalt over 9 inches of base material over moisture conditioned subgrade. As an alternative, 6 inches of reinforced concrete over moisture conditioned subgrade may be used. We suggest 6 inches of concrete in dumpster collection areas.
- Pavements in medium duty traffic areas should be designed with at least 7 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
CIRCLE K – PFLUGERVILLE
SEC WEST PECAN STREET AND SARAH'S CREEK DRIVE
PFLUGERVILLE, TEXAS

Project No. 96135184
October 25, 2013

1.0 INTRODUCTION

Terracon is pleased to submit our Geotechnical Engineering Report for the proposed construction of a Circle K store in Pflugerville, Texas. This project was authorized by Mr. Bill Bunch with Circle K Stores, Inc., through signature of our "Agreement for Services" dated September 30, 2013. The project scope was performed in general accordance with Terracon Proposal No. P96131147 dated September 23, 2013.

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

- Foundation design and construction for the proposed building and fuel canopy;
- Seismic site classification according to IBC 2009 and IBC 2012;
- Lateral earth pressures for site retaining walls;
- 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 consists of a single-story convenience store building with a proposed footprint of approximately 4,480 square feet, along with underground storage tanks (UST's), a fuel canopy, fueling stations, a dumpster enclosure, and pavements and surface pavements.
Construction	Store: light metal or wood framing on monolithic slab-on-grade Fuel Station Canopy: steel framing on drilled piers or spread footings

Item	Description
Finished floor elevation (FFE)	Unknown – assumed to be within one to two feet of existing grades.
Maximum loads	Columns: up to 12 kips (reported) Walls: 1.8 klf (reported) Slabs: 100 psf maximum (reported)
Grading	Cuts and fills up to about 2 feet (assumed)
Cut and fill slopes	Assumed to be no steeper than 3H:1V (Horizontal to Vertical)
Free-standing retaining walls	Some walls up to 4 feet in height are anticipated.
Below-grade areas	Underground fuel storage tanks at up to 15 feet below existing grades

2.2 Site Location and Description

Item	Description
Location	The project is located on an approximately 1.603 acres tract of land at the southeast corner of the intersection of West Pecan Street and Sarah's Creek Drive, in Pflugerville, Texas. (See Exhibit A-1).
Existing improvements	None.
Current ground cover	Exposed soils, grass, weeds, and some trees along the western perimeter.
Existing Topography	Based on visual observations and Google Earth® software, the site slopes down gently from southeast to northwest and west with a grade differential of about 5 to 7 feet.

3.0 SUBSURFACE CONDITIONS

3.1 Geology

Based on our review of available geological information[i] and the recovered samples, the site lies within an area characterized by outcrops of the Austin Group of Upper Cretaceous Age. The Austin Group is comprised primarily of tan to light gray limestone and marl. The limestone generally weathers into low to moderate plasticity soils, while the marl generally weathers into moderate to high plasticity clays. Marl seams and layers are interbedded in the primary limestone bedrock. The Austin Group is commonly overlain by a layer of variable plasticity clayey soils.

[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.

3.2 Typical Profile

Based on the results of the borings, subsurface conditions on the project site can be generalized as below.

Description	Approximate Depth Range of Stratum (feet)	Material Encountered	Consistency/Density
Stratum I [1]	0 to 2	Fat Clay (CH) to Gravelly Fat Clay (CH) to Lean Clay (CL)	Very Stiff to Hard
Stratum II [2]	0.5 to 2.5	Lean Clay (CL) to Sandy Lean Clay with Gravel (CL) to Clayey Gravel with Sand (GC)	Hard; Very Dense
Stratum III [3]	2 to 25	Limestone (Glen Rose Group)	-

1. The Stratum I dark brown to brown soils generally exhibited moderate to moderately high shrink/swell potential as indicated by measured plasticity indices (PI's) of about 20 and 31 percent and a fines content (percent passing the No. 200 sieve) of about 68 percent. In-situ moisture contents were about 5 and 7 percent dry of the corresponding plastic limits. Pocket penetrometer values of over 4.5 tons per square foot (tsf) were recorded for the stratum. Measured unconfined compressive strengths of about 2.75 and 3.55 tsf were recorded for the stratum. Typically, dark brown to brown clayey soils exhibit high PI's of about 30 and greater. A low PI of about 20 percent was measured for these soils at boring B-4. This low PI was due to the limestone fragments observed in the sample.
2. The Stratum II tan to light brown soils (not observed in boring B-2) exhibited low to moderate shrink/swell potential as indicated by measured PI's of about 9 and 16 percent and fines contents of about 40 and 58 percent. In-situ moisture contents were about 7 and 12 percent dry of the corresponding plastic limits. Standard penetration resistance values ranging from about 55 blows per foot to 85 blows per 7 inches of penetration were recorded for the stratum. These soils appear to be the completely weathered residual portions of the underlying Austin Group limestone and contained weathered limestone seams and layers. Limestone fragments, seams, and layers may be present throughout the Stratum II soils.
3. Stratum III tan to gray Austin Group limestone was encountered in the borings at depths of about 2 to 4 feet below the existing ground surface. Weathered portions of the limestone yielded a PI of about 10 percent. Standard penetration resistance values ranging from about 50 blows per 2 inches to about 50 blows per 0.5 inches were recorded for the upper portion of the stratum. Measured values of Recovery and RQD ranged from about 73 to 100 percent (average of about 89 percent), and 53 to 100 percent (average of about 83 percent), respectively. Measured uniaxial compressive strengths of intact samples varied from about 124.9 to 189.7 tsf, with an average of about 147.6 tsf or 2,050 psi.

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 5 feet below existing grades. The deeper borings were then drilled to the completion depths of about 20 to 25 feet using wet rotary drilling techniques to facilitate rock coring, making subsequent water level readings difficult to obtain. Groundwater was not observed 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 (portions of Stratum I and Stratum II) to moderately highly (Stratum I) 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 expansion and contraction due to changes in moisture content. The soils exhibit a Potential Vertical Rise (PVR) of up to about 1½ inches, as estimated by the Texas Department of Transportation (TxDOT) Method TEX-124-E.

4.2 Earthwork

Construction areas should be stripped of all vegetation, topsoil, and other unsuitable material. Site stripping could frequently loosen limestone rocks and boulders, which should be excavated and removed from the construction area. Roots of trees to be removed within construction areas should be grubbed to full depths, including the dry soil around the roots. 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 tree roots, 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 cause 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 to at least 95 percent of the Standard Proctor (ASTM D 698) maximum dry density. Select fill and on-site soils should meet the following criteria.

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

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) 2004 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 Stratum I dark brown to brown soils are not consistently suitable for re-use as select fill. We do not recommend these soils be considered for re-use as select fill when planning budgets.
4. The excavated Stratum II tan to light brown soils and Stratum III limestone may be used as select fill

in the building areas provided that it meets the select fill requirements given above. The fill soils should be properly processed as outlined below and also moisture conditioned and recompacted to at least 95 percent of the Standard Proctor (ASTM D 698) maximum dry density.

The excavated material should be acceptable provided that it is processed such that a relatively well-graded grain size distribution with a maximum rock size of 4 inches is achieved and the plasticity index is less than 20 percent. Please note that removal of higher plasticity zones within the Stratum II/III soils/limestone will be necessary to maintain plasticity indices of the material within the acceptable range. In some situations, the difference between more highly plastic clay and lower plasticity silty clay soils, as well as the presence of the clayey zones within the limestone, may not be readily distinguishable without the performance of appropriate laboratory testing. If the highly plastic clayey zones are not removed, the material may be unsuitable for use as select fill. After initial processing of the fill material, samples should be submitted to Terracon for approval of proper gradation, plasticity index, and maximum rock size prior to use as select fill. We recommend that periodic testing be performed throughout the material excavation phase to check for conformance with the select fill requirements given above.

It has been our experience that proper processing of excavated limestone often involves such processes as breaking down of larger rock with equipment, screening, removal of more highly plastic clay layers, etc. The Contractor's proposed methods of processing these materials should be reviewed prior to initiation of construction to check that these methods will produce an acceptable select fill material with a proper grain size distribution.

5. Excavated on-site soils and processed limestone, if free of organics, debris, and rocks larger than 4 inches, may be considered for use as fill in pavement, landscape, or other general areas. The use of rock fill in areas where underground utilities areas are planned will likely result in construction difficulties during trenching and excavation of the utility alignments. If utilities are to be placed in areas that are planned to receive rock fill, we recommend that the maximum rock size be limited to no greater than 4 inches for the full depth of the rock fill in these areas to reduce the potential for construction difficulties during utility trench excavation.

   - The maximum lift height recommended is 1.5 feet, which will be controlled by the maximum boulder size. A maximum nominal rock size of 9 inches should be maintained.
   - The largest nominal rock size of any given lift shall not exceed one-half of the lift height.
   - The upper 12 inches of the fill placement shall be composed of lifts no more than 6 inches in compacted thickness (8-inch loose lift thickness) and contain no rocks larger than 4 inches in their largest dimensions.
   - The rock fill shall be of sufficient size distribution such that no voids are present between larger rock sizes during placement.
   - Such a rock fill placement operation should be continuously monitored by Terracon personnel to check that the fill operation is in accordance with the recommendations stated herein. (In-place density testing for such a fill operation is often not practical.)
   - Please note that rock fills can create increased difficulty in terms of future excavation for utilities, etc. This should be considered prior to and during placement of the fill.

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	All fill should be placed in uniform lifts compacted to at least 95 percent of the Standard Proctor (ASTM D 698) maximum dry density. The Stratum I dark brown to brown soils should be moisture conditioned to between 0 and +4 of optimum moisture content. Select fill, Stratum II tan to light brown soils, and processed Stratum III limestone 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 Excavation into Limestone

Excavation operations at the site for the proposed construction of foundation and utility lines will likely penetrate into the Stratum III Austin Group limestone. It is understood that the proposed UST's are planned to be up to about 15 feet below existing grades. Therefore, excavation operations will penetrate into the Stratum III Austin Group limestone for these tanks. In tested limestone samples, the total densities varied from about 140 to 147 pcf and the unconfined compressive strengths varied from about 1,735 to 2,635 psi.

Our past experience with the Austin Group limestone, along with the data obtained during our field and laboratory programs, indicates that the upper portions of the limestone at this site should be rippable with proper equipment. However, zones of resistant limestone which could require sawcutting, jackhammering, hoe-ramming, milling, or similar techniques to excavate should be expected. In addition, the Austin limestone at this site typically became more competent with depth. Please note that the Stratum II tan to light brown soils also contained limestone fragments, seams, and layers.

Our comments on excavation are based on our experience with the rock formation. Rock excavation depends on not only the rock hardness, weathering, and fracture frequency, but also the contractor's equipment, capabilities, and experience. Therefore, it should be the contractor's responsibility to determine the most effective methods for excavation. The above comments are intended for informational purposes for the design team only and may be used for planning purposes.

4.3 Foundation System

Based upon the subsurface conditions observed during this exploration and anticipated loading, the following foundation systems would be appropriate to support the proposed structures at the site.

- A monolithic slab-on-grade foundation system (either conventionally reinforced or post-tensioned) for the proposed convenience store building, and
- Drilled straight-sided pier foundation system bearing into the Stratum III Austin Group limestone or a spread footing foundation system for the proposed fuel canopy.

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 building 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.

Grade beams should bear on compacted select fill/Stratum II soils or Stratum III limestone, but not a combination of these materials within the same building. If grade beams are to bear on select fill and the Stratum III limestone is encountered during site preparation, the limestone should be over-excavated as necessary to provide at least 12 inches of select fill under <u>all</u> grade beams.

Conventional Slab and Beam System Parameters		
Minimum embedment of grade beams below final grade[1]		18 inches, or directly on top of intact Stratum III limestone
Bearing Pressures (allowable)[2]	**Select Fill/Stratum II Soils**	Net dead plus sustained live load – 1,700 psf Net total load – 2,500 psf
	Stratum III Limestone	Net dead plus sustained live load – 2,600 psf Net total load – 4,000 psf
Subgrade Modulus (k)[3]		150 pci
Approximate Potential Vertical Rise (PVR)		1¼ 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/Stratum II soils or Stratum III limestone.
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**	**Unprepared Subgrade**	31
		Prepared Subgrade (as in Section 4.4)	16
	WRI/PCI	**Unprepared Subgrade**	20
		Prepared Subgrade (as in Section 4.4)	16
Climatic Rating (C_w)			17
Unconfined Compressive Strength			1.0 tsf
Soil Support Index (C) for BRAB	**Unprepared Subgrade**		0.83
	Prepared Subgrade (as in Section 4.4)		0.99

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) Parameters[1]		
Depth of Seasonal Moisture Change[2]		4 feet (or top of limestone)
Plasticity Index [3]		Select Fill – 15 Stratum I Soils – 20 to 31 Stratum II Soils – 9 to 16
Percent Finer than 2 Microns [3]		Select Fill – 20 (estimated) Stratum I Soils – 38 (measured) Stratum II Soils – 23 (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**	8.5 feet (9.0 feet) [6]
	Edge Lift	4.4 feet (4.9 feet) [6]
Differential Soil Movement, y_m (Center Lift) [5]	**Center Lift**	0.7 inches (0.5 inches) [6]
	Edge Lift	1.1 inches (0.7 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) method[ii] 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

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.

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 parenthesis 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. Expansive soils should not be a concern under the building provided that the recommendations presented in **Section 4.4 – Building Pad Preparation** are followed. 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 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 Design Recommendations – Drilled Pier Foundation System

The proposed fuel canopy may be supported on drilled straight-sided piers embedded at least 3 feet into the Stratum III tan to gray Austin Group limestone.

Significant clay layers (6 inches in thickness or greater) and zones of highly weathered limestone (i.e. residual soils) should not be included in determining the required pier embedment into the rock. (For example, if a one-foot thick clay layer is observed within the rock for a pier with a design embedment of 5 feet, the embedment into limestone should be extended to 6 feet.) At locations where the design embedment results in the pier terminating on a severely weathered or clay layer, the pier should be extended to bear upon more competent limestone. Due to the subsurface conditions mentioned above, along with planned cuts and fills, the total pier lengths may vary across each structure; therefore, appropriate base bid depths should be determined for the project. The pier lengths will also vary based on the planned cuts and fills. Due to the fact that many of the piers may extend deeper due to the presence of clay layers, the contract documents should include unit rates for additional drilled pier footage at various pier diameters. In addition, the construction budget for this project should include overages due to the likelihood of additional costs associated with extending many of the drilled piers to greater depths.

Description	Drilled Pier Design Parameter
Bearing Stratum	Stratum III Austin Group limestone
Minimum embedment into bearing stratum[1]	3 feet
Minimum pier diameter	18 inches
Bearing pressure (net allowable)	40,000 psf
Side Friction (net allowable)	4,000 psf for pier portions embedded beyond the 3 foot minimum embedment depth
Minimum percentage of steel[2]	0.5 percent
Approximate total settlement[3]	¾ inch
Estimated differential settlement[4]	Approximately ½ to ¾ of total settlement

1. To bear within the Stratum III Austin Group limestone.
2. Based on subsurface conditions encountered at the site, soil-related uplift does not appear to be a concern at this site, assuming proper site preparation and building pad construction. However, we do recommend that the minimum percentage of reinforcing steel be no less than ½ percent of the gross shaft area and extend over the full length of the pier.
3. Provided proper construction practices are followed. For adjacent piers, we recommend a minimum edge-to-edge spacing of at least 1 pier diameter (or 2 pier diameters center-to-center) based on the larger diameter of the two adjacent piers. In locations where this minimum spacing criterion cannot be accomplished, Terracon should be contacted to evaluate the locations on a case-by-case basis.
4. Will result from variances in subsurface conditions, loading conditions and construction procedures, such as cleanliness of the bearing area or flowing water in the shaft.

4.3.3 Design Recommendations – Spread Footings

As an alternative, the proposed fuel canopy may be supported by spread footings. For a spread footing foundation alternative to be considered, the Stratum I dark brown to brown fat clay soils should be excavated and completely removed from the proposed fuel canopy areas. Spread footings should be placed to bear into properly compacted select fill soils/Stratum II tan to light brown soils or Stratum III limestone. (Footings should <u>not</u> be placed on or within the Stratum I fat clays due to potential movements associated with the fat clay soils).

Description		Footing Design Parameter
Bearing Stratum		Select Fill or Stratum II soils or Stratum III limestone
Minimum embedment below final grade[1]		24 inches below final grade, or 12 inches into intact limestone
Bearing Pressures	**Select fill/Stratum II Soils**	Net allowable total load – 2,500 psf
	Stratum III Limestone	Net allowable total load – 10,000 psf
Approximate total settlement [2]		1 inch
Estimated differential settlement[3]		½ to ¾ inch
Allowable passive resistance [4]	**Select fill/Stratum II Soils**	300 psf per foot of depth
	Stratum III Limestone	1,000 psf per foot of depth
Coefficient of sliding friction[5]	**Select fill/Stratum II Soils**	0.4
	Stratum III Limestone	0.7
Uplift Resistance[6]		Foundation Weight (150 pcf) & Soil Weight (120 pcf)

1. Lowest adjacent final grade at the time of construction.
2. This estimated post-construction settlement of the shallow footings is assuming proper construction practices are followed.
3. Differential settlements may result from variances in subsurface conditions, loading conditions and construction procedures. The settlement response of the footings will be more dependent upon the quality of construction than upon the response of the subgrade to the foundation loads.
4. Passive resistance should be neglected in the first 12 inches below final grade. Care should be taken to avoid disturbance of the footing bearing area since loose material could increase settlement and decrease resistance to lateral loading. If the footing is formed during construction, the open space between the footing and the in-situ soils should be backfilled with concrete.
5. Lateral loads transmitted to the footings will be resisted by a combination of soil-concrete friction on the base of the footings and passive pressure on the side of the footings. We recommend that the allowable frictional resistance be limited to 500 psf for soils and 1,500 psf for limestone.
6. The ultimate uplift capacity of shallow footings should be reduced by an appropriate factor of safety to compute allowable uplift capacity.

4.3.4 Foundation Construction Considerations

4.3.4.1 Grade Beams/Footings

Grade beams/footings 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/footing excavation completed with a smooth-mouthed bucket or by hand labor. In limestone subgrade areas, rock-trenching equipment will be needed. 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.

4.3.4.2 Drilled Piers

Drilled pier foundations should be augered and constructed in a continuous manner. Concrete should be placed in the pier excavations following drilling and evaluation for proper bearing stratum, embedment, and cleanliness. The piers should not be allowed to remain open overnight before concrete placement. Surface runoff or groundwater seepage accumulating in the excavation should be pumped out and the condition of the bearing surface should be evaluated immediately prior to placing concrete. The drilling equipment utilized should be readily capable of excavating the Austin Group limestone observed at this site. Drilling equipment with insufficient torque and/or augers/bits/core barrels that are not suited for variable and/or hard rock conditions will likely result in poor production rates.

Although not observed during our field program, zones of groundwater inflow and/or sloughing soils are a possibility during pier construction at this site. Therefore provisions must be incorporated into the plans and specifications to utilize casing to control sloughing and/or groundwater seepage during pier construction. Removal of the casing should be performed with extreme care and under proper supervision to minimize mixing of the surrounding soil and water with the fresh concrete. If water infiltration becomes excessive, slurry drilling techniques (or other drilling means) could be necessary. Concrete should exhibit slump as stated in the Structural Engineer's specifications. Under no circumstances should loose soil be placed in the space between the casing and the pier sidewalls. The concrete should be placed using a rigid tremie or by the free-fall method provided the concrete falls to its final position through air without striking the sides of the hole, the reinforcing steel cage or any other obstruction. A drop chute should be used for this free-fall method.

The use of casing should help to minimize groundwater inflow into the pier excavation. If seepage persists even after casing installation, the water should be pumped out of the excavation immediately prior to placing concrete. If groundwater inflow is too severe to be controlled by pumping, the concrete should be tremied to the full depth of the excavation to effectively displace the water. In this case, a "clean-out" bucket should be utilized to remove loose soil and/or rock fragments from the pier bottom before placing steel and concrete.

4.3.4.3 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 Floor Slab Subgrade Preparation

Information about existing and proposed grades and FFE for the proposed structures has not been provided to Terracon at this time. However, we assume that the planned FFE is at or slightly above (within one to two feet of) existing grade for the structures. If these assumptions are incorrect, Terracon should be notified to review and modify and/or verify recommendations in writing.

For the proposed structures, the on-site Stratum I dark brown to brown fat clay soils (observed to depths of about 1 to 2 feet) should be excavated and completely removed from the building areas. The removed soils should be replaced with properly compacted select fill within all the building areas up to final grades. At least 12 inches of select fill should be placed below all building areas. If Stratum III limestone is exposed at subgrade level, the select fill thickness may be reduced to 6 inches. 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. ***All fill material placed within the building footprint should meet the requirements of Select Fill described 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
2009 and 2012 International Building Code (IBC)	A[1]	B[2]

1 Per IBC 2009 Section 1613.5.1 and IBC 2012 Section 1613.3.1.

Per IBC 2009, S_s=0.080; S_1=0.033; S_{MS}=0.080; S_{M1}=0.033; S_{DS}=0.054; S_{D1}=0.022

Per IBC 2012, S_s=0.063; S_1=0.034; S_{MS}=0.063; S_{M1}=0.034; S_{DS}=0.042; S_{D1}=0.023

2 Per IBC 2009 Table 1613.5.2 and per IBC 2012 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 25 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 Lateral Earth Pressures

Presented below are at-rest, active, and passive earth pressure coefficients for various backfill types adjacent to below-grade walls or site retaining walls. At-rest earth pressures are recommended in cases where little wall yield is expected (such as structural below-grade walls). Active earth pressures may be used in cases where the walls can exhibit a certain degree of horizontal movement (such as cantilevered retaining walls). The recommendations in this section apply to those walls which are installed in open cut or embankment fill areas such that the backfill extends out from the base of the wall at an angle of at least 45 degrees from vertical for the entire height and length of the wall.

BACKFILL TYPE	ESTIMATED TOTAL UNIT WEIGHT (PCF)	LATERAL EARTH PRESSURE COEFFICIENTS[1]		
		AT REST (K_O)	ACTIVE (K_A)	PASSIVE (K_P)
Crushed Limestone	140	0.45	0.3	3.5
Clean Sand	120	0.5	0.35	3.0
Clean Gravel	120	0.45	0.3	3.5
On-site Stratum II/III	130	0.5	0.35	3.0

BACKFILL TYPE	ESTIMATED TOTAL UNIT WEIGHT (PCF)	LATERAL EARTH PRESSURE COEFFICIENTS[1]		
		AT REST (K_O)	ACTIVE (K_A)	PASSIVE (K_P)
Crushed/Processed Rock [2]				

1. Coefficients represent ultimate values. Appropriate safety factors should be applied.
2. Contingent upon preparation of the on-site Stratum II/III soils/limestone as recommended in **Section 4.2 – Earthwork**.

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.

The compactive effort should be controlled during backfill operations adjacent to walls. Overcompaction can produce lateral earth pressures in excess of at-rest magnitudes. Compaction levels adjacent to walls should be maintained between 95 and 100 percent of Standard Proctor (ASTM D 698) maximum dry density.

For retaining walls bearing on on-site soils, we recommend a coefficient of sliding resistance of 0.4 (maximum allowable sliding resistance of 500 psf) and a maximum footing bearing capacity of 2,500 psf. For wall footings bearing directly on top of intact Stratum III limestone subgrade, a coefficient of sliding resistance of 0.7 (up to a maximum allowable sliding resistance of 1,200 psf) and a maximum bearing capacity of 4,000 psf may be used. 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. Retaining walls placed to bear upon the highly expansive Stratum I fat clay soils observed on this site will be subject to potential movements of up to 1½ inches.

We recommend that a buffer area of at least 5 feet for all pavement areas be placed between retaining walls (with a minimum height of 4 feet or more), and the adjacent construction. In building areas, this buffer zone from retaining walls should be increased to at least 10 feet. These recommended buffer zones are to reduce the potential of distress from any long-term ("creep") movements of the wall and backfill. Pedestrian sidewalks may be exempted from the above criteria; however, some distress could still be observed in the sidewalks due to movements of the retaining walls and backfill.

A wall drain (consisting of freely-draining aggregate or manufactured drainage mat, along with outlet piping) is recommended for collection and removal of surface water percolation behind the walls. Proper control of surface water percolation will help to prevent buildup of higher wall pressures. In unpaved areas, the final 12 inches of backfill should preferably consist of clayey soils to help to reduce percolation of surface water into the backfill.

4.7 Pavements

Both flexible (asphaltic concrete) and rigid (reinforced Portland cement concrete) pavement systems may be considered for site pavement applications. These two types of pavement are not considered equal. Over the life of the pavement, concrete pavements would be expected to exhibit better performance and require less maintenance. At a minimum, concrete pavements should be strongly considered in waste collection areas and delivery truck loading/unloading areas.

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* < 5)
Driveways (Light Duty):	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)
Driveways, dumpster enclosures, and truck traffic areas (Medium Duty)	DI-3	Medium traffic – Including not over 300 heavily loaded two axle trucks plus lightly loaded trucks with three or more axles and no more than 30 heavily loaded trucks with more than three axles per day. (EAL = 21 – 75)

* Equivalent daily 18-kip single axle load applications.

Listed below are pavement component thicknesses which may be used as a guide for pavement systems at the site assuming that the Stratum I clay 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.

FLEXIBLE PAVEMENT SYSTEM

Component	Material Thickness (Inches)	
	DI-1	DI-2
Asphaltic Concrete (HMAC)	2.0	2.5
Crushed Limestone Base	8.0	9.0
Moisture Conditioned Subgrade[1]	6.0	6.0

1. If the Stratum I fat clay soils are completely removed to expose Stratum II lean clay soils, the base thickness may be decreased by 2 inches. If the Stratum III limestone is exposed, the base may be reduced to a minimum thickness of 6 inches.

We strongly suggest the use of reinforced concrete pavements in fuel canopy areas, UST areas, and fuel truck delivery lanes. In addition, waste dumpster areas should be constructed of reinforced concrete.

RIGID PAVEMENT SYSTEM

Component	Material Thickness (Inches)		
	DI-1	DI-2	DI-3
Reinforced Concrete[1]	5.0	6.0[2]	7.0[2]
Moisture Conditioned Subgrade	6.0	6.0	6.0

1. A thin course of crushed limestone base or clean sand at least 1 to 2 inches thick is recommended under the reinforced concrete in exposed Stratum III limestone subgrade areas. Moisture conditioning of the subgrade is not necessary in intact limestone areas.
2. In Stratum III limestone areas, the DI-2 and DI-3 concrete thicknesses may be reduced by ½ inch.

Reinforcing Steel: DI-1: #3 bars spaced at 18 inches on centers in both directions. DI-2 and DI-3: #4 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 ¼ 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: ¾-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 various pavement sections.

<u>Hot Mix Asphaltic Concrete (HMAC)</u> – The asphaltic concrete surface course should be plant mixed, hot laid Type D (Fine-Graded Surface Course) meeting the master specification requirements in TxDOT Item 340 or City of Austin (COA) Item 340. For acceptance and payment evaluation purposes, we recommend the use of the provisions in COA Item 340.

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

<u>Crushed Limestone Base</u> – Base material should be composed of crushed limestone meeting the requirements of TxDOT Item 247, Type A, Grade 1 or COA Item 210. The base should be compacted to a minimum of 95 percent of the maximum density as determined by the modified moisture/density relation (ASTM D 1557) at -3 to +3 percent of optimum moisture content. (As an option, compaction to at least 100 percent of the TEX-113-E maximum dry density may also be considered.) Each lift of base should be thoroughly proofrolled 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. Placement of the base material should extend at least 18 inches behind curbs or pavement edges.

<u>Moisture Conditioned Subgrade</u> – 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. Moisture conditioning is not required in exposed limestone subgrade areas. 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 I fat clay soils encountered in 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 ¼ 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

N

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

Project Mgr: AM	Project No. 96135184		
Drawn By: AM	Scale: N.T.S		
Checked By: BSM	File Name: SITE PLAN		
Approved By: BSM	Date: 10-22-2013		

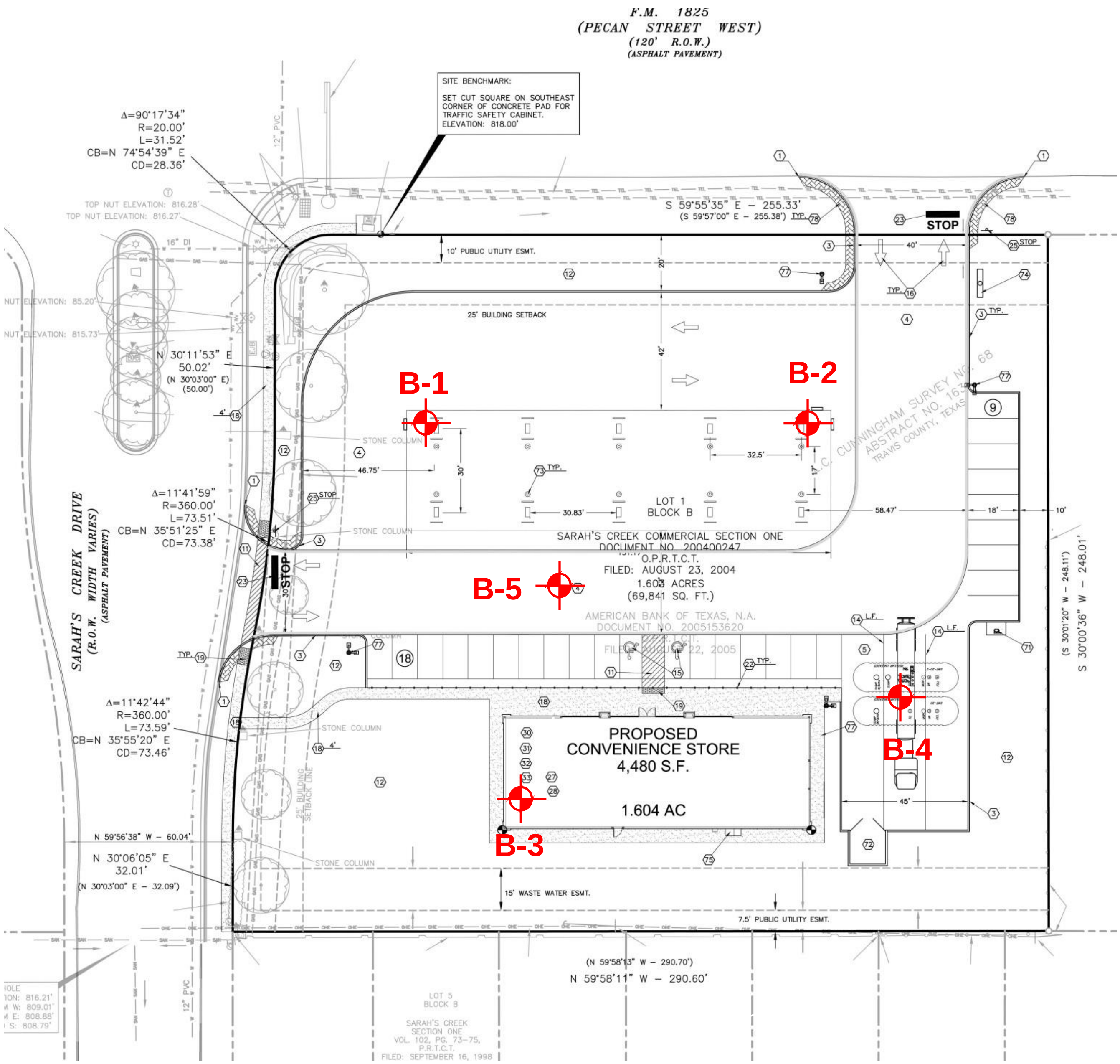
Terracon
Consulting Engineers & Scientists

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

SITE AERIAL AND LOCATION PLAN

Circle K – Pflugerville
SEC West Pecan St. and Sarah's Creek Drive
Pflugerville, Texas

EXHIBIT
A-1



Boring Location

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

Project Mgr: AM	Project No. 96135184	Terracon Consulting Engineers & Scientists	BORING LOCATION PLAN	EXHIBIT
Drawn By: AM	Scale: N.T.S	5307 Industrial Oaks Blvd, Suite 160, Austin, Texas 78735	Circle K – Pflugerville	A-2
Checked By: BSM	File Name: SITE PLAN	PH. (512) 442-1122 FAX. (512) 442-1181	SEC West Pecan St. and Sarah's Creek Drive	
Approved By: BSM	Date: 10-22-2013		Pflugerville, Texas	

Field Exploration Description

Subsurface conditions were evaluated by drilling:

- Two borings (B-1 and B-2) to depths of about 20 and 25 feet within the proposed fuel canopy areas,
- One boring (B-3) to a depth of about 25 feet within the proposed building area,
- One boring (B-4) to a depth of about 20 feet within the proposed UST area, and
- One boring (B-5) to a depth of about 5 feet within the proposed pavement areas.

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 logs, which include the subsurface descriptions, types of sampling used, and additional field data for this study, are presented on Exhibits A-4 through A-8 of Appendix A. Criteria defining terms, abbreviations and descriptions used on the boring logs are presented in Appendix C.

When possible, soil samples were generally recovered using thin-walled, open-tube samplers (Shelby tubes). A pocket penetrometer test was performed on each sample of cohesive soil in the field to serve as a general measure of consistency.

Soils for which good quality tube samples could not be obtained and upper portion of the limestone were 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 deeper 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

PROJECT: Circle K - Pflugerville

CLIENT: Circle K Stores, Inc.
Tempe, AZ 85284

SITE: SEC West Pecan St. and Sarah's Creek Dr.
Pflugerville, Texas

LOCATION See Exhibit A-2

DEPTH	Description	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Recovery (%) RQD (%)	Test Type	Compressive Strength (tsf)	Strain (%)	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI	Percent Fines
1.0	**GRAVELLY FAT CLAY (CH)** Very stiff to hard, dark brown				4.5+ tsf (HP)		UC	2.54	3.9	25	88	61-30-31	68
2.5	**LEAN CLAY (CL)** Hard, tan, with numerous limestone seams				20-25-50/2" N=75/8"								
	LIMESTONE (Austin Group) Tan to light brown				50/1" N=50/1"								
	-moderately fractured 5 to 15 feet	5											
							UC	129.24		9	130		
		10				91 / 88							
	-gray below 12 feet												
		15											
	-tan below 18 feet					95 / 95							
20.0	***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 5 feet; Wet Rotary 5 to 20 feet

Abandonment Method:
Borings backfilled with soil cuttings upon completion.

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
No free water observed

Terracon
5307 Industrial Oaks Blvd., Suite 160
Austin, Texas

Boring Started: 10/9/2013	Boring Completed: 10/9/2013
Drill Rig: Mobile B-57	Driller: Texas Geo Bore
Project No.: 96135184	Exhibit: A-4

BORING LOG NO. B-2

PROJECT: Circle K - Pflugerville

CLIENT: Circle K Stores, Inc.
Tempe, AZ 85284

SITE: SEC West Pecan St. and Sarah's Creek Dr.
Pflugerville, Texas

LOCATION See Exhibit A-2

DEPTH	Description	DEPTH (Ft.)	FIELD TEST RESULTS	RECOVERY (%) / RQD (%)	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	FAT CLAY (CH) Hard, dark brown, with calcareous nodules		4.5+ tsf (HP)								
2.0	**LIMESTONE (Austin Group)** Tan to light brown		50/2" N=50/2"					7		27-17-10	
	-moderately fractured 5 to 20 feet	5	50/1½" N=50/1½"								
		10		87 / 83							
		15									
					UC	124.92		7	136		
	-gray below 20 feet	20		88 / 83							
25.0	***Boring Terminated at 25 Feet***	25									

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

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 5 feet; Wet Rotary 5 to 25 feet

Abandonment Method:
Borings backfilled with soil cuttings upon completion.

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
No free water observed

Terracon
5307 Industrial Oaks Blvd., Suite 160
Austin, Texas

Boring Started: 10/8/2013	Boring Completed: 10/8/2013
Drill Rig: Mobile B-57	Driller: Texas Geo Bore
Project No.: 96135184	Exhibit: A-5

BORING LOG NO. B-3

PROJECT: Circle K - Pflugerville

CLIENT: Circle K Stores, Inc.
Tempe, AZ 85284

SITE: SEC West Pecan St. and Sarah's Creek Dr.
Pflugerville, Texas

LOCATION See Exhibit A-2

DEPTH	Description	DEPTH (Ft.)	FIELD TEST RESULTS	RECOVERY (%) / RQD (%)	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.5	**FAT CLAY (CH)** Hard, dark brown, with calcareous nodules		4.5+ tsf (HP)								
2.0	**SANDY LEAN CLAY WITH GRAVEL (CL)** Hard, tan to light brown, with limestone seams		19-25-30 N=55					15		38-22-16	58
	LIMESTONE (Austin Group) Tan to light brown		50/½" N=50/½"								
	-moderately weathered, moderately fractured 5 to 10 feet	5		73 / 73							
	-tan to gray below 10 feet	10									
		15		96 / 93							
		20		100 / 100	UC	189.73		5	140		
25.0	***Boring Terminated at 25 Feet***	25									

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

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 5 feet; Wet Rotary 5 to 25 feet

Abandonment Method:
Borings backfilled with soil cuttings upon completion.

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
No free water observed

Terracon
5307 Industrial Oaks Blvd., Suite 160
Austin, Texas

Boring Started: 10/9/2013	Boring Completed: 10/9/2013
Drill Rig: Mobile B-57	Driller: Texas Geo Bore
Project No.: 96135184	Exhibit: A-6

BORING LOG NO. B-4

PROJECT: Circle K - Pflugerville

CLIENT: Circle K Stores, Inc.
Tempe, AZ 85284

SITE: SEC West Pecan St. and Sarah's Creek Dr.
Pflugerville, Texas

LOCATION See Exhibit A-2

DEPTH	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	RECOVERY (%) RQD (%)	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1.0	**LEAN CLAY (CL)** Very stiff to hard, dark brown, with calcareous nodules				4.5+ tsf (HP)		UC	3.13	3.5	15	107	42-22-20	
4.0	**LEAN CLAY (CL)** Hard, tan to light brown, with limestone seams				15-34-50/2½" N=84/8½"								
	LIMESTONE (Austin Group) Tan to light brown -weathered, fractured 5 to 10 feet	5			50/½" N=50/½"								
						75 / 53							
	-moderately weathered, moderately fractured below 10 feet	10											
							UC	146.65		8	130		
20.0		15				92 / 78							
	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 5 feet; Wet Rotary 5 to 20 feet

Abandonment Method:
Borings backfilled with soil cuttings upon completion.

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
5307 Industrial Oaks Blvd., Suite 160
Austin, Texas

Boring Started: 10/8/2013	Boring Completed: 10/8/2013
Drill Rig: Mobile B-57	Driller: Texas Geo Bore
Project No.: 96135184	Exhibit: A-7

BORING LOG NO. B-5

PROJECT: Circle K - Pflugerville

CLIENT: Circle K Stores, Inc.
Tempe, AZ 85284

SITE: SEC West Pecan St. and Sarah's Creek Dr.
Pflugerville, Texas

GRAPHIC LOG	LOCATION See Exhibit A-2 / DEPTH	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	RECOVERY (%) RQD (%)	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	FAT CLAY (CH) Hard, dark brown (1.0)				4.5+ tsf (HP)								
	CLAYEY GRAVEL WITH SAND (GC) Very dense, tan to light brown, with limestone seams (2.0)				15-35-50/1" N=85/7"					9		30-21-9	40
	LIMESTONE (Austin Group) Tan, moderately weathered (5.0)	5			50/1" N=50/1"								
	Boring Terminated at 5 Feet												

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

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 5 feet

Abandonment Method:
Borings backfilled with soil cuttings upon completion.

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
No free water observed

Terracon
5307 Industrial Oaks Blvd., Suite 160
Austin, Texas

Boring Started: 10/9/2013	Boring Completed: 10/9/2013
Drill Rig: Mobile B-57	Driller: Texas Geo Bore
Project No.: 96135184	Exhibit: A-8

APPENDIX B

LABORATORY TESTING

Laboratory Testing

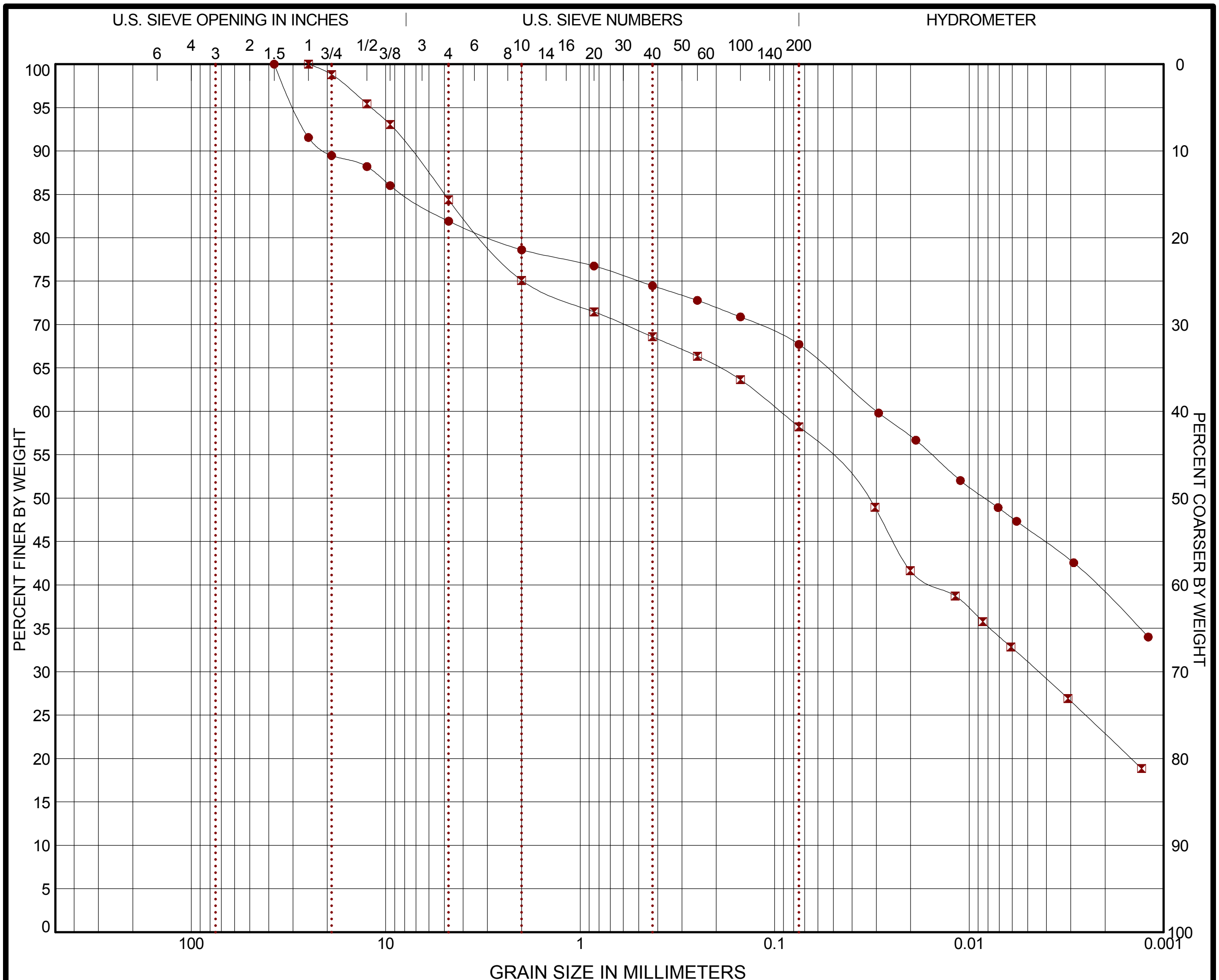
Samples obtained during the field program were visually classified in the laboratory by a geotechnical engineer. A testing program was conducted on selected samples, as directed by the geotechnical engineer, to aid in classification and evaluation of engineering properties required for analyses.

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



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BORING ID	DEPTH	% COBBLES	% GRAVEL	% SAND	% SILT	% FINES	% CLAY	USCS
●	**B-1**	**0 - 1**	**0.0**	**18.1**	**14.2**	**21.3**		**46.4**	**CH**
⧗	**B-3**	**0.5 - 2**	**0.0**	**15.6**	**26.2**	**27.1**		**31.1**	**CL**

	GRAIN SIZE		
	●	⧗	
D_{60}	**0.03**	**0.094**	
D_{30}		**0.004**	
D_{10}			
	COEFFICIENTS		
C_C			
C_U			

SIEVE (size)	PERCENT FINER ●	PERCENT FINER ⧗	
1 1/2"	**100.0**		
1"	**91.55**	**100.0**	
3/4"	**89.47**	**98.8**	
1/2"	**88.2**	**95.41**	
3/8"	**86.01**	**93.05**	
#4	**81.91**	**84.38**	
#10	**78.6**	**75.08**	
#20	**76.75**	**71.46**	
#40	**74.47**	**68.59**	
#60	**72.78**	**66.36**	
#100	**70.88**	**63.64**	
#200	**67.72**	**58.23**	

SOIL DESCRIPTION

● GRAVELLY FAT CLAY(CH)

⧗ SANDY LEAN CLAY with GRAVEL(CL)

REMARKS

●

⧗

PROJECT: Circle K - Pflugerville

SITE: SEC West Pecan St. and Sarah's Creek Dr.
Pflugerville, Texas

Terracon
5307 Industrial Oaks Blvd., Suite 160
Austin, Texas

PROJECT NUMBER: 96135184

CLIENT: Circle K Stores, Inc.
Tempe, AZ 85284

EXHIBIT: B-1

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS 1 96135184 BORING LOGS.GPJ TERRACON2012.GDT 10/25/13

APPENDIX C

SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

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

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

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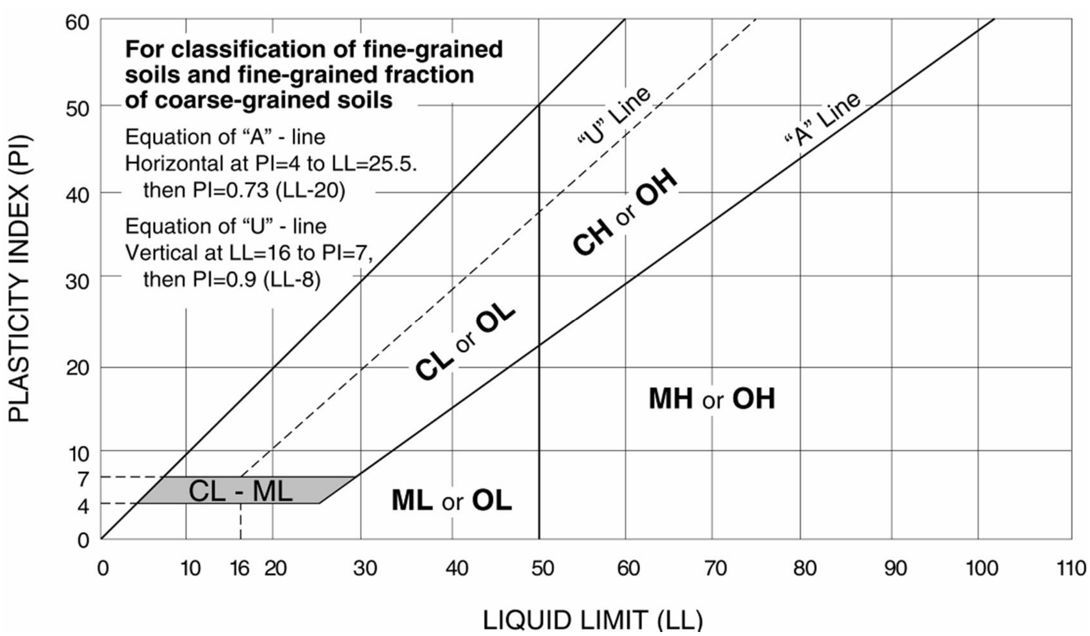
UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification: Group Symbol	Soil Classification: 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]
			$Cu < 4$ 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]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [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] $Cu = D_{60}/D_{10} \quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 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 ≥ 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 ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 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

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