Geotechnical Engineering Report

921 Main Street Office Reconstruction

921 Main Street

Bastrop, Texas

December 2, 2016

Terracon Project No. 96165290

Prepared for:

KSA Engineers, Inc.
Austin, Texas

Prepared by:

Terracon Consultants, Inc.
Austin, Texas

December 2, 2016

KSA Engineers, Inc.
4833 Spicewood Springs Road, Suite 204
Austin, Texas 78759

Attn: Mr. Eric J. Davis
P: 877.572.3647
E: edavis@ksaeng.com

Re: Geotechnical Engineering Report
921 Main Street Office Reconstruction
921 Main Street
Bastrop, Texas
Terracon Project No. 96165290

Dear Mr. Davis:

Terracon Consultants, Inc. (Terracon) is pleased to submit our Geotechnical Engineering Report for the 921 Main Street Office Reconstruction project located at 921 Main Street in Bastrop, 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)

STATE OF TEXAS
12/2/16
EDWARD ESCOBAR JAIMES
123388
LICENSED
PROFESSIONAL ENGINEER

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921 MAIN STREET
BASTROP, TEXAS

Terracon Project No. 96165290
December 2, 2016

1.0 INTRODUCTION

Terracon is pleased to submit our Geotechnical Engineering Report for the proposed construction of the 921 Main Street Office Reconstruction project located at 921 Main Street in Bastrop, Texas. The project was authorized through mutual signature of KSA Engineers, Inc. Task Order dated October 17, 2016. The project scope was performed in general accordance with Terracon Proposal No. P96165290 dated August 12, 2016.

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

- Foundation design and construction recommendations;
- Site, subgrade, and fill preparation; and
- Seismic site classification according to IBC 2012/2015.

2.0 PROJECT INFORMATION

2.1 Site Location and Description

Item	Description
Location	The project site is located at 921 Main Street in Bastrop, Texas. (See Exhibit A-1 Site and Aerial Location Map in Appendix A).
Existing Improvements	The site currently consists of an existing floor slab and exterior wall. The previous building burned down and was subsequently demolished, except for the rear wall and slab.
Existing Ground Cover	Concrete.
Existing Topography	Unknown at this time, but the existing slab appears relatively flat.

2.2 Project Description

Item	Description
Site layout	See Exhibit A-2, Boring Location Plan, in Appendix A.
Proposed Improvements	The project will include the construction of a two-story commercial structure.
Building Construction	Assumed to be interior light gage steel framing with a masonry or stucco façade.
Finished Floor Elevation	Unknown at this time. Assumed to be within one foot of existing grades.
Maximum Loads (Assumed)	Columns: Up to 150 kips Walls: 1 to 4 klf Slabs: 100 to 150 psf max
Grading	Minimal site grading anticipated.
Cut and fill slopes	Not anticipated.
Free-Standing Retaining Walls	Not anticipated.
Below Grade Areas	Not anticipated.

3.0 SUBSURFACE CONDITIONS

3.1 Geology

Based on our review of available geological geological information[1] and the samples obtained from the borings, the site appears to lie within in area characterized by the Upper Colorado River terrace deposits of Pleistocene Age. The terrace deposits typically consist of gravel, sand, silt, and clay mixtures deposited through historic river action.

3.2 Typical Profile

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

Description	Approximate Depth Range of Stratum, feet	Material Encountered	Soil Consistency/ Soil Density
Stratum Ia	0.3 – 2.5	Fill – Dark reddish-brown to brown sandy lean clay (CL)	Medium stiff

[1] Fisher, W.L., “Geologic Atlas of Texas – Austin Sheet”, Bureau of Economic Geology, The University of Texas at Austin, 1981.

Description	Approximate Depth Range of Stratum, feet	Material Encountered	Soil Consistency/ Soil Density
Stratum I	0.3 – 6	Dark brown to brown fat clay (CH) to lean clay (CL)	Very stiff to hard
Stratum II	4 – 14	Brown to light brown lean clay with sand (CL)	Stiff to hard
Stratum III	6.5 – 25	Light brown clayey sand (SC) to clayey sand with gravel (SC) to poorly graded sand (SP)	Very loose to dense

Conditions encountered at the boring locations are indicated on each individual boring log. Stratification boundaries on the boring logs represent the approximate location of changes in subsurface material types; in-situ, the transition between materials may be gradual. Details for the borings can be found on the boring logs on Exhibits A-4 through A-6 of Appendix A.

3.3 Groundwater

The borings were dry augered to completion depths of about 25 feet below existing grade. No groundwater was encountered at any time during drilling.

Although not observed during our field exploration, groundwater at the site may be encountered in the form of seepage traveling along pervious seams/fissures in the soil, along soil interfaces, and/or in fissures in the soil. 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.

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, moderate to highly expansive soils that exhibit a potential for volumetric change during moisture variations are present under the existing slab. These subgrade soils may experience expansion and contraction due to changes in moisture content;

however there is minimal exposed ground since the building is surrounded by pavements to the west and other buildings to the north and south. The soils at the surface could exhibit a Potential Vertical Rise (PVR) of up to about 1 inch, as estimated by the Texas Department of Transportation (TxDOT) Method TEX-124-E, at current conditions.

Based on the field and laboratory data available, along with our previous experience, it is our opinion that a monolithic slab-on-grade foundation system placed to bear on the existing soils would be appropriate to support the building. Alternatively, spread/continuous footings with a flat slab could also be used. Recommendations for these types of foundation systems are presented in the following subsections, along with other geotechnical engineering considerations for this project.

4.2 Earthwork

Construction areas should be stripped of all concrete slabs, old construction materials, loose soils, fill soils, and other unsuitable material currently present at the site. All remnants of existing foundations should be completely excavated and removed to at least 2 feet below finished grades. If any unusual items are unearthed during or after demolition, please contact us for further evaluation. Utilities to be abandoned should be completely removed from all proposed construction areas. 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. We recommend that Terracon be retained to assist in evaluating exposed subgrades during earthwork so that unsuitable materials, if any, are removed at the time of construction.

Once final subgrade elevations have been achieved (including the over-excavation required for building pad), the exposed subgrade should be carefully proofrolled with a 10-ton pneumatic roller to detect weak zones in the subgrade. Weak areas detected during proofrolling 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 as per **Section 4.2.1 – Minimum Compaction Requirements**. Select fill and on-site soils should meet the following criteria.

Fill Type [1]	USCS Classification	Acceptable Location For Placement
Imported Select Fill [2]	CL, SC, and/or GC ($7 \leq PI \leq 20$)	Select fill material should be used for all grade adjustments within the building limits.

Fill Type [1]	USCS Classification	Acceptable Location For Placement

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 7 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. Crushed concrete (per TxDOT Item 247, Type D, Grade 3 or better) is also acceptable provided it is free of reinforcing steel and other miscellaneous objects. As an alternative, a low-plasticity granular fill material which does not meet these specifications may be used only if approved by Terracon.

4.2.1 Minimum Compaction Requirements

Recommended compaction and moisture content criteria for engineered fill materials are as follows:

Material Type and Location		Per the Standard Proctor Test (ASTM D 698)		
		Minimum Compaction Requirement (%)	Range of Moisture Contents for Compaction	
			Minimum	Maximum
Crushed Limestone Base		95	-3%	+3%
Imported Select Fill		95	-3%	+3%
Moisture Conditioned Subgrade	PI ≤ 25	95	-3%	+3%
	PI > 25	95	Optimum	+4%

Engineered fill materials should be placed in horizontal, loose lifts not exceeding 8 inches in thickness and should be thoroughly compacted. Where light compaction equipment is used, as is customary within a few feet of walls and in utility trenches, the lift thickness may need to be reduced to achieve the desired degree of compaction.

We recommend that engineered fill be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

4.2.2 Grading and Drainage

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

Positive drainage away from the structure 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 structure during and after construction. Adjacent concrete sidewalks should be sloped to provide drainage away from the building and all joints should be sealed, particularly those directly abutting the building.

Roof runoff and surface drainage should be collected and discharged away from the structure to prevent wetting of the foundation soils. Roof gutters should be installed and connected to downspouts and pipes directing roof runoff into storm water collection systems, or discharged onto positively sloped pavements. Special care should be taken such that underground utilities do not develop leaks with time.

4.2.3 Temporary Groundwater Control

Although not encountered during our drilling operations, groundwater seepage may be encountered 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 any interior excavation could be required to remediate isolated water pockets.

4.3 Foundation System

As previously mentioned in **Section 4.1 – Geotechnical Considerations**, we recommend that a monolithic slab-on-grade foundation system placed to bear in select fill soils would be appropriate to support the proposed structure. Alternatively, spread/continuous footings with a flat slab may also be used. These recommendations should be used in conjunction with the subgrade preparation recommendations provided in **Section 4.4 – Building Subgrade Preparation**, to reduce shrink/swell potential to below 1 inch.

4.3.1 Design Recommendations – Monolithic Slab-on-Grade

Monolithic slab-on-grade foundation systems (either conventionally reinforced or post-tensioned) would be appropriate to support the structure at the site provided subgrade preparation as described in ***Section 4.4 – Building Subgrade Preparation***. 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 grade[1]		18 inches	
Bearing Pressures (allowable) [2]	**On-site Soils**	Net dead plus sustained live load – 1,700 psf Net total load – 2,500 psf	
Subgrade Modulus (k) [3]		150 pci	
Approximate Potential Vertical Rise (PVR)		**Prepared Subgrade**	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 existing subgrade 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. Dependent on the amount of subgrade preparation employed. 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**	**Prepared Subgrade**	21
Climatic Rating (C_w)			18
Unconfined Compressive Strength			1.0 tsf
Soil Support Index (C) for BRAB		**Prepared Subgrade**	0.94

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]		
Maximum Depth of Seasonal Moisture Change[2]		15 feet
Plasticity Index [3]		Select Fill – 15 Stratum I Soils – 26 Stratum II Soils – 15 Stratum III Soils – 15
Percent Finer than 2 Microns (estimated) [3]		Select Fill – 20 Stratum I Soils – 40 Stratum II Soils – 25 Stratum III Soils - 20
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 (ft)** [6]	8.5 feet
	Edge Lift (ft) [6]	4.3 feet
Differential Soil Movement, y_m [5]	**Center Lift (in)** [6]	1.1 inches
	Edge Lift (in) [6]	1.6 inches

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[2] 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 may be used provided subgrade preparation is implemented as described in **Section 4.4** below.

2. 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.

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 I fat clay soils at boring B-2 are a concern, however the risk is low considering that the amount of exposed ground surface is limited due to front sidewalks/paving and buildings to the north and south. We recommend that the potential effects of these soils be reduced by following the recommendations presented in ***Section 4.4 – Building Subgrade 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 about 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 – Continuous/Spread Footings

As an alternative, spread/strip footings placed to bear in on-site soils would be appropriate to support the proposed structure. Design parameters for continuous/spread footing foundations are provided below.

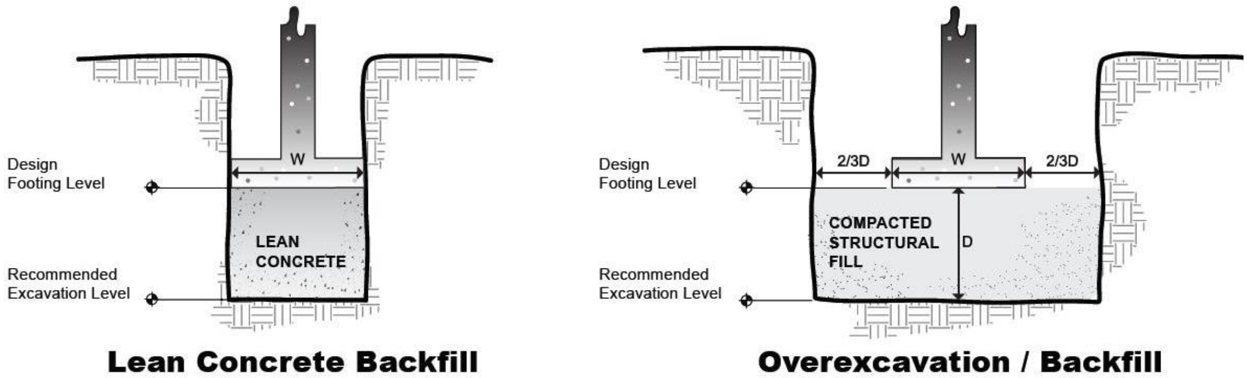
Description		Design Parameter
Bearing Stratum		On-site Soils
Minimum Embedment below final grades [1]		18 inches
Bearing Pressure (net allowable)		2,500 psf
Minimum Footing Dimensions	**Continuous (Strip)**	18 inches wide
	Isolated (Spread)	3 feet by 3 feet square
Approximate Total Settlement [2]		1-inch maximum
Estimated Differential Settlement [3]		Approximately ½ to ¾ of total settlement
Allowable Passive Resistance [4]		300 psf per foot of depth
Coefficient of Sliding Friction [5]		0.35
Uplift Resistance [6]		Foundation Weight (150 pcf) & Soil Weight (120 pcf)

1. The minimum embedment is intended to provide footings that bear in on-site soils.
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 overexcavated during construction, the open space between the design footing dimensions and the surrounding sides 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.
6. The ultimate uplift capacity of shallow footings should be reduced by an appropriate factor of safety to compute allowable uplift capacity.

4.3.3 Foundation Construction Considerations

Grade beams and 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. 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 additional unsuitable soils such as low strength or disturbed soils are encountered below the design footing elevation, the footing excavations should be deepened to expose suitable bearing materials and backfilled with either lean concrete or granular material. If lean concrete backfill (minimum 28-day compressive strength of 1,500 psi) is used, widening of the footing excavation will not be required. For granular (crushed limestone or clean well-graded granular material) backfill beneath footings, the excavations should be widened at least 8 inches beyond each footing edge for every foot of new fill placed below the design footing base elevation. The overexcavated depth should then be backfilled up to the foundation base elevation with approved material, placed in lifts and compacted to at least 95% of the material's standard Proctor (ASTM D 698) maximum dry density. The recommended extents of the overexcavation and backfill procedure are illustrated in the following figure.



NOTE: Excavations in sketches shown vertical for convenience. Excavations should be sloped as necessary for safety.

Concrete should be placed as soon as possible after excavation to reduce bearing soil disturbance. Soils at bearing level that become disturbed or saturated should be removed prior to placing reinforcing steel and concrete. Adequate water control/dewatering system will aid in minimizing need for over-excavation and backfill of any soils disturbed by prolonged exposure. It is important that the foundation subgrade not be disturbed by construction activities (e.g., setting forms and placing reinforcing steel). If disturbance occurs, we recommend that the disturbed soils be removed and that the foundation subgrade be protected with the placement of a lean concrete "mud mat".

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.

4.3.3.1 Foundation Construction Monitoring

The performance of the foundation system for the proposed structure 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 Subgrade Preparation

Information about proposed grades and FFE for the proposed building has not been provided to Terracon at this time. However, Terracon is assuming that the structure will be at or slightly above (≤ 1 feet) from existing grades. If this is incorrect, Terracon should be notified to review and modify and/or verify recommendations in writing. Please provide grading and FFE information to Terracon as soon as it is known for verification of the below recommendations.

In order to maintain a PVR of 1-inch, we recommend that the on-site soils be excavated to a depth of 12 inches below existing grades. The removed soils should then be replaced with properly compacted select fill, up to finished grades.

Prior to placement and compaction of select fill, the subgrade should be scarified, moisture adjusted, compacted, and thoroughly proofrolled with a 10-ton roller to detect weak zones in the subgrade as discussed in **Section 4.2 – Earthwork**. ***All fill material placed within the building footprint should meet the requirements of Select Fill described in Section 4.2 – Earthwork.*** Material and placement requirements for select fill, as well as other subgrade preparation recommendations, are presented in **Section 4.2 – Earthwork**. 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
2012/2015 International Building Code (IBC)	A[1]	D[2]

1 Per IBC 2012/2015 Section 1613.3.1. Latitude: 30.1101°N Longitude: 97.3197°W

Per IBC 2012/2015, S_s=0.068; S_1=0.035; S_{MS}=0.109; S_{M1}=0.083; S_{DS}=0.073; S_{D1}=0.055

2 Per IBC 2012/2015 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 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. If you require parameters for earlier versions of IBC, please contact us.

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

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

Project Mgr: EEJ	Project No. 96165290	Terracon Consulting Engineers & Scientists	SITE AERIAL AND LOCATION MAP	EXHIBIT
Drawn By: EEJ	Scale: NTS	5307 Industrial Oaks Blvd, Suite 160, Austin, Texas 78735	921 Main Street Reconstruction	A-1
Checked By: BSM	File Name: 96165290	PH. (512) 442-1122 FAX. (512) 442-1181	921 Main Street	
Approved By: BSM	Date: Nov 28, 2016		Bastrop, Texas	

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

Project Manager:	EEJ	Project No.	96165290
Drawn by:	EEJ	Scale:	N.T.S
Checked by:	BSM	File Name:	96165290
Approved by:	BSM	Date:	Nov 28, 2016

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Consulting Engineers & Scientists
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BORING LOCATION PLAN

921 Main Street Reconstruction
921 Main Street
Bastrop, Texas

Exhibit

A-2

Field Exploration Description

Subsurface conditions were evaluated by drilling 3 borings (B-1 through B-3) to depths of about 25 feet. 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. GPS coordinates for the borings were obtained in the field using a hand-held Garmin GPS unit.

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

Soil samples were recovered using a thin-walled, open-tube sampler (Shelby tube). A pocket penetrometer test was performed on the 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 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. A CME automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. A greater efficiency is typically achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. Published correlations between the SPT values 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 over what would be obtained using the cathead and rope method. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

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: 921 Main Street Office Reconstruction

**CLIENT: KSA Engineers, Inc.
Austin, TX 78759**

**SITE: 921 Main Street
Bastrop, Texas**

LOCATION See Exhibit A-2

Latitude: 30.1101° Longitude: -97.3198°

DEPTH	Description
0.3	4" Concrete (Approximate)
4.0	**LEAN CLAY (Stratum I) (CL)**, dark brown, very stiff to hard
8.0	**LEAN CLAY WITH SAND (Stratum II) (CL)**, brown to light brown, hard
25.0	**CLAYEY SAND (Stratum III) (SC)**, light brown, very loose to medium dense; -becomes more coarse-grained at 18.5 feet
	Boring Terminated at 25 Feet

FIELD TEST RESULTS	SWELL (%)	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2.75 tsf (HP)					17			
4.0 tsf (HP)	0.9				17	110	43-15-28	87
4.5+ tsf (HP)					15			
4.5+ tsf (HP)					13		27-15-12	75
N/A					8			
2-1-2 N=3					11			43
6-8-8 N=16								
5-8-9 N=17								

DEPTH (Ft.): 5, 10, 15, 20, 25

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

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 25 feet

Abandonment Method:
Backfilled with Auger Cuttings and/or Bentonite
Surface Capped with Asphalt

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 Ste 160
Austin, TX

Boring Started: 10/28/2016	Boring Completed: 10/28/2016
Drill Rig: CME 55	Driller: Austin Geo-Logic
Project No.: 96165290	Exhibit: A-4

BORING LOG NO. B-2

PROJECT: 921 Main Street Office Reconstruction

CLIENT: KSA Engineers, Inc.
Austin, TX 78759

SITE: 921 Main Street
Bastrop, Texas

LOCATION See Exhibit A-2

Latitude: 30.1101° Longitude: -97.3197°

DEPTH	Description
0.4	4.5" Concrete (Approximate)
6.0	**FAT CLAY (Stratum I) (CH)**, dark brown to brown, very stiff
14.0	**LEAN CLAY WITH SAND (Stratum II) (CL)**, brown, stiff to very stiff
25.0	**POORLY GRADED SAND (Stratum III) (SP)**, light brown, medium dense to dense -with gravel at 18 feet
	Boring Terminated at 25 Feet

FIELD TEST RESULTS	SWELL (%)	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2.75 tsf (HP)					19			
2.5 tsf (HP)					21			
2.5 tsf (HP)		UC	2.58	12.4	23	101	51-16-35	91
2.5 tsf (HP)					20		33-15-18	85
1.75 tsf (HP)					18			
2.5 tsf (HP)					6			
4-6-5 N=11								
6-15-15 N=30								

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

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 25 feet

Abandonment Method:
Backfilled with Auger Cuttings and/or Bentonite
Surface Capped with Asphalt

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 Ste 160
Austin, TX

Boring Started: 10/28/2016
Boring Completed: 10/28/2016
Drill Rig: CME 55
Driller: Austin Geo-Logic
Project No.: 96165290
Exhibit: A-5

BORING LOG NO. B-3

PROJECT: 921 Main Street Office Reconstruction

CLIENT: KSA Engineers, Inc.
Austin, TX 78759

SITE: 921 Main Street
Bastrop, Texas

LOCATION See Exhibit A-2

Latitude: 30.1101° Longitude: -97.3196°

DEPTH	Description
0.3	4" Concrete (Approximate)
2.5	**FILL - SANDY LEAN CLAY (Stratum Ia) (CL)**, dark reddish-brown to brown, medium stiff, with light brown seams
6.5	**LEAN CLAY (Stratum I) (CL)**, dark brown to brown, very stiff to hard
13.5	**SILTY SAND (Stratum III) (SM)**, light brown, loose
25.0	**CLAYEY SAND WITH GRAVEL (Stratum III) (SC)**, light brown, dense -becomes loose to medium dense with a decrease in gravel at 18.5 feet
	Boring Terminated at 25 Feet

FIELD TEST RESULTS	SWELL (%)	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2-3-2 N=5					13		32-15-17	55
2.75 tsf (HP)					14		39-15-24	
4.5+ tsf (HP)					17			
N/A					9			
4-3-4 N=7					9		20-18-2	46
4-22-26 N=48					4			13
3-4-3 N=7								
2-5-12 N=17								

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

Hammer Type: Automatic

Advancement Method:
Dry Augered 0 to 25 feet

Abandonment Method:
Backfilled with Auger Cuttings and/or Bentonite
Surface Capped with Asphalt

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 Ste 160
Austin, TX

Boring Started: 10/28/2016	Boring Completed: 10/28/2016
Drill Rig: CME 55	Driller: Austin Geo-Logic
Project No.: 96165290	Exhibit: A-6

APPENDIX B

LABORATORY TESTING

Laboratory Testing

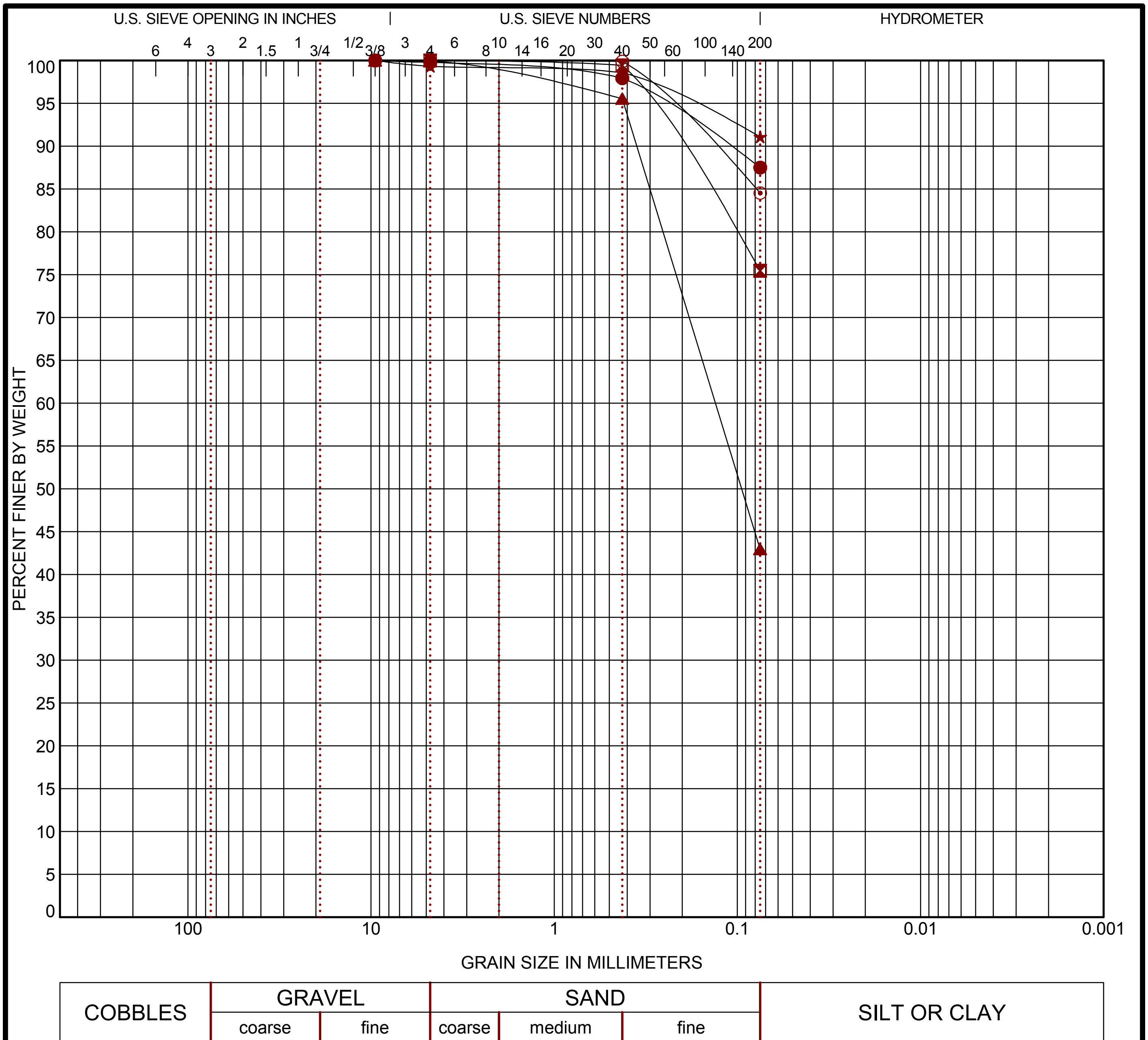
Samples obtained during the field program were visually classified in the laboratory by a geotechnical engineer. A testing program was conducted on selected samples, as directed by the geotechnical engineer, to aid in classification and evaluation of engineering properties required for analyses.

Results of the laboratory tests are presented on the boring logs located in Appendix A, in 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



Symbol	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	B-1	2 - 4	LEAN CLAY (CL)		43	15	28		
⊠	B-1	6 - 8	LEAN CLAY with SAND (CL)		27	15	12		
▲	B-1	13.5 - 15							
★	B-2	4 - 6	FAT CLAY (CH)		51	16	35		
⊙	B-2	6 - 8	LEAN CLAY with SAND (CL)		33	15	18		

Symbol	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	B-1	2 - 4	9.5				0.2	12.3		87.5	
⊠	B-1	6 - 8	4.75				0.0	24.6		75.4	
▲	B-1	13.5 - 15	9.5	0.132			0.1	57.0		42.9	
★	B-2	4 - 6	9.5				0.7	8.2		91.1	
⊙	B-2	6 - 8	4.75				0.0	15.5		84.5	

PROJECT: 921 Main Street Office Reconstruction

SITE: 921 Main Street
Bastrop, Texas

Terracon
5307 Industrial Oaks Blvd Ste 160
Austin, TX

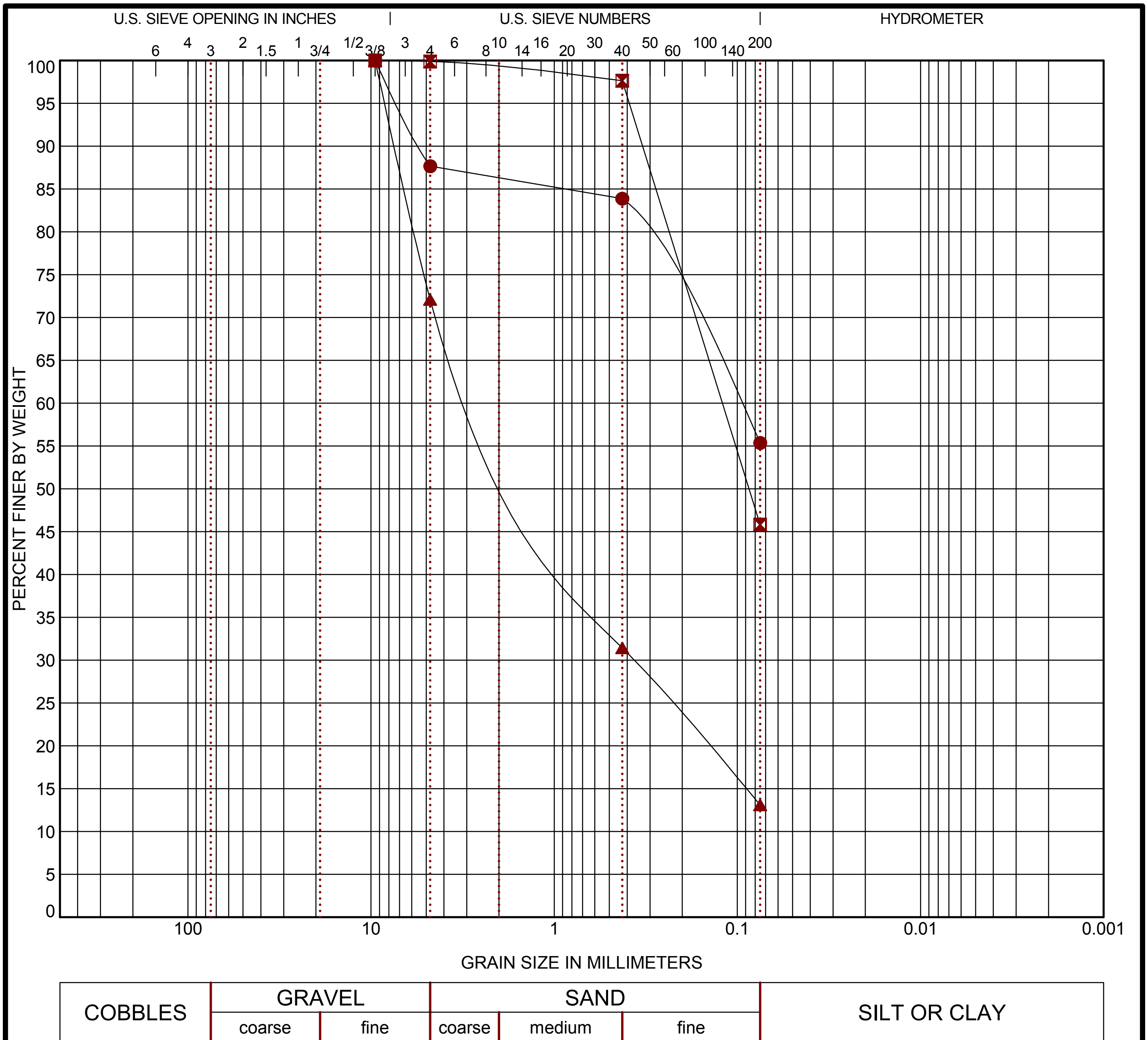
PROJECT NUMBER: 96165290

CLIENT: KSA Engineers, Inc.
Austin, TX 78759

EXHIBIT: B-2

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
● B-3	0.5 - 2	SANDY LEAN CLAY (CL)		32	15	17		
⊠ B-3	8.5 - 10	SILTY SAND (SM)		20	18	2		
▲ B-3	13.5 - 15							

Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
● B-3	0.5 - 2	9.5	0.099			12.3	32.3		55.4	
⊠ B-3	8.5 - 10	9.5	0.121			0.1	54.1		45.8	
▲ B-3	13.5 - 15	9.5	2.319	0.371		27.9	59.0		13.1	

PROJECT: 921 Main Street Office Reconstruction

SITE: 921 Main Street
Bastrop, Texas

Terracon
5307 Industrial Oaks Blvd Ste 160
Austin, TX

PROJECT NUMBER: 96165290

CLIENT: KSA Engineers, Inc.
Austin, TX 78759

EXHIBIT: B-3

APPENDIX C

SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING	WATER LEVEL	FIELD TESTS
Auger Cuttings 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.	N — Standard Penetration Test Resistance (Blows/Ft.) (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

Terracon

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 ≥ 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.

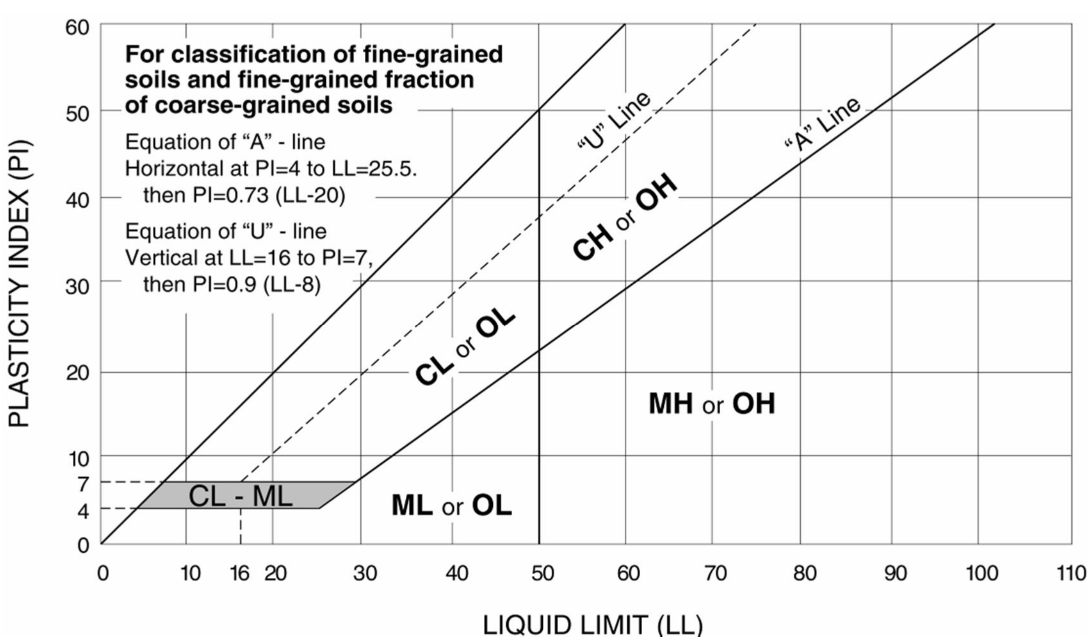
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[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