RABA KISTNER

# GEOTECHNICAL ENGINEERING STUDY

FOR

# MEYER RANCH - UNIT 14
# COMAL COUNTY, TEXAS

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Project No. ANA23-025-00
August 24, 2023

Mr. James Wilson
CCD Meyer Ranch Land, Ltd.
9666 West State Highway 46
New Braunfels, Texas 78132

**RE: Geotechnical Engineering Study**
**Meyer Ranch - Unit 14**
**Comal County, Texas**

Dear Mr. Wilson:

RABA KISTNER Inc. (RKI) is pleased to submit the report of our Geotechnical Engineering Study for the above-referenced project. This study was performed in accordance with RKI Proposal No. PNA23-034-00, dated May 19, 2023. The purpose of this study was to drill borings within the proposed residential lots and roadways, to perform laboratory testing to classify and characterize subsurface conditions, and to prepare an engineering report presenting foundation design and construction recommendations for the proposed residential development, as well as to provide pavement design and construction guidelines.

The following report contains our design recommendations and considerations based on our current understanding of the project information provided to our office. There may be alternatives for value engineering of the pavement systems, and RKI recommends that a meeting be held with the Owner and design team to evaluate these alternatives.

We appreciate the opportunity to be of service to you on this project. Should you have any questions about the information presented in this report, or if we may be of additional assistance with value engineering or on the materials testing-quality control program during construction, please call.

Very truly yours,

**RABA KISTNER, INC.**

Santosh Shrestha, E.I.T.
Graduate Engineer

Ian Perez, P.E.
Vice President

STATE OF TEXAS
TERRANCE IAN PEREZ
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Attachments

Copies Submitted: Above (1) – Email Only

**GEOTECHNICAL ENGINEERING STUDY**

For

**MEYER RANCH - UNIT 14**
**COMAL COUNTY, TEXAS**

Prepared for

**CCD MEYER RANCH LAND, LLC**
New Braunfels, Texas

Prepared by

**RABA KISTNER, INC.**
New Braunfels, Texas

**PROJECT NO. ANA23-025-00**

August 24, 2023

RABA KISTNER

# TABLE OF CONTENTS

**TABLE OF CONTENTS**

## TABLE OF CONTENTS



## ATTACHMENTS

The following figures are attached and complete this report:

## INTRODUCTION

RABA KISTNER Inc. (RKI) has completed the authorized subsurface exploration and foundation analysis for the proposed single family residences and roadways located within Unit 14 of the Meyer Ranch subdivision in Comal County, Texas as illustrated on Figure 1. This report briefly describes the procedures utilized during this study and presents our findings along with our recommendations for foundation design and construction considerations, as well as for pavement design and construction guidelines.

## PROJECT DESCRIPTION

To be considered in this study are 35 single-family residential structures within Unit 14 of the Meyer Ranch subdivision in Comal County, Texas. The proposed structures are anticipated to create relatively light structural loads to be carried by the individual foundation systems. Floor systems consisting of slabs-on-ground or slabs-on-fill are expected to be preferred, provided soil-related, potential vertical movements will not cause structural performance problems.

In addition, the roadways interior to Unit 14 are considered in this study. It is our understanding that the interior roadways will be local roads and we have included options for Local Type A roadways (both with and without Bus Traffic) and Local Type B roadways. The aforementioned roadways are designed using guidance from The City of San Antonio's *Transportation and Capital Improvements Design Guidance Manual*, dated October 2017.

Our understanding of the existing topography and proposed site grading are based on a drawing entitled "C7.00 Overall Grading Plan" dated July 2023 provided to us in an email on August 10, 2023 from Ms. Catherine Lundberg, P.E., Project Manager with Pape-Dawson Engineers. Based on this drawing, the topographic high and low within the proposed site are estimated to be 1196.0 and 1169.0 ft, respectively.

## LIMITATIONS

This engineering report has been prepared in accordance with accepted Geotechnical Engineering practices in the region of south/central Texas and for the use of CCD Meyer Ranch Land, LLC (CLIENT) and its representatives for design purposes. This report may not contain sufficient information for purposes of other parties or other uses. This report is not intended for use in determining construction means and methods. The attachments and report text should not be used separately.

The recommendations submitted in this report are based on the data obtained from 9 borings and our understanding of the project information provided to us. If the project information described in this report is incorrect, is altered, or if new information is available, we should be retained to review and modify our recommendations.

This report may not reflect the actual variations of the subsurface conditions across the site. This is particularly true with respect to the depth of the surficial soils, the depth to the top of the limestone, and the potential presence of karstic features. The nature and extent of variations across the site may not become evident until construction commences. The construction process itself may also alter subsurface conditions. If variations appear evident at the time of construction, it may be necessary to reevaluate our recommendations after performing on-site observations and tests to establish the engineering impact of the variations.

The scope of our Geotechnical Engineering Study does not include an environmental assessment of the air, soil, rock, or water conditions either on or adjacent to the site. No environmental opinions are presented in this report.

If additional mass site grading is performed at the site which results in elevations that vary significantly from proposed grades (more than plus or minus 1 ft), our office should be informed about these changes. If needed and/or if desired, we will reexamine our analyses and make supplemental recommendations. A review of the report is not required if the only additional fill materials placed at the site are select fill materials placed in building pad areas.

## BORINGS AND LABORATORY TESTS

Subsurface conditions at the site were evaluated by 9 borings drilled/hand augered at the locations shown on the Boring Location Map, Figure 1. These locations are approximate and distances were measured using a hand-held, recreational-grade GPS locator. Due to access issues, Borings B-2 through B-9 were hand sampled at the site. The borings were drilled using a truck-mounted drilling rig or hand augered to depths ranging from 1/2 ft to 7 ft below the existing ground surface. During drilling operations, split-spoon samples with Standard Penetration Testing (SPT) and hand samples were collected. Where split-spoon samples achieved little to no recovery, supplemental grab samples of auger cuttings were collected.

**Boring Summary**

| Associated Boring | Lot No. |
|---|---|
| B-1 | - |
| B-2 | 32 through 35 |
| B-3 | 1 through 5 |
| B-4 | 26 through 31 |
| B-5 | 6 through 12 |
| B-6 | 23 through 25 |
| B-7 | 13 and 14 |
| B-8 | 20 through 22 |
| B-9 | 15 through 19 |

Each sample was visually classified in the laboratory by a member of our geotechnical engineering staff. The geotechnical engineering properties of the strata were evaluated by natural moisture content testing, Atterberg limits determinations, and grain size analyses (percent passing No. 200 sieve and hydrometer testing).

The results of all laboratory tests are presented in graphical or numerical form on the boring logs illustrated on Figures 2 through 10. A key to classification terms and symbols used on the logs is presented on Figure 11. The results of the laboratory and field testing are also tabulated on Figure 12 for ease of reference. The results of our hydrometer tests are presented on the Grain Size Distribution on Figure 13.

Standard Penetration Test results are noted as "blows per ft" on the boring logs and Figure 12, where "blows per ft" refers to the number of blows by a falling hammer required for 1 ft of penetration into the soil/weak rock (N-value). Where hard or dense materials were encountered, the tests were terminated at 50 blows even if one foot of penetration had not been achieved. When all 50 blows fall within the first 6 in. (seating blows), refusal "ref" for 6 in. or less will be noted on the boring logs and on Figure 12.

In addition to the above listed testing and sampling, 1 bulk sample from the surficial soils was collected for use in CBR testing, pH-Lime Series testing, and sulfate content testing. Additional testing on the bulk sample includes Atterberg Limits determination at the percent lime content determined from the pH-Lime Series results (requires a lime content that achieves a pH of 12.4 or higher). The results of the CBR tests are presented on the Moisture-Density Relationship Curve presented on Figure 14. The results of the pH-lime series test are presented on the pH-Lime Series Curve on Figure 15 and the Dry Density vs. CBR is presented graphically on Figure 16. A summary of the bulk sample testing results are presented in the following table:

| Material Type | Location | Depth, (ft) | Maximum Dry Density, (pcf) | Optimum Moisture Content (%) | Corrected Laboratory CBR | Average Percent Swell (%) | Sulfate Content (ppm) |
|---|---|---|---|---|---|---|---|
| Dark Brown Clay with sand | 50 ft East of Boring B – 2 | 0 - 1 | 102.7 | 17.2 | 4.8 | 0.9 | Less than 100 |

Dynamic Cone Penetrometer (DCP) tests were also performed at select boring locations near proposed pavement areas from the existing ground surface to approximately 2 ft or practical equipment refusal and are the results are presented on Figure 17.

Samples will be retained in our laboratory for 30 days after submittal of this report. Other arrangements may be provided at the request of the Client.

## GENERAL SITE CONDITIONS

### SITE DESCRIPTION

The project site is an undeveloped tract of land located within the Meyer Ranch subdivision in New Braunfels, Comal County, Texas. There are no existing structures within Unit 14; however, it is covered with bushes and boulders/rock outcrops and traversing the site with a standard vehicle was difficult.

### GEOLOGY

A review of the *Geologic Atlas of Texas, San Antonio Sheet*, indicates that this site is naturally underlain with the soils/rock (limestone) of the Edwards Group.

Edwards limestone is generally considered hard in induration and typically contains harder zones/seams of chert and dolomite. Edwards limestone also typically contains karstic features in the form of open and/or clay-filled vugs, voids, and/or solution cavities that form as a result of solution movement through fractures in the rock mass.

Key geotechnical engineering considerations for development supported on these formations will be the depth to rock, the expansive nature of the overlying clays, the condition of the rock, porous zones and the hardness of the limestone as it impacts excavation operations and the presence/absence of karstic features.

## SEISMIC CONSIDERATIONS

The following information has been summarized for seismic considerations associated with this site per ASCE 7-16 edition.

- Site Class Definition: **Class C**. Based on the soil borings conducted for this investigation and our experience in the area, the upper 100 ft of soil may be characterized as very dense soil and soft rock.
- Risk-Targeted Maximum Considered Earthquake Ground Motion Response Accelerations for the Conterminous United States of 0.2-Second Spectral Response Acceleration (5% Of Critical Damping): $\mathbf{S_s = 0.050g}$.
- Risk-Targeted Maximum Considered Earthquake Ground Motion Response Accelerations for the Conterminous United States of 1-Second Spectral Response Acceleration (5% Of Critical Damping): $\mathbf{S_1 = 0.027g}$.
- Values of Site Coefficient: $\mathbf{F_a = 1.3}$
- Values of Site Coefficient: $\mathbf{F_v = 1.5}$
- Where g is the acceleration due to gravity.

The Maximum Considered Earthquake Spectral Response Accelerations are as follows:

- 0.2 sec, adjusted: $\mathbf{S_{ms} = 0.065g}$
- 1 sec, adjusted: $\mathbf{S_{m1} = 0.041g}$

The Design Spectral Response Acceleration Parameters (SA) are as follows:

- 0.2 sec SA: $\mathbf{S_{DS} = 0.043g}$
- 1 sec SA: $\mathbf{S_{D1} = 0.027g}$

## STRATIGRAPHY

In general, the subsurface stratigraphy at this site can generally be described as highly plastic dark brown clay with plasticity indices ranging from 42 to 65 overlying tan limestone. In Boring B-1, 4 ft of fill was encountered overlying the dark brown clay and is associated with development of the adjacent units/roadways. The existing fill is comprised of dark brown and tan clay with gravel. In our borings, depth to the top of bedrock ranged from 0 ft to 6 ft.

Each stratum has been designated by grouping soils that possess similar physical and engineering characteristics. The boring logs should be consulted for more specific stratigraphic information. Unless noted on the boring logs, the lines designating the changes between various strata represent approximate boundaries. The transition between materials may be gradual or may occur between recovered samples. The stratification given on the boring logs, or described herein, is for use by RKI in its analyses and should not be used as the basis of design or construction cost estimates without realizing that there can be variation from that shown or described.

The boring logs and related information depict subsurface conditions only at the specific locations and times where sampling was conducted. The passage of time may result in changes in conditions, interpreted to exist, at or between the locations where sampling was conducted.

## GROUNDWATER

Groundwater was not observed in the borings either during or immediately upon completion of the drilling operations. However, it is possible for groundwater to exist beneath this site at shallow depths on a transient basis, particularly at the clay/limestone interface, within weathered seams or karst features, and following periods of precipitation. Fluctuations in groundwater levels occur due to variation in rainfall and surface water run-off. The construction process itself may also cause variations in the groundwater level.

# FOUNDATION ANALYSIS

## EXPANSIVE SOIL-RELATED MOVEMENTS

The anticipated ground movements due to swelling of the underlying soils at the site were estimated for slab-on-grade construction using the empirical procedure, Texas Department of Transportation (TxDOT) Tex-124-E, Method for Determining the Potential Vertical Rise (PVR). PVR values within the proposed lots were estimated to be 1 inch or less, whereas a PVR value of 2-1/2 inches was estimated for Boring B-1, where fill was encountered. A surcharge load of 1 psi (concrete slab and sand layer), an active zone based on the depth to rock, and dry moisture conditions were assumed in estimating the above PVR values. The estimated PVR values are also presented in the following table.

| Lot No. | Estimated PVR (in.) |
|---|---|
| All Lots | 1 in. or less(1) |

(1)Based on existing ground condition/select fill to the FFE. Select fill material should be selected and placed in accordance with the *Select Fill* section of this report.

The TxDOT method of estimating expansive soil-related movements is based on empirical correlations utilizing the measured plasticity indices and assuming typical seasonal fluctuations in moisture content. If desired, other methods of estimating expansive soil-related movements are available, such as estimations based on swell tests and/or soil-suction analyses. However, the performance of these tests and the detailed analysis of expansive soil-related movements were beyond the scope of the current study. It should also be noted that actual movements can exceed the calculated PVR values due to isolated changes in moisture content (such as due to leaks, landscape watering....) or if water seeps into the soils to greater depths than the assumed active zone depth due to deep trenching or excavations.

## FOUNDATION RECOMMENDATIONS

### SITE GRADING

Site grading plans can result in changes in almost all aspects of foundation recommendations. We have prepared all foundation recommendations based on the grading information provided to us and the stratigraphic conditions encountered at the time of our study. If site grading changes by plus or minus 1 ft from what is discussed in this report, RKI must be retained to review the site grading plans prior to bidding the project for construction. This will enable RKI to provide input for any changes in our original recommendations that may be required as a result of site grading operations or other considerations. A review of the report is not required if the only additional fill materials placed at the site are select fill materials placed within the interior of grade beams for slab support. We recommend that site grading for individual lots limit the differential in building pad thickness to 3 ft to avoid problems with differential settlement unless all grade beams are being excavated to natural materials.

Limestone is anticipated to be encountered at a relatively shallow depth. For rock bearing foundations, we recommend that the grade beams, if utilized, penetrate 4 inches or more into the native, intact limestone. We do not recommend that the grade beams for an individual residence be founded partially in limestone and partially in natural clays or select fill as this condition may result in greater differential movements than are provided by the PTI criteria. In this instance it is recommended that all grade beams either be extended down into the limestone or, if constructed on a select fill building pad, that a minimum of 6 inches of select fill be placed and compacted prior to installing the grade beams.

### RIGID-ENGINEERED BEAM AND SLAB FOUNDATION

The single-family residential homes may be founded on rigid-engineered beam and slab foundations, provided the selected foundation type can be designed to withstand the anticipated soil-related movements (see *Expansive Soil-Related Movements*) without impairing either the structural or the operational performance of the structures.

#### Allowable Bearing Capacity

Shallow foundations should be proportioned using the design parameters in the following table, for clay subgrade, select fill, or limestone subgrades.

| Shallow Foundation Design Parameters | |
|---|---|
| Minimum depth below final grade | 12 in. |
| Minimum beam width | 10 in. |
| **Maximum Allowable Bearing Pressure** | |
| Grade beams bearing on natural soil | 2,250 psf |
| Grade beams bearing on compacted select fill | 2,750 psf |
| Grade beams bearing on limestone | 3,500 psf |
| Widened beams bearing on natural soil | 2,500 psf |
| Widened beams bearing on compacted select fill | 3,000 psf |
| Widened beams bearing on limestone | 4,000 psf |

The above presented maximum allowable bearing pressures will provide a calculated factor of safety of about 3 with respect to the measured shear strength, provided that the subgrade is prepared in accordance with the recommendations outlined in the *Site Preparation* section of this report or that fill is selected and placed as recommended in the *Select Fill* section of this report.

We recommend that a vapor barrier comprised of polyethylene or polyvinylchloride (PVC) sheeting be placed between the supporting soils and the concrete floor slab.

## B.R.A.B. Criteria

Beam and slab foundations are sometimes designed using criteria developed by the Building Research Advisory Board (B.R.A.B.). Recommended values for the Climatic Rating ($C_w$) and minimum unconfined compressive strength ($q_u$) are as listed in the table below:

| Design Parameter | Foundations Bearing in Clay or Select Fill | Foundation Bearing on Native, Intact Limestone |
|---|---|---|
| Climatic Rating, $C_w$ | 16 | 16 |
| Unconfined Compressive Strength, $q_u$ | 2,000 psf | 3,000 psf |

Recommended design plasticity index (PI) values are presented below for each of the lots considered in this study, as are estimated soil support index (C) values.

| Lot Numbers | Recommended Design Plasticity Index (PI) | Soil Support Index (C) |
|---|---|---|
| 26 through 31 | 42 | 0.72 |
| All other lots | >50 | 0.61 |

The design parameters presented above apply for conditions encountered in the associated test boring and for the grades existing at the time of our field exploration.

It should be noted that if the highest plasticity index (PI) value encountered in the subsurface profile occurs in the uppermost subsurface layer, B.R.A.B. criteria requires that this PI value be selected as the design PI. If desired, the design PI value may be reduced to 20 (Soil Support Index of 0.94), provided that all of the native clays are completely stripped from the residential building areas. If this operation is implemented, all subsequent fill placed in building areas must consist of non-expansive select fill.

**PTI Design Parameters**

Post Tensioning Institute (PTI) design parameters were estimated for existing stratigraphic conditions using the procedures and criteria discussed in the Post-Tensioning Institute Manual entitled *"Design of Post-Tensioned Slabs-on-Ground, Third Edition"* dated 2004 with the 2008 supplement.

Differential vertical swell has been estimated for center lift and edge lift conditions for use in designing foundation slabs for the stratigraphy encountered in our borings. These values were determined using a computer program entitled VOLFLO Win 1.5, as recommended by the Post Tensioning Institute. As recommended by PTI, we have evaluated differential swell for both 1) conditions varying from equilibrium and 2) conditions varying between extremes (wet/dry). The values for both of these conditions are presented in the following tables. Because soil moisture conditions are likely to vary from wet to dry and dry to wet over many cycles during the lifetime of the structure, we recommend that the conditions varying between the extremes be assumed for design. We have also evaluated the various conditions both without (Design condition A) and with (Design condition B) a 30 in. vertical moisture barrier (exterior grade beam) considering select fill to the FFE.

**Without Vertical Moisture Barrier (Design Condition A)**

| Lots | Edge Moisture Variation Distance (EL)(1), ft | Edge Moisture Variation Distant (CL)(1), ft | Differential Swell (in) | | | |
|---|---|---|---|---|---|---|
| | | | From E to W(1) | From E to D(1) | From D to W(1) | From W to D(1) |
| 13 and 14 | 4.1 | 8.0 | 1 (EL) | 1 (CL) | 2-3/4 (EL) | 1-3/4 (CL) |
| 1 through 12; and 15 through 35 | 4.0 | 7.8 | 1 (EL) | 3/4 (CL) | 2-1/2 (EL) | 1-1/2 (CL) |

(1) (EL) Edge Lift Condition, (CL) Center Lift Condition, (E) Equilibrium, (W) Wet, (D) Dry

**With Vertical Moisture Barrier (30 inch, Minimum, Exterior Grade Beam – Design Condition B)**

| Lots | Edge Moisture Variation Distance (EL)(1), ft | Edge Moisture Variation Distant (CL)(1), ft | Differential Swell (in) | | | |
|---|---|---|---|---|---|---|
| | | | From E to W(1) | From E to D(1) | From D to W(1) | From W to D(1) |
| 13 and 14 | 4.1 | 8.0 | 1/4 (EL) | 1/4 (CL) | 1 (EL) | 3/4 (CL) |
| 1 through 12, and 15 through 35 | 4.0 | 7.8 | 1/4 (EL) | 1/4 (CL) | 3/4 (EL) | 1/2 (CL) |

(1) (EL) Edge Lift Condition, (CL) Center Lift Condition, (E) Equilibrium, (W) Wet, (D) Dry

Additional design parameters are summarized in the following table:

| PTI Design Parameters | |
|---|---|
| Percent Fine Clay | 33 - 38[(1)] |
| Depth to Constant Suction, ft | 3 to 6 |
| Thornthwaite Index, IM | -13 |
| Constant Soil Suction | 3.8 pF |

[(1)]Based on the results of our hydrometer testing

## AREA FLATWORK

It should be noted that ground-supported flatwork such as walkways, courtyards, etc. will be subject to the same magnitude of potential soil-related movements as discussed previously (see *Expansive Soil-Related Movement* section). Thus, where these types of elements abut rigid building foundations or isolated/suspended structures, differential movements should be anticipated. As a minimum, we recommend that flexible joints be provided where such elements abut the main structure to allow for differential movement at these locations. Where the potential for differential movement is objectionable, it may be beneficial to consider methods of reducing anticipated movements or to consider structurally suspending critical areas to match the adjacent building performance.

# FOUNDATION CONSTRUCTION CONSIDERATIONS

## SITE DRAINAGE

Drainage is an important key to the successful performance of any foundation. Good surface drainage should be established prior to and maintained after construction to help prevent water from ponding within or adjacent to the building foundation and to facilitate rapid drainage away from the building foundation. Failure to provide positive drainage away from the structure can result in localized differential vertical movements in soil supported foundations and floor slabs (which can in turn result in cracking in the sheetrock partition walls, and shifting of ceiling tiles, as well as improper operation of windows and doors).

Also to help control drainage in the vicinity of the structure, we recommend that roof/gutter downspouts and landscaping irrigation systems not be located adjacent to the building foundation. Where a select fill overbuild is provided outside of the floor slab/foundation footprint, the surface should be sealed with an impermeable layer (pavement or clay cap) to reduce infiltration of both irrigation and surface waters. Careful consideration should also be given to the location of water bearing utilities, as well as to provisions for drainage in the event of leaks in water bearing utilities. All leaks should be immediately repaired.

Other drainage and subsurface drainage issues are discussed in the *Expansive Soil-Related Movements* section of this report and under *Pavement Construction Considerations*.

**SITE PREPARATION**

Each residential lots should be properly prepared for slab-on-grade foundation construction. The improvement areas should be stripped of all vegetation, loose topsoil and large rocks, if any. Tree roots greater than 1 in. in diameter should be grubbed and removed. Excavations resulting from removal of tree roots or stripping activities should be backfilled with a suitable, compacted onsite fill material, free of organics, degradable material, and particles exceeding 4 in. in size.

Exposed subgrades should be thoroughly proofrolled in order to locate weak, compressible zones. A minimum of 5 passes of a fully-loaded dump truck or a similar heavily-loaded piece of construction equipment should be used for planning purposes. Proofrolling operations should be observed and documented. Weak or soft areas identified during proofrolling should be removed and replaced with suitable, compacted on-site clays, free of organics, oversized materials, and degradable or deleterious materials.

Upon completion of the proofrolling operations and just prior to fill placement or slab construction, the exposed subgrade should be moisture conditioned by scarifying to a minimum depth of 6 in. and recompacting to a minimum of 95 percent of the maximum density determined from TxDOT Tex-114-E, or ASTM D698 Compaction Tests. The moisture content of the subgrade should be maintained within the range of optimum moisture content to 3 percentage points above optimum moisture content.

**SELECT FILL**

Recommendations for imported granular select fill building pad materials are provided in the following:

> **Imported Crushed Limestone Base** – Imported crushed limestone base materials should be should be crushed stone or gravel aggregate. We recommend that materials specified for use as select fill meet the TxDOT 2014 Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Item 247, Flexible Base, Type A or B, Grades 1-2 or 3.

Alternative select fill materials consist of the following:

> **Granular Pit Run Materials** – Granular pit run materials should consist of GC, SC & combination soils (clayey gravels), as classified according to the Unified Soil Classification System (USCS). Alternative select fill materials shall have a maximum liquid limit not exceeding 40, a plasticity index between 7 and 20, and a maximum particle size not exceeding 4 inch. In addition, if these materials are utilized, grain size analyses and Atterberg Limits must be performed during placement at a rate of one test each per 5,000 cubic yards of material due to the high degree of variability associated with pit-run materials. **Rock millings from onsite may be utilized if the material can be processed to meet these requirements.**

> **Low PI Materials** – Low PI materials should consist of lean clays, as classified according to the Unified Soil Classification System (USCS). Alternative select fill materials shall have a maximum liquid limit not exceeding 40, a plasticity index between 7 and 20, and a maximum particle size not exceeding 4 inch. In addition, if these materials are utilized, grain size analyses and Atterberg

Limits must be performed during placement at a rate of one test each per 5,000 cubic yards of material due to the high degree of variability associated with these materials.

**Treated Onsite Materials** – Lime/cement/super slurry treatment of the onsite soils may be considered in reducing the soil plasticity index (TxDOT Item 260 for lime and Item 275 for cement). This option reduces the potential for the "bathtub" effect as discussed in the section titled *Drainage Considerations.* A sufficient quantity of product should be mixed with the subgrade soils to reduce the soil-product mixture plasticity index to approximately 20 or less. Based on the results of the pH-Lime Series Curves, we recommend that at least 4 percent hydrated lime or 4 percent cement treatment by weight be used to increase the pH of the subgrade clays to 12.4 or higher. If cement treatment is selected, the mellowing period may be reduced to 24 hours prior to placing subsequent lifts. The final lift shall be cured for a minimum of 48 hours prior to placement of building foundation.

Alternatively, super slurry treatment can be used to reduce the PI and increase the soil stiffness. However, this is a proprietary product and the supplier should be contacted to evaluate the appropriate dosage rate. For this process, the contractor should allow a minimum of 12 hours, preferably 24 hours, before placing subsequent lifts.

We recommend that during site grading operations additional laboratory testing be performed to determine the appropriate treatment dosage rate and concentration of soluble sulfates in the onsite and imported soils.

If the above-listed materials or alternative select fills are being considered for bidding purposes, the materials should be submitted to the Geotechnical Engineer for evaluation at a minimum of 10 working days or more prior to the bid date. Failure to do so will be the responsibility of the contractor. The contractor will also be responsible for ensuring that the properties of all delivered alternate select fill materials are similar to those of the pre-approved submittal**. It should also be noted that when using alternative fill materials such as *Granular Pit Run or Low PI Materials*, difficulties may be experienced with respect to moisture control during and subsequent to fill placement, as well as with erosion, particularly when exposed to inclement weather. This may result in sloughing of beam trenches and/or pumping of the fill materials.**

Granular Pit Run or Low PI Materials will be very susceptible to small changes in moisture content and to disturbance from foot traffic during the placement of steel reinforcement in beam trenches, particularly in periods of inclement weather. Disturbance from such foot traffic and from the accumulation of excess water can result in losses in bearing capacity and increased settlement. If inclement weather is anticipated at the time construction, consideration should be given to protecting the bottom of foundation excavations by placing a thin mud mat (layer of flowable fill or lean concrete) at the bottom of trenches immediately following excavation. This will reduce disturbance from foot traffic and will impede the infiltration of surface water. The side slopes of beam trench excavations may also need to be flattened to reduce sloughing in cohesionless soils. All necessary precautions should be implemented to protect open excavations from the accumulation of surface water runoff and rain.

Soils classified as CH, MH, ML, SM, GM, OH, OL and Pt under the USCS are not considered suitable for use as select fill materials at this site.

If excavations extend to significant depths into the limestone formation, consideration can be given to utilizing the excavated limestone as “alternative select fill”. However, processing of the excavated material will be required to reduce the maximum particle size to 4 in. Furthermore, special care will be required during excavation activities to separate organics and any plastic clay seams encountered. Alternative select fill materials shall have a maximum liquid limit not exceeding 40 and a plasticity index between 7 and 20. In addition, if these materials are utilized, grain size analyses and Atterberg Limits must be performed during placement at a rate of one test each per 5,000 cubic yards of material due to the high degree of variability associated with pit-run materials. If on-site materials cannot be processed to meet the required criteria, imported select fill materials should be utilized.

If the above listed alternative materials are being considered for bidding purposes, the materials should be submitted to the Geotechnical Engineer for pre-approval at a minimum of 10 working days or more prior to the bid date. Failure to do so will be the responsibility of the contractor. The contractor will also be responsible for ensuring that the properties of all delivered alternate select fill materials are similar to those of the pre-approved submittal. It should also be noted that when using alternative fill materials, difficulties may be experienced with respect to moisture control during and subsequent to fill placement, as well as with erosion, particularly when exposed to inclement weather. This may result in sloughing of beam trenches and/or pumping of the fill materials.

## ON-SITE CLAY FILL

We recommend that the on-site soils be placed to conform to the 2014 TxDOT Standard Specifications, Item 132 – *Embankment*, Type B, and should be placed in compacted lifts not exceeding 6 in. in thickness and compacted to the requirements of Table 2 in Item 132 based on the maximum density and optimum moisture content as determined by TxDOT, Tex-114-E. The moisture content of the fill should be maintained to be at least equal to the optimum water content, but not exceed 3 percentage points above the optimum water content until permanently covered. Fill materials shall be free of roots and other organic or degradable material. We recommend that the maximum particle size not exceed 3 in. or one half the compacted lift thickness, whichever is smaller. If other import fill materials are utilized, RKI should be notified, as additional CBR testing and thicker pavement sections may be required.

It is imperative that the subgrade modulus utilized in the pavement design process be met or exceeded by the fill material. In the event that the clay fill used is different than the existing subgrade, the recommendations in this report could be invalidated and the design engineer must be consulted to determine if additional CBR testing and thicker pavement sections are required.

## ON-SITE ROCK FILL

If excavations extend to significant depths into the limestone formation, consideration can be given to utilizing the excavated limestone for select fill. However, processing of the excavated material will be required to reduce the maximum particle size to 4 in. Furthermore, special care will be required during excavation activities to separate organics and any plastic clay seams encountered. In addition, the processed material must meet the specifications given above for alternative select fill materials. If on-site materials cannot be processed to meet the required criteria, imported select fill materials should be utilized.

## FILL PLACEMENT AND COMPACTION

### Select Fill

Select fill should be placed in loose lifts not exceeding 8 in. in thickness and compacted to at least 95 percent of maximum density as determined by TxDOT, Tex-113-E, Compaction Test, or 98 percent of maximum density as determined by ASTM D698. The moisture content of the fill should be maintained within the range of 2 percentage points below to 2 percentage points above the optimum moisture content until final compaction.

### General Fill

General fill should be placed in loose lifts not exceeding 8 in. in thickness and compacted to a minimum of 95 percent of the maximum density determined from the TxDOT, Tex-114-E or ASTM D698. The moisture content of the fill should be maintained within the range of optimum to plus 3 percentage points above the optimum moisture content until final compaction.

## SHALLOW FOUNDATION EXCAVATIONS

Shallow foundation excavations should be observed by the Geotechnical Engineer or their representative prior to placement of reinforcing steel and concrete. This is necessary to observe that the bearing soils at the bottom of the excavations are similar to those encountered in our borings and that excessive loose materials and water are not present in the excavations. If soft pockets of soil are encountered in the foundation excavations, they should be removed and replaced with a compacted non-expansive fill material or lean concrete up to the design foundation bearing elevations.

## EXCAVATION SLOPING AND BENCHING

If utility trenches or other excavations extend to or below a depth of 5 ft below construction grade, the contractor or others shall be required to develop a trench safety plan to protect personnel entering the trench or trench vicinity. The collection of specific geotechnical data and the development of such a plan, which could include designs for sloping and benching or various types of temporary shoring, are beyond the scope of the current study. Any such designs and safety plans shall be developed in accordance with current OSHA guidelines and other applicable industry standards.

## EXCAVATION EQUIPMENT

It should be noted that limestone and limestone boulders were encountered at relatively shallow depths during our field exploration. Excavations at this site may require removal of these rock boulders and/or layers. Thus, the need for rock excavation equipment should be anticipated for construction at this site. Our borings logs are not intended for use in determining construction means and methods and may therefore be misleading if used for that purpose. We recommend that earth-work and utility contractors interested in bidding on the work perform their own tests in the form of test pits to determine the quantities of the different materials to be excavated, as well as the preferred excavation methods and equipment for this site.

## UTILITIES

Utilities which project through slab-on-grade, slab-on-fill, or any other rigid unit should be designed with either some degree of flexibility or with sleeves. Such design features will help reduce the risk of damage to the utility lines as vertical movements occur.

Our experience indicates that significant settlement of backfill can occur in utility trenches, particularly when trenches are deep, when backfill materials are placed in thick lifts with insufficient compaction, and when water can access and infiltrate the trench backfill materials. The potential for water to access the backfill is increased where water can infiltrate flexible base materials due to insufficient penetration of curbs, and at sites where geological features can influence water migration into utility trenches (such as fractures within a rock mass or at contacts between rock and clay formations). It is our belief that another factor which can significantly impact settlement is the migration of fines within the backfill into the open voids in the underlying free-draining bedding material.

To reduce the potential for settlement in utility trenches, we recommend that consideration be given to the following:

- All backfill materials should be placed and compacted in controlled lifts appropriate for the type of backfill and the type of compaction equipment being utilized and all backfilling procedures should be tested and documented.
- Curbs should completely penetrate base materials and be installed to a sufficient depth to reduce water infiltration beneath the curbs into the pavement base materials.
- Consideration should be given to wrapping free-draining bedding gravels with a geotextile fabric (similar to Mirafi 140N) to reduce the infiltration and loss of fines from backfill material into the interstitial voids in bedding materials.

## PAVEMENT RECOMMENDATIONS

Recommendations for both flexible and rigid pavements are presented in this report. The Owner and/or design team may select either pavement type depending on the performance criteria established for the project. In general, flexible pavement systems have a lower initial construction cost as compared to rigid pavements. However, maintenance requirements over the life of the pavement are typically much greater for flexible pavements. This typically requires regularly scheduled observation and repair, as well as overlays and/or other pavement rehabilitation at approximately one-half to two-thirds of the design life. Rigid pavements are generally more "forgiving", and therefore tend to be more durable and require less maintenance after construction.

For either pavement type, drainage conditions will have a significant impact on long term performance, particularly where permeable base materials are utilized in the pavement section. Drainage considerations are discussed in more detail in a subsequent section of this report.

### SUBGRADE STRENGTH CHARACTERIZATION

We have assumed the pavement subgrade will either consist of recompacted on-site clays or rock subgrade (as discussed further in this section). A bulk sample of the surficial clay was collected for use in

CBR testing. The CBR was determined using the soaked sample methodology in accordance with *ASTM D 1883 Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils* and the results are tabulated below.

| Sample Location | Streets | Corrected Laboratory CBR | Design CBR |
|---|---|---|---|
| 50 ft east of Boring B-2 | Lone Grapevine and Kay CV | 4.8 | 4.0 |

This value was determined using 3-points compacted at varying efforts to determine the corrected CBR value at 95 percent of the maximum dry density as determined by TxDOT, Tex-114-E. Swell was also measured as part of the CBR procedure. The average swell for the samples from the vicinity of Boring B-2 was determined to be 0.9 percent. Based on these results and our experience with the soils in this area, we have assumed the above Design CBR value for use in our pavement section analysis for the clay fill subgrade (hereafter referred to as the 'clay subgrade'). If clay soils are imported for the purpose of constructing the roadbed, imported materials must be selected that have a CBR value of at least 4.0 the streets. If lower quality clay fill materials are utilized, the pavement sections will have to be increased based on the quality (tested CBR value) of the clays imported.

If select fill material, in accordance with the *Select Fill* section of this report, is utilized as the subgrade fill up to the bottom of the pavement section elevation, or if native, intact rock is exposed prior to select fill placement (if necessary), a CBR of 10.0 may be utilized for pavement design (hereafter referred to as the 'rock subgrade'). For areas that transition between a clay and rock subgrade, we recommend that geogrid be utilized to relieve stress concentrations at the subgrade transitions. The geogrid should be used as a transition for 5 ft on either side of the transition.

It should be noted that the thickness of the existing soil overlying the limestone rock is relatively thin at this site. Depending on site grading plans, it may be practical to overexcavate the clay soil, place compacted select fill to the bottom of flexible base, and construct the pavement section using the design CBR of 10.0 described above.

## SWELL/HEAVE POTENTIAL

We do not anticipate that the dark brown clays will be used substantially as a fill material over a majority of the alignment. However, existing clays not likely to be removed prior to placement of fill may contribute to expansive soil-related movements. The following discussion covers potential issues with pavements supported on highly expansive subgrade soils.

Subgrade soils that are highly expansive when water is introduced (i.e. highly plastic soils) will heave, causing the pavement to become rough or uneven over time. Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle costs, fuel consumption, and maintenance costs. Pavement heave can be reduced through various measures but cannot be totally eliminated without full removal of the problematic soil. Measures available for reducing heave include:

- Soil Treatment with Lime or Other Chemicals
- Removal and Replacement of High PI Soils
- Drains or Barriers to Collect or Inhibit Moisture Infiltration

These treatments are options and are **not** required. Soil treatment with lime (or other chemicals) is typically used to reduce the swelling potential of the upper portion of the pavement subgrade containing moderately plastic soils. Lime and water are mixed with the top 6 to 12 inches (or possibly more) of the subgrade and allowed to mellow or cure for a period of time. After mellowing the soil-lime mixture is compacted to form a strong soil matrix that can improve pavement performance and potentially reduce soil heave. However, the chemical reaction between the calcium-based additives and the sulfates and/or sulfide minerals in the soil can create a heaving problem on the pavement. If lime treatment is utilized, we recommend additional testing to determine sulfate content and whether traditional lime stabilization can be used according to the *Texas Department of Transportation – Guidelines for treatment of sulfate-Rich soils and Bases in pavement Structures, 09/2005*.

In addition, capturing water infiltration via French drains, pavement edge drains, or inhibiting water through the use of vertical moisture barriers would reduce the potential for heave since one important component of the heaving mechanism, water, would be reduced. Geocomposite membranes, like geogrids, are also another tool available that may help reduce the damage that heaving subgrades cause to flexible pavements and may be considered in addition to or as an alternative to other mitigation techniques.

*It should be noted that the pavement sections derived in the following sections are structurally adequate for the given traffic levels and subgrade strength, but do not consider the long-term effects of pavement roughness due to heave, which can only be addressed by the measures discussed in this section.*

**DESIGN PARAMETERS – HOT MIX ASPHALT PAVEMENTS**

The proposed roadways were evaluated using guidance from the *City of San Antonio's Design Guidance Manual*. Typical traffic loading scenarios were utilized based on the anticipated use at this site. We have included Local Type A with and without Bus Traffic, and Local Type B recommendations for consideration by the design team. Based on information provided by the City of San Antonio, we understand that the following design parameters are required for use in the design of flexible pavements for these types of streets.

| Street Classification | Equivalent 18-kip Single Axle Load Applications (ESALs) | Reliability (%) | Serviceability (Initial/Terminal) | Standard Deviation | Structural Number (Minimum/Maximum) |
|---|---|---|---|---|---|
| Local Type A Without Bus Traffic | 100,000 | 70 | 4.2/2.0 | 0.45 | 2.02/3.18 |
| Local Type A With Bus Traffic | 1,000,000 | 70 | 4.2/2.0 | 0.45 | 2.58/4.20 |
| Local Type B | 2,000,000 | 90 | 4.2/2.0 | 0.45 | 2.92/5.08 |

The required structural number is related to the CBR value of the pavement subgrade and the amount of traffic that the pavement will carry over its service life. The CBR provides an estimate of the relative strength of the subgrade and consequently indicates the ability of the pavement section to carry load. This site specific CBR value is utilized in conjunction with the above specified parameters to determine the required Structural Number (SN) for use in the design of the pavement section.

To determine the required design SN value, we utilized a method based on the 1993 edition of the AASHTO Guide for Design of Pavement Structures. Also shown are the values subsequently determined in the design of the pavement sections for this site.

**Structural Number Recommendations**

Structural numbers for each street classification and each subgrade condition were calculated using the parameters provided in the table presented in the previous section. The resulting Structural Numbers are presented in the pavement section tables.

**PAVEMENT DESIGN PARAMETERS – HOT MIX ASPHALT PAVEMENTS**

The following input variables are utilized to design flexible base pavements (commonly referred to as Asphaltic Cement Concrete or Asphalt pavements) when using the procedures detailed in the 1993 *AASHTO Guide for Design of Pavement Structures*:

- Performance Period
- Roadbed Soil Resilient Modulus psi
- Serviceability Indices
- Overall Standard Deviation
- Reliability, %
- Design Traffic, 18-kip ESALs

**Performance Period**

The pavement structure was designed for a 20-year performance period which is typical for most flexible pavements.

**Roadbed Soil Resilient Modulus**

The Resilient Modulus ($M_R$) is the material property used to characterize the support characteristics of the roadbed soils in flexible pavement design. It is a measure of the soil's deformation response to cyclic applications of loads much smaller than a failure load. Using conventional correlations, local experience and design CBR values of 4.0 and 10.0, as discussed above, resilient moduli of 6,000 and 15,000 psi have been used for this project, respectively.

To determine the resilient modulus ($M_r$) of the subgrade, we utilized the correlation equation shown below:

$M_r$ = 1,500 x CBR

**Serviceability Indices**

Initial serviceability is a measure of the pavement's smoothness or rideability immediately after construction. Terminal serviceability is the minimum tolerable serviceability of a pavement. When the serviceability of a pavement reaches its terminal value, rehabilitation is required. See the recommended Initial and Terminal Serviceability Indices on the table presented in the *Design Parameters – Hot Mix Asphalt Pavements* section of this report.

**Overall Standard Deviation**

Overall standard deviation accounts for both chance variation in the traffic prediction and normal variation in pavement performance prediction for a given traffic. Higher values represent more variability; thus, the pavement thickness increases with higher overall standard deviations. A value of 0.45 was utilized for the flexible pavement designs presented herein.

**Reliability, %**

The reliability value represents a "safety factor," with higher reliabilities representing pavement structures with less chance of failure. The AASHTO Guide recommends values ranging from 50 to 99.9%, depending on the functional classification and the location (urban vs. rural) of the roadway. See the recommended Reliability values on the table presented in the *Design Parameters – Hot Mix Asphalt Pavements* section of this report.

**Design Traffic 18-kip ESAL**

The 18-kip ESALs were determined from the traffic data specified in the Unified Development Code for the City of San Antonio. See the recommended values on the table presented in the *Design Parameters – Hot Mix Asphalt Pavements* section of this report.

If on-site clay fill is utilized for fill grading, it should be placed and compacted as discussed in the *On-Site Clay Fill* section of this report. Where the remaining clays or the clay fill grading exceed 2 ft in thickness, the clay subgrade pavement recommendations should be utilized. For areas that require fill and where pavement sections will utilize the clay subgrade recommendations, the final 6 in. of fill should be lime treated (see *Lime Treatment of Subgrade*). If fill grading is not planned and clays remain in place, then the surficial clays should be stripped to the limestone elevation (where possible), the subgrade should be prepared as described in the *Subgrade Preparation* section of this report, and the rock subgrade pavement sections should be utilized.

If fill grading is completed utilizing select fill in accordance with the *Select Fill* section of this report, or if native, intact rock is exposed prior to fill placement (if necessary), the lime treated subgrade may be eliminated from the pavement section and the rock subgrade recommendations should be utilized.

Utilizing the design SN values discussed above and minimum layer thicknesses, the following options for pavement sections are available.

**Clay Subgrade**

| CBR = 4.0 | Layer Description | Layer Thickness | Recommended SN Coeff. | S.N. Extension |
|---|---|---|---|---|
| **Local Type A without Bus Traffic (Required SN = 2.23)** | Type D Surface Course<br>Flexible (Granular) Base<br>Lime-Treated Subgrade<br>**Combined Total** | 2.5 in.<br>9.0 in.<br>6.0 in.<br>**17.5 in.** | 0.44<br>0.14<br>0.00 | 1.10<br>1.26<br>0.00<br>**2.36** |
| **Local Type A with Bus Traffic (Required SN = 3.19)** | Type C/D Surface Course<br>Type C Surface Course<br>Flexible (Granular) Base<br>Lime-Treated Subgrade<br>**Combined Total** | 1.5 in.<br>2.0 in.<br>12.0 in.<br>6.0 in.<br>**21.5 in.** | 0.44<br>0.44<br>0.14<br>0.00 | 0.66<br>0.88<br>1.68<br>0.00<br>**3.22** |
| **Local Type B (Required SN = 3.97)** | Type C/D Surface Course<br>Type C Binder Course<br>Flexible (Granular) Base<br>Lime-Treated Subgrade<br>**Combined Total** | 2.0 in.<br>2.5 in.<br>15.0 in.<br>6.0 in.<br>**25.5 in.** | 0.44<br>0.44<br>0.14<br>0.00 | 0.88<br>1.10<br>2.10<br>0.00<br>**4.08** |

A Mechanically Stabilized Layer (MSL) is a composite layer consisting of flexible (granular) base overlying a geogrid product.

**Rock Subgrade**

| CBR = 10.0 | Layer Description | Layer Thickness | Recommended SN Coeff. | S.N. Extension |
|---|---|---|---|---|
| **Local Type A without Bus Traffic** | Type C/D Surface Course<br>Flexible (Granular) Base<br>Rock Credit<br>**Combined Total** | 2.0 in.<br>6.0 in.<br>--<br>**8.0 in.** | 0.44<br>0.14<br>-- | 0.88<br>0.84<br>0.48<br>**2.20** |
| **Local Type A with Bus Traffic** | Type C/D Surface Course<br>Flexible (Granular) Base<br>Rock Credit<br>**Combined Total** | 2.5 in.<br>8.0 in.<br>--<br>**10.5 in.** | 0.44<br>0.14<br>-- | 1.10<br>1.12<br>0.48<br>**2.70** |
| **Local Type B** | Type C/D Surface Course<br>Flexible (Granular) Base<br>Rock Credit<br>**Combined Total** | 3.0 in.<br>9.0 in.<br>--<br>**12.0 in.** | 0.44<br>0.14<br>-- | 1.32<br>1.26<br>0.48<br>**3.06** |

**DESIGN PARAMETERS – PORTLAND CEMENT CONCRETE PAVEMENTS**

The proposed roadways are to be evaluated in accordance with the *City of San Antonio's Design Guidance Manual* regarding Local Type A (with and without bus traffic) and Local Type B. Based on information provided by the City of San Antonio, we understand that the following design parameters are required for use in the design of rigid pavements for these types of streets.

| Street Classification | Equivalent 18-kip Single Axle Load Applications (ESALs) | Reliability (%) | Serviceability (Initial/Terminal) | Standard Deviation | Rigid Pavement Slab Thickness (Minimum/Maximum) |
|---|---|---|---|---|---|
| Local Type A (without bus Traffic) | 150,000 | 70 | 4.5/2.0 | 0.35 | 5.0/6.0 |
| Local Type A (With Bus Traffic) | 1,500,000 | 70 | 4.5/2.0 | 0.35 | 6.0/8.0 |
| Local Type B | 3,000,000 | 90 | 4.5/2.0 | 0.35 | 7.0/9.0 |

To determine the required design rigid pavement thickness, we utilized a method based on the 1993 edition of the AASHTO "Guide for the Design of Pavement Structures."

**PAVEMENT DESIGN PARAMETERS – PORTLAND CEMENT CONCRETE PAVEMENTS**

The following input variables are utilized to design rigid pavements (commonly referred to as Portland Cement Concrete or PCC pavements) when using the procedures detailed in the *1993 AASHTO Guide for Design of Pavement Structures*:

- Performance Period
- 28-day Concrete Modulus of Rupture, psi
- 28-day Concrete Elastic Modulus, psi
- Effective Modulus of Subbase/Subgrade Reaction, pci
- Serviceability Indices
- Load Transfer Coefficient
- Drainage Coefficient
- Overall Standard Deviation
- Reliability, %
- Design Traffic, 18-kip ESALs

**Performance Period**

The pavement structure was designed for a 30-year performance period which is typical for most rigid pavements.

**28-day Concrete Modulus of Rupture, $M_r$**

The $M_r$ of concrete is a measure of the flexural strength of the concrete as determined by breaking concrete beam test specimens. An $M_r$ of approximately 600 psi at 28 days was used in the analysis and is typical of local concrete production.

**28-day Concrete Elastic Modulus**

Elastic modulus of concrete is an indication of concrete stiffness and varies depending on the coarse aggregate type used in the concrete. A modulus of 4,000,000 psi was used for this pavement design.

**Effective Modulus of Subbase/Subgrade Reaction: k-value**

Concrete slab support is characterized by the modulus of subgrade/subbase reaction, otherwise known as the k-value, with units typically shown as psi/in. A subbase layer is typically recommended for higher traffic volume roadways or in areas where additional concrete slab support is warranted. Based on the CBR values of 4.0 and 10.0, k-values of 90 and 120 psi/in. were used for the roadways, respectively.

**Serviceability Indices**

Initial serviceability is a measure of the pavement's smoothness or rideability immediately after construction. Terminal serviceability is the minimum tolerable serviceability of a pavement. When the serviceability of a pavement reaches its terminal value, rehabilitation is required. See the recommended Initial and Terminal Serviceability Indices on the table presented in the *Design Parameters – Portland Cement Concrete Pavements* section of this report.

**Load Transfer Coefficient**

The load transfer coefficient is used to incorporate the effect of dowels, reinforcing steel, tied shoulders, and tied curb and gutter on reducing the stress in the concrete slab due to traffic loading and therefore causing a reduction in the required concrete slab thickness.

The load transfer coefficient used in this pavement design is 3.2 for pavements designed with load transfer devices (i.e. dowels) at control joints or CRCP.

**Drainage Coefficient**

The drainage coefficient characterizes the quality of drainage of the subbase layers under the concrete slab. Good draining pavement structures do not give water the chance to saturate the subbase and subgrade; thus, pumping is not as likely to occur. A drainage coefficient of 1.01 is utilized for rigid pavement design.

**Overall Standard Deviation**

Overall standard deviation accounts for both chance variation in the traffic prediction and normal variation in pavement performance prediction for a given traffic. Higher values represent more variability; thus, the pavement thickness increases with higher overall standard deviations. See the recommended Overall Standard Deviation on the table presented in the *Design Parameters – Portland Cement Concrete Pavements* section of this report.

**Reliability, %**

The reliability value represents a "safety factor," with higher reliabilities representing pavement structures with less chance of failure. The AASHTO Guide recommends values ranging from 50 to 99.9%, depending on the functional classification and the location (urban vs. rural) of the roadway. See the recommended Reliability on the table presented in the *Design Parameters – Portland Cement Concrete Pavements* section of this report.

**Design Traffic 18-kip ESAL**

The 18-kip ESALs were determined from the street classifications as discussed previously in the *Design Parameters – Portland Cement Concrete Pavements* section of this report.

**RECOMMENDED PAVEMENT SECTIONS – PORTLAND CEMENT CONCRETE PAVEMENTS**

The recommended concrete slab thicknesses determined with the inputs discussed above are presented in the table below. We recommend that pavements on a clay subgrade at this site include a minimum of 6 in. of lime-treated subgrade. We recommend that the required lime content reduce the PI of the subgrade soil to less than 20 and increases the pH of the soil to 12.4 or greater. If the exposed soil has a natural PI of less than 20 or is founded on a "rock subgrade", then the lime treatment may be waived.

| Portland Cement Concrete Design - Cross Sections | Layer Description | Layer Thickness |
|---|---|---|
| **Local Type A without Bus Traffic** | Concrete(1)<br>Lime Treated Subgrade(3)<br>**Combined Total** | 5.0 in.<br>6.0 in.<br>**11.0 in.** |
| **Local Type A with Bus Traffic** | Concrete(2)<br>Lime Treated Subgrade(3)<br>**Combined Total** | 7.0 in.<br>6.0 in.<br>**13.0 in.** |
| **Local Type B** | Concrete(2)<br>HMA Bond Breaker(3)<br>Cement Treated Base(3)<br>Lime Treated Subgrade(3)<br>**Combined Total** | 8.5 in.<br>1.0 in.<br>6.0 in.<br>6.0 in.<br>**21.5 in.** |

(1) Concrete pavement should consist of jointed plain concrete pavement with load transfer devices at control joints.
(2) Concrete pavement should consist of continuously reinforced concrete pavement (CRCP), or jointed plain concrete pavement with load transfer devices at control joints.
(3) These layers may be waived for a rock subgrade condition.

## PAVEMENT CONSTRUCTION CONSIDERATIONS

### SUBGRADE PREPARATION

Preparation for the right-of-way (for streets, sidewalks, utilities, etc.) should be performed in accordance with the 2014 TxDOT Standard Specifications, Item 100 – *Preparing Right of Way*. Exposed subgrades should be thoroughly proofrolled in order to locate any weak, compressible zones. A minimum of 5 passes of a fully-loaded dump truck or a similar heavily-loaded piece of construction equipment should be used for planning purposes. Proofrolling operations should be observed by the Geotechnical Engineer or his representative to document subgrade condition and preparation. Weak or soft areas identified during proofrolling should be removed and replaced with a suitable, compacted backfill.

In areas where clay will remain in place, the exposed subgrade should be moisture conditioned. This should be done after completion of the proofrolling operations and just prior to flexible base placement. Moisture conditioning is done by scarifying to a minimum depth of 6 in. and recompacting to a minimum of 95 percent of the maximum density determined from the Texas Department of Transportation Compaction Test (TxDOT, Tex-114-E). The moisture content of the subgrade should be maintained within the range of optimum moisture content to 3 percentage points above optimum until permanently covered.

Upon completion of fill grading using the on-site clays (for clay subgrade pavement sections), the final 6 in. of fill should be lime treated (see *Lime Treatment of Subgrade*). If fill grading is not planned, then lime treatment of the stripped clay subgrade should be performed in conjunction with the scarifying, moisture conditioning, and recompaction described previously.

If fill grading is completed utilizing select fill in accordance with the *Select Fill* section of this report or if native, intact rock is exposed prior to flexible base placement, the lime treated subgrade may be eliminated from the pavement section and the rock subgrade recommendations should be utilized. The rock subgrade may also be utilized for those pavements that are placed directly over box culverts.

### DRAINAGE CONSIDERATIONS

As with any soil-supported structure, the satisfactory performance of a pavement system is contingent on the provision of adequate surface and subsurface drainage. Insufficient drainage which allows saturation of the pavement subgrade and/or the supporting granular pavement materials will greatly reduce the performance and service life of the pavement systems.

Surface and subsurface drainage considerations crucial to the performance of pavements at this site include (but are not limited to) the following:

1) Any known natural or man-made subsurface seepage at the site which may occur at sufficiently shallow depths as to influence moisture contents within the subgrade should be intercepted by drainage ditches or below grade French drains.
2) Final site grading should eliminate isolated depressions adjacent to curbs which may allow surface water to pond and infiltrate into the underlying soils. **Curbs should completely**

**penetrate base materials and should be installed to sufficient depth to reduce infiltration of water beneath the curbs**.

3) Pavement surfaces should be maintained to help minimize surface ponding and to provide rapid sealing of any developing cracks. These measures will help reduce infiltration of surface water downward through the pavement section.

## LIME TREATMENT OF SUBGRADE

Lime treatment of the subgrade soils with PIs greater than 20 should be in accordance with the 2014 TxDOT Standard Specifications, Item 260 – *Lime Treatment (Road-Mixed)*. Lime-treated subgrade soils should be compacted to a minimum of 95 percent of the maximum density at a moisture content within the range of optimum moisture content to 3 percentage points above the optimum moisture content as determined by Tex-113-E. Based on the results of the pH-Lime Series Curve, we recommend that at least 6 percent hydrated lime by weight be used to reduce the PI of the subgrade clays or a minimum of 27 pounds/S.Y. for 6 in. of lime treated subgrade, whichever results in the greater percentage of lime. If dry placement of lime is used during construction, an additional 1 percent of lime should be added to account for expected loss.

It is also recommended to perform additional laboratory testing to determine the concentration of soluble sulfates in the subgrade soils, in order to investigate the potential for adverse reaction to lime in certain sulfate-containing soils. The adverse reaction, referred to as sulfate-induced heave, has been known to cause cohesive subgrade soils to swell in short periods of time, resulting in pavement heaving and possible failure. The sulfate content for the bulk sample was determined to be less than 100 ppm, which is indicative of a low potential for sulfate-induced heave.

## GEOGRID REINFORCEMENT

The geogrid reinforcement should be selected in accordance with TxDOT DMS6240, Type II geogrid. The geogrid should be placed at the bottom of the flexible (granular) base section in all cases. An alternative to the above geogrid should not be considered without approval from RKI.

## GRANULAR BASE COURSE

The flexible base course should be crushed limestone conforming to the 2014 TxDOT Standard Specifications, Item 247 – *Flexible Base*, Type A, Grade 1-2. The base course should be placed in lifts with a maximum compacted thickness of 8 in. (10 inches loose) and compacted to a minimum of 95 percent of the maximum density determined by Tex-113-E at a moisture content within the range of 2 percentage points below to 2 percentage points above the optimum moisture content as determined by Tex-113-E. **In our opinion, incorporating geogrid into the pavement section will enhance overall pavement performance and reduce the potential for cracking and maintenance in asphalt pavements.** The geogrid reinforcement should conform to TxDOT Type 2 geogrid, or an approved substitute.

## CEMENT TREATED BASE COURSE

The cement treated base course should conform to TxDOT 2014 Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Item 275 or 276. In our experience, cement percentages typically range from 2 to 5 percent, but should be verified with laboratory testing. For estimating purposes we estimate 4% cement be included. We recommend microcracking be performed approximately 1 - 3 days after placement.

## PRIME COAT

A prime coat should be placed on top of the flexible base course (if used) and should be a MC-30, AE-P, EAP&T, or PCE conforming to the 2014 TxDOT Standard Specifications, Item 310 – *Prime Coat* or Item 314 – *Emulsified Asphalt Treatment* as well as Item 300 – *Asphalts, Oils and Emulsions*. Prime coat application rates are typically between 0.1 to 0.3 gal/yd$^2$ and are generally dependent upon the absorption rate of the granular base and other environmental conditions at the time of placement. The prime coat layer should be placed on the prepared flexible base as soon as possible. This will facilitate plugging the capillary voids in the flexible base surface to reduce migration of moisture and providing a water resistant surface. The asphalt layer should be placed as soon as possible after the prime coat has been properly set/cured.

## TACK COAT

A tack coat should be placed between asphaltic concrete base and/or surface lifts and should be a PG binder with a minimum high-temperature grade of PG 58, SS-1H, CSS-1H, or EAP&T conforming to the 2014 TxDOT Standard Specifications, Item 300 – *Asphalts, Oils and Emulsions*. See additional requirements for tack coats in the appropriate TxDOT Standard Specifications for Asphaltic Concrete Materials.

## ASPHALTIC CONCRETE SURFACE AND/OR BINDER[1] COURSES

The asphaltic concrete surface and/or binder courses should conform to the 2014 TxDOT Standard Specifications, Item 341 – *Dense Graded Hot Mix Asphalt*, Types C or D for the surface and binder, and Type B for the base, if the full depth asphalt section is selected for construction. Recycled asphalt pavement (RAP) should be limited to 20 percent of the total weight of the mix for Types C and D mixes and 30 percent for Type B mixes. Higher percentages of RAP may be permissible depending on the material source. If higher percentages of RAP are desired, contact RKI for consideration. Asphalt cement grades should conform to the table shown below, which conforms to the requirements of Item 341.

<table>
<tr><th rowspan="2">Street Classifications</th><th colspan="3">Minimum PG Asphalt Cement Grade</th></tr>
<tr><th>Surface Courses</th><th>Binder & Level Up Courses</th><th>Base Courses</th></tr>
<tr><td>Local Type B Streets</td><td rowspan="2">PG 70-22</td><td>PG 70-22</td><td rowspan="3">PG 64-22</td></tr>
<tr><td>Local Type A Street With Bus Traffic</td><td rowspan="2">PG 64-22</td></tr>
<tr><td>Local Type A Street Without Bus Traffic</td><td>PG 64-22</td></tr>
</table>

[1] A binder course is defined as the hot mixed asphalt concrete (HMAC) layer placed directly beneath the HMAC surface or wearing course but is not an asphalt treated base layer.

The asphaltic concrete should be compacted on the roadway to contain from 5 to 9 percent air voids computed using the maximum theoretical specific gravity (Rice) of the mixture determined according to Test Method Tex-227-F. Pavement specimens, which shall be either cores or sections of asphaltic pavement, will be tested according to Test Method Tex-207-F. The nuclear-density gauge or other methods which correlate satisfactorily with results obtained from project roadway specimens may be used when approved by the Engineer. Unless otherwise shown on the plans, the Contractor shall be responsible for obtaining the required roadway specimens at their expense and in a manner and at locations selected by the Engineer.

It is recommended that the hot mix asphalt concrete pavement be placed with a paving machine only and not with a motor grader unless prior approval is granted by the Engineer for special circumstances. The asphalt layer should preferably be placed as soon as possible after the flexible base has been accepted and the prime coat has been placed. This will further protect the flexible base and subgrade from undue moisture fluctuation due to precipitation or sheet flow from rain events.

## HOT-MIX ASPHALT BOND BREAKER

The hot-mix asphalt bond breaker should be in accordance with the TxDOT 2014 Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Item 340, Dense-Graded Hot-Mix Asphalt (Small Quantity), Type D, a Performance Graded Binder 76-22 (PG-76-22), and designed with a laboratory density target of 97.5 percent.

## PORTLAND CEMENT CONCRETE

The Portland cement concrete should be in accordance with Class P concrete of the TxDOT 2014 Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Item 421, Portland Cement Concrete. Requirements include concrete designed to meet a minimum average compressive strength of 3,500 psi at 7-days or a minimum average compressive strength of 4,400 psi at 28-days in accordance with TxDOT standard laboratory test procedure Tex-448-A or Tex-418-A. Liquid membrane-forming curing compound should be applied as soon as practical after broom finishing the concrete surface. The curing compound will help reduce the loss of water from the concrete. The reduction in the rapid loss in water will help reduce shrinkage cracking of the concrete.

## CONCRETE PAVEMENT CONSTRUCTION CONTROL

Construction of Portland Cement Concrete Pavements should be controlled by the 2014 TxDOT Standard Specifications, Item 341 – *Concrete Pavement*. The surface of all concrete pavements should be textured or tined. Texturing using carpet dragging or tining should be in accordance with Item 360, Sections 3.4.1 and 3.4.2. Other texturing techniques may be utilized as described in ACI 330.1-03, Section 3, Subparagraph 9.

## CONCRETE PAVEMENT TYPE

Jointed Plain Concrete Pavement (which is referred to by TxDOT as Concrete Pavement Contraction Design or CPCD) or Continuously Reinforced Concrete Pavement is suggested for roadways with crosswalks, adjacent parking, or sidewalks and is recommended as the pavement type for this city street.

**JOINT SPACING AND DETAILS**

Construction joint spacing should not exceed 15 ft in either the longitudinal or transverse direction. All control joints should be formed or sawed to a depth of at least 1/4 the thickness of the concrete slab and should extend completely through monolithic curbs (if used). Sawing of control joints should begin as soon as the concrete will not ravel, preferably within 1 to 3 hours using an early entry saw or 4 to 8 hours with a conventional saw. Timing will be dictated by site conditions. The width of the joint will be a function of the sealant chosen to seal the joint. It is recommended that a joint seal be utilized to minimize the introduction of incompressible material into the joint.

It is recommended that dowel bars be used to provide load transfer and reduce differential movement (or faulting) across transverse joints. Dowels should be smooth #9 bars (Grade 60 steel) spaced 12 in. on center with an embedment length of at least 8 in.

Tie bars should be used to tie longitudinal joints within the pavement lanes and at the shoulder. Tie bars should be deformed #4 bars at a minimum (Grade 60 steel) spaced 36 in. on center with a minimum length of 30 in.

Isolation joints must be used around fixed structures including light standard foundations and drainage inlets to offset the effects of differential horizontal and vertical movements. Premolded joint fillers should be used around the fixed structures prior to placing the concrete pavement to prevent bonding of the slab to the structure and should extend through the depth of the slab but slightly recessed from the pavement surface to provide room for the joint sealant.

**SUGGESTED PAVEMENT DETAILS**

Suggested details that can be utilized for construction are:

- TxDOT CRCP (1)-20, Continuously Reinforced Concrete Pavement, One Layer Steel Bar Placement, T-7 to 13 inches;
- TxDOT CPCD-14, Concrete Paving Details, Contraction Design, T-6 to 12 inches; and
- TxDOT JS-14, Concrete Paving Details, Joint Seals.

## MISCELLANEOUS PAVEMENT RELATED CONSIDERATIONS

**Drainage Considerations**

As with any soil-supported structure, the satisfactory performance of a pavement system is contingent on the provision of adequate surface and subsurface drainage. Insufficient drainage which allows saturation of the pavement subgrade and/or the supporting granular pavement materials will greatly reduce the performance and service life of the pavement systems.

Surface and subsurface drainage considerations crucial to the performance of pavements at this site include (but are not limited to) the following:

- Any known natural or man-made subsurface seepage at the site which may occur at sufficiently shallow depths as to influence moisture contents within the subgrade should be intercepted by drainage ditches or below grade French drains.
- Final site grading should eliminate isolated depressions adjacent to curbs, which may allow surface water to pond and infiltrate into the underlying soils. Curbs should be installed to a sufficient depth to reduce infiltration of water beneath the curbs and into the pavement base materials.
- Pavement surfaces should be maintained to help minimize surface ponding and to provide rapid sealing of any developing cracks. These measures will help reduce infiltration of surface water downward through the pavement section.

**Utilities**

Our experience indicates that significant settlement of backfill can occur in utility trenches, particularly when trenches are deep, when backfill materials are placed in thick lifts with insufficient compaction, and when water can access and infiltrate the trench backfill materials. The potential for water to access the backfill is increased where water can infiltrate flexible base materials due to insufficient penetration of curbs, and at sites where geological features can influence water migration into utility trenches (such as fractures within a rock mass or at contacts between rock and clay formations). It is our belief that another factor which can significantly impact settlement is the migration of fines within the backfill into the open voids in the underlying free-draining bedding material.

To reduce the potential for settlement in utility trenches, we recommend that consideration be given to the following:

- All backfill materials should be placed and compacted in controlled lifts appropriate for the type of backfill and the type of compaction equipment being utilized and all backfilling procedures should be tested and documented.
- Consideration should be given to wrapping free-draining bedding gravels with a geotextile fabric (similar to Mirafi 140N) to reduce the infiltration and loss of fines from backfill material into the interstitial voids in bedding materials.

Alternatively, consideration may be given to utilizing a low strength flowable fill in utility trenches located within the roadway alignments.

**Longitudinal Cracking**

It should be understood that asphalt pavement sections in highly expansive soil environments, such as those encountered at portions of this site, can develop longitudinal cracking along unprotected pavement edges. In the semi-arid climate of south central Texas, this condition typically occurs along the unprotected edges of pavements where moisture fluctuation is allowed to occur over the lifetime of the pavements.

Pavements that do not have a protective barrier to reduce moisture fluctuation of the highly expansive clay subgrade between the exposed pavement edge and that beneath the pavement section tend to develop longitudinal cracks 1 to 4 ft from the edge of the pavement. Once these cracks develop, further degradation and weakening of the underlying granular base may occur due to water seepage through the cracks. The occurrence of these cracks can be more prevalent in the absence of lateral restraint and steep embankments. This problem can best be addressed by providing either a horizontal or vertical moisture barrier at the unprotected pavement edge.

A horizontal barrier is commonly in the form of a paved shoulder extending 8 feet or greater beyond the edge of the pavement. Other methods of shoulder treatment, such as using geofabrics beyond the edge of the roadway, are sometimes used in an effort to help reduce longitudinal cracking. Although this alternative does not eliminate the longitudinal cracking phenomenon, the location of the cracking is transferred to the shoulder rather than within the traffic lane.

Vertical barriers installed along the unprotected edges of roadway pavements are also effective in preventing non-uniform drying and shrinkage of the subgrade clays. These barriers are typically in the form of a vertical moisture barrier/membrane extending 6 feet or greater below the top of the subgrade at the pavement edge. Both types of barriers must be sealed at the edge of the pavement to prevent a crack that would facilitate the drying of the subgrade clays.

At a minimum, we recommend that the curbs are constructed such that the depth of the curb extends through the entire depth of the granular base material and into the subgrade to act as a protective barrier against the infiltration of water into the granular base.

In most cases, a longitudinal crack does not immediately compromise the structural integrity of the pavement system. However, if left unattended, infiltration of surface water runoff into the crack will result in isolated saturation of the underlying base. This will result in pumping of the flexible base, which could lead to rutting, cracking, and pot-holes. For this reason, we recommend that the owner of the facility immediately seal the cracks and develop a periodic sealing program.

**Pavement Maintenance**

Regular pavement maintenance is critical in maintaining pavement performance over a period of several years. All cracks that develop in asphalt pavements should be regularly sealed. Areas of moderate to severe fatigue cracking (also known as alligator cracking) should be saw cut and removed. The underlying base should be checked for contamination or loss of support and any insufficiencies fixed or removed and the entire area patched. All cracks that develop in concrete pavements should be routed and sealed regularly. Joints in concrete pavements should be maintained to reduce the influx of incompressible materials that restrain joint movement and cause spalling and/or cracking. Other typical maintenance techniques should be followed as required.

**Construction Traffic**

Construction traffic on prepared subgrade, granular base or asphalt treated base (black base) should be restricted as much as possible until the protective asphalt surface pavement is applied. Significant damage to the underlying layers resulting in weakening may occur if heavily loaded vehicles are allowed to use these areas.

## CONSTRUCTION RELATED SERVICES

### CONSTRUCTION MATERIALS TESTING AND OBSERVATION SERVICES

As presented in the attachment to this report, *Important Information About Your Geotechnical Engineering Report*, subsurface conditions can vary across a project site. The conditions described in this report are based on interpolations derived from a limited number of data points. Variations will be encountered during construction, and only the geotechnical design engineer will be able to determine if these conditions are different than those assumed for design.
Construction problems resulting from variations or anomalies in subsurface conditions are among the most prevalent on construction projects and often lead to delays, changes, cost overruns, and disputes. These variations and anomalies can best be addressed if the geotechnical engineer of record, RKI is retained to perform construction observation and testing services during the construction of the project. This is because:

- RKI has an intimate understanding of the geotechnical engineering report's findings and recommendations. RKI understands how the report should be interpreted and can provide such interpretations on site, on the client's behalf.
- RKI knows what subsurface conditions are anticipated at the site.
- RKI is familiar with the goals of the owner and project design professionals, having worked with them in the development of the geotechnical workscope. This enables RKI to suggest remedial measures (when needed) which help meet the owner's and the design teams' requirements.
- RKI has a vested interest in client satisfaction, and thus assigns qualified personnel whose principal concern is client satisfaction. This concern is exhibited by the manner in which contractors' work is tested, evaluated and reported, and in selection of alternative approaches when such may become necessary.
- RKI cannot be held accountable for problems which result due to misinterpretation of our findings or recommendations when we are not on hand to provide the interpretation which is required.

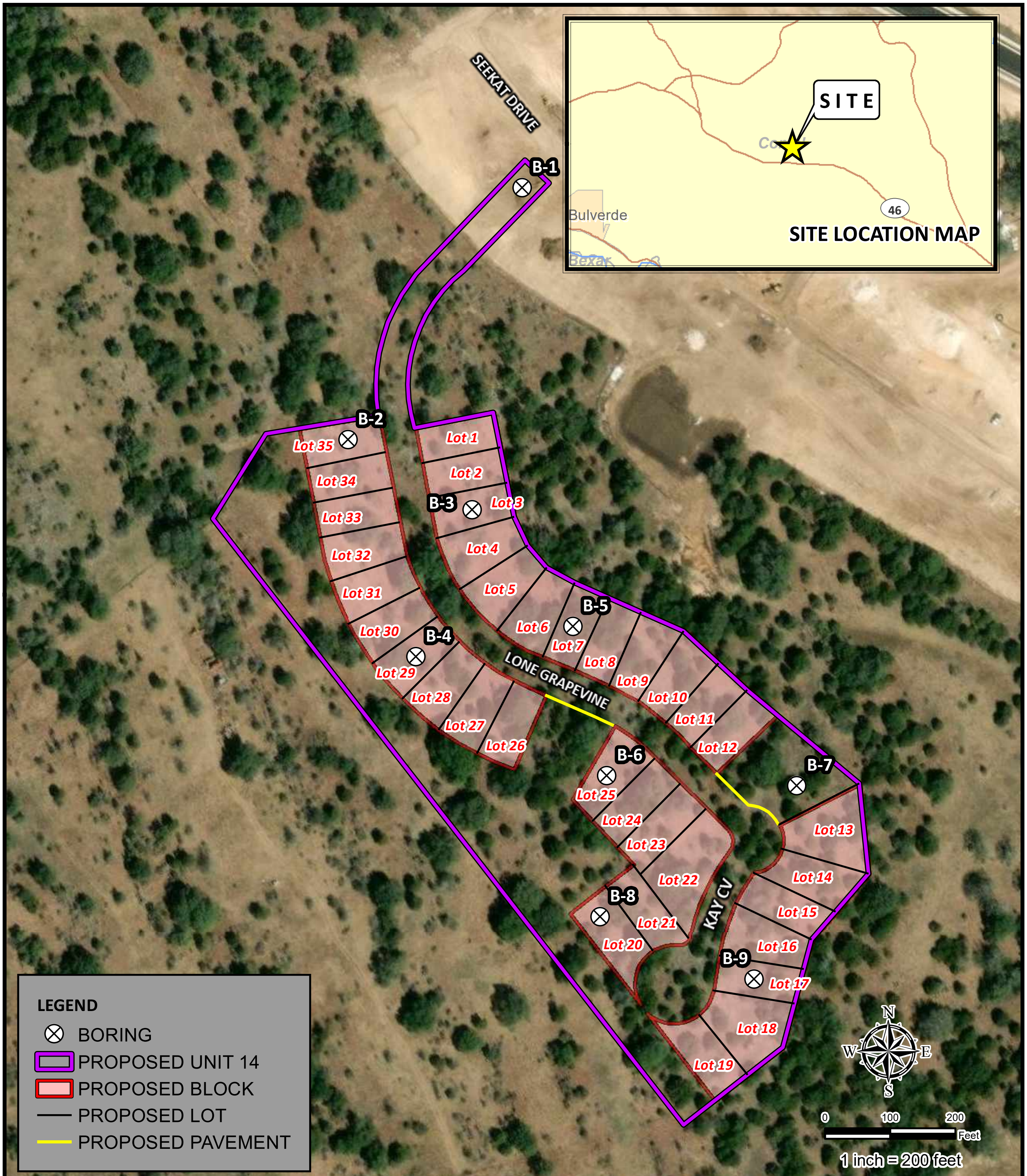
### BUDGETING FOR CONSTRUCTION TESTING

Appropriate budgets need to be developed for the required construction testing and observation activities. At the appropriate time before construction, we advise that RKI and the project designers meet and jointly develop the testing budgets, as well as review the testing specifications as it pertains to this project.

Once the construction testing budget and scope of work are finalized, we encourage a preconstruction meeting with the selected contractor to review the scope of work to make sure it is consistent with the construction means and methods proposed by the contractor. RKI looks forward to the opportunity to provide continued support on this project, and would welcome the opportunity to meet with the Project Team to develop both a scope and budget for these services.

* * * * * * * * * * * * * * * * * *

# ATTACHMENTS

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**TBPE Firm Number 3257**

SOURCE: Aerial imagery from Google Earth Pro - 2021

## BORING LOCATION MAP

Meyer Ranch - Unit 14
Comal County, Texas

COMAL COUNTY

| | |
|---|---|
| PROJECT No.: | ANA23-025-00 |
| ISSUE DATE: | 8/24/2023 |
| DRAWN BY: | BM |
| CHECKED BY: | SS |
| REVIEWED BY: | TIP |

**FIGURE**

**1**

NOTE: This Drawing is Provided for Illustration Only, May Not be to Scale and is Not Suitable for Design or Construction Purposes

# LOG OF BORING NO. B-1

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Straight Flight Auger

**LOCATION:** N 29.78310; W 98.29290

SHEAR STRENGTH, TONS/FT$^2$: 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT: 10 20 30 40 50 60 70 80

SURFACE ELEVATION: 1192 ft

| DEPTH, FT | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|
| 0–4 | FILL MATERIAL: FAT CLAY, Stiff to Very Stiff, Dark Brown and Tan, with gravel | 12 | | 36 | |
| | | 18 | | | |
| 4–6 | FAT CLAY, Stiff, Dark Brown to Reddish Brown | | | | |
| 5 | | 12 | | | |
| | - with trace gravel at 5.5 ft. | | | | |
| 6–6.6 | LIMESTONE, Hard, Light Tan | ref/1" | | | |
| 6.6 | Boring Terminated | | | | |

Depth scale: 5, 10, 15

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

**DEPTH DRILLED:** 6.6 ft
**DATE DRILLED:** 7/27/2023
**DEPTH TO WATER:** Dry
**DATE MEASURED:** 7/27/2023
**PROJ. No.:** ANA23-025-00
**FIGURE:** 2

# LOG OF BORING NO. B-2

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78214; W 98.29364

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL (SURFACE ELEVATION: 1184 ft) | BLOWS PER FT | UNIT DRY WEIGHT, pcf | SHEAR STRENGTH, TONS/FT² (0.5–4.0) / PLASTIC LIMIT – WATER CONTENT – LIQUID LIMIT (10–80) | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Sandy, Dark Brown | | | | 56 | 58 |
| | | | Limestone, Light Tan | | | | | |
| | | | Boring Terminated | | | | | |
| 5 | | | | | | | | |
| 10 | | | | | | | | |
| 15 | | | | | | | | |

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | | | |
|---|---|---|---|---|---|
| **DEPTH DRILLED:** | 0.5 ft | **DEPTH TO WATER:** | Dry | **PROJ. No.:** | ANA23-025-00 |
| **DATE DRILLED:** | 7/19/2023 | **DATE MEASURED:** | 7/19/2023 | **FIGURE:** | 3 |

# LOG OF BORING NO. B-3

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78184; W 98.29304

SURFACE ELEVATION: 1179 ft

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | SHEAR STRENGTH, TONS/FT$^2$ (0.5–4.0); PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10–80) | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Dark Brown | | | | 65 | |
| | | | Limestone, Light Tan | | | | | |
| | | | Boring Terminated | | | | | |

Depth scale: 5, 10, 15

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

**DEPTH DRILLED:** 1.3 ft
**DATE DRILLED:** 7/19/2023
**DEPTH TO WATER:** Dry
**DATE MEASURED:** 7/19/2023
**PROJ. No.:** ANA23-025-00
**FIGURE:** 4

# LOG OF BORING NO. B-4

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78122; W 98.29332

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL (SURFACE ELEVATION: 1185 ft) | BLOWS PER FT | UNIT DRY WEIGHT, pcf | SHEAR STRENGTH, TONS/FT$^2$ (0.5–4.0); PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10–80) | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Dark Brown | | | | 53 | |
| | | | Limestone, Light Tan | | | | | |
| | | | Boring Terminated | | | | | |

Depth scale: 5, 10, 15

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | | | |
|---|---|---|---|---|---|
| **DEPTH DRILLED:** | 0.8 ft | **DEPTH TO WATER:** | Dry | **PROJ. No.:** | ANA23-025-00 |
| **DATE DRILLED:** | 7/19/2023 | **DATE MEASURED:** | 7/19/2023 | **FIGURE:** | 5 |

# LOG OF BORING NO. B-5

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78135; W 98.29255

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | SHEAR STRENGTH, TONS/FT$^2$ (0.5 – 4.0) / PLASTIC LIMIT, WATER CONTENT, LIQUID LIMIT (10 – 80) | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|---|
| | | | SURFACE ELEVATION: 1179 ft | | | | | |
| 0 | | | FAT CLAY, Dark Brown | | | | 49 | |
| | | | Limestone, Light Tan | | | | | |
| | | | Boring Terminated | | | | | |
| 5 | | | | | | | | |
| 10 | | | | | | | | |
| 15 | | | | | | | | |

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | | | |
|---|---|---|---|---|---|
| **DEPTH DRILLED:** | 0.5 ft | **DEPTH TO WATER:** | Dry | **PROJ. No.:** | ANA23-025-00 |
| **DATE DRILLED:** | 7/19/2023 | **DATE MEASURED:** | 7/19/2023 | **FIGURE:** | 6 |

# LOG OF BORING NO. B-6

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78072; W 98.29239

SURFACE ELEVATION: 1181 ft

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | SHEAR STRENGTH, TONS/FT² / PLASTIC LIMIT – WATER CONTENT – LIQUID LIMIT | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Dark Brown | | | | 42 | |
| | | | Limestone, Light Tan | | | | | |
| | | | Boring Terminated | | | | | |

Shear strength scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0
Moisture scale: 10, 20, 30, 40, 50, 60, 70, 80
Depth scale: 5, 10, 15

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | |
|---|---|---|---|
| **DEPTH DRILLED:** 0.5 ft | **DEPTH TO WATER:** Dry | **PROJ. No.:** ANA23-025-00 | |
| **DATE DRILLED:** 7/19/2023 | **DATE MEASURED:** 7/19/2023 | **FIGURE:** 7 | |

# LOG OF BORING NO. B-7

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78067; W 98.29148

SURFACE ELEVATION: 1172 ft

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | SHEAR STRENGTH, TONS/FT$^2$ / PLASTIC LIMIT – WATER CONTENT – LIQUID LIMIT | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Dark Brown | | | | 51 | 92 |
| | | | Limestone, Light Tan | | | | | |
| | | | Boring Terminated | | | | | |

Shear strength scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0
Plastic limit / water content / liquid limit scale: 10, 20, 30, 40, 50, 60, 70, 80

Depth scale: 5, 10, 15

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | | | |
|---|---|---|---|---|---|
| **DEPTH DRILLED:** | 0.5 ft | **DEPTH TO WATER:** | Dry | **PROJ. No.:** | ANA23-025-00 |
| **DATE DRILLED:** | 7/19/2023 | **DATE MEASURED:** | 7/19/2023 | **FIGURE:** | 8 |

# LOG OF BORING NO. B-8

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.78012; W 98.29243

SURFACE ELEVATION: 1185 ft

SHEAR STRENGTH, TONS/FT$^2$: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

PLASTIC LIMIT, WATER CONTENT, LIQUID LIMIT: 10, 20, 30, 40, 50, 60, 70, 80

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Dark Brown | | | 51 | |
| | | | Limestone, Light Tan | | | | |
| | | | Boring Terminated | | | | |
| 5 | | | | | | | |
| 10 | | | | | | | |
| 15 | | | | | | | |

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | | | |
|---|---|---|---|---|---|
| **DEPTH DRILLED:** | 1.3 ft | **DEPTH TO WATER:** | Dry | **PROJ. No.:** | ANA23-025-00 |
| **DATE DRILLED:** | 7/19/2023 | **DATE MEASURED:** | 7/19/2023 | **FIGURE:** | 9 |

# LOG OF BORING NO. B-9

Meyer Ranch - Unit 14
Comal County, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

**DRILLING METHOD:** Hand Auger

**LOCATION:** N 29.79854; W 98.29169

SURFACE ELEVATION: 1177 ft

SHEAR STRENGTH, TONS/FT$^2$: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT: 10, 20, 30, 40, 50, 60, 70, 80

| DEPTH, FT | SYMBOL | SAMPLES | DESCRIPTION OF MATERIAL | BLOWS PER FT | UNIT DRY WEIGHT, pcf | PLASTICITY INDEX | % -200 |
|---|---|---|---|---|---|---|---|
| | | | FAT CLAY, Sandy, Dark Brown | | | 49 | 59 |
| | | | Limestone, Light Tan | | | | |
| | | | Boring Terminated | | | | |

Depth scale: 5, 10, 15

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

| | | | | | |
|---|---|---|---|---|---|
| **DEPTH DRILLED:** | 0.5 ft | **DEPTH TO WATER:** | Dry | **PROJ. No.:** | ANA23-025-00 |
| **DATE DRILLED:** | 7/19/2023 | **DATE MEASURED:** | 7/19/2023 | **FIGURE:** | 10 |

# KEY TO TERMS AND SYMBOLS

## MATERIAL TYPES

### SOIL TERMS

- CALCAREOUS
- CALICHE
- CLAY
- CLAYEY
- GRAVEL
- GRAVELLY
- PEAT
- SAND
- SANDY
- SILT
- SILTY
- FILL

### ROCK TERMS

- CHALK
- CLAYSTONE
- CLAY-SHALE
- CONGLOMERATE
- DOLOMITE
- IGNEOUS
- LIMESTONE
- MARL
- METAMORPHIC
- SANDSTONE
- SHALE
- SILTSTONE

### OTHER

- ASPHALT
- BASE
- CONCRETE/CEMENT
- BRICKS / PAVERS
- WASTE
- NO INFORMATION

## WELL CONSTRUCTION AND PLUGGING MATERIALS

- BLANK PIPE
- SCREEN
- BENTONITE
- CEMENT GROUT
- BENTONITE & CUTTINGS
- CONCRETE/CEMENT
- CUTTINGS
- GRAVEL
- SAND
- VOLCLAY

## SAMPLE TYPES

- AIR ROTARY
- GRAB SAMPLE
- CORE
- GEOPROBE SAMPLER
- ROTOSONIC -DAMAGED
- MUD ROTARY
- NO RECOVERY
- NX CORE
- PITCHER
- ROTOSONIC -INTACT
- SHELBY TUBE
- SPLIT BARREL
- SPLIT SPOON
- TEXAS CONE PENETROMETER
- DISTURBED

## STRENGTH TEST TYPES

- POCKET PENETROMETER
- TORVANE
- UNCONFINED COMPRESSION
- TRIAXIAL COMPRESSION UNCONSOLIDATED-UNDRAINED
- TRIAXIAL COMPRESSION CONSOLIDATED-UNDRAINED

NOTE: VALUES SYMBOLIZED ON BORING LOGS REPRESENT SHEAR STRENGTHS UNLESS OTHERWISE NOTED

PROJECT NO. ANA23-025-00

RABAKISTNER

REVISED 04/2012

FIGURE 11a

# KEY TO TERMS AND SYMBOLS (CONT'D)

## TERMINOLOGY

Terms used in this report to describe soils with regard to their consistency or conditions are in general accordance with the discussion presented in Article 45 of SOILS MECHANICS IN ENGINEERING PRACTICE, Terzaghi and Peck, John Wiley & Sons, Inc., 1967, using the most reliable information available from the field and laboratory investigations. Terms used for describing soils according to their texture or grain size distribution are in accordance with the UNIFIED SOIL CLASSIFICATION SYSTEM, as described in American Society for Testing and Materials D2487-06 and D2488-00, Volume 04.08, Soil and Rock; Dimension Stone; Geosynthetics; 2005.

The depths shown on the boring logs are not exact, and have been estimated to the nearest half-foot. Depth measurements may be presented in a manner that implies greater precision in depth measurement, i.e 6.71 meters. The reader should understand and interpret this information only within the stated half-foot tolerance on depth measurements.

### RELATIVE DENSITY

| Penetration Resistance Blows per ft | Relative Density |
|---|---|
| 0 - 4 | Very Loose |
| 4 - 10 | Loose |
| 10 - 30 | Medium Dense |
| 30 - 50 | Dense |
| > 50 | Very Dense |

### COHESIVE STRENGTH

| Resistance Blows per ft | Consistency | Cohesion TSF |
|---|---|---|
| 0 - 2 | Very Soft | 0 - 0.125 |
| 2 - 4 | Soft | 0.125 - 0.25 |
| 4 - 8 | Firm | 0.25 - 0.5 |
| 8 - 15 | Stiff | 0.5 - 1.0 |
| 15 - 30 | Very Stiff | 1.0 - 2.0 |
| > 30 | Hard | > 2.0 |

### PLASTICITY

| Plasticity Index | Degree of Plasticity |
|---|---|
| 0 - 5 | None |
| 5 - 10 | Low |
| 10 - 20 | Moderate |
| 20 - 40 | Plastic |
| > 40 | Highly Plastic |

## ABBREVIATIONS

B = Benzene
T = Toluene
E = Ethylbenzene
X = Total Xylenes
BTEX = Total BTEX
TPH = Total Petroleum Hydrocarbons
ND = Not Detected
NA = Not Analyzed
NR = Not Recorded/No Recovery
OVA = Organic Vapor Analyzer
ppm = Parts Per Million

Qam, Qas, Qal = Quaternary Alluvium
Qat = Low Terrace Deposits
Qbc = Beaumont Formation
Qt = Fluviatile Terrace Deposits
Qao = Seymour Formation
Qle = Leona Formation
Q-Tu = Uvalde Gravel
Ewi = Wilcox Formation
Emi = Midway Group
Mc = Catahoula Formation
EI = Laredo Formation
Kknm = Navarro Group and Marlbrook Marl
Kpg = Pecan Gap Chalk
Kau = Austin Chalk

Kef = Eagle Ford Shale
Kbu = Buda Limestone
Kdr = Del Rio Clay
Kft = Fort Terrett Member
Kgt = Georgetown Formation
Kep = Person Formation
Kek = Kainer Formation
Kes = Escondido Formation
Kew = Walnut Formation
Kgr = Glen Rose Formation
Kgru = Upper Glen Rose Formation
Kgrl = Lower Glen Rose Formation
Kh = Hensell Sand

# KEY TO TERMS AND SYMBOLS (CONT'D)

## TERMINOLOGY

## SOIL STRUCTURE

| | |
|---|---|
| Slickensided | Having planes of weakness that appear slick and glossy. |
| Fissured | Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical. |
| Pocket | Inclusion of material of different texture that is smaller than the diameter of the sample. |
| Parting | Inclusion less than 1/8 inch thick extending through the sample. |
| Seam | Inclusion 1/8 inch to 3 inches thick extending through the sample. |
| Layer | Inclusion greater than 3 inches thick extending through the sample. |
| Laminated | Soil sample composed of alternating partings or seams of different soil type. |
| Interlayered | Soil sample composed of alternating layers of different soil type. |
| Intermixed | Soil sample composed of pockets of different soil type and layered or laminated structure is not evident. |
| Calcareous | Having appreciable quantities of carbonate. |
| Carbonate | Having more than 50% carbonate content. |

## SAMPLING METHODS

### RELATIVELY UNDISTURBED SAMPLING

Cohesive soil samples are to be collected using three-inch thin-walled tubes in general accordance with the Standard Practice for Thin-Walled Tube Sampling of Soils (ASTM D1587) and granular soil samples are to be collected using two-inch split-barrel samplers in general accordance with the Standard Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). Cohesive soil samples may be extruded on-site when appropriate handling and storage techniques maintain sample integrity and moisture content.

### STANDARD PENETRATION TEST (SPT)

A 2-in.-OD, 1-3/8-in.-ID split spoon sampler is driven 1.5 ft into undisturbed soil with a 140-pound hammer free falling 30 in. After the sampler is seated 6 in. into undisturbed soil, the number of blows required to drive the sampler the last 12 in. is the Standard Penetration Resistance or "N" value, which is recorded as blows per foot as described below.

### SPLIT-BARREL SAMPLER DRIVING RECORD

| Blows Per Foot | Description |
|---|---|
| 25 | 25 blows drove sampler 12 inches, after initial 6 inches of seating. |
| 50/7" | 50 blows drove sampler 7 inches, after initial 6 inches of seating. |
| Ref/3" | 50 blows drove sampler 3 inches during initial 6-inch seating interval. |

NOTE: To avoid damage to sampling tools, driving is limited to 50 blows during or after seating interval.

# RESULTS OF SOIL SAMPLE ANALYSES

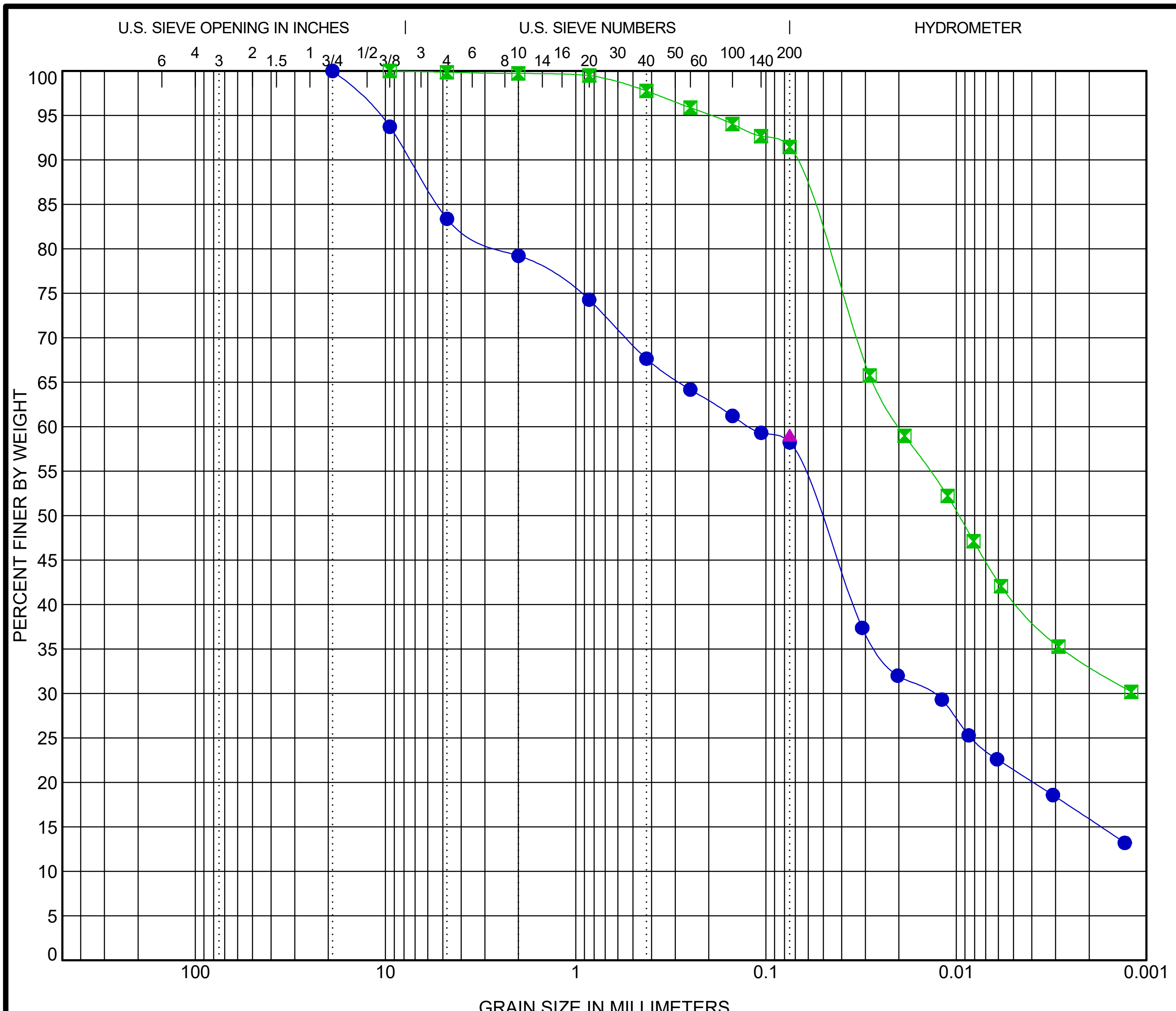
PROJECT NAME: Meyer Ranch - Unit 14
Comal County, Texas

FILE NAME: ANA23-025-00.GPJ 8/22/2023

| Boring No. | Sample Depth (ft) | Blows per ft | Water Content (%) | Liquid Limit | Plastic Limit | Plasticity Index | USCS | Dry Unit Weight (pcf) | % -200 Sieve | Shear Strength (tsf) | Strength Test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B-1 | 0.0 to 1.5 | 12 | 12 | 52 | 16 | 36 | CH | | | | |
| | 2.5 to 4.0 | 18 | 5 | | | | | | | | |
| | 4.5 to 6.0 | 12 | 37 | | | | | | | | |
| | 6.0 to 6.5 | | 2 | | | | | | | | |
| | 6.5 to 6.6 | ref/1" | | | | | | | | | |
| B-2 | 0.0 to 0.3 | | 5 | 80 | 24 | 56 | CH | | 58 | | |
| B-3 | 0.0 to 1.0 | | 18 | 88 | 23 | 65 | CH | | | | |
| B-4 | 0.0 to 0.5 | | 12 | 83 | 30 | 53 | CH | | | | |
| B-5 | 0.0 to 0.3 | | 12 | 71 | 22 | 49 | CH | | | | |
| B-6 | 0.0 to 0.3 | | 5 | 62 | 20 | 42 | CH | | | | |
| B-7 | 0.0 to 0.3 | | 11 | 74 | 23 | 51 | CH | | 92 | | |
| B-8 | 0.0 to 1.0 | | 14 | 76 | 25 | 51 | CH | | | | |
| B-9 | 0.0 to 0.4 | | 10 | 75 | 26 | 49 | CH | | 59 | | |

PP = Pocket Penetrometer TV = Torvane UC = Unconfined Compression FV = Field Vane UU = Unconsolidated Undrained Triaxial

CU = Consolidated Undrained Triaxial




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| Specimen Identification | | Classification | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|
| ● B-2 | 0.0 | **SANDY FAT CLAY with GRAVEL(CH)** | **80** | **24** | **56** | | |
| ⊠ B-7 | 0.0 | **FAT CLAY(CH)** | **74** | **23** | **51** | | |
| ▲ B-9 | 0.0 | **SANDY FAT CLAY(CH)** | **75** | **26** | **49** | | |
| ★ | | | | | | | |
| ⊙ | | | | | | | |

| Specimen Identification | | D60 | D50 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|
| ● B-2 | 0.0 | **0.12** | **0.053** | **0.014** | | **16.6** | **25.1** | **36.8** | **21.4** |
| ⊠ B-7 | 0.0 | **0.02** | **0.01** | | | **0.1** | **8.4** | **50.9** | **40.6** |
| ▲ B-9 | 0.0 | | | | | **0.0** | **0.0** | **59.0** | |
| ★ | | | | | | | | | |
| ⊙ | | | | | | | | | |

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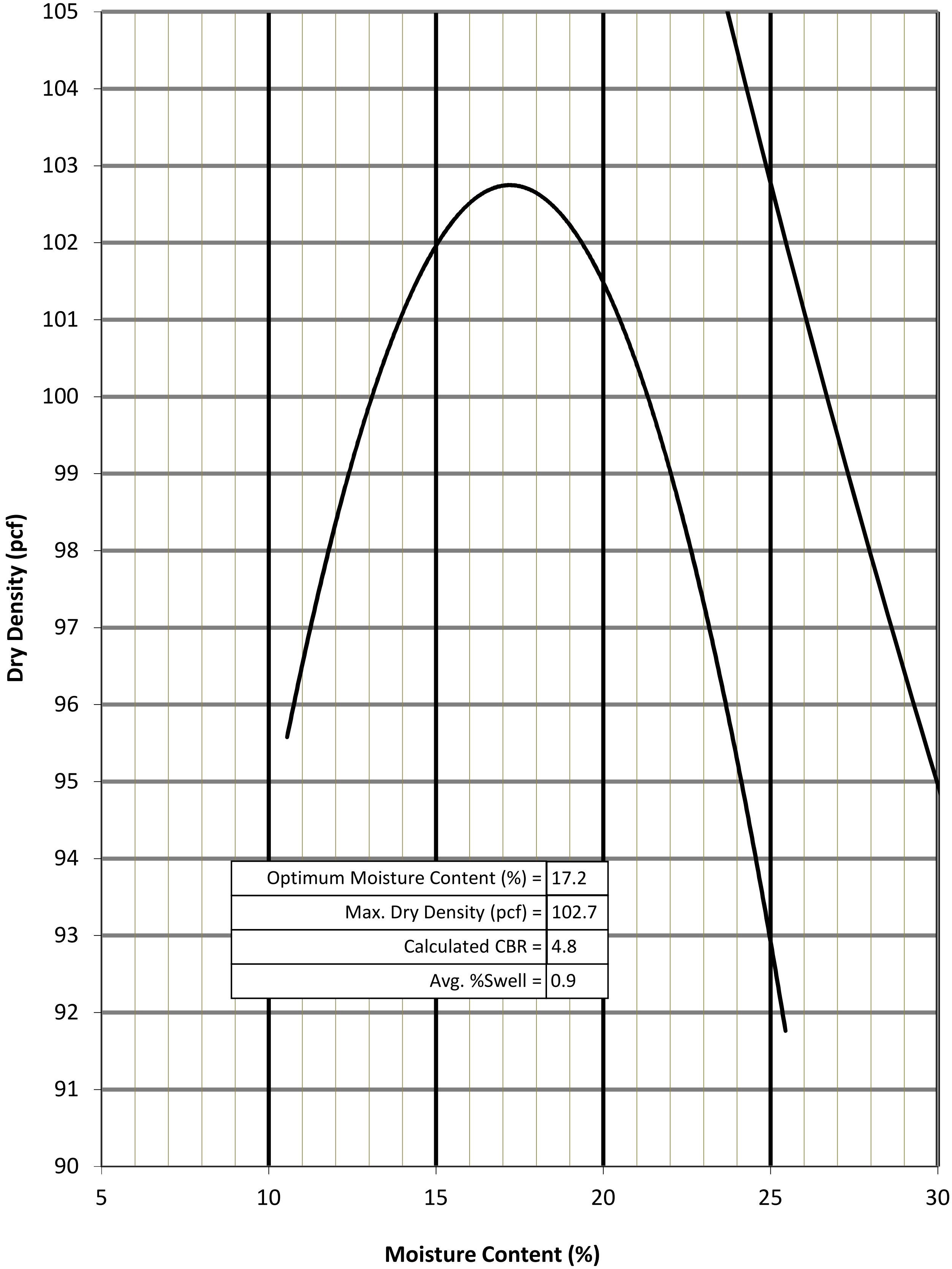
## GRAIN SIZE DISTRIBUTION

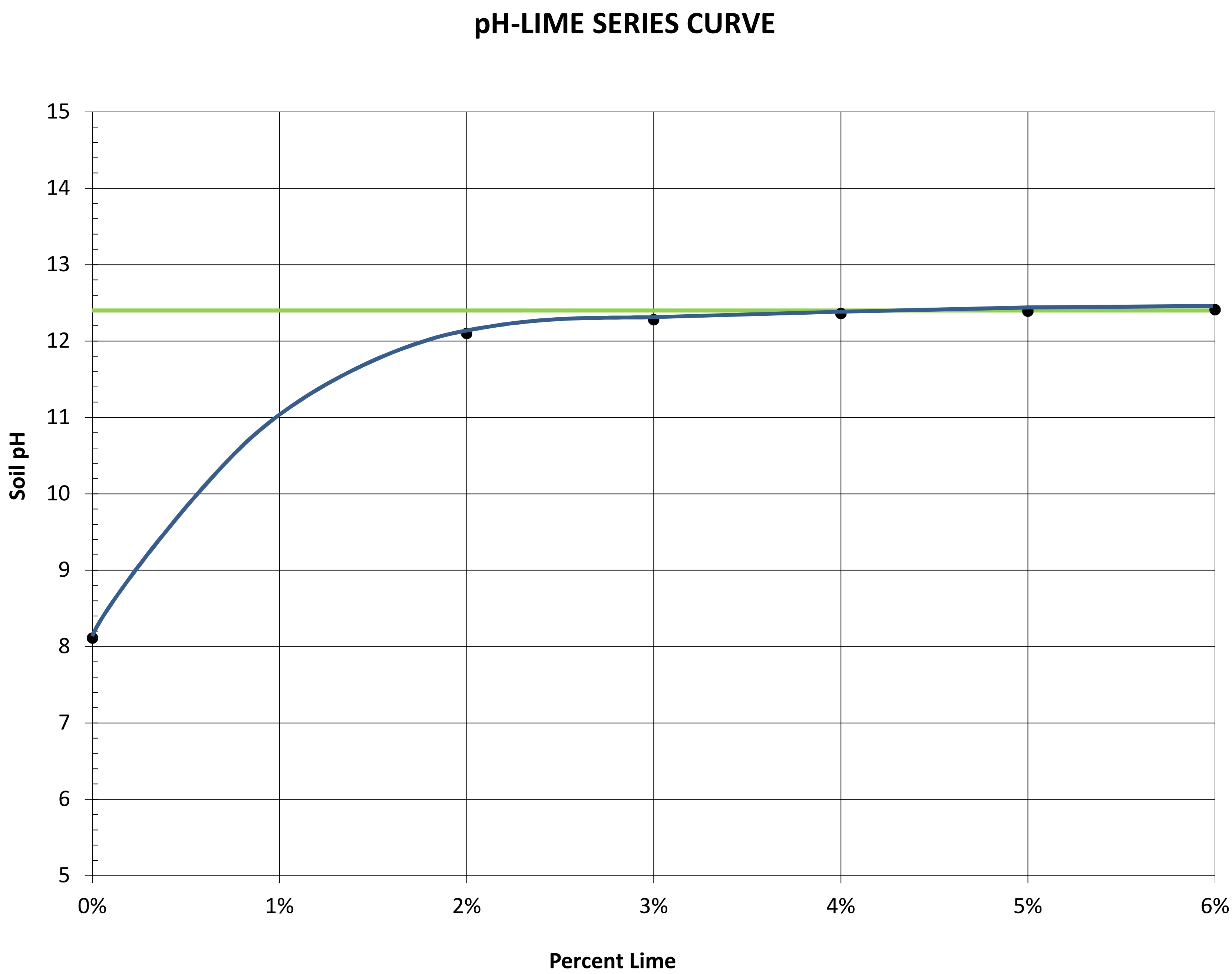
Meyer Ranch - Unit 14
Comal County, Texas

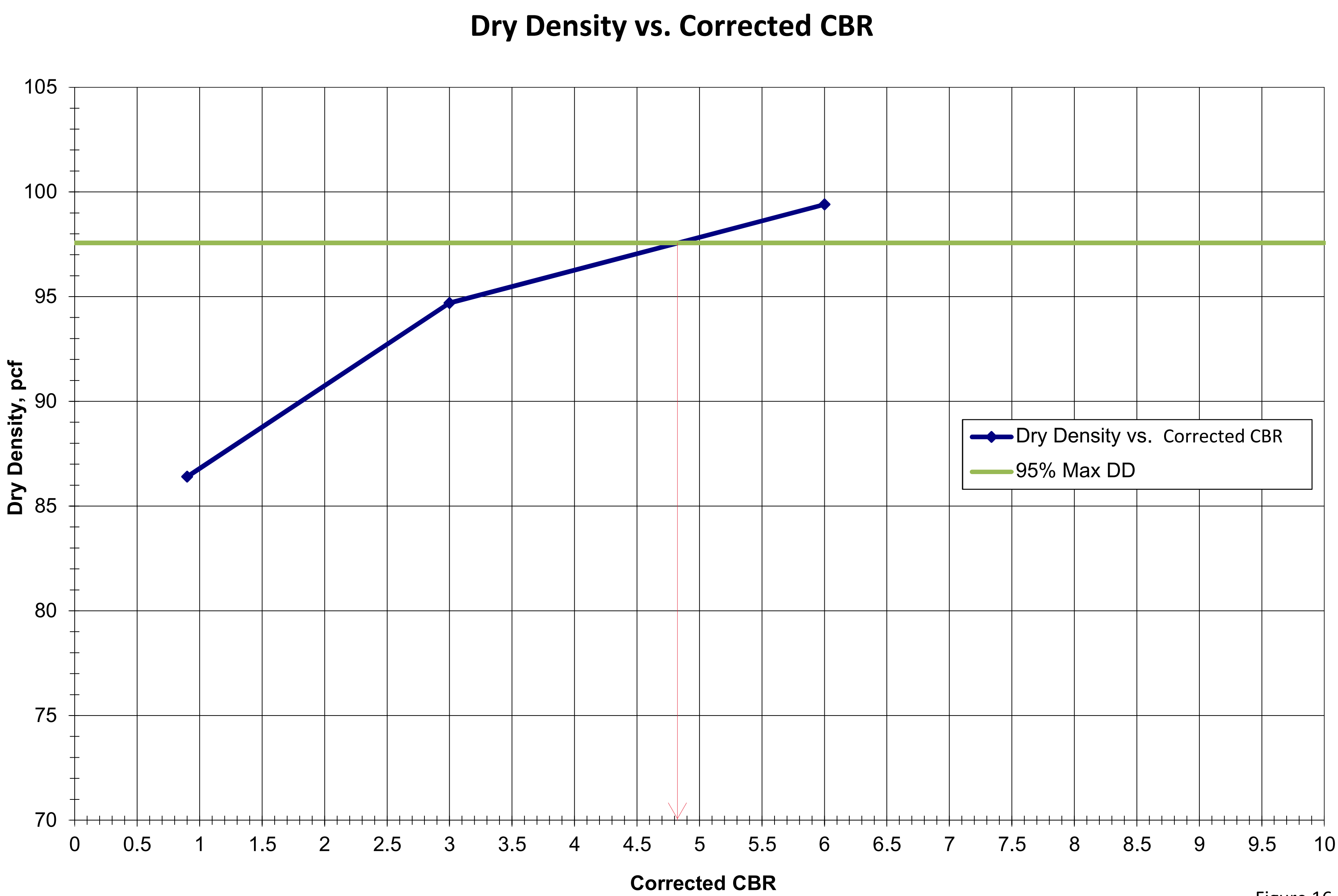
R-K GRAIN SIZE - TEMP ANA23-025-00.GPJ RKCI.GDT 8/22/23

FIGURE 13

# MOISTURE DENSITY RELATIONSHIP CURVE




pH-LIME SERIES CURVE
15
14
13
12
11
10
9
8
7
6
5
Soil pH
0%
1%
2%
3%
4%
5%
6%
Percent Lime



Dry Density vs. Corrected CBR
105
100
95
90
85
80
75
70
Dry Density, pcf
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
Corrected CBR
Dry Density vs. Corrected CBR
95% Max DD


Figure 16

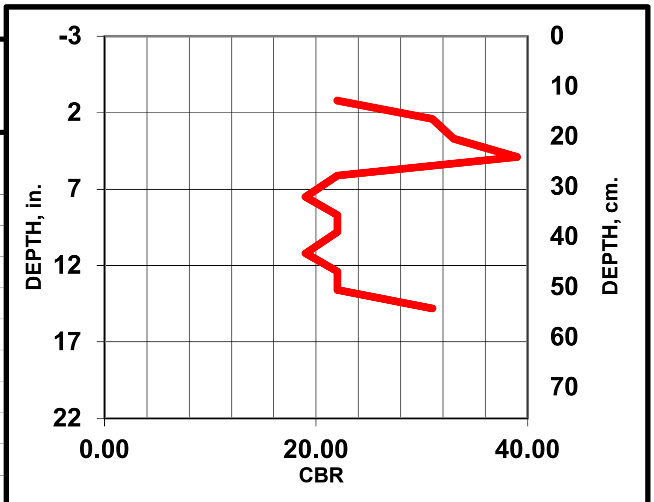
Project Number: ANA23-025-00
Test Date: July 27, 2023

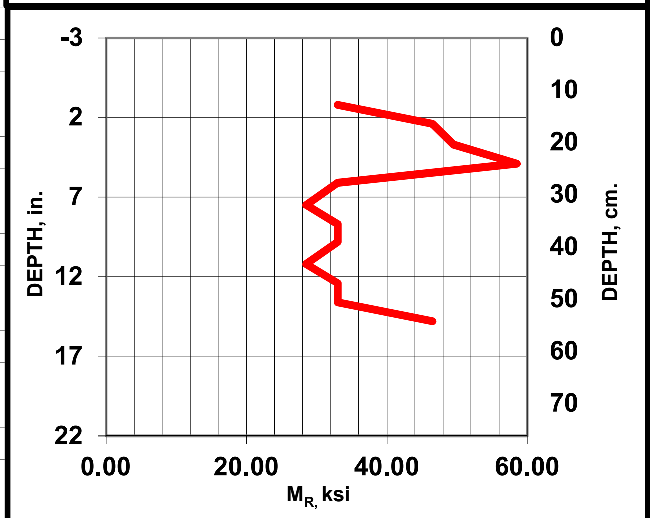
# DCP TEST DATA

**50 ft East of B-2**
Meyer Ranch - Unit 14
Comal County, Texas

| Type of Ham. | No. of Blows | Penetration Incre. (mm) | Penetration Cumm. (in) | CBR (%) | $M_R$ (ksi) | $q_{ult}$ (ksf) |
|---|---|---|---|---|---|---|
| 1 | 3 | 30 | 1.2 | 22 | 33 | 4.25 |
| 1 | 4 | 30 | 2.4 | 31 | 46.5 | 5.34 |
| 1 | 5 | 35 | 3.7 | 33 | 49.5 | 5.57 |
| 1 | 5 | 30 | 4.9 | 39 | 58.5 | 6.22 |
| 1 | 3 | 30 | 6.1 | 22 | 33 | 4.25 |
| 1 | 3 | 35 | 7.5 | 19 | 28.5 | 3.86 |
| 1 | 3 | 30 | 8.7 | 22 | 33 | 4.25 |
| 1 | 3 | 30 | 9.8 | 22 | 33 | 4.25 |
| 1 | 3 | 35 | 11.2 | 19 | 28.5 | 3.86 |
| 1 | 3 | 30 | 12.4 | 22 | 33 | 4.25 |
| 1 | 3 | 30 | 13.6 | 22 | 33 | 4.25 |
| 1 | 4 | 30 | 14.8 | 31 | 46.5 | 5.34 |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |
| - | - | - | - | - | - | - |

NOTES: Hammer 17.6 lbs = 1 Hammer 10.1 lbs = 2



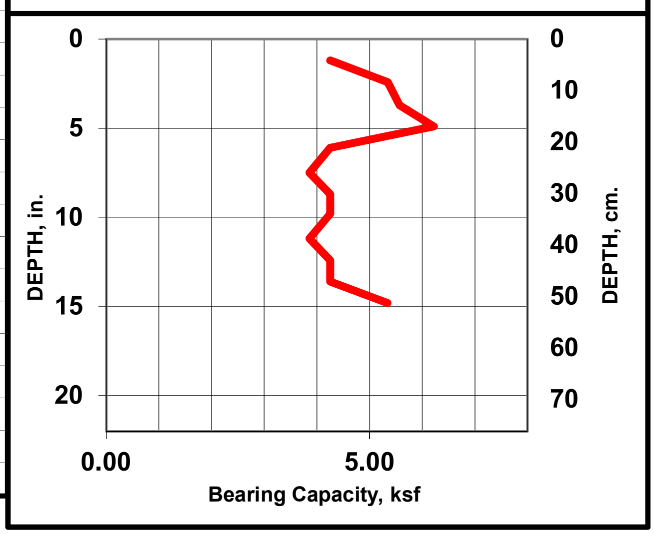




FIGURE 17

# Important Information about This

# Geotechnical-Engineering Report

**Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.**

**While you cannot eliminate all such risks, you can manage them. The following information is provided to help.**

## Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a civil engineer may not fulfill the needs of a constructor — a construction contractor — or even another civil engineer. Because each geotechnical- engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. No one except you should rely on this geotechnical-engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply this report for any purpose or project except the one originally contemplated.

## Read the Full Report

Serious problems have occurred because those relying on a geotechnical-engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

## Geotechnical Engineers Base Each Report on a Unique Set of Project-Specific Factors

Geotechnical engineers consider many unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk-management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical-engineering report that was:

- not prepared for you;
- not prepared for your project;
- not prepared for the specific site explored; or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical-engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse;
- the elevation, configuration, location, orientation, or weight of the proposed structure;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

## Subsurface Conditions Can Change

A geotechnical-engineering report is based on conditions that existed at the time the geotechnical engineer performed the study. *Do not rely on a geotechnical-engineering report whose adequacy may have been affected by*: the passage of time; man-made events, such as construction on or adjacent to the site; or natural events, such as floods, droughts, earthquakes, or groundwater fluctuations. *Contact the geotechnical engineer before applying this report to determine if it is still reliable.* A minor amount of additional testing or analysis could prevent major problems.

## Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ — sometimes significantly — from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide geotechnical-construction observation is the most effective method of managing the risks associated with unanticipated conditions.

## A Report's Recommendations Are Not Final

Do not overrely on the confirmation-dependent recommendations included in your report. *Confirmation-dependent recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations *only* by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's confirmation-dependent recommendations if that engineer does not perform the geotechnical-construction observation required to confirm the recommendations' applicability.*

## A Geotechnical-Engineering Report Is Subject to Misinterpretation

Other design-team members' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Constructors can also misinterpret a geotechnical-engineering report. Confront that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing geotechnical construction observation.

### Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical-engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

### Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make constructors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give constructors the complete geotechnical-engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise constructors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure constructors have sufficient time* to perform additional study. Only then might you be in a position to give constructors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

### Read Responsibility Provisions Closely

Some clients, design professionals, and constructors fail to recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

### Environmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform an *environmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical-engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. *Do not rely on an environmental report prepared for someone else.*

### Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold-prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, many mold- prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical- engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; *none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.*

### Rely, on Your GBC-Member Geotechnical Engineer for Additional Assistance

Membership in the Geotechnical Business Council of the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you GBC-Member geotechnical engineer for more information.

GBC GEOTECHNICAL BUSINESS COUNCIL
of the Geoprofessional Business Association

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