Geotechnical Engineering Study

Market Ridge Phase 4
San Antonio, Texas

Arias Job No. 2023-458

Prepared For
Sitterle Homes

October 6, 2023

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October 6, 2023
Arias Job No. 2023-458

Email: jeffk@sitterlehomes.com

Mr. Jeff Kuwamura
Sitterle Homes
2015 Evans Road, Ste 100
San Antonio, Texas 78258

RE: Geotechnical Engineering Study
Market Ridge Phase 4
San Antonio, Texas

Dear Mr. Kuwamura:

Arias & Associates, Inc. (Arias) is pleased to submit this report presenting the results of a Geotechnical Engineering Study for the above referenced project. This study was authorized by Jeff Kuwamura, via signed acceptance (on June 5, 2023) of Arias Proposal No. 2023-458, dated May 26, 2023.

The purpose of this geotechnical engineering study was to establish foundation engineering properties of the subsurface soil and groundwater conditions present at the site. The scope of the study is to provide geotechnical engineering criteria for use by design engineers in preparing the foundation and pavement design. Our findings and recommendations should be incorporated into the design and construction documents for the proposed development.

The long-term success of the project will be affected by the quality of materials used for construction and the adherence of the construction to the project plans and specifications. The quality of construction can be evaluated by implementing Quality Assurance (QA) testing. As the Geotechnical Engineer of Record (GER), we recommend that the earthwork and foundation construction be tested and observed by Arias in accordance with the report recommendations. A summary of our qualifications to provide QA testing is discussed in the "Quality Assurance Testing" section of this report. Furthermore, a message to the Owner with regard to QA testing is provided in the GBA publication included in Appendix E.

Thank you for the opportunity to be of service to you.

10-6-23

STATE OF TEXAS
MARK J. O'CONNOR
79252
REGISTERED
PROFESSIONAL ENGINEER

Sincerely,
Arias & Associates, Inc.
TBPE Registration No: F-32

James R. Murphree, E.I.T.
Graduate Engineer

Mark J. O'Connor, P.E.
Senior Geotechnical Engineer

REPORT FORMAT INFORMATION

To improve clarity in the intent of our geotechnical recommendations for this project, the report is organized into two separate, but equally important sections.

Section I – *Synopsis* is a summary of our geotechnical recommendations specific to this project.

Section II - The *Main Report* contains more detailed information including foundation design parameters and site work recommendations.

A study of both of the above referenced sections is recommended for the Project Team Members. Arias & Associates, Inc. cautions that Section I is a consolidated quick reference overview of the more detailed geotechnical recommendations contained in Section II and should not be utilized exclusively from the remainder of the report.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS

Page

Tables

SECTION I: SYNOPSIS

This synopsis includes a brief description of the project, subsurface findings, preferred foundation type, generalized earthwork requirements for building pad construction, and specific items of concern from a geotechnical standpoint for consideration during the design, construction, and maintenance phases of this project.

Table 1: Project Description

Project:	Market Ridge Phase 4
Project Location:	San Antonio, Texas
Proposed Development:	4 Single Story Buildings at 6,000 sq ft each 1 Single Story Building at 5,400 sq ft And Associated Pavements
Preferred Foundation Type:	Spread Footings
Improved Site Condition (Design PVR):	½ inches or less

Table 2: Existing Conditions at Time of Geotechnical Study

Ground Cover:	Topsoil and exposed Limestone
Predominant Soil Types:	Limestone
Plasticity Index (PI):	Range: NP – 17
Groundwater Depth Measured:	Groundwater was not encountered during field exploration on July 30 – August 9, 2023
Estimated Potential Vertical Rise (PVR):	Approximately ¾ inch

Table 3: Building Pad Recommendations

Recommended Foundation Type:	Slab on Grade with Spread Footings
Site Improvement Method:	Compacted Select Fill as needed to meet final elevation.
Improved Site Condition (PVR):	½ inch or less
Minimum Undercut Depth:	**Remove topsoil down to weathered limestone and as Required to Meet Final Floor Elevation of Buildings.**
Minimum Select Fill Thickness Under Foundation Elements:	**Unless bearing in bedrock, a minimum of 1 foot ofof select fill should exist under foundation elements and slabs.**
Exposed Subgrade Preparation (See Note 4):	**Proof Roll with a rubber wheeled compactor. Excavate and replace with new material, if needed.**
Pumping/Rutting/Soft Areas Discovered During Proof rolling:	Remove to firmer materials and replace with compacted material under direction of Geotechnical Engineer's representative
Scarify, Moisten & Compact Exposed Subgrade:	**After topsoil removals, exposed weathered limestone present. Only proofroll recommended.**
Select Fill Type:	• LEAN CLAY (CL) with LL <40, PI = 8 – 20, #200>50%, 3" Maximum Particle Size. • Working Surface: At Least Top 6" to be Crushed Limestone Base Meeting Requirements of TxDOT Item 247 Type A, Grade 1 or 2
Moisture Barrier:	See Note 7

Notes:

1. The building pad improvements will be used with a slab on grade with perimeter grade beams and interior spread footings.
2. Any existing below grade structures (if found) should be demolished and debris properly removed from the site. Existing pavements, footings, floor slabs, and utilities, as well as any associated undocumented backfill, should be removed from below, and at least 5 feet beyond the proposed improvement footprints, where possible. As an exception, deep utilities (if any) may be grouted in place rather than being removed. However, the existing backfill associated with deep utilities should be removed and replaced or recompacted. Excavations resulting from the removal of existing site improvements should be backfilled with properly compacted fill. To avoid the double handling of the soil, the undercut operation of the existing soils to mitigate the PVR condition should be performed concurrently. Select Fill material should be utilized to achieve the planned final floor elevation. If subgrade improvements are not made beneath the entryways and surrounding flatwork, the full extent of the PVR movements should be expected. An Arias rep should be present on-site during excavation operations to determine the extent of the undocumented fills for removal.
3. After excavation or before fill placement, the topsoil and clay (if present) should be removed down to weathered limestone. TheThe exposed subgrade should be thoroughly proof rolled with a rubber wheeled vehicle. Passes should be performed with passes alternating in directions perpendicular to each other.. Any area that yields under the roller loading should be undercut to the depth specified by the geotechnical engineer and replaced with compacted fill as specified by the Geotechnical Engineer and outlined in Table 5. If deleterious material, rubble, or debris is encountered, they should be removed to firmer materials and disposed of properly. The void should then be replaced with properly compacted select fill. It is important that the site preparation operations be observed and tested by one of our representatives to verify that

these recommendations are followed. After approval of the proof roll operation, the select fill may be placed in lifts, as outlined in SECTION I, Table 5.

4. The building pad should be constructed using select fill. The select fill material should be placed within 48 hours of completion of the subgrade proofrollproofroll and should be placed in maximum 8-inch loose lifts as specified in SECTION I, Table 5 (Project Compaction, Moisture and Testing Requirements).

5. For construction equipment access, and to help in providing a more "all-weather" working surface, we recommend placing at least six (6) inches of compacted crushed limestone base meeting the requirements of 2004 TXDOT Item 247, Type A, Grade 1 - 2 which can be considered as the top six (6) inches of the select fill.

6. If additional select fill thickness is necessary to achieve final design grade, fill should consist of material meeting the requirements in Table 3 above.

7. A horizontal barrier should extend at least 10 feet horizontally beyond the perimeter of the foundation. The barrier can consist of concrete or asphalt paving, concrete flatwork or at least 18" of compacted import clay (PI between 20 and 40). All joints within the pavement, flatwork, and at pavement/flatwork interfaces should be sealed. Any landscaping located within 10 feet of the structure's foundation should be placed in watertight above-grade planter boxes with drainage discharge on top of adjacent flatwork/paving. We recommend that the perimeter grade beam be constructed to a depth of at least 24 inches to aid in reducing the potential for moisture fluctuation beneath the building pad. The final grade beam depth and recommended construction should be determined by the structural engineer. The slab vapor retarder plastic should be extended from beneath the slab down the inside face (building pad side) of the grade beam trench.

Table 4: Recommended Pavement Sections

Layer	Material	Flexible Asphaltic Concrete		Rigid Concrete	
		Parking Area - Light Duty	Access Drive, Truck Lane - Medium Duty	Parking Area - Light Duty	Access Drives, Truck Lane - Medium Duty
Surface	HMAC/PCC	2"	2.5"	6"	7"
Base	Flexible Base	8"	12"	--	--
Subgrade	Moisture conditioned and compacted	6"	6"	6"	6"

Notes:

1. Pavements founded on top of expansive soils will be subjected to PVR soil movements estimated and presented in this report (*i.e.,* approximately ¾ inches). These potential soil movements are typically activated to some degree during the life of the pavement. Consequently, pavements can be expected to crack and require periodic maintenance. Periodic/preventative maintenance should be planned for to reduce deterioration of the pavement structure while aiding to preserve the investment.

2. Light duty areas include parking and drive lanes that are subjected to passenger vehicle traffic only. Light duty areas exclude entrance aprons and drives to the site and single access route drive lanes to parking areas.

3. Medium duty areas include entrance aprons and drives into the site, single access route drive lanes (Drive Through Lane) to parking areas, and areas where paving will be subjected to lightly loaded trucks. Medium duty areas exclude areas where tractor trailers may travel or park, dock areas, areas where trash collection vehicles may travel and load or unload.

4. Heavy duty areas include areas subjected to 18-wheel tractor trailers, trash collection vehicles, forklifts, dumpster pad including dumpster truck path from street to pad, loading and unloading areas, and areas

where truck turning and maneuvering may occur and drive through lanes. Asphalt pavement should not be used for the Dumpster Pad or drive through lane. **At least eight (8)-inch thick concrete is recommended for heavy duty pavement areas (such as Dumpster Pads and drive through lanes) and is not shown in Table 4.**

5. During the paving life, maintenance to seal surface cracks within concrete or asphalt paving and to reseal joints within concrete pavement should be undertaken to achieve the desired paving life. Perimeter drainage should be controlled to reduce the influx of surface water from areas surrounding the paving. Water penetration into base or subgrade materials, sometimes due to irrigation or surface water infiltration leads to pre-mature paving degradation. Curbs should be used in conjunction with paving to reduce potential for infiltration of moisture into the base course. Curbs should extend the full depth of the base course and should extend at least 3 inches into the underlying clayey subgrade. The base layer should be tied into the area inlets to drain water that may collect in the base.

6. Material specifications, construction considerations, and section requirements are presented under “Pavement Subgrade and Section Materials” included in Section II of this report.

Table 5: Project Compaction, Moisture and Testing Requirements

Description	Material	Percent Compaction	Optimum Moisture Content	Testing Requirement
		According to Standard Proctor ASTM D 698		
Building Pad Area	(after topsoil & clay removals) Subgrade Soil	ProofrollProofroll	--	--
	Select Fill (Pit Run Select Fill Body; Crushed Limestone Base Cap)	≥ 98%	-1 to +3%	1 per 2,500 SF; min. 3 tests per lift
Pavement Areas	Scarified, Moisture Conditioned On-site Soil (Subgrade)	≥ 95%	0 to +4%	1 per 2,500 SF; min. 3 tests
	General Fill (Onsite Material)	≥ 95%	0 to +4%	1 per 2,500 SF; min. 3 tests per lift
	Base Material	≥ 95% (ASTM D 1557)	±3%	1 per 2,500 SF; min. 3 tests
	Hot-mix asphaltic concrete	91% to 95% Theoretical Lab Density (TEX 207 F)	Not applicable	1 per 2,500 SF; min. 3 tests
Non-Structural Areas (Outside Building Pad)	General Fill (On-site Material)	≥ 95%	0 to +4%	1 per 2,500 SF; min. 3 tests per lift

SECTION II: MAIN REPORT

INTRODUCTION

This report presents the results of a Geotechnical Engineering Study for the proposed Market Ridge Phase 4 in San Antonio, Texas. This project was authorized by Mr. Jeff Kuwamura through the signing of Arias proposal 2023-458 dated May 26, 2023, on June 5, 2023.

SCOPE OF SERVICES

The purpose of this geotechnical engineering study was to conduct a subsurface exploration and laboratory testing to establish the engineering properties of the subsurface materials present on the project site. This information was used to develop the geotechnical engineering criteria for use by design engineers to aid in preparing the foundations and pavement design.

PROJECT AND SITE DESCRIPTION

The proposed project will consist of 5 single-story buildings of approximately 5,400 square feet to 6,000 square feet and includes associated drives and parking areas. The project site is located on the north side of Market Ridge in North San Antonio, Texas, as shown on the Site Vicinity Map provided in Appendix A. The site is currently an undeveloped space and generally slopes down to the northern boundary of the site. The foundation loads have not been provided but are assumed to be relatively light. We understand that the finished floor elevations of the five buildings are proposed to be as follows: **BuildingBuilding A** 1075.00', **Building B** 1074.00', **Building C** 1075.00', **Building D** 1074', and **Building E** 1070.50'. After reviewing the grading plan provided by Colliers Engineering and Design, the following approximate cut and fills to meet the above finished grade elevations, are as follows: **BuildingBuilding A** - 3' to 11' cut, **Building B**- 0' to 10' cut and 0' to 5' fill, **BuildingBuilding C**- 5' to 16' fill, **BuildingBuilding D**- 5' to 17' fill, **BuildingBuilding E-** 1.5' to 11.5' fill. The site contains relatively heavy brush with some trees and limited clearing was performed in order for us to access the site with our drill rig.

SOIL BORINGS

Ten (10) soil borings were drilled to depths ranging from about 6 to 10 feet each on July 30 through August 9, 2023, at the approximate locations shown on the Boring Location Plan provided in Appendix A. The boring depths were measured from below the ground surface elevation that existed at the time of our drilling and sampling activities. The borings were sampled in accordance with ASTM D1586 for Split Spoon sampling and ASTM D 1452 for material taken from the auger as it was advanced as described in Appendix C. A truck-mounted drill rig using continuous flight augers together with the sampling tool noted was used to secure the subsurface soil samples.

Soil classifications and borehole logging were conducted during the exploration by one of our field-logging technicians who are under the supervision of the project Geotechnical Engineer. Final soil classifications, as seen on the attached borings logs (Appendix B), were determined based on laboratory and field test results and applicable ASTM procedures.

LABORATORY TESTS

As a supplement to the field exploration, laboratory testing was conducted to determine soil water content, Atterberg Limits, and percent passing the US Standard No. 200 sieve. The laboratory results are reported in the attached borings logs included in Appendix B.

A key to the terms and symbols used on the logs is also included in Appendix B. The soil laboratory testing for this project was done in accordance with applicable ASTM procedures with the specifications and definitions for these tests listed in Appendix C.

Remaining soil samples recovered from this exploration will be routinely discarded following submittal of this report.

SUBSURFACE CONDITIONS

Geology

A Geologic Map for the project site is presented on Figure 3 in Appendix A. According to the Geologic Atlas of Texas, the project area has been regionally mapped as the Edwards Limestone (Ked).

<u>The Edwards Limestone (Ked)</u> is Cretaceous age limestone consisting of relatively soft to extremely hard limestone, dolomitic limestone, and dolomite. The limestone is typically described as vuggy, honeycombed, and porous, having solution cavities and voids (karst), as well as nodules and lenticular layers of very hard chert. The voids are often infilled with red clay and brecciated limestone. The dolomite and dolomitic limestone of the Edwards are typically softer and when exposed to weathering, may take on a soil-like consistency. Surficial weathered remnants of the parent limestone consist of clayey soils with various amounts of sand and limestone fragment content.

Site Stratigraphy and Engineering Properties

The generalized subsurface stratigraphy encountered at this site is summarized in Table 6. The presence and thickness of the various subsurface materials can be expected to vary away from and between the exploration locations. The descriptions generally conform to the Unified Soils Classification System.

It should be noted that very dense to very hard soil materials were encountered in the borings. It is anticipated that heavy-duty excavating equipment capable of digging in

such materials would be required for this project. The contractor should be experienced with and prepared for such conditions.

Table 6: Generalized Soil Conditions

Stratum	Depth (ft)	Material Type	PI range	No. 200 range	N range
I	0 to 6 - 10	Weathered Limestone – very stiff to very hard – gray, brown, tan, light tan, white	NP – 17	8 – 32	24 – **50/1"

Where: Depth - Depth from existing ground surface at the time of geotechnical field exploration, feet
PI - Plasticity Index, %
NP - Non-plastic
No. 200 - Percent passing #200 sieve, %
N - Standard Penetration Test (SPT) value, blows per foot
* - Test Performed in one sample

Groundwater

A dry soil sampling method was used to obtain the soil samples at the project site. Groundwater was not encountered during the soil sampling activities, which were performed on July 30 through August 9, 2023. The open boreholes were backfilled with soil cuttings generated during the drilling process.

It should be noted that water levels in open boreholes may require several hours to several days to stabilize depending on the permeability of the soils. Groundwater levels at the time of construction may differ from the observations obtained during the field exploration because perched groundwater is subject to seasonal conditions, recent rainfall, flooding, drought or temperature affects. Leaking underground utilities can also impact subsurface water levels.

Groundwater levels should be verified immediately prior to construction. Gravels and sandy soils, as well as seams of these more permeable type materials, can transmit "perched" groundwater. Granular utility backfills can provide a conduit for water to collect under pavements and can ultimately lead to pavement distress. Provisions to intercept and divert "perched" or subsurface water should be made if subsurface water conditions become problematic. Should dewatering become required, it is considered "means and methods" and is solely the responsibility of the Contractor.

Variations

Soil conditions vary between the sample boring locations. Transition boundaries noted on the boring logs are approximate. Subsurface conditions at other locations may differ from those observed at the boring locations, and subsurface conditions at the boring locations may vary at different times of the year. The scope of work may not fully define the viability of the subsurface materials and conditions that are present on the site. The nature and extent of variations between borings may not become evident until construction. If significant variations then appear evident, our office should be contactedcontacted to re-evaluate our recommendations after performing on-site observations and possibly other tests. Actual contacts may be gradual and vary at different locations.

ENGINEERING ANALYSIS AND DISCUSSION

The type of foundation most appropriate for a given structure depends on several factors: the function of the structure and the loads it may carry, the subsurface conditions, and the cost of the foundation in comparison with the cost of the superstructure.[1] In addition, the performance criteria for the structure is significant relative to the foundation system selected.

Deep drilled piers are best suited to buildings with moderate to heavy loading conditions over expansive soils where little to no cracking can be tolerated. The piers, when properly founded, can minimize foundation movement of the superstructure. Grade beams isolated from the soil typically span between the piers and a structurally supported slab is used at the ground floor level. The structurally suspended slab option is used when excellent performance is expected from the structure in terms of minimal aesthetic distress, such as tile, dry wall or masonry cracking.

A shallow foundation type consisting of a structural Beam and Slab-On-Grade or Spread Footings is a common less costly alternative approach for small to moderate sized buildings. This foundation type is commonly used for light to moderate loading conditions and is much more cost-effective than a deep foundation system with a suspended floor slab. Some aesthetic distress and cracking in the floors and walls are normally acceptable to the owner and design team with this foundation alternative.

Each approach has its advantages and disadvantages in terms of cost and overall performance. Positive drainage away from the foundation will play a key role in reducing the possibility of differential foundation movement and related aesthetic distress. Structures founded on expansive clayey soils can be expected to experience some aesthetic distress even with soil improvement measures performed.

The presence of expansive clays at the project site is a major factor in the foundation design details for this structure. Geotechnical design criteria applicable to expansive soil conditions

[1]Peck, R. B., Hanson, W.E., and Thornburn, T. H., 1953 Foundation Engineering, Second Edition, John Wiley and Sons Inc., New York, Page 263.

are presented herein. Reductions of potential distress can be accomplished by following our recommendations.

In consideration of the following factors: the function of the structures and the site conditions; a shallow foundation system consisting of Spread Footings may be used for the proposed buildings provided the client is willing to consider the risks as previously described with a shallow foundation.

Soil Shrink-Swell Potential

The expansive soils found at this site can swell and shrink in volume dependent on potentially changing soil water content conditions during or after construction. The term swelling soils implies not only the tendency to increase in volume when water is available, but also to decrease in volume or shrink if water is removed.[2] Shrinkage is merely the reverse process of swelling.

Several methods such as the AASHTO or TXDOT methods are available to estimate possible soil shrink -swell movements. These methods provide an estimate of potential vertical rise, PVR. These methods use the liquid limits, plasticity indices, and existing water contents for soils in the seasonally active zone, estimated to be about ten to fifteen feet in this area of Texas.

Our PVR is estimated to be approximately ¾" or less (non-expansive site) based on dry conditions. Soil movements greater than this estimated value can result if they are subject to isolated soil moisture content changes, such as flooding, poor drainage, or leaking plumbing, which allow them to approach soil saturation known as the "bathtub" effect. Actual soil movement will depend on the degree of moisture content change.

FOUNDATION TYPE AND CAPACITY – SHALLOW FOUNDATIONS

The structures may be supported on spread footings. Guidelines for this foundation type are provided by the International Building Code and this report. Subgrade improvements are also recommended for use in order to reduce the effect of the PVR.

An allowable soil bearing capacity of 2,500 pounds per square foot may be utilized for the perimeter beam footings and interior spread footings when founded in select fill or site weathered limestone materials. It is recommended that all perimeter beam spread footings

[2] Peck, R. B., Hanson, W.E., and Thornburn, T. H., 1953 Foundation Engineering, Second Edition, John Wiley and Sons Inc., New York, Page 337.

be placed into limestone bedrock a minimum of 2 inches and be poured level in stair steps down slopes to avoid the creep potential for the sloping rock/footing interface. All interior spread footings should also be placed into limestone bedrock 2 inches minimum and be poured level. However, due to the relatively deep depth of fills on several of the buildings, if more than 4 feet of excavation is required to reach the limestone bedrock, the interior spread footings may be placed into the select fill materials in lieu of the limestone bedrock. The bearing capacity includes a factor of safety of at least 3. A minimum of 12 inches of select fill is recommended beneath footings and slabs if exposed rock is not available, due to depth. All footings for a given building should bear into similar materials (either rock or select fill).

Footings subjected to lateral forces or overturning should be proportioned such that the resultant reaction force on the base of the footing lies within the middle one-third of the footing width. Footings should bear at least 24" below the final exterior grade. Interior spread footings should have a least dimension of 36" for bearing capacity considerations. Resistance to sliding will be developed by friction along the base of the footings and passive earth pressure acting on the vertical face of the footing. We recommend a coefficient of base friction of 0.35 along the bottom of the footing bearing on properly placed and compacted select fill or limestone bedrock. Passive resistance on the vertical face of the footing may be taken at 400 psf per foot.

Post construction settlements for the foundations as described above should be less than 1" with differential settlements on the order of ¾" assuming proper construction. Careful monitoring during construction is necessary to locate any pockets or seams of unsuitable materials which might be encountered in the excavation for footings. Unsuitable soils encountered at the foundation bearing level should be removed and replaced with either lean concrete (about 1,000 psi strength at 28 days), structural concrete, or compacted select fill. The bearing stratum exposed in the base of all foundation excavations should be protected against any detrimental change in conditions. Surface runoff water should be drained away from excavations and not allowed to collect. All concrete for foundations should be placed as soon as practical after the excavation is made. Prolonged exposure of the bearing surface to air or water will result in changes in strength and compressibility of the bearing stratum. Excavations should not be left open for more than 48 hours, therefore, if delays occur, foundation excavations should be slightly deepened and cleaned to provide a fresh bearing surface.

These recommendations are for proper development of bearing capacity and to reduce the potential for water to migrate beneath the footings and grade beams. The concrete beams and footings should be reinforced in accordance with the soil design criteria provided.

A vapor barrier such as Stego Wrap, 10 mil minimum, should be placed beneath the floor slab in order to break the rise of capillary moisture. All foundation elements should be evaluated and designed by a structural engineer. In addition, if planters and landscaping are planned, they should be self-contained in boxes as described below to avoid the bathtub effect. The bathtub effect is where surface water migrates beneath the foundation causing movements. If grass is planned against the building, a minimum of 18" of clay liner should be provided under the topsoil and over the select fill overbuild. The clay should be compacted in two 9" lifts to 90% standard proctor density within 0 to +6% of optimum moisture. Clay liners may also be used beneath planters.

Pilot Holes

Due to the possibility of a void existing below the bottom of the perimeter grade beam and spread footings , pilot holes should be drilled into the bedrock. Pilot holes should be drilled below all footings and grade beams that are founded in bedrock. If isolated spread footings are founded in a minimum of 1 foot of select fill (over the rock subgrade) no pilot holes are required. Pilot holes should be drilled at 50' on center for the perimeter grade beams and in each isolated spread footing to 3'3 minimum below the bottom of the footing. The contractor should submit a plan of the proposed hole layout for our review prior to hole drilling. If voids are found, they should be filled with flowable fill upon confirmation by the Geotechnical Engineer. Soil filled voids within the rock should be brought to the attention of the Geotechnical Engineer for recommendations. The Geotechnical Engineer or his representative should witness all pilot hole drilling.

Recommended Building Subgrade Improvement for the Slabs

The subgrade improvements described in this section will reduce the PVR or soil shrink swell potential of the subsurface soils to approximately ½" or less which (in our opinion) is considered a non-expansive site in accordance with the IBC code. Post construction settlements should be about 1" and the settlement response of a select fill supported slab is more influenced by the quality of construction than by soil-structure interaction. Therefore, it is essential that the recommendations for the foundation construction be strictly followed during the construction phase of the building pad and foundation. If this amount of soil and related foundation movement is not acceptable to the overall future performance of the structure and client, we should be consulted for additional recommendations.

1. Strip away the topsoil, clay, roots, and otherwise unsuitable materials from the construction area. The stripped materials consisting of vegetation and organic materials should be wasted from the site or used to revegetate landscaped areas.

2. After the stripping is completed, it is recommended that the clays (if present) be completely removed over the weathered limestone bedrock from under the building pad. If rock is encountered, no further excavation is required. This material should be discarded; however, it may be used to raise the parking areas if the grading plan requires such and if organic material is not present. The building pad area is defined as the area that extends at least 5' beyond the perimeter of the proposed building and should include movement sensitive flatwork. The pad can stop at the outside edge of

the movement sensitive flatwork. Select structural fill should be used to raise the foundations and a minimum of 12" is required beneath all floor slabs and foundation elements. Arias should witness and confirm the extent of the removals on the site.

3. The exposed subgrade should be proof rolled with a loaded dump truck to check for pockets or soft/loose materials hidden beneath a thin crust of possibly better materials. The filling with select fill should extend a minimum of 5' beyond the building perimeter, however, building entryway slabs should not be placed over highly expansive clays. If rock is encountered, no density testing is required for the subgrade. We recommended that all fills be placed on level rock surfaces free of slopes. If this is not possible due to the large amount of rock excavation required, the fills should be benched a minimum of 3' laterally and 1' thick (two lifts) into the rock on the uphill side of the slope for the total thickness of select fill, in a stair step configuration. This is to avoid the possibility of creep developing due to gravitational forces acting on the fill mass and the smooth plane interface between the rock and placed structural select fills. The exposed downhill sloped portion of the fills should be protected from erosion and should be no steeper than a 4:1 slope (horizontal to vertical).

4. Pavement and/or flatwork should be placed against the building perimeter to protect the select fill overbuild from wetting and drying (the bathtub effect). Any planters against the building should be placed in watertight boxes. If grass is planned against the building, a minimum of 18" of clay liner should be provided under the topsoil and over the select fill overbuild. The clay should be placed in two 9" lifts and compacted as outlined in Tables 3 & 5 of this report. The intent of these recommendations is to reduce potential soil movements while minimizing potential surface water seepage into the select fill. Future seepage of water into the select fill can create a "bathtub" effect and be detrimental to the foundation and superstructure.

5. The overlying select fill should be compacted and tested and tested as outlined in Table 3 & 5 of this report.

6. The Select Structural fill should consist of TXDOT Standard Specifications Item 247 Type A Grade 1-2 base. A minimum of 12" of select fill should be used beneath all floor slabs and foundation elements that do not bear at least 2" into competent limestone.

7. Prior to any filling operations, samples of the proposed borrow and on-site materials should be obtained for laboratory Atterberg Limits and Proctor testing. The tests will provide a basis for evaluation of fill compaction by in-place density testing.

BRAB/WRI Design Criteria

Because the upper expansive soils will be removed over the low expansive materials, the site conditions can be considered "non-expansive" in accordance with the International Building Code. These foundations can also be designed as "Type I and Type II" slabs in accordance with BRAB Report 33. An effective PI of 15 may be used for the design calculations.

Design Measures to Reduce Changes in Soil Moisture

It will be very important to consider measures to reduce future moisture fluctuations of the soils under the slab-on-grade. Movements of foundation soil can be effectively reduced by providing horizontal and/or vertical moisture barriers around the edge of the slab. Typically, the moisture barriers would consist of concrete flatwork or asphalt or concrete pavement placed adjacent to the edge of the building, or deepened grade beams.

Although subgrade modification through excavation and replacement is recommended to reduce potential soil-related foundation movements, the design and construction of a grade-supported foundation should also include the following elements:

- Roof drainage should be controlled by gutters and carried well away from the structure. The ground surface adjacent to the building perimeter should be sloped and maintained a minimum of 5% grade away from the building for 10 feet to result in positive surface flow or drainage away from the building perimeter.
- Hose bibs, sprinkler heads, and other external water connections should be placed well away from the foundation perimeter such that surface leakage cannot readily infiltrate into the subsurface or compacted fills placed under the proposed foundations and slabs.
- No trees or other vegetation over 6 feet in height shall be planted within 15 feet of the structure unless specifically accounted for in the foundation design.
- Utility bedding should not include gravel within 4 feet of the perimeter of the foundation. Compacted clay or flowable fill trench backfill should be used in lieu of permeable bedding materials between 2 feet inside the building to a distance of 4 feet beyond the exterior of the building edge to reduce the potential for water to infiltrate within utility bedding and backfill material.
- Paved areas around the structure are helpful in maintaining equilibrium within the soil water content. If possible, pavement and sidewalks should be located immediately adjacent to the building.
- Flower beds and planter boxes should be piped or watertight to prevent water infiltration under the building. Experience indicates that landscape irrigation is a common source of foundation movement problems and pavement distress.

- Site work excavations should be protected and backfilled without delay to reduce changes in the natural moisture regime.

Flatwork Considerations

Differential movements (tripping hazards) between the planned structures and abutting flatwork should be expected if the flatwork is supported on similar existing unmodified soil conditions. Thus, we recommend that select fill placement beneath the building be extended to include adjacent movement-sensitive flatwork. Flatwork supported on unimproved, natural site soil conditions will result in differential foundation movement. We recommend that the flatwork and the building be designed to include details that permit foundation movements without resulting in vertical separations and without distressing either element. Control joints should be incorporated that include steel reinforcing to prevent vertical shear, but to allow bending.

The flatwork and abutting sidewalks should be designed and constructed to allow for positive drainage away from the building foundation. The planned site grading should allow for potential future differential movements and should never be allowed to reach a level or negative slope that promotes drainage toward the foundation.

IBC Site Classification and Seismic Design Coefficients

Section 1613 of the International Building Code (2021) requires that every structure be designed and constructed to resist the effects of earthquake motions, with the seismic design category to be determined in accordance with Section 1613 or ASCE 7. Site classification according to the International Building Code (2021) is based on the soil profile encountered to the 100-foot depth. The stratigraphy at the site location was explored to a maximum 20-foot depth.

Soils having similar consistency were extrapolated to be present between the 20 and 100-foot depths. On the basis of the site class definitions included in the 2021 Code and the encountered generalized stratigraphy, we characterize the site as Site Class A.

Seismic design coefficients were determined using the on-line software. Analyses were performed considering the 2021 International Building Code. Input included GPS coordinates and Site Class A. Seismic design parameters for the site are summarized in the following table.

Table 7: Seismic Design Parameters

Site Class	F_a	F_v	S_s	S_1
A	0.8	0.8	0.05g	0.024g

Where: Fa = Site coefficient
Fv = Site coefficient

Ss = Mapped spectral response acceleration for short periods
S_1 = Mapped spectral response acceleration for a 1-second period

RETAINING WALL CONSIDERATIONS

Lateral Earth Pressures

We are providing at-rest and active earth pressure coefficients for various backfill types adjacent to the proposed retaining walls on the north sides of Buildings C & D that may be used for the design in the table below. The values consider that the backfill will extend behind walls to a lateral distance equal to the about wall height. At-rest earth pressures are recommended in cases where little wall yield is expected (structural below-grade walls which are fixed at the top). Active earth pressures may be utilized in cases where the walls can exhibit a small amount of horizontal movement at the top (such as cantilevered retaining walls).

The following Table indicates the recommended Lateral Earth Pressure Coefficients for the project site:

Table 8: Lateral Pressure Parameters

Backfill Type	Estimated Total Unit Weight (pcf)	Lateral Earth Pressure Coefficients			
		At Rest (Ko)	EFP[1]	Active (Ka)	EFP[1]
Crushed Limestone	135	0.41	55	0.30	41
Clean Sand	120	0.50	60	0.35	42
Clean Gravel	120	0.45	54	0.30	36

Notes:

1. The equivalent fluid pressure acts as a triangular distribution on the walls. The design lateral pressure is equal to the soil equivalent fluid weight noted above multiplied by the depth below the ground surface.

The above values do not include a hydrostatic or ground level surcharge component. The effect of surcharge loads, where applicable, should be incorporated into wall pressure diagrams by adding a pressure component equal to the applicable lateral earth pressure coefficient times the surcharge load to the full height of the wall.

A passive soil resistance modeled by an equivalent fluid unit weight of 250 pcf may be used for natural soil against the face of the exterior base or a key below the base of the wall. The upper 2 feet of soil backfilled against the exterior face of the walls and uncontrolled backfill soils should be ignored when calculating the lateral resistance. A lower passive pressure value of about 100 pcf should be used if the ground surface slopes downward away from the face of the wall.

At the time of this report, we have not been provided proposed retaining wall specifications, dimensions, surcharges, or cross-sections required for global stability analysis. We should be provided with this information prior to final retaining wall design to check for Global Stability.

All retaining walls should be checked against failure due to bearing, overturning, and sliding by the structural designersdesigners.

Backfill Compaction

Backfill used adjacent to below-grade structures should be placed and compacted in controlled lifts. The compaction effort should be controlled during backfill operations. Over compaction can produce lateral earth pressures in excess of at-rest magnitudes. Compaction levels adjacent to below-grade walls should be maintained between 95 and 98 percent of (ASTM D 698) maximum dry density.

We do not recommend the use of high plasticity soil as backfill behind retaining structures. Free-draining backfill should be wrapped in a geo-textile filter fabric (Mirafi 140N or equivalent) to prevent adjacent finer-grained soils from infiltrating into the pore spaces of the free-draining backfill. Furthermore, weep holes and a perforated/slotted wall drain should be considered to reduce the potential for hydrostatic forces to develop.

Alternately, drainage can be provided directly through the weepholes without a drainpipe, provided that filter fabric is used, or other measures are taken to prevent the granular backfill from migrating out through the weepholes. Any interior sumps (if any) must be isolated “watertight” from the interior subgrade to prevent the movement of moisture from the sump into the underlying soils.

Foundation Bearing

Passive pressures should be neglected in the lateral earth pressure calculations. Due to the presence of fills at the site, we recommend that the footings bear on either the natural undisturbed weatheredweatheredlimestone material at this site or select fill, as previously recommended. An allowable net bearing capacity of 2,500 psf may be taken with footings bearing on natural weathered rock or select fill.fill Friction along the base of the wall footings will develop resistance to sliding. An ultimate coefficient of base friction of 0.5 can be used. . Foundations bearing on the different material types such as undocumented fills, may experience differential settlement and other issues.

ADDITIONAL DESIGN CONSIDERATIONS

Utilities

Utilities which go through the slab and beams should be designed with some flexibility to allow free movement in the lines as a result of potential soil shrinkage or swelling.

Slab-Bearing Partition Walls & Flooring

Slab bearing partition walls and brittle floor tiles are susceptible to various degrees of cracking due to potential slab and foundation movements. Accordingly, the potential foundation movements cited earlier should be accounted for in the overall design.

Control and Construction Joints

Concrete, mortar, grout, and concrete or clay masonry units as well as numerous other construction materials shrink and swell upon a loss or gain of moisture in much the same manner as expansive soils. Accordingly, material volume changes or potential foundation movements can cause wall or slab cracking to occur. In general, however, unsightly cracking can normally be eliminated by controlling crack locations and making them inconspicuous so that they do not detract from the appearance of the building. Crack control should typically be implemented in the overall building design by the implementation of control or contraction joints in the structure at proper intervals.

PAVEMENT RECOMMENDATIONS

The pavement recommendations were prepared in accordance with the 1993 AASHTO Guide for the Design of Pavement Structures for asphalt and the ACI 330R (Guide for Design and Construction of Concrete Parking Lots) for concrete. No specific traffic design information was received for this project. Therefore, the following design parameters and assumptions were used in our analysis:

Table 9: Pavement Design Assumptions

Traffic Load for Light Duty Pavement	15,000 equivalent single axle loads (ESALs)
Traffic Load for Heavy Duty Pavement	50,000 equivalent single axle loads (ESALs)
Average Daily Truck Traffic vehicle with at least 6 Wheels	One (1)
Concrete Compressive Strength	4,000 psi
Raw Subgrade California Bearing Ratio (CBR)	3.0 for clayey subgrade
Raw Subgrade Modulus of Subgrade Reaction, k in pci	75 for clayey subgrade

Options for section thickness for flexible and rigid pavements are provided in SECTION I: SYNOPSIS, Table 4. Note that the truck lane traffic sections correspond to only one heavy-duty truck per day. If more heavy-duty truck traffic is anticipated, we recommend the use of an eight (8)-inch thick concrete pavement.

A truck traffic section (8-inches thick) is recommended for use at loading docks, entrances, driveways, dumpster pads and channeled traffic areas. Areas subjected to truck traffic stopping, starting, loading, unloading or turning should not utilize asphalt pavement. For these areas, a concrete section is recommended.

Rigid Concrete Pavement Joints

Placement of expansion joints in concrete paving on potentially expansive subgrade or on granular subgrade subject to piping often results in horizontal and vertical movement at the joint. Many times, concrete spalls adjacent to the joint and eventually a failed concrete area results. This problem is primarily related to water infiltration through the joint.

One method to mitigate the problem of water infiltration through the joints is to eliminate all expansion joints that are not absolutely necessary. It is our opinion that expansion or isolation joints are needed only adjacent where the pavement abuts intersecting drive lanes and other structures. Elimination of all expansion joints within the main body of the pavement area would significantly reduce access of moisture into the subgrade. Regardless of the type of expansion joint sealant used, eventually openings in the sealant occur resulting in water infiltration into the subgrade.

The use of sawed and sealed joints should be designed in accordance with current Portland Cement Association (PCA) or American Concrete Institute (ACI) guidelines. Research has proven that joint design and layout can have a significant effect on the overall performance of concrete pavement.

Recommendations presented herein are based on the use of reinforced concrete pavement. Local experience has shown that the use of distributed steel placed at a distance of 1/3 slab thickness from the top is of benefit in crack control for concrete pavements. Improved crack control also reduces the potential for water infiltration.

Performance Considerations

Our pavement recommendations have been developed to provide an adequate structural thickness to support the anticipated traffic volumes. Some shrink/swell movements due to moisture variations in the underlying soils, or potential movement from settling utility backfill material, should be anticipated over the life of the pavements. The owner should recognize that over a period of time, pavements may crack and undergo some deterioration and loss of serviceability. We recommend the project budgets include an allowance for maintenance such as patching of cracks or occasional overlays over the life of the pavement.

Pavement Subgrade and Section Materials

Recommendations for the planned pavement subgrade and section materials are as follows:

Table 10: Pavement Subgrade Materials

Subgrade Preparation Prior to Paving Section Construction	
Minimum undercut depth	6 inches or as needed to remove organics and unsuitable material
Reuse excavated soils	Provided they are free of roots and debris and meet the material requirements for their intended use
Horizontal extent for undercut	2 feet beyond the paving limits
Exposed subgrade treatment (before moisture conditioning)	Proof roll with rubber tired vehicle weighing at least 20 tons such as a loaded dump truck with Geotechnical Engineer's representative present during proof rolling. A minimum of 20 passes should be performed with passes alternating in directions perpendicular to each other.
Pumping/rutting, soft, or deleterious areas discovered during proof rolling	Remove to firmer materials and replace with compacted general or select fill under direction of Geotechnical Engineer's representative

Table 11: Pavement Fill, Compaction and Testing Requirements

Fill Requirements for Grade Increases	
General fill type	Material free of roots, debris and other deleterious material with a maximum rock size of 3 inches; on-site clays having CBR $\geq$ 3.0 may be used
Minimum general fill thickness	As required to achieve grade
Maximum general fill loose lift thickness	8 inches
General fill compaction and moisture criteria	ASTM D 698 ≥ 95% compaction at 0 to +4 from optimum
Subgrade Treatment Option - Moisture Conditioning	
Depth of moisture conditioning	9 inches (disk in place and moisture condition)
Compaction and moisture criteria	ASTM D 698 ≥ 95% compaction at 0 to +4 from optimum
Treatment layer compaction and moisture criteria	ASTM D 698 ≥ 95% compaction at 0 to +4 from optimum
In-Place Density and Moisture Verification Testing	
Testing frequency (Subgrade)	1 test per 5,000 square feet per lift with minimum of 3 tests per lift

Table 12: Pavement Section Requirements

Flexible Pavement Section Requirements	
Flexible Base Materials	2014 TxDOT Item 247, Type A, Grade 1or 2
Maximum Flexible Base Loose Lift Thickness	8 inches
Flexible Base Placement Criteria	Compact to <u>></u> 95% maximum dry density at -2 to +3 percentage points of optimum moisture content (ASTM D 1557)
Hot Mix Asphaltic Concrete (HMAC) Type	TxDOT Item 340, Type D
HMAC Placement Criteria	91% to 95% Theoretical Lab Density (TEX 207 F)
Portland Cement Concrete Section Requirements	
Minimum compressive strength at 28 days	4,000 psi
Desired slump during placement	5 ± 1 inch
Reinforced Steel	#4 @ 18” each way placed D/3 from top of slab
Construction Joint Dowels	• Light duty 5, 6-inch section: 5/8” diameter, 12” long @ 12” on center and lubricated both sides, dowel embedment of 5”. • Medium duty 6, 7 -inch section: 3/4” diameter, 14” long @ 12” on center and lubricated both sides, dowel embedment of 6”. • Heavy duty 8-inch section: 1” diameter, 14” long @ 12” on center and lubricated both sides, dowel embedment of 6”.
Expansion Joints	May be eliminated except at tie-ins with existing concrete and structures
Contraction Joints – transverse and longitudinal	Meet spacing and sawing requirements of ACI 330R (Guide for Design and Construction of Concrete Parking Lots)
Placement	In accordance with ACI 304R (guide for measuring, mixing, transporting, and placing), ACI 305R (hot weather concreting, and ACI 306R (cold weather concreting)

To help reduce degradation of the prepared subgrade, paving preferably should be placed within 14 days. Alternately, the paving section could be slightly overbuilt, so blading performed to remove distressed sections does not reduce the finalfinal thickness.

CONSTRUCTION CRITERIA

Site Preparation

Strip away any topsoil, vegetations and any deleterious debris as needed and dispose outside of the planned building areas. Undercut to the required depth and extent as noted in this report. To avoid the double handling of the soil, the undercut for potential vertical rise mitigation should be performed to the required depth and extent as noted in the main report. Additional excavation may be required to accommodate the required select fill thickness. Additional excavation may also be necessary due to encountering fill, soft, deleterious materials such as buried debris and/or rubble, or undesirable soft and wet subgrade conditions. The site representative of the geotechnical engineer should observe undercutting and proofrolling operations.

After the surface topsoil and clay (if present)materials are removed, proof rolling of the exposed surface with a heavily loaded dump truck should be performed. Any areas which excessively yield or pump under the wheel loading should be undercut to the depth specified by the geotechnical engineer's representative and replaced with compacted select fill to existing grade as specified.

If fill is needed to raise site grade outside of the building pads and flatwork areas, general fill obtained from on-site excavations may be used. Requirements for compacted general fill are outlined in the following table.

Table 13: Site Work (Non Structural/General Fill) Requirements

Non Structural/General Fill Type	On-site material free of roots, debris and other deleterious material with a maximum particle size of 4 inches or less
Maximum Non Structural/General Fill Loose Lift Thickness	9 inches

General Fill should be placed and compacted in accordance with the General Fill requirements in Table 5 in Section I.

At least one density test should be conducted per 2,500 square feet of building pad per lift of prepared fill and subgrade or a minimum of 3 density tests should be taken per lift within the building pad areas.

Drainage

Good positive drainage during and after construction is very important to reduce expansive soil volume changes that can detrimentally affect the performance of the planned development. Proper attention to surface and subsurface drainage details during the design and construction phase of development can aid in preventing many potential soil shrink-swell related problems during and following the completion of the project.

Earthwork and Foundation Acceptance

Exposure to the environment may weaken the soils at the foundation bearing level if the excavation remains open for long periods of time. Therefore, it is recommended that all foundation excavations be extended to final grade and constructed as soon as possible in order to reduce potential damage to the bearing soils. If bearing soils are exposed to severe drying or wetting, the unsuitable soil must be re-conditioned or removed as appropriate and replaced with compacted fill, prior to concreting. The foundation bearing level should be free of loose soil, ponded water or debris and should be observed prior to concreting by the geotechnical engineer or his representative.

Foundation concrete should not be placed on soils that have been disturbed by rainfall or seepage. If the bearing soils are softened by surface water intrusion during exposure or by desiccation, the unsuitable soils must be removed from the foundation excavation and replaced with compacted select fill prior to placement of concrete.

Subgrade preparation and fill placement operations should be monitored by the geotechnical engineer or his representative. As a guideline, at least one in-place density test should be performed for each 5,000 sq. ft. of compacted surface per lift or a minimum of 3 tests per lift. Any areas not meeting the required compaction should be re-compacted and retested until compliance is met.

Trench Excavations

Excavations should comply with OSHA Standard 29CFR, Part 1926, Subpart P and all State of Texas and local requirements. Trenches 20 feet deep or greater require that the protective system be designed by a registered professional engineer. A trench is defined as a narrow excavation in relation to its depth. In general, the depth is greater than the width, but the bottom width of the trench is not greater than 15 feet. Trenches greater than 5 feet in depth require a protective system such as trench shields, trench shoring, or sloping back the excavation side slopes.

The Contractor's "Competent Person" shall perform daily inspections of the trench to verify that the trench is properly constructed, and that surcharge and vibratory loads are not excessive, that excavation spoils are sufficiently away from the edge of the trench, proper ingress and egress into the trench is provided, and all other items are performed as outlined in these OSHA regulations. It is especially important for the inspector to observe the effects of changed weather conditions, surcharge loadings, and cuts into adjacent backfills of existing utilities. The flow of water into the base and sides of the excavation, and the presence of any surface slope cracks, should also be carefully monitored by the Trench Safety Engineer.

Although the geotechnical report provides an indication of soil types to be anticipated, actual soil and groundwater conditions will vary along the trench route. The "Competent Person" must evaluate the soils and groundwater in the trench excavation at the time of construction to verify that proper sloping or shoring measures are performed.

Appendix B to the regulations has sloping and benching requirements for short-term trench exposure for various soil types up to the maximum allowable 20-foot depth requirement.

GENERAL COMMENTS

The scope of this study is to provide geotechnical engineering criteria for use by design engineers in preparing the foundation and pavement designs. Environmental studies of any kind were not a part of our scope of work or services even though we are capable of providing such services.

This report was prepared as an instrument of service for this project exclusively for the use of Sitterle Homes and the project design team. If the development plans change relative to the overall site layout, size, or anticipated loads, or if different subsurface conditions are encountered, we should be informed and retained to ascertain the impact of these changes on our recommendations. We cannot be responsible for the potential impact of these changes if we are not informed.

Geotechnical Design Review

Arias should be given the opportunity to review the design and construction documents. The purpose of this review is to check to see if our geotechnical recommendations are properly interpreted into the project plans and specifications. Please note that design review was not included in the authorized scope and additional fees may apply.

Subsurface Variations

Soil and groundwater conditions may vary between the sample boring locations. Transition boundaries or contacts, noted on the boring logs to separate soil types, are approximate. Actual contacts may be gradual and vary at different locations. The Contractor should verify that similar conditions exist throughout the proposed area of excavation. If different subsurface conditions or highly variable subsurface conditions are encountered during construction, we should be contacted to evaluate the significance of the changed conditions relative to our recommendations.

Quality Assurance Testing

The long-term success of the project will be affected by the quality of materials used for construction and the adherence of the construction to the project plans and specifications. As Geotechnical Engineer of Record (GER), we should be engaged by the Owner to provide Quality Assurance (QA) testing. Our services will be to evaluate the degree to which constructors are achieving the specified conditions they’re contractually obligated to achieve and observe that the encountered materials during earthwork for foundation and pavement installation are consistent with those encountered during this study. In the event that Arias is not retained to provide QA testing, we should be immediately contacted if differing subsurface conditions are encountered during construction. Differing materials may require modification to the recommendations that we provided herein. A message to the Owner with regard to the project QA is provided in the ASFE publication included in Appendix E.

Arias has an established in-house laboratory that meets the standards of the American Standard Testing Materials (ASTM) specifications of ASTM E-329 defining requirements for Inspection and Testing Agencies for soil, concrete, steel and bituminous materials as used in construction. We maintain soils, concrete, asphalt, and aggregate testing equipment to provide the testing needs required by the project specifications. All of our equipment is calibrated by an independent testing agency in accordance with the National Bureau of Standards. In addition, Arias is accredited by the American Association of State Highway & Transportation Officials (AASHTO), the United States Army Corps of Engineers (USACE) and the Texas Department of Transportation (TxDOT), and also maintains AASHTO Materials Reference Laboratory (AMRL) and Cement and Concrete Reference Laboratory (CCRL) proficiency sampling, assessments and inspections.

Furthermore, Arias employs a technical staff certified through the following agencies: the National Institute for Certification in Engineering Technologies (NICET), the American Concrete Institute (ACI), the American Welding Society (AWS), the Precast/Prestressed Concrete Institute (PCI), the Mine & Safety Health Administration (MSHA), the Texas Asphalt Pavement Association (TXAPA), and the Texas Board of Professional Engineers (TBPE). Our services are conducted under the guidance and direction of a Professional Engineer (P.E.) licensed to work in the State of Texas, as required by law.

Standard of Care

Subject to the limitations inherent in the agreed scope of services as to the degree of care and amount of time and expenses to be incurred, and subject to any other limitations contained in the agreement for this work, Arias has performed its services consistent with that level of care and skill ordinarily exercised by other professional engineers practicing in the same locale and under similar circumstances at the time the services were performed. Information about this geotechnical report is provided in the GBA publication included in Appendix D.

APPENDIX A: FIGURES AND PHOTOGRAPHS

Photo 1 – View looking at site location of boring B-3

Photo 2 – View looking at site location of boring B-5

ARIAS
142 Chula Vista, San Antonio, Texas 78232
Phone: (210) 308-5884 • Fax: (210) 308-5886

SITE PHOTOS

Market Ridge Phase 4
San Antonio, Texas

Date: August 21, 2023	Job No.: 2023-458
Drawn By: MEB	Checked By: JRM
Approved By: MJO	Scale: N.T.S.

Appendix A

Photo 1 – View looking at site location of boring B-2

Photo 2 – View looking at site location of boring B-10

ARIAS

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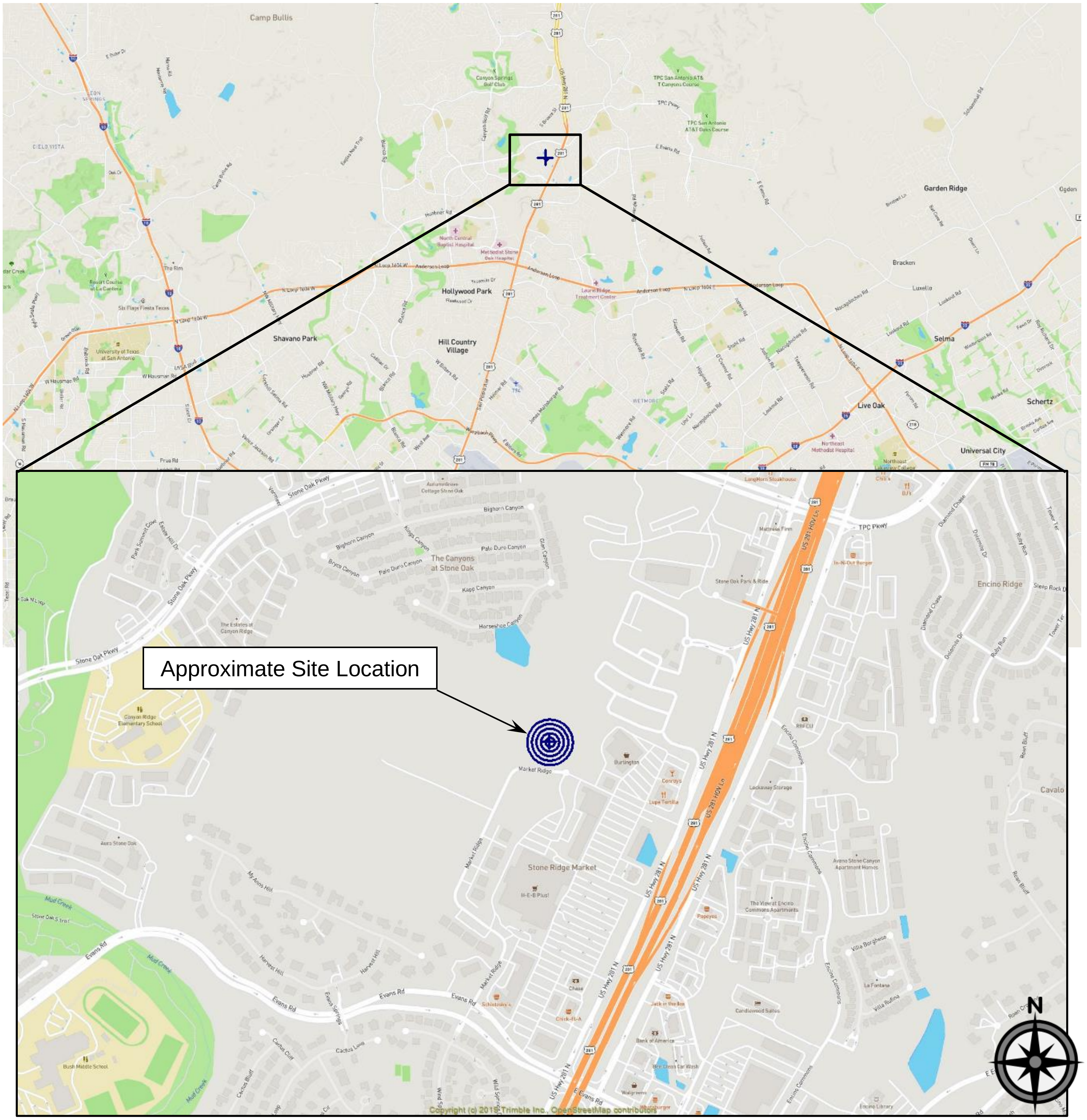
SITE PHOTOS

Market Ridge Phase 4
San Antonio, Texas

Date: August 21, 2023	Job No.: 2023-458
Drawn By: MEB	Checked By: JRM
Approved By: MJO	Scale: N.T.S.

Appendix A



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VICINITY MAP

Market Ridge Phase 4
San Antonio, Texas

Date: August 21, 2023	Job No.: 2023-458
Drawn By: MEB	Checked By: JRM
Approved By: MJO	Scale: N.T.S.

Figure 1

ARIAS
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BORING LOCATION PLAN

Market Ridge Phase 4
San Antonio, Texas

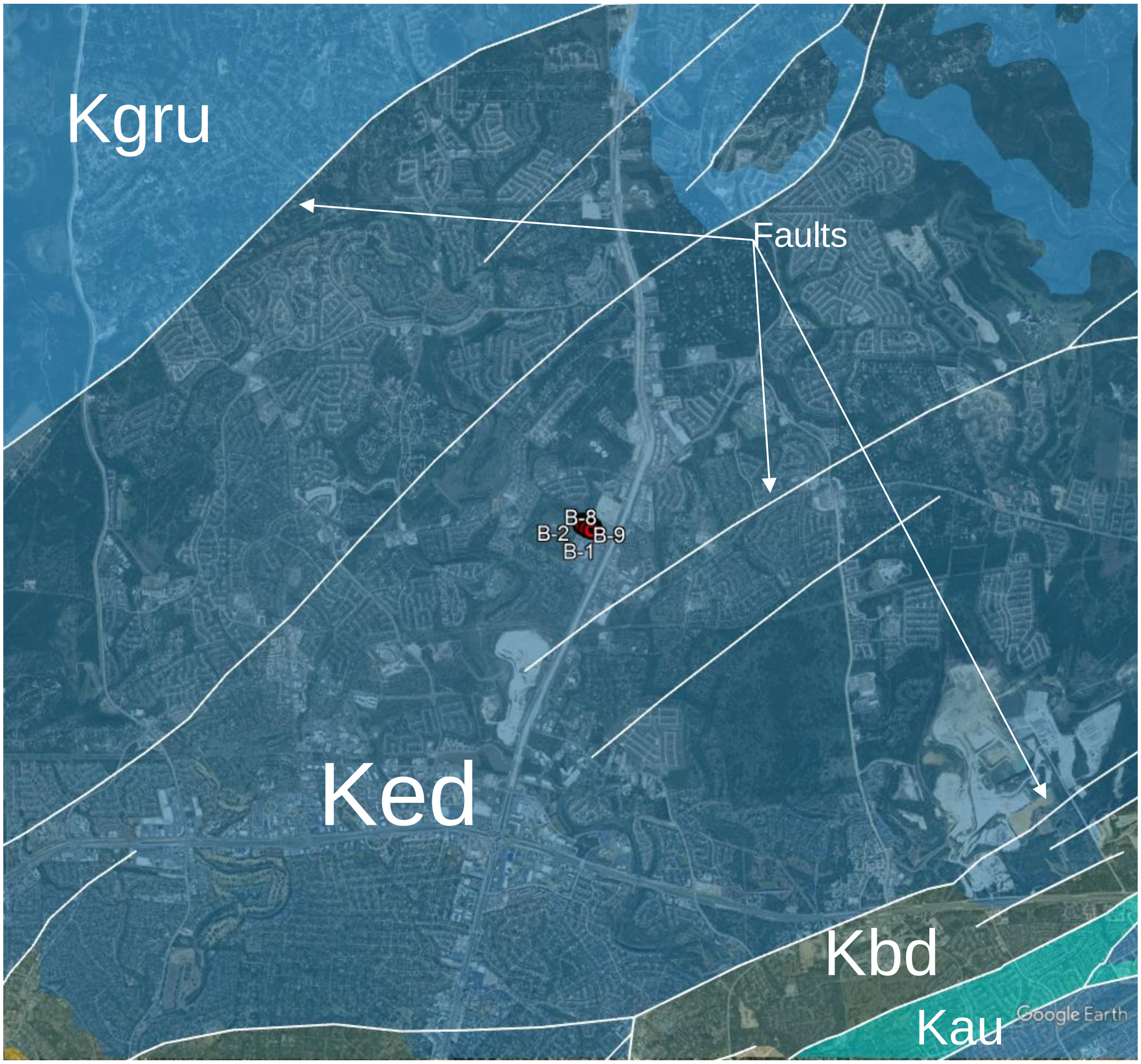
Date: August 21, 2023	Job No.: 2023-458
Drawn By: MEB	Checked By: JRM
Approved By: MJO	Scale: N.T.S.

REVISIONS:

No.:	Date:	Description:

Figure 2

1 of 1



LEGEND

Symbol	Name	Age
Ked	Edwards Limestone Undivided	Cretaceous Period / Early
Kgru	Glen Rose Formation (Upper)	Cretaceous Period / Early
Kbd	Buda Limestone & Del Rio Clay undivided	Cretaceous Period / Late
Kau	Austin Chalk	Cretaceous Period / Late

N

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GEOLOGIC MAP

Market Ridge Phase 4
San Antonio, Texas

Date: August 21, 2023	Job No.: 2023-458
Drawn By: MEB	Checked By: JRM
Approved By: MJO	Scale: N.T.S.

Figure 3

APPENDIX B: BORING LOGS AND KEY TO SYMBOLS

Boring Log No. B-01

Project:	Market Ridge Phase 4 San Antonio, Texas	Sampling Date: 7/30/23
Location: See Boring Location Plan		Coordinates: N29°38'37.88" W98°27'24.7" Backfill: Cuttings/bentonite

Soil Description	Depth (ft)	SN	WC	N	-200
Weathered LIMESTONE, very hard, light tan	0	SS	2	50/3"	21
	2	SS	1	**50/1"	
	4	SS	1	**50/1"	
	6	SS	1	**50/1"	
	8	SS	0	**50/0"	
	10				

Borehole terminated at 10 feet

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: R. Arizola
Driller: Blue Hole Drilling
Equipment: Truck-mounted drill rig

Air rotary: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
N = SPT Blow Count
** = Blow Counts During Seating Penetration
-200 = % Passing #200 Sieve

Boring Log No. B-02

Project:	**Market Ridge Phase 4 San Antonio, Texas**	Sampling Date: 7/30/23	
		Coordinates:	N29°38'37.5" W98°27'24.86"
Location: See Boring Location Plan		Backfill:	Cuttings/bentonite

Soil Description	Depth (ft)	SN	WC	N	-200
Weathered LIMESTONE, very hard, light tan - with trace of brown top soil from 0'-2'	0	SS	1	50/2"	
	2	SS	1	**50/0"	
	4	SS	1	**50/1"	8
	6	SS	0	**50/1"	
	8	SS	0	**50/1"	
	10				

Borehole terminated at 10 feet

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: R. Arizola
Driller: Blue Hole Drilling
Equipment: Truck-mounted drill rig

Air rotary: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
N = SPT Blow Count
** = Blow Counts During Seating Penetration
-200 = % Passing #200 Sieve

Boring Log No. B-03

Project: **Market Ridge Phase 4**
San Antonio, Texas

Sampling Date: 8/9/23

Coordinates: N29°38'38.78" W98°27'27.14"

Location: See Boring Location Plan

Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	N
Weathered LIMESTONE, very hard, gray to light tan		SS	0	50/3"
	2	SS	0	**50/1"
	4	SS	0	**50/1"
	6			
Borehole terminated at 6 feet				

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Single flight auger: 0 - 6 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
N = SPT Blow Count
** = Blow Counts During Seating Penetration

GINT.GPJ 8/31/23 (BORING LOG SA13-02,ARIASSA13-02.GDT,ARIAS-ARWA LIBRARY.GLB)

Arias and Associates, Inc.

Job No.: 2023-458

Boring Log No. B-04

Project: **Market Ridge Phase 4** **San Antonio, Texas**	Sampling Date: 8/9/23
	Coordinates: N29°38'39.04" W98°27'26.25"
Location: See Boring Location Plan	Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	N
Weathered LIMESTONE, very hard, gray to light tan	0	SS	1	**50/2"
	2	SS	1	**50/2"
	4	SS	1	**50/1"
	6			
Borehole terminated at 6 feet				

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Single flight auger: 0 - 6 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
N = SPT Blow Count
** = Blow Counts During Seating Penetration

Boring Log No. B-05

Project:	**Market Ridge Phase 4** **San Antonio, Texas**	Sampling Date: 8/9/23	
		Coordinates:	N29°38'10.17" W98°27'26.96"
Location: See Boring Location Plan		Backfill:	Cuttings

Soil Description	Depth (ft)	SN	WC	PL	LL	PI	N
Weathered LIMESTONE, very hard, light brown to white - with trace of topsoil from 0'-2'	0	SS	4	21	26	5	**50/3"
	2	SS	0				**50/2"
	4	SS	0				**50/1"
	6						

Borehole terminated at 6 feet

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Single flight auger: 0 - 6 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
PL = Plastic Limit
LL = Liquid Limit
PI = Plasticity Index
N = SPT Blow Count

** = Blow Counts During Seating Penetration

Boring Log No. B-06

Project: **Market Ridge Phase 4** **San Antonio, Texas**	Sampling Date: 8/9/23
	Coordinates: N29°38'39.58" W98°27'25.94"
Location: See Boring Location Plan	Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	PL	LL	PI	N
Weathered LIMESTONE, very hard, light tan - with trace of topsoil from 0'-2'	0	SS	1				**50/3"
	2	SS	0				**50/2"
	4	SS	1	15	18	3	**50/1"
	6	SS	1				**50/1"
	8	SS	1				**50/1"
	10						

Borehole terminated at 10 feet

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Single flight auger: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
PL = Plastic Limit
LL = Liquid Limit
PI = Plasticity Index
N = SPT Blow Count

** = Blow Counts During Seating Penetration

Boring Log No. B-07

Project: **Market Ridge Phase 4**
San Antonio, Texas

Sampling Date: 8/9/23

Coordinates: N29°38'38.26" W98°27'22.18"

Location: See Boring Location Plan

Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	PL	LL	PI	N	-200
Weathered LIMESTONE, hard to very hard, light brown to gray and tan - with trace of clay from 0'-4'		SS	1	16	33	17	59	
	2	SS	2	16	29	13	49	
	4	SS	2				**50/6"	
	6	SS	5				**50/2"	28
	8	SS	5				**50/2"	
	10							

Borehole terminated at 10 feet

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Single flight auger: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
PL = Plastic Limit
LL = Liquid Limit
PI = Plasticity Index
N = SPT Blow Count

** = Blow Counts During Seating Penetration
-200 = % Passing #200 Sieve

GINT.GPJ 8/31/23 (BORING LOG SA13-02,ARIASSA13-02.GDT,ARIAS-ARWA LIBRARY.GLB)

Boring Log No. B-08

Project: **Market Ridge Phase 4**
San Antonio, Texas

Sampling Date: 8/9/23

Coordinates: N29°38'38.71" W98°27'24.09"

Location: See Boring Location Plan

Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	PL	LL	PI	N	-200
Weathered LIMESTONE, very hard, light tan, with trace of brown clayey top soil	0	SS	2				50/2"	25
LIMESTONE, very hard, light tan	2	SS	1				**50/1"	
	4	SS	1				**50/2"	
	6	SS	1				**50/1"	
	8	SS	0	15	18	3	**50/0"	
	10							

Borehole terminated at 10 feet

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Single flight auger: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
PL = Plastic Limit
LL = Liquid Limit
PI = Plasticity Index
N = SPT Blow Count

** = Blow Counts During Seating Penetration
-200 = % Passing #200 Sieve

GINT.GPJ 8/31/23 (BORING LOG SA13-02,ARIASSA13-02.GDT,ARIAS-ARWA LIBRARY.GLB)

Boring Log No. B-09

Project: **Market Ridge Phase 4**
San Antonio, Texas

Sampling Date: 8/9/23

Coordinates: N29°38'36.82" W98°27'22.86"

Location: See Boring Location Plan

Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	PL	LL	PI	N	-200
Weathered LIMESTONE, very stiff to very hard, brown to light brown - with trace of topsoil from 0'-2'		SS	2				24	
	2	SS	2				30	
- with clay	4	SS	4				33	32
	6	SS	3	15	20	5	**50/3"	
	8	SS	2				**50/1"	
	10							
Borehole terminated at 10 feet								

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Air rotary: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
PL = Plastic Limit
LL = Liquid Limit
PI = Plasticity Index
N = SPT Blow Count

** = Blow Counts During Seating Penetration
-200 = % Passing #200 Sieve

Boring Log No. B-10

Project: **Market Ridge Phase 4**
San Antonio, Texas

Sampling Date: 8/9/23

Coordinates: N29°38'37.2" W98°27'21.93"

Location: See Boring Location Plan

Backfill: Cuttings

Soil Description	Depth (ft)	SN	WC	N	-200
Weathered LIMESTONE, very hard, light brown, with trace of clay		SS	2	39	
	2	SS	2	**50/5"	
LIMESTONE, very hard, brown and tan	4	SS	1	**50/2"	
	6	SS	5	**50/2"	
		SS		**50/1"	
	8		5		27
	10				
Borehole terminated at 10 feet					

Groundwater Data:
During drilling: Not encountered

Field Drilling Data:
Coordinates: Hand-held GPS Unit
Logged By: L. Arizola
Driller: CoreCo USA
Equipment: Truck-mounted drill rig

Air rotary: 0 - 10 ft

Nomenclature Used on Boring Log

Split Spoon (SS)

WC = Water Content (%)
N = SPT Blow Count
** = Blow Counts During Seating Penetration
-200 = % Passing #200 Sieve

GINT.GPJ 8/31/23 (BORING LOG SA13-02,ARIASSA13-02.GDT,ARIAS-ARWA LIBRARY.GLB)

Arias and Associates, Inc.

Job No.: 2023-458

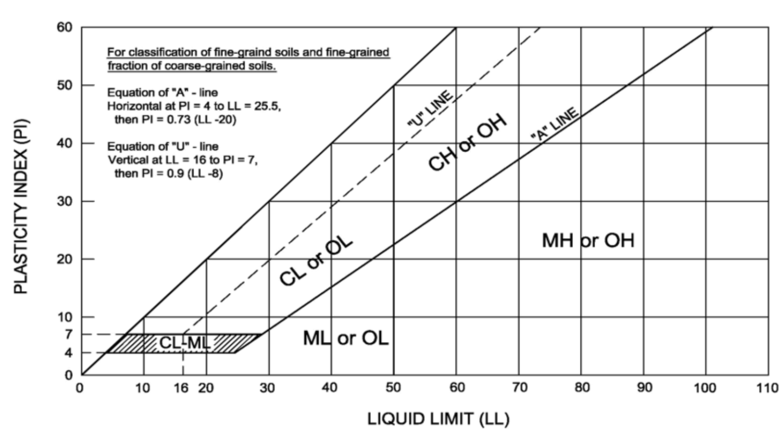
KEY TO TERMS AND SYMBOLS USED ON BORING LOGS

MAJOR DIVISIONS					GROUP SYMBOLS	DESCRIPTIONS
COARSE-GRAINED SOILS	More than half of material LARGER than No. 200 Sieve size	GRAVELS	More than Half of Coarse fraction is LARGER than No. 4 Sieve size	Clean Gravels (little or no Fines)	GW	Well-Graded Gravels, Gravel-Sand Mixtures, Little or no Fines
					GP	Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or no Fines
				Gravels with Fines (Appreciable amount of Fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
					GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
		SANDS	More than half of Coarse fraction is SMALLER than No. 4 Sieve size	Clean Sands (little or no Fines)	SW	Well-Graded Sands, Gravelly Sands, Little or no Fines
					SP	Poorly-Graded Sands, Gravelly Sands, Little or no Fines
				Sands with Fines (Appreciable amount of Fines)	SM	Silty Sands, Sand-Silt Mixtures
					SC	Clayey Sands, Sand-Clay Mixtures
FINE-GRAINED SOILS	More than half of material SMALLER than No. 200 Sieve size	SILTS & CLAYS		Liquid Limit less than 50	ML	Inorganic Silts & Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity
					CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
		SILTS & CLAYS		Liquid Limit greater than 50	MH	Inorganic Silts, Micaceous or Diatomaceous Fine Sand or Silty Soils, Elastic Silts
					CH	Inorganic Clays of High Plasticity, Fat Clays
FORMATIONAL MATERIALS		SANDSTONE				Massive Sandstones, Sandstones with Gravel Clasts
		MARLSTONE				Indurated Argillaceous Limestones
		LIMESTONE				Massive or Weakly Bedded Limestones
		CLAYSTONE				Mudstone or Massive Claystones
		CHALK				Massive or Poorly Bedded Chalk Deposits
		MARINE CLAYS				Cretaceous Clay Deposits
		GROUNDWATER			▼	Indicates Final Observed Groundwater Level
					▽	Indicates Initial Observed Groundwater Location

Density of Granular Soils	
Number of Blows per ft., N	Relative Density
0 - 4	Very Loose
4 - 10	Loose
10 - 30	Medium
30 - 50	Dense
Over 50	Very Dense

Consistency and Strength of Cohesive Soils		
Number of Blows per ft., N	Consistency	Unconfined Compressive Strength, q_u (tsf)
Below 2	Very Soft	Less than 0.25
2 - 4	Soft	0.25 - 0.5
4 - 8	Medium (Firm)	0.5 - 1.0
8 - 15	Stiff	1.0 - 2.0
15 - 30	Very Stiff	2.0 - 4.0
Over 30	Hard	Over 4.0

PLASTICITY CHART (ASTM D 2487-11)



KEY TO TERMS AND SYMBOLS USED ON BORING LOGS

TABLE 1 Soil Classification Chart (ASTM D 2487-11)

Criteria of Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	Gravels (More than 50% of coarse fraction retained on No. 4 sieve)	Clean Gravels (Less than 5% fines[C])	Cu ≥ 4 and 1 ≤ Cc ≤ 3[D]	GW	Well-Graded Gravel[E]
			Cu < 4 and/or [Cc < 1 or Cc > 3][D]	GP	Poorly-Graded Gravel[E]
		Gravels with Fines (More than 12% fines[C])	Fines classify as ML or MH	GM	Silty Gravel[E,F,G]
			Fines classify as CL or CH	GC	Clayey Gravel[E,F,G]
	Sands (50% or more of coarse fraction passes No. 4 sieve)	Clean Sands (Less than 5% fines[H])	Cu ≥ 6 and 1 ≤ Cc ≤ 3[D]	SW	Well-Graded Sand[I]
			Cu < 6 and/or [Cc < 1 or Cc > 3][D]	SP	Poorly-Graded Sand[I]
		Sands with Fines (More than 12% fines[H])	Fines classify as ML or MH	SM	Silty Sand[F,G,I]
			Fines classify as CL or CH	SC	Clayey Sand[F,G,I]
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean Clay[K,L,M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	Liquid limit - oven dried / Liquid limit - not dried <0.75	OL	Organic Clay[K,L,M,N] / Organi Silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat Clay[K,L,M]
			PI plots on or below "A" line	MH	Elastic Silt[K,L,M]
		organic	Liquid limit - oven dried / Liquid limit - not dried <0.75	OH	Organic Clay[K,L,M,P] / Organic Silt[K,L,M,Q]
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75mm) sieve
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name
[C] Gravels with 5% to 12% fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly-graded gravel with silt
GP-GC poorly-graded gravel with clay
[D] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$
[E] If soil contains ≥ 15% sand, add "with sand" to group name
[F] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM
[G] If fines are organic, add "with organic fines" to group name
[H] Sand with 5% to 12% fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly-graded sand with silt
SP-SC poorly-graded sand with clay
[I] If soil contains ≥ 15% gravel, add "with gravel" to group name
[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay
[K] If soil contains 15% to < 30% plus No. 200, add "with sand" or "with gravel," whichever is predominant
[L] If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name
[N] PI ≥ 4 and plots on or above "A" line
[O] PI < 4 or plots below "A" line
[P] PI plots on or above "A" line
[Q] PI plots below "A" line

TERMINOLOGY

Boulders	Over 12-inches (300mm)
Cobbles	12-inches to 3-inches (300mm to 75mm)
Gravel	3-inches to No. 4 sieve (75mm to 4.75mm)
Sand	No. 4 sieve to No. 200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing No. 200 sieve (0.075mm)
Calcareous	Containing appreciable quantities of calcium carbonate, generally nodular

Parting	Inclusion < 1/8-inch thick extending through samples
Seam	Inclusion 1/8-inch to 3-inches thick extending through sample
Layer	Inclusion > 3-inches thick extending through sample

Stratified	Alternating layers of varying material or color with layers at least 6mm thick
Laminated	Alternating layers of varying material or color with the layers less than 6mm thick
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Homogeneous	Same color and appearance throughout

KEY TO TERMS AND SYMBOLS USED ON BORING LOGS

Hardness Classification of Intact Rock

Class	Hardness	Field Test		Approximate Range of Uniaxial Compression Strength kg/cm² (tons/ft²)
I	Extremely hard	Many blows with geologic hammer required to break intact specimen.		> 2,000
II	Very hard	Hand held specimen breaks with hammer end of pick under more than one blow.		2,000 – 1,000
III	Hard	Cannot be scraped or pealed with knife, hand held specimen can be broken with single moderate blow with pick.		1,000 – 500
IV	Soft	Can just be scraped or peeled with knife. Indentations 1mm to 3mm show in specimen with moderate blow with pick.		500 – 250
V	Very soft	Material crumbles under moderate blow with sharp end of pick and can be peeled with a knife, but is too hard to hand-trim for triaxial test specimen.		250 – 10

Rock Weathering Classifications

Grade	Symbol	Diagnostic Features
Fresh	F	No visible sign of Decomposition or discoloration. Rings under hammer impact.
Slightly Weathered	WS	Slight discoloration inwards from open fractures, otherwise similar to F.
Moderately Weathered	WM	Discoloration throughout. Weaker minerals such as feldspar decomposed. Strength somewhat less than fresh rock, but cores cannot be broken by hand or scraped by knife. Texture preserved.
Highly Weathered	WH	Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becoming indistinct, but fabric preserved.
Completely Weathered	WC	Minerals decomposed to soil, but fabric and structure preserved (Saprolite). Specimens easily crumbled or penetrated.
Residual Soil	RS	Advanced state of decomposition resulting in plastic soils. Rock fabric and structure completely destroyed. Large volume change.

Rock Discontinuity Spacing

Description for Structural Features: Bedding, Foliation, or Flow Banding	Spacing	Description for Joints, Faults or Other Fractures
Very thickly (bedded, foliated, or banded)	More than 6 feet	Very widely (fractured or jointed)
Thickly	2 – 6 feet	Widely
Medium	8 – 24 inches	Medium
Thinly	2½ – 8 inches	Closely
Very thinly	¾ – 2½ inches	Very closely
Description for Micro-Structural Features: Lamination, Foliation, or Cleavage	**Spacing**	**Descriptions for Joints, Faults, or Other Fractures**
Intensely (laminated, foliated, or cleaved)	¼ – ¾ inch	Extremely close
Very intensely	Less than ¼ inch	

Engineering Classification for in Situ Rock Quality

RQD %	Velocity Index	Rock Mass Quality
90 – 100	0.80 – 1.00	Excellent
75 – 90	0.60 – 0.80	Good
50 – 75	0.40 – 0.60	Fair
25 – 50	0.20 – 0.40	Poor
0 – 25	0 – 0.20	Very Poor

APPENDIX C: LABORATORY AND FIELD TEST PROCEDURES

FIELD AND LABORATORY EXPLORATION

The field exploration program included drilling at selected locations within the site and intermittently sampling of the encountered materials. The boreholes were drilled using a single flight auger (ASTM D 1452). Samples of encountered materials were obtained using a split-barrel sampler while performing the Standard Penetration Test (ASTM D 1586) or by taking material from the auger as it was advanced (ASTM D 1452). The sample depth interval and type of sampler used is included on the soil borings logs. Arias' field representative visually logged each recovered sample and placed a portion of the recovered sampled into a plastic bag for transport to our laboratory.

SPT N values and blow counts for those intervals where the sampler could not be advanced for the required 18-inch penetration are shown on the soil borings logs. If the test was terminated during the 6-inch seating interval or after 10 hammer blows were applied used and no advancement of the sampler was noted, the logs denotes this condition as blow count during seating penetration.

Arias performed soil mechanics laboratory tests on selected samples to aid in soil classification and to determine engineering properties. Tests commonly used in geotechnical exploration, the method used to perform the test, and the column designations on the borings logs where data are reported are summarized as follows:

Test Name	Test Method	Logs Designation
Water (moisture) content of soil and rock by mass	ASTM D 2216	WC
Liquid limit, plastic limit, and plasticity index of soils	ASTM D 4318	PL, LL, PI
Amount of material in soils finer than the No. 200 sieve	ASTM D 1140	-200

The laboratory results are reported on the soil borings logs.

APPENDIX D: GBA INFORMATION – GEOTECHNICAL REPORT

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.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, clients can benefit from a lowered exposure to the subsurface problems that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed below, contact your GBA-member geotechnical engineer. Active involvement in 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.

Geotechnical-Engineering 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 given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. *Those who rely on a geotechnical-engineering report prepared for a different client can be seriously misled.* No one except authorized client representatives 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 this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read it *in its entirety*. Do not rely on an executive summary. Do not read selected elements only. *Read this report in full.*

You Need to Inform Your Geotechnical Engineer about Change

Your geotechnical engineer considered unique, project-specific factors when designing the study behind this report and developing the confirmation-dependent recommendations the report conveys. A few typical factors include:

- the client's goals, objectives, budget, schedule, and risk-management preferences;
- the general nature of the structure involved, its size, configuration, and performance criteria;
- the structure's location and orientation on the site; and
- other planned or existing site improvements, such as retaining walls, access roads, parking lots, and underground utilities.

Typical changes that could erode the reliability of this report include those that affect:

- the site's size or shape;
- 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. *The geotechnical engineer who prepared this report cannot accept responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

This Report May Not Be Reliable

Do not rely on this report if your geotechnical engineer prepared it:

- for a different client;
- for a different project;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, that it could be unwise to rely on a geotechnical-engineering report whose reliability may have been affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If your geotechnical engineer has not indicated an "apply-by" date on the report, ask what it should be*, and, in general, *if you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying it. A minor amount of additional testing or analysis – if any is required at all – could prevent major problems.

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface through various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing were performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgment to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team from project start to project finish, so the individual can provide informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, *they are not final*, because the geotechnical engineer who developed them relied heavily on judgment and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* revealed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation*.

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a full-time member of the design team, to:

- confer with other design-team members,
- help develop specifications,
- review pertinent elements of other design professionals' plans and specifications, and
- be on hand quickly whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction observation.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for informational purposes only*. To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report, but they may rely on the factual data relative to the specific times, locations, and depths/elevations referenced. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include 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.

Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering 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 subsurface environmental problems have led to project failures*. If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. As a general rule, *do not rely on an environmental report prepared for a different client, site, or project, or that is more than six months old.*

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, none of the engineer's services were designed, conducted, or intended to prevent uncontrolled migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will not of itself be sufficient to prevent moisture infiltration.*** Confront the risk of moisture infiltration by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are not building-envelope or mold specialists.***

GEOPROFESSIONAL BUSINESS ASSOCIATION

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e-mail: info@geoprofessional.org www.geoprofessional.org

APPENDIX E: PROJECT QUALITY ASSURANCE

A Message to Owners from ASFE/GBA

Construction-materials engineering and testing (CoMET) consultants perform quality-assurance (QA) services to evaluate how well constructors are achieving the specified conditions they're contractually obligated to achieve. Done right, QA can save you time and money while helping you manage project risks by detecting molehills before they grow into mountains you and the design team are forced to climb.

Done right, QA can save you time and money; prevent claims and disputes; and reduce risks. Many owners don't do QA right because they follow bad advice.

It's ironic that, as important as CoMET consultants can be, some owners and design professionals treat them as though they were commodities. Often referred to incorrectly as "testing labs," CoMET consultants create the last line of defense against costly construction errors and the delays, change orders, claims, disputes, and litigation that can result. Why would owners entrust such an important responsibility to the firm offering to fulfill it for the lowest fee as opposed to the one whose qualifications enable it to offer the best service and the most value? The answer: Too many owners follow bad advice; e.g., "CoMET consultants are all the same. They all follow the same standards. They all have accredited laboratories and certified personnel. Go with the low bidder." That's bad advice because there's no such thing as a standard QA scope of service, meaning that – to bid – each interested firm *must* develop its own scope…and it has to be a cheap scope in order to offer the low fee the owner apparently prefers. A cheap scope cannot help but jeopardize service quality, aggravating risk for you and the entire project team. Of course, some firms will offer what seems to be a better scope at a "low-ball," less-than-cost bid in order to win the commission and then earn a profit through multiple change orders.

You have too much at stake to follow bad advice. Consider these facts.

Fact: ***Most CoMET firms are not accredited,*** including some that say they are and some that don't even follow the correct standards, even when they say they do. And the quality of those that are accredited varies significantly; some practice at a high level; others just barely scrape by. As such, while accreditation is extremely important, it is far from being a "be-all and end-all." It signifies only that a firm's facilities or operations met the *minimum criteria* of an accrediting body whose concerns in some cases may have little to do with your project. And the condition of what an accrediting body typically evaluates – management systems, technical staff, facilities, and equipment – can change substantially between on-site accreditation assessments.

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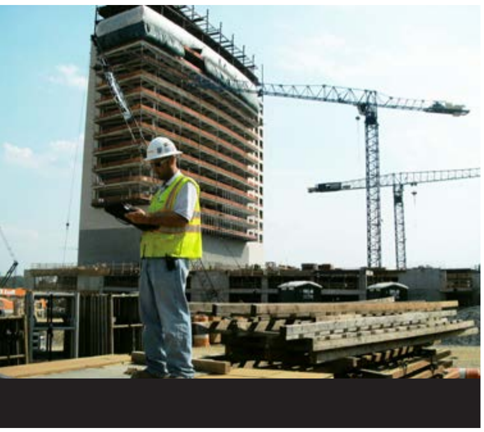

Fact: ***It's dangerous to assume CoMET personnel are certified.*** Many have no credentials; some are certified by organizations of questionable merit, while others have a valid certification, but *not* for the services they're assigned. All too many have little training or none at all.

Some CoMET firms – the "low-cost providers" – *want* you to believe that price is the only difference between QA providers. It's not: Firms that sell low price typically lack:

- facilities appropriate for many of the projects they accept,
- equipment that is well maintained and properly calibrated,
- field and laboratory personnel who are well trained and appreciate the importance of their responsibilities,
- management with the education, experience, and judgment to provide technical oversight, and
- the professional-liability insurance you should require to enjoy peace of mind.

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To derive maximum value from your QA investment, have the CoMET firm's project manager serve actively on the project team from beginning to end, a level of service that's relatively inexpensive and can pay huge dividends. During the project's planning and design stages, experienced CoMET professionals can help the design team develop consistent, cost-effective technical specifications and establish appropriate observation, testing, and instrumentation protocols. They can analyze plans and specs much as constructors do, looking for the little errors, omissions, conflicts, and ambiguities that often lead to the misunderstandings and confusion that become the basis for big extras and big claims. They can also provide guidance about operations and materials that need closer review than others, because of their criticality or potential for error or abuse, and even suggest reduced levels of review or testing for areas of a less critical nature, based on local experience. You can also benefit from a CoMET professional's frank assessments of the various constructors that have expressed interest in the project.

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CoMET consultants' construction-phase QA services focus on two distinct issues:

- those that relate to geotechnical engineering and
- those that relate to the other elements of construction.

Geotechnical-engineering issues are critically important because they are essential to the "observational method" geotechnical engineers use to help their clients save time and money while maintaining a "healthy respect" for the unknown in the underground.

In essence, the observational method is an overall approach that begins during the earliest element of the design phase and carries through to the construction phase. Geotechnical engineers initiate this approach by applying their knowledge of local geological conditions to develop an economical subsurface-sampling plan. Proper execution of the plan should derive just enough samples from just enough areas to permit an experienced geotechnical engineer to develop an assumed-subsurface profile. Because so much depends on the reliability of each sample, quality-focused geotechnical engineers often insist that their own personnel perform or oversee the sampling process, from obtaining the samples to packaging, storing, and transporting them to a trusted laboratory, using their own equipment and facilities or relying on others' they know they can trust.

Combining the assumed subsurface profile with knowledge of what is being constructed – e.g., its dimensions, weight, anticipated use, and performance objectives – geotechnical engineers develop *provisional* recommendations for the structure's foundations and for the specifications of various "geo" elements, like excavations, site grading, foundation-bearing grades, and roadway and parking-lot preparation and surfacing. When geotechnical engineers know that their personnel will be on site observing subsurface conditions as they are exposed, they usually will recommend the most cost-effective design their assumptions make practical, knowing that – if their assumed-subsurface profile is "off" in any significant way – the variances will be caught (that's what they teach their field personnel to do), permitting them to "tweak" their recommendations in the field. *It is essential to realize that geotechnical engineers cannot finalize their recommendations until they or their field representatives are on site to observe what's excavated to verify that the subsurface conditions the engineers predicted are those that actually exist.*

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Insofar as **other elements of construction** are concerned, many geotechnical-engineering firms have obliged their clients by expanding their field-services mix, so they're able to perform overall construction QA, encompassing – in addition to geotechnical issues – reinforced concrete, structural steel, structural masonry, fireproofing, and so on. Unfortunately, that's caused some confusion. Believing that all CoMET consultants are alike, some owners take bids for the overall CoMET package, including the geotechnical field observation, thus curtailing services of the geotechnical engineer of record (GER). ***Entrusting geotechnical field observation to someone other than the GER creates a significant risk.***

GERs have developed a variety of protocols to optimize the quality of their field-observation procedures. Quality-focused GERs meet with their field representatives before the representatives leave for a project site, to brief them on what to look for and where, when, and how to look. (***No one can duplicate this briefing***, because no one else knows as much about a project's geotechnical issues.) And once they arrive at a project site, the field representatives know to maintain timely, effective communication with the GER, because that's what the GER has trained them to do. By contrast, it's extremely rare for a different

firm's field personnel to contact the GER, even when they're concerned or confused about what they observe, because they regard the GER's firm as "the competition." Convoluted project-communications protocols can make this communications breakdown even worse.

A different firm is often willing to perform on-site geotechnical review for less money than the GER, frequently because it treats geotechnical field services as a "loss leader" in order to obtain the far larger, overall CoMET commission. Given the significant risk that supplanting the GER creates, accepting the offer is almost always penny-wise and pound-foolish. Still, because some owners accept bad advice, it's commonly done, helping to explain why ***"geo" issues are the number-one source of construction-industry claims and disputes.***

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To derive the biggest bang for the QA buck, identify three or even four quality-focused CoMET consultants. (If you don't know any, use the "Find a Geoprofessional" service available free at www.asfe.org.) Ask about the firms' ongoing and recent projects and the clients and client representatives involved; *insist upon receiving verification of all claimed accreditations, certifications, licenses, and insurance coverages.*

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Once you identify the two or three most qualified firms, meet with their key personnel, preferably at their own facility, so you can inspect their laboratory, speak with management and technical staff, and form an opinion about the firm's capabilities and attitude.

Insist that each firm's designated project manager and lead field representative participate in the meeting. You will benefit when those individuals are seasoned QA professionals familiar with construction's rough-and-tumble. Ask about others the firm will assign, too. There's no substitute for experienced, certified personnel who are familiar with the codes and standards involved and know how to:

- read and interpret plans and specifications;
- perform the necessary observation, inspection, and testing;
- document their observations and findings;
- interact with constructors' personnel; and
- respond to the unexpected.

Important: Many of the services CoMET QA field representatives perform – like observing operations and outcomes – require the good judgment afforded by extensive training and experience. Who will be on hand when the unexpected occurs: a 15-year "veteran" or a rookie?

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Also consider the tools CoMET personnel use. Some firms are fanatical about proper maintenance and calibration; others, less so. Ask to see the firm's calibration records. If the firm doesn't have any, or if they are not current, be cautious: *You cannot trust test results derived using equipment that may be out of calibration.* Also ask if the firm's laboratory participates in

proficiency testing, relying on a program like the one sponsored by the American Association of State Highway and Transportation Officials (AASHTO). And be sure to ask a firm's representatives about their reporting practices, including report distribution and timeliness, how they handle notifications of nonconformance, and how they resolve complaints.

Once you identify your preferred firm, meet with its representatives again. Provide the approved plans and specifications and other pertinent materials, like a construction schedule, and discuss what's needed to finalize a scope of service that reflects what will be happening on site and when it will occur. Recognize that most CoMET services are performed periodically or randomly, not continuously. Also recognize that a CoMET consultant's field representatives cannot be in all places at all times, an important issue when multiple activities are ongoing simultaneously. Ask for guidance about appropriate staffing levels and discuss the trade-offs that may be available.

Creating a detailed scope of CoMET QA service can help avoid surprises. Still, scope flexibility is needed to deal promptly with the unanticipated, like the additional services required to check the rework performed because of an error caught in QA.

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For financing purposes, some owners require the constructor to pay for CoMET services. ***Consider an alternative approach*** so you don't convert the constructor into the CoMET consultant's client. If it's essential for you to fund QA via the constructor, have the CoMET fee included as an allowance in the bid documents. This arrangement ensures that you remain the CoMET consultant's client, and it prevents the CoMET fee from becoming part of the constructor's bid-price competition. (Note that the International Building Code (IBC) *requires the owner to pay* for Special Inspection (SI) services commonly performed by the CoMET consultant as a service separate from QA, to help ensure the independence of the SI process. Because failure to comply could result in denial of an occupancy or use permit, having a contractual agreement that conforms to local code requirements is essential.)

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CoMET consultants can usually quote their fees as unit fees, unit fees with estimated total (invoiced on a unit-fee basis), or lump-sum (invoiced on a percent-completion basis referenced to a schedule of values). No matter which method is used, estimated quantities need to be realistic. Some CoMET firms lower their total-fee estimates by using quantities they know are too low and then request change orders long before construction and the need for QA are complete.

Once you and the CoMET consultant settle on the scope of service and fee, enter into a written contract. Established CoMET firms have their own contracts; most owners sign them. Some owners prefer to use different contracts, but that can be a mistake when the contract was prepared for construction services. *Professional services are different.* Wholly avoidable problems occur when a contract includes provisions that don't apply to the services involved and fails to include those that do.

Some owners create wholly avoidable problems by using a contract prepared for construction services.

This final note: CoMET consultants perform QA for owners, not constructors. While constructors are commonly given review copies of QA reports *as a courtesy*, you need to make it clear that constructors do *not* have a legal right to rely on those reports; i.e., if constructors want to forgo their own observation and testing and rely on results derived from a scope created to meet *only* the needs of the owner, they *must do so at their own risk.* In all too many cases where owners have failed to make that clear, constructors have alleged that they *did* have a legal right to rely on QA reports and, as a result, the CoMET consultant – not they – are responsible for their failure to deliver what they contractually promised to provide. The outcome can be delays and disputes that entangle you and all other principal project participants. Avoid that. Rely on CoMET professionals with the resources and attitude needed to manage this and other risks as an element of a quality-focused service. Involve them early. Keep them engaged. And listen to what they say. Good CoMET consultants can provide great value.

For more information, speak with representatives of a firm that's part of ASFE/ The Geoprofessional Business Association (GBA) or contact GBA staff. In either case, your inquiries will be warmly welcomed.

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