ECS Southeast, LLP

Geotechnical Engineering Report

Quadrant Expansion (Quad 2)

12500 Plantside Drive
Louisville, Kentucky 40299

ECS Project Number 61:2769

June 22, 2022

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Quadrant International
12500 Plantside Drive
Louisville, Kentucky 40299

Attention: Mr. Phil Pascoe

ECS Project No. 61:2769

Reference: Geotechnical Engineering Report
Quadrant Expansion (Quad 2)
12500 Plantside Drive
Louisville, Jefferson County, Kentucky 40299

Dear Mr. Pascoe,

ECS Southeast, LLP (ECS) has completed the subsurface exploration and geotechnical engineering analyses for the above-referenced project. Our services were performed in general accordance with ECS Proposal No. 61:P2749, dated May 31, 2022.

This report presents our understanding of the geotechnical aspects of the project along with the results of the field exploration, laboratory testing conducted, and our geotechnical related design and construction recommendations.

It has been our pleasure to be of service to Quadrant International and Foresee Investment, LLC during the design phase of this project. We would appreciate the opportunity to remain involved during the continuation of the design phase and would like to provide our services during construction operations as well to confirm the interpreted subsurface conditions utilized in this report. Should you have any questions concerning the information contained in this report, or if we can be of further assistance to you, please contact the writers.

Respectfully submitted,

ECS Southeast, LLP

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EXECUTIVE SUMMARY

This Executive Summary presents as a very brief overview of the geotechnical conditions at this site that are expected to affect design and construction. The following conditions were characteristic of the encountered site and subsurface conditions:

- The project consists of construction of a new 55,000 square-feet, single story, industrial building with tilt up walls and associated driveways and parking areas, located at 12500 Plantside Drive, in Louisville, Kentucky.
- The site is to the south side of the existing Quadrant facility and consists of mainly undeveloped land, covered with field grass and trees with an existing residential building and its associated gravel driveway in the western portion of the site. A creek/swale crosses along the eastern and southern borders of the site. The site slopes down from northwest to southeast with approximately 21 feet of relief across the proposed building footprint.
- Surface materials consisted of approximately 4 to 8 inches of topsoil.
- Existing fill was encountered below surface materials in one boring (Boring B-04) and consisted of clay with a trace of crushed stone which extended to a depth of approximately 1 foot below existing grades in our boring.
- Fill or surface materials were underlain by native soils. Native soils consisted of brown, tan brown, orange brown, and dark brown low to moderate plasticity, very soft to very stiff, slightly moist to very moist, silty LEAN CLAY (CL). The LEAN CLAY (CL) extended to refusal in three of the borings (Borings B-03, B-08m and B-09). In the reminder of the borings, the LEAN CLAY (CL) was underlain by brown, tan brown, and orange brown, high plasticity, stiff to hard, slightly moist to very moist FAT CLAY (CH) which extended to refusal.
- In two (2) borings (Borings B-8 and B-09), very soft to soft soils were encountered within the upper approximate 3 feet.
- Refusal was encountered between approximately 0.5 and 7.3 feet below existing grades in the borings.
- Groundwater was not encountered in our borings at the time of drilling.

GEOTECHNICAL CONCERNS:

- Shallow Refusal
- Deep Fills
- Highly Plastic Clays
- Creek
- Existing Structure
- Existing Pavements
- Trees
- Existing Fill
- Degradable Soils
- Reuse of On-Site Soils
- Soft Surface Soils
- Subgrade Improvement
- Weather Considerations

DESIGN & CONSTRUCTION RECOMMENDATIONS:

- The proposed buildings may be supported on conventional shallow foundations bearing on stiff or stronger undisturbed inorganic clay, structural fill as defined in this report, flowable fill, lean concrete, or relatively unweathered bedrock. The following net allowable design bearing pressures may be used in foundation design:
  - 2,000 psf for continuous wall foundations bearing on soil.
  - 2,500 psf for isolated column foundations bearing on soil.
  - 5,000 psf for foundations bearing on relatively unweathered bedrock.
- Soil bearing foundations are expected to be dominant. Individual foundations must not bear on soil and rock simultaneously unless they are specifically designed to accommodate the stress concentrations associated with variable bearing conditions (e.g., use of grade beams).
- Floors may be designed as slabs-on-grade with a subgrade modulus of 100 pci.
- A site class of "C" may be used in seismic design per the 2018 Kentucky Building Code.

- Foundation excavations and floor and pavement subgrades should be evaluated by an ECS representative during construction to confirm that encountered conditions are consistent with the findings of this exploration.
- Flexible and/or rigid pavements may be used in proposed pavement areas. Rigid pavements should be considered for entranceways, dumpster pads, or other areas where heavy vehicles will turn on a tight radius or be parked for extended periods of time.

This Executive Summary is intended as a very brief overview of the primary geotechnical conditions that are expected to affect design and construction. Information gleaned from this Executive Summary should not be utilized in lieu of reading the entire geotechnical report.

1.0 INTRODUCTION

1.1 GENERAL

The purpose of this report is to provide the results of our subsurface exploration, engineering analyses, and geotechnical recommendations for the design of foundations, retaining walls, floor slabs, and pavements for the proposed development on 12500 Plantside Drive in Louisville, Kentucky. Also included are geotechnical subgrade preparation and fill placement guidelines. The recommendations developed for this report are based on project information supplied by Mr. Doug Wood of Foresee Investment, LLC.

1.2 SCOPE OF SERVICES

Nine (9) soil test borings were performed at the selected locations in the proposed construction areas. A laboratory testing program was also implemented to characterize the physical and engineering properties of the subsurface soils. This report describes our exploratory and testing procedures, presents our findings and evaluations, and includes the following:

- Summary of the project information provided.
- Description of existing site conditions, reported geology, and encountered subsurface conditions.
- Assessment of general adequacy of the site for the intended use from a geotechnical standpoint.
- Site preparation and structural fill placement recommendations.
- Recommended foundation type(s), design parameters, and construction guidelines.
- Recommended floor slab design parameters and construction guidelines.
- Recommended flexible and rigid pavement design parameters and construction guidelines.
- Site class for seismic design based on the boring data and on available data from the vicinity.
- Other identified geotechnical concerns and recommended additional sampling/testing/analysis.

Our services were provided in accordance with our Terms and Conditions of Service included in our Proposal No. 61:P2749, dated May 31, 2022.

2.0 PROJECT INFORMATION

2.1 SITE INFORMATION

SUBJECT	SUMMARY OF EXISTING SITE CONDITIONS
Site Address	The site is located at 12500 Plantside Drive, in Louisville, Kentucky. For location, refer to **Site Location Diagram** and **Boring Location Plan** in **Appendix**.
General Description & Topography	The site consists of mainly undeveloped land, covered with field grass and trees with an existing residential building and its associated gravel driveway in the western portion of the site. A creek/swale crosses along the eastern and southern borders of the site. The site slopes down from northwest to southeast with approximately 21 feet of relief across the proposed building footprint.
Surface Water Drainage	Surface drainage appeared to be poor to fair.
Ground Cover	Mostly topsoil, with an existing building and gravel driveway on the west side of the site.

2.2 PROPOSED CONSTRUCTION

SUBJECT	DESIGN INFORMATION / EXPECTATIONS
Project Description	The project consists of construction of a new 55,000 square-feet, single story, industrial building with tilt up walls and associated driveways and parking areas.
Usage	Industrial
Maximum Column Loads	Less than 150 kips (assumed)
Maximum Wall Loads	Less than 5 kips per linear foot (assumed)
Finish Floor Elevation	Proposed Building 3: EL 672 feet (assumed)
Maximum Cut/Fill	± 10 feet overall site grading for building area (assumed).
Design Traffic Loads	Light Duty: Daily 18-kip equivalent axle load of 7 (parking areas for cars and light trucks). Heavy Duty: Daily 18-kip equivalent axle load of 25 (drive lanes and entrances for cars, light trucks, and the occasional garbage truck).

3.0 SITE GEOLOGY

According to the Geologic map of the Jeffersontown quadrangle, Jefferson County, Kentucky, published by the United States Geological Survey (USGS), and information obtained from the Kentucky Geological Survey (KGS) Geologic Information Service website, the subject site was underlain by the Saluda Dolomite Member of the Drakes Formation and Osgood Formation & Brassfield Dolomite. See **Geologic Map** in **Appendix**.

Site Geology - Underlying Formations (1)		
FORMATION	**DESCRIPTION**	**KARST POTENTIAL[2,3]**
Saluda Dolomite Member of the Drakes Formation (mapped over vast majority of site)	**Primary Lithology:** Limestone and shale. Limestone is light to dark gray, in part carbonaceous, very fine to coarse grained, even beds 1 to 10 inches thick, finely laminated on some weathered surfaces. Shale is grayish black, carbonaceous, calcareous, imperfectly fissile, in beds 1 to 5 inches thick. Dolomite, greenish gray, weathers grayish orange to brown; on surface, banded brown and greenish gray; very fine grained; scattered small calcite clots; appears massive but weathered surface shows unit composed of beds 1/2 to 2 inches thick alternating with less resistant interbeds 1/8 to 1/2 inch thick; upper 2 to 6 feet thinly laminated with abundant filled worm borings. Dolomite and limestone: Dolomite is greenish gray, muddy, calcitic in part; contains scattered fossils and few thin lenses of calcite cemented fossiliferous limestone. A single persistent bed of medium gray, dense, fine grained, unfossiliferous limestone 1 to 6 inches thick, which crops out and is conspicuous in float, forms excellent marker bed in lower part of unit. Basal part of unit, generally poorly exposed, grades through interval of about 5 feet by decreasing dolomite content and increasing fossil content into underlying unit. Base arbitrarily taken as 5 feet below marker bed, thus placing base in about middle of zone of gradation	Low[4]
Osgood Formation & Brassfield Dolomite (mapped in the northwest corner of the site)	**Primary Lithology:** Shale and Dolomite. Shale is greenish gray, silty, poorly fissile, dolomitic; weathers to gray flakes or to yellowish gray or grayish yellow clay. Dolomite is yellowish gray with reddish or orange mottling (probably a weathered color), fine grained; occurs at base of unit; resembles lowest dolomite bed of the Laurel Dolomite.	Non-Karst[4]

Notes:

(1) Source: Geologic map of the Jeffersontown quadrangle, Jefferson County, Kentucky, published by the United States Geological Survey, and information obtained from the Kentucky Geological Survey Geologic Information Service website.

(2) Karst is topography commonly formed over limestone and characterized by sinkholes, irregular rock conditions, underground drainage, springs, and caves.

(3) The karst potential is based on the tendency for the unit to develop or have karst features as shown on the Kentucky Geological Survey (KGS) Geologic Information Service Karst Potential Map and is not necessarily indicative of the actual presence or absence of existing karst activity at the site.

(4) According to the KGS Karst Potential Classification definitions, formations designated with a **"Low"** karst potential have karst features that are poorly developed or absent; karst features are rare or absent in formations designated with a "Non-Karst" karst potential.

4.0 FIELD EXPLORATION AND LABORATORY TESTING

4.1 SUBSURFACE CHARACTERIZATION

SUBJECT	SUMMARY OF SUBSURFACE EXPLORATION (1)
Boring Method	Direct Push
Sampling Method	Standard Penetration Testing (ASTM D-1586)
Number of Borings	Nine (9) soil test borings: – Building – Borings B-01 through B-06 – Pavement areas – Borings B-07 through B-09
Boring Locations	Refer to **Boring Location Plan** in the **Appendix** for specific locations.
Boring Depths	Refer to **Boring Records** and **Refusal Summary Sheet** in the **Appendix.**
Logging Method	Full-time presence of an ECS engineer to observe, manage, and document the drilling, sampling, and testing results, and encountered conditions. Water level measurement obtained in boreholes during drilling.
Groundwater	Groundwater was not encountered in our borings at the time of drilling.
Refusal (2)	Refusal was encountered between approximately 0.5 and 7.3 feet below existing grades.

Notes:

(1) Detailed descriptions of the exploration methods are listed in the **Field Procedures** section of the **Appendix**.

(2) Refusal is the term applied to material that cannot be penetrated with drilling tools or has a standard penetration resistance exceeding 50 blows per 6-inch increment or 10 blows with little to no penetration of the split spoon. Refusal may be encountered on continuous bedrock, discontinuous floaters, cemented soil, weathered rock, buried construction debris, buried structures, or other hard subsurface materials.

The following sections provide generalized characterizations of the soil strata. Please refer to the **Boring Records** and **Boring Composite(s)** in the **Appendix** for detail at specific boring locations.

APPROXIMATE DEPTH (FT)	STRATUM	DESCRIPTION	N-VALUES BLOWS PER FOOT (BPF)[2]
0 – 0.8	N/A	**TOPSOIL –** Approximately 4 to 8 inches.	N/A
0.3 – 4.8	I	**LOW TO MODERATE PLASTICITY CLAY (CL) –** Brown, tan brown, orange brown, and dark brown low to moderate plasticity, very soft to very stiff, slightly moist to very moist, silty LEAN CLAY. Encountered below the topsoil in the nine (9) borings.	0 to 50/4”
1.5 – 7.3	II	**HIGH PLASTICITY CLAY (CH) –** Brown, tan brown, and orange brown, high plasticity, stiff to hard, slightly moist to very moist FAT CLAY. Encountered below Stratum I in six (6) borings.	8 to 50/3”

Notes:

(1) This summary is generalized and does not describe the actual conditions in each boring. These zones also may not occur at each location. Depths are approximate. Detailed descriptions of the encountered materials are listed on the **Boring Records** in the **Appendix**.

(2) BPF – Blows per Foot

4.2 LABORATORY TEST SUMMARY

Laboratory testing was performed on selected samples obtained during our field exploration operations. Classification and index property tests were performed. The laboratory testing program included:

- Natural Moisture Content
- Atterberg Limits

Each sample was visually classified based on texture and plasticity in accordance with ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedures), including Unified Soil Classification System (USCS) classification symbols, and ASTM D2487 Standard Practice for Classification for Engineering Purposes. After classification, the samples were grouped in the major zones noted on the **Boring Records** in the **Appendix**. The group symbols for each soil type are indicated in parentheses along with the soil descriptions. The stratification lines between strata on the logs are approximate; in situ, the transitions may be gradual.

SUMMARY OF LABORATORY TEST RESULTS [(1), (2)]					
STRATUM	**MOISTURE CONTENT (%)**	**LIQUID LIMIT**	**PLASTIC LIMIT**	**PLASTICITY INDEX**	**UNIFIED SOIL CLASSIFICATION**
I	19.7 – 33.9	-	-	-	CL
II	17.7 – 31.7	65, 70	27, 30	38, 47	CH

Notes:

(1) A more detailed summary of the laboratory test results is included on the **Boring Records** in the **Appendix**. Detailed descriptions of the laboratory test methods are listed in the **Laboratory Procedures** section of the **Appendix.**

(2) This table only summarizes the laboratory test results conducted on samples obtained from the recent exploration.

5.0 GEOTECHNICAL CONCERNS

Analysis of the provided project information, observed site conditions, encountered subsurface conditions, and our experience with similar projects, revealed the following important geotechnical considerations. These considerations must be properly addressed in planning, budgeting, design, and construction phases to reduce impacts on construction cost, completion schedule, performance of the building and site improvements, and long-term maintenance of the proposed construction. Our recommendations for addressing these concerns are provided in subsequent sections of this report.

5.1 SHALLOW REFUSAL

- Direct push refusal was encountered approximately 0.5 to 7.3 feet below existing grades.
- Based on our assumed FFEs, rock will likely be anticipated at some foundation bearing depths, but soil bearing conditions should predominate throughout the planned foundation areas.
- The presence of refusal above planned foundation, slab, or utility elevations can increase site development costs and slow construction, especially if the cost of excavation methods is not considered in planning and design.
- Foundation design should accommodate the different materials that will be encountered at the foundation depths.
- It is possible that the depth to rock in unexplored areas may vary significantly from the depths indicated by the test borings.
- Removal of most of the on-site refusal material, if necessary, with conventional excavation equipment is not expected to be effective. The competent rock on-site requires special rock removal equipment (e.g., hoe ram, blasting, etc.) for efficient excavation.
- The difficulty of removal will be affected by the methodology used, the experience of the operator, and the type of equipment used.
- Greater than normal differential settlement likely will occur if foundations are supported on both rock and soil simultaneously. Alternatives to address this concern are included in **Section 6.4**.

5.2 DEEP FILLS

- Deep fills are considered those more than 10 feet. As fill depths exceed 10 feet, settlement and differential support issues become more of a concern.
- In general, we would anticipate that properly placed and compacted clay fill will consolidate 1 to 2 percent of the height of the fill, which for 10 feet of fill, translates to approximately 1 to 2 ½ inches of settlement associated exclusively from consolidation of the new fill under its own weight.
- While much of this settlement would occur during or shortly after placement, as fills get deeper, the settlement periods lengthens so that some settlement would occur well after placement and could damage overlying construction.
- In addition to the settlement of the new fill, the underlying residual soils also will consolidate under the weight of the new fill. This settlement will increase as both the height of the new fill and the compressibility of the underlying residual soil increases.

- For the anticipated depth of deep fills (generally in the range of 10 to 20 feet), the anticipated settlement of the residual soils under the weight of new deep fills likely would be less than 1 inch.
- Settlement rates can be accelerated by filling above planned grade to surcharge the area.
- Flexible utility connections can be used to accommodate expected differential settlement.
- The concerns associated with deep fills can be reduced by following the fill placement recommendations provided in subsequent sections of this report.

5.3 HIGHLY PLASTIC CLAYS

- Highly plastic clays (i.e., plasticity index greater than 30 – generally designated as "CH" or FAT CLAYS in the report and on boring logs) were encountered in most borings.
- Highly plastic clays are susceptible to volume changes (shrink/swell problems) with changes in moisture. Accordingly, it is advisable to reduce the potential for moisture changes to the soil because of the shrink/swell concerns and the possible impact on the proposed construction.
- Volume changes associated with the highly plastic clays in the geologic formation underlying the site have the potential to produce building or other improvement damage (e.g., floor heave or subsidence, door/window alignment changes, hardscape movements, and drywall cracking).
- Movement may be cyclic (shrink when dry, swell when wet), continuing to produce building distortions that require increased and regular maintenance or repair.
- Typically, the volume changes are not of the magnitude to result in damage that would impair the structural integrity of buildings.
- Exposure to prolonged wet or dry weather conditions during construction can result in volume changes in bearing and subgrade materials or problems achieving the required compaction levels.
- The risks associated with highly plastic clays are common for the project vicinity and are not unique to the site. Most of the effects of highly plastic clays can be reduced by employing the design and construction recommendations described in subsequent sections of this report.

5.4 SWALE AND CREEK

- A creek was observed along the eastern and southern borders of the site. Soft, poor quality soils (e.g., organic, saturated deposits) requiring remediation and/or stabilization typically are encountered in and around these areas. In addition, trapped and/or perched groundwater can be encountered within these areas.
- The soft, inadequate soils and groundwater issues may complicate construction and increase site development costs. Both conditions should be anticipated along existing drainage swale and creek areas and can be addressed during construction with proper planning and budgeting.
- The impact of swale and creek on site development costs can be reduced by scheduling site work during the drier months of the year.

5.5 EXISTING CONSTRUCTION

- The planned construction area included existing buildings in the west section of the site.

- The buried (below grade) components associated with the existing structures (e.g., foundations, utilities, etc.) can cause new construction to behave poorly for many reasons, including stress concentrations resulting from point loading and poor support caused by old backfill.
- Cosmetic and structural damage to the overlying construction can result if the existing building components are not properly addressed during construction.
- Care should be exercised during demolition to reduce the area that is disturbed during removal activities (e.g., do not push or pull foundations from the ground because this process commonly disturbs large zones of adjacent soils). Excavations resulting from the demolition process (including the existing basement) should be properly benched and then backfilled with structural fill placed in accordance with recommendations in this report.
- Existing construction (and its removal) should be appropriately addressed in budget documents and during construction to reduce the potential impact to the planned construction, including poor quality soil conditions that will require remediation and result in additional costs.

5.6 EXISTING PAVEMENTS

- Existing gravel paved surfaces were observed in the west section of the site.
- Existing pavements should be left in-place as long as possible, to act as a construction platform.
- Water is commonly trapped under paved surfaces. Accordingly, soft, saturated soils may be present in some areas below these existing surfaces.
- Water seepage into excavations from the existing gravel base and utility backfill should be anticipated.
- Moisture conditioning of soils underlying these surface materials commonly is necessary and should be anticipated for this project.
- In addition, pavements, commonly obscure the presence of soft soils. Some undercutting of soft soils below these surface materials should be anticipated.

5.7 TREES

- Mature trees were located within the boundaries of the proposed building and paved areas.
- Care must be taken to remove the entire rootball of trees since soils high in organic contents will not provide adequate support characteristics for the proposed facility.
- In addition, the resulting excavation must be backfilled with properly placed and compacted fill to avoid localized soft spots that can compromise the performance of the proposed construction.
- Fill material that contains significant tree roots (i.e., more than 3 percent organics as determined by loss-on-ignition testing) is inadequate for use as controlled fill.

5.8 EXISTING FILL

- Existing uncontrolled fill, extending to approximately 1 foot below existing grades, was encountered in Boring B-04. The existing fill generally consisted of moderate plasticity clay with a trace of crushed stone.
- The existing fill should be considered uncontrolled/undocumented fill since no records are available documenting the material quality or content. The unknown quality, consistency,

and behavior characteristics of uncontrolled fill creates concerns for the behavior of overlying construction.

- Potential problems for the proposed construction created by the presence of the existing uncontrolled fill include: larger than normal total and differential settlements, collapse of buried objects, and poor bearing support. The manifestation of these problems can cause poor foundation, floor slab, and pavement performance.
- Perched or trapped water also may be encountered in the existing fill.

5.9 DEGRADABLE SOILS

- Most of the soils on-site are susceptible to degradation. Degradable soils readily lose strength, become soft, and “pump” when subjected to construction equipment, especially under wet conditions.
- Undercutting and/or stabilization of soft clay soils could have a cost impact on the project, especially if not properly addressed in the project documents (e.g., definition of what is poor quality soils and the responsibility for maintenance of these soils once stabilized) or if not properly addressed during construction (e.g., subjected to repeated construction traffic with no protection).

5.10 REUSE OF ON-SITE SOILS

- In general, most of the on-site soils appeared adequate for reuse as structural fill provided the soils are moisture conditioned to appropriate moisture contents for compaction.
- Some wetting, drying, mixing or chemical treatment of the soils may be necessary to obtain workable moisture contents for the on-site soils, especially during wetter times of the year.
- Reuse of the on-site soils will be subject to the weather considerations described subsequently.

5.11 SOFT SURFACE SOILS

- The upper approximate 3 feet of soils were very soft in two of the borings on the south side of the site (Borings B-08 and B-09). The soft soils improved in consistency with depth.
- Improvement of the soft soils should be expected in subgrade areas, with the lateral extent and depth of improvement increasing during wetter periods of the year. Improvement of some of the firm soils also may be necessary. Refer to the following subsection for additional comments regarding subgrade improvement.
- Depending on final grades, undercutting of soft soils in foundation and pavement areas, if encountered, should be expected.
- Soft surface soils must either be undercut or stabilized prior to construction.
- The extent of soft surface soils will typically be reduced if earthwork takes place during the warmer, drier summer and fall months.

5.12 SUBGRADE IMPROVEMENT

- The upper approximate 3 feet in Borings B-08 and B-09 were soft and, depending on final grades, will need some form of subgrade improvement.
- Localized improvements will likely be needed in some areas, especially if construction occurs during the wetter/cooler periods of the year.

- The required extent of improvement will depend to a large degree on when earthwork operations take place as well as on how the earthwork contractor prepares the site. The level of improvement likely will increase if:
  - Construction traffic is concentrated along localized soft or poor subgrade routes.
  - Earthwork occurs during cool, wet periods (typically November through May).
- Provided construction occurs during the drier time of the year, it would be our expectation that much of the improvement could be achieved by scarifying, drying and recompacting the soils. If construction occurs during the wetter periods of the year, more aggressive treatment would likely be required (i.e., removal and replacement or lime drying).
- Subgrade improvement alternatives, if required, include but are not limited to:
  - Scarification, drying, and recompaction of surface materials.
  - Removal of inadequate materials and replacement with structural fill.
  - Bridging with a thick lift of limestone aggregate.
  - Placement of a geosynthetic or geo-grid in combination with granular fill.
  - Chemical stabilization and/or modification (e.g., kiln dust, lime, or Portland cement).
- The type of subgrade improvement chosen should take weather limitations, or other limitations unique to each method, into consideration.
- In addition to the soft soils encountered on the south side of the site, a closed depression was observed close to the location of Boring B-03. The depression was mainly covered with trees. Therefore, we recommend future investigations during construction for karst related activities at the location of the depression.

5.13 WEATHER CONSIDERATIONS

- Conducting site work during periods of cool and/or wet weather (typically November to May) can be problematic for sites in the project region.
- Proper compaction of clay fill generally is very difficult to achieve during periods of cool and/or wet weather. Some drying, mixing, or chemical treatment of the soils would be necessary to obtain workable moisture contents for the on-site soils or proposed borrow materials if placed during the cool, wet seasons.
- If compaction of clay fill takes place under wet weather conditions, increased earthwork costs, an extended construction schedule, and soil improvement (likely chemical stabilization) likely would be required. In addition, reuse of the site soils may be severely limited.
- Surface soils tend to be softer during wet weather conditions due to the excess moisture in the near surface soils.
- Weather-softened surface soils tend to result in more undercutting and/or stabilization than would be required during dry weather conditions, which increases site development costs.
- Project specifications should include definitions and require contractors to provide unit rates for subgrade stabilization, removal of inadequate soils, and replacement of inadequate soils with structural fill appropriate for use during the anticipated construction season.

6.0 SITE CONSTRUCTION RECOMMENDATIONS

6.1 PLANNING

- Adjust project plans, specifications, schedules, and budgets to incorporate the issues discussed in **Section 5.0** and the recommendations provided herein.
- It will be critical that the planning of earthwork operations is carefully considered and executed given the presence of degradable soils.
- Findings and recommendations in this report were based on assumed finish floor elevations. As such, ECS should be contacted to provide appropriate values and recommendations for changes to the assumed elevations.

6.2 SUBGRADE PREPARATION

- Localized improvements will likely be needed in some areas, especially if construction occurs during the wetter/cooler periods of the year. The upper approximate 3 feet in borings on the south side of the site (Borings B-08 and B-09) were soft and, depending on final grades, will need some form of subgrade improvement.
- The depth and extent of improvement required will be dependent on the time of year of construction, the weather preceding site work, and the site work techniques employed.
- The following subsections describe our general recommendations for preparing the site subgrade prior to fill placement operations.

Stripping and Grubbing:

- Materials required to be stripped:
  - Topsoil, vegetation, large root zones, organic material, gravel paved areas, existing structure, and excessively wet, desiccated, frozen, contaminated, or otherwise inadequate materials.
- Minimum extent of stripping:
  - 10 feet beyond the building limits.
  - 5 feet beyond the pavement limits.
- ECS should observe and document that topsoil and poor surficial materials have been removed prior to the placement of structural fill or construction of structures.
- Stripped material not meeting structural fill requirements should be considered for reuse in landscaped areas only.

Subgrade Improvement:

- Existing fill and low strength soils may require stabilization, as described in **Section 5.0.**
- The construction budget should be adjusted to reflect the adverse subgrade conditions expected in some areas as described in **Section 5.0**.
- If it is determined that the subgrade needs improvement, the improvements should adhere to the options described in **Section 5.0**.

Subgrade Evaluation:

- Proofroll the site in the presence of an ECS representative with a pneumatic-tired vehicle (e.g., triaxial dump truck) loaded as recommended by the ECS representative.
- Proofroll subgrades prior to filling or after excavation to grade.
- Proofroll slab and pavement subgrades prior to granular base placement.
- Areas judged by the ECS representative to deflect excessively during proofrolling should be remediated in accordance with ECS recommendations provided at that time.
- Prepare subgrades with a slight slope to maintain surface drainage.

Other Measures:

- Roll subgrade surfaces smooth if rain is expected.
- Slope final subgrades away from the proposed structure.
- Rough grade subgrades high to allow for removal of degraded soil.
- Remove soil frozen or softened by rain.

6.3 STRUCTURAL FILL

Subgrade Requirements:

- Subgrade proofrolled and required improvements completed.

Fill Material Requirements:

- No deleterious debris.
- No rock pieces larger than 3 inches.
- Less than 3% organic material (loss on ignition).
- Maximum dry density of at least 100 pcf according to the Standard Proctor compaction method (ASTM D-698), unless specifically reviewed otherwise by ECS.
- Acceptable Unified Soil Classifications (USCS): CL, ML, GW, GM, GC, GP, SW, SP, SM, SC.
- Unacceptable USCS classifications: CH, OL, OH, Pt, MH.
- Evaluated and approved by ECS prior to construction.

Fill Placement Guidelines:

- Minimum compaction:
  - 98 % Standard Proctor maximum dry density (ASTM D-698).
- Moisture Content:
  - Within 2 % of optimum (ASTM D-698).
- Maximum loose lift thickness: 8 inches.
- Compaction test frequency:
  - One test per lift for each 5,000 square feet of fill placed.
  - Minimum of 3 tests per lift.
- Bench new fill into existing slopes or sidewalls of deep excavations in 1-foot steps or as recommended by ECS at the time of construction.
- Compact and test each lift prior to placing additional lifts.

- Scarify smoothed fill surfaces prior to placing the next lift.
- Maintain positive surface drainage on fill surfaces during placement to avoid ponding of water.
- Roll fill surfaces smooth if rain is expected.
- Rough grade high to allow for removal of degraded surface soils if fill will be exposed to adverse weather conditions.
- Do not place fill on a frozen subgrade. At a minimum, remove frozen material, or allow to thaw and then recompact.

6.4 SHALLOW ROCK

- Direct push refusal was encountered in the borings at approximately 0.3 to 7.3 feet below existing grades.
- Greater than normal differential settlement likely will occur if foundations are supported on both rock and soil simultaneously. Alternatives to address this concern include:
  - Adjust the floor elevation and/or building location to avoid this condition.
  - Remove rock and backfill with compacted clay or manufactured sand fill where necessary, so that foundations bear on at least 12 inches of approved native soil or controlled fill.
  - Support the building on isolated column foundations tied together with grade beams to reduce the effects of differential settlement. Isolated columns may bear entirely on rock or on soil but not both simultaneously. Adjacent columns may bear entirely on rock or soil.
  - Divide the building into sections that are entirely support on rock or on soil. Design for approximately 1 inch of differential settlement between sections.
- The method used to remove the on-site rock, if necessary, should be selected by the contractor. Removal of the on-site rock with conventional excavation equipment is not expected to be effective. The competent rock on-site requires special rock removal equipment (e.g., blasting, hoe-ram, etc.) for efficient excavation.

6.5 PLASTIC CLAY

- The measures provided below will significantly reduce, but not eliminate, the likelihood the proposed construction will be impacted by the presence of plastic clays:
  - Test the moisture content of subgrade soils. Adjust soil moisture if the results fall outside the range of optimum to plus 3% above optimum.
  - Roof drains and surface drainage should not discharge or be directed to the ground surface within 20 feet of the proposed structures, unless the surface is impervious (such as concrete or pavement), to reduce moisture changes of the foundation soils.
  - Proper drainage should be provided around the proposed construction (e.g., slope the surface away from the building).
- If the risks associated with the plastic clays are not acceptable, then:

- Do not place plastic clay fills within 2 feet of the planned finish subgrades (building and pavement).
- Undisturbed plastic clays within 2 feet of planned finish subgrades and foundation bearing elevations are removed and replaced with low to moderate plasticity clay fill soils.

6.6 EXISTING CONSTRUCTION

General Comments:

- Recommendations to address existing construction can be affected by many factors, including factors that are not obvious until construction (e.g., removal of some features creates more potential problems and risks than leaving them in-place).
- As such, the recommendations provided below should be considered general guidelines. If modification to the recommendations provided below is needed, ECS should be contacted for guidance.

Building Components:

- Demolish and remove existing construction within the proposed foundation areas from existing or former construction in the area. Be sure to remove existing foundations, slabs, possible below grade walls, pavements, and buried utilities.
- Backfill the resulting excavations with properly placed and compacted fill that is keyed into the native soil in one-foot steps to provide a gradual transition in support conditions.
- It may be feasible to leave below grade structures in-place in proposed floor slab and pavement areas provided the below grade structures are removed to 2 feet below the subgrade, the surrounding soils are determined to be unyielding under proofrolling, below grade structures do not conflict with new construction, and the owner is willing to accept the associated risks.
- Old floors or pavements, if encountered, must be broken up or penetrated at regular intervals to promote water drainage or be removed completely if in new foundation areas.
- The areas where existing construction was located need to be carefully proofrolled in the presence of an ECS representative.
- In addition to proofrolling, very careful earthwork evaluations must be conducted during construction to detect the presence and/or potential anomalies associated with the existing construction.

Utilities:

- Utilities should be relocated as necessary.
- Existing utilities within the proposed building area should be removed in their entirety (including line and associated backfill) unless the risk of damage to the proposed structure has been understood and accepted by the owner. The resulting excavation should then be backfilled in accordance with the recommendations in this report (including benching side slopes and proper compaction).
- Provided the risks associated with leaving utilities in-place are acceptable to the owner, abandoned lines should be grouted full.

- Needed improvements to poor backfill conditions should be identified during construction via proofrolling and surface probing by an ECS representative and remediated in accordance with the recommendations provided by ECS at the time of construction.

6.7 UNCONTROLLED FILL

- Existing fill was encountered in Boring B-04 extending to approximately 1 foot below existing grades.
- The fill was considered uncontrolled/undocumented fill since no records were available documenting the material quality or content.
- Existing fill is not adequate for support of the planned foundations. The foundations should penetrate the existing fill to penetrate on native soils.
- Support of new slabs and pavements over the existing fill is possible provided the fill is firm under proofroll, improved as necessary, and the owner accepts an elevated risk for future support issues associated with the fill.
- Based on the conditions encountered, the existing fill generally appeared feasible for reuse in pavement areas provided that the poor quality materials are removed.

7.0 DESIGN RECOMMENDATIONS

7.1 SHALLOW FOUNDATIONS

General Comments:

- The proposed building may be supported on conventional shallow foundations.
- Foundations must bear on stiff or better undisturbed clay, structural fill, flowable fill, lean concrete, or competent bedrock. However, soil bearing foundations are expected to be dominant.
- Foundation bearing conditions should be carefully evaluated by ECS during construction.

Variable Bearing Conditions:

- Individual foundations must not bear on soil and rock simultaneously unless they are specifically designed to accommodate the stress concentrations associated with variable bearing conditions (e.g., use of grade beams).
- Individual foundations should bear entirely on soil or entirely on rock (i.e., one isolated column foundation may bear on soil while an adjacent one may bear on rock, but each isolated foundation may not bear on soil and rock simultaneously).
- To address the concerns associated with variable bearing concerns, a minimum 1-foot soil cushion should be present below soil-bearing foundations. This may require the removal of some rock to construct the soil cushion.
- The soil cushion may consist of clay or sand, but not gravel. The cushion should be placed and compacted in accordance with the "Structural Fill" recommendations provided in this report.

Foundation Design Recommendations:

- The design of the foundation should utilize the following parameters:

FOUNDATION DESIGN RECOMMENDATIONS				
DESIGN PARAMETER	**SOIL BEARING**		**ROCK BEARING**	
	CONTINUOUS WALL FOUNDATIONS	**ISOLATED COLUMN FOUNDATIONS**	**CONTINUOUS WALL FOUNDATIONS**	**ISOLATED COLUMN FOUNDATIONS**
Net Allowable Bearing Pressure (1)	2,000 psf	2,500 psf	5,000 psf	5,000 psf
Acceptable Bearing Material	Stiff Undisturbed Native Soils, Structural Fill, Flowable Fill, or Lean Concrete.	Stiff Undisturbed Native Soils, Structural Fill, Flowable Fill, or Lean Concrete.	Bedrock: Relatively Unweathered	Bedrock: Relatively Unweathered
Minimum Width	18 inches	24 inches	18 inches	24 inches
Depth of Foundations Subject to Freezing (Below slab or finished grade) (2)	30 inches	30 inches	30 inches	30 inches
Depth Foundations Protected from Freezing	12 inches	12 inches	12 inches	12 inches
Estimated Total Settlement (4)	≤ 1 inch	≤ 1 inch	Negligible	Negligible
Estimated Differential Settlement (4)	≤ ¾ inch along 50 feet	≤ ¾ inch between columns	Negligible	Negligible

Notes:

(1) Net allowable bearing pressure is the applied pressure in excess of the surrounding overburden soils above the base of the foundation.

(2) The 2018 Kentucky Building Code requires a minimum foundation embedment depth of 24 inches for foundations subject to freezing in Jefferson County. However, a minimum embedment of 30 inches is common for commercial development in the project region.

(3) The recommended net allowable bearing pressures may be increased 33 percent for transient loading.

(4) The estimated settlement potential is based on the following: empirical guidelines for the project material types and consistencies; the assumption that ECS will observe and test each foundation excavation during construction; and the provided project information. Actual settlements will depend, in part, on site preparation and conditions at each foundation location.

PARAMETERS FOR FOUNDATION LATERAL RESISTANCE	**ESTIMATED VALUE (1)**
Coefficient of Active Earth Pressure (K_a) (2)	0.45
Coefficient of At-Rest Earth Pressure (K_o) (2)	0.58
Coefficient of Passive Earth Pressure (K_p) (2)	2.46
Moist Unit Weight of Soil (γ)	125 pcf
Base Shear Adhesion [Concrete on Undisturbed Clay]	400 psf
Coefficient of Friction [Concrete on Clay] (μ)	0.30
Coefficient of Friction [Concrete on Rock] (μ)	0.50

Notes:

(1) These design parameters do not include factors of safety. Appropriate factors of safety should be included in the designs.

(2) Provided earth pressure coefficients are based on an assumed internal angle of friction (ϕ) of 25 degrees for clay.

- Desiccation or disturbance may result in soil voids or cracks adjacent to foundations, reducing passive and uplift resistance. As a result, for these calculations, the upper 2.5 feet of soils should be neglected for passive resistance.
- Ignore passive earth pressure if the soil against the sides of the foundations may not be present during the life of the structure (e.g., the soil could be excavated or be subject to erosion).

Construction Guidelines:

- The bearing conditions of each foundation should be evaluated by ECS at the time of construction to confirm the presence of adequate bearing soils or rock and to provide recommendations for the remediation of poor soils, if present. This evaluation should be performed before the reinforcing steel is placed in the excavations.
- At rock bearing foundations, the exposed bedrock should be cleaned of loose rock or soils and scratch tested with a backhoe bucket. An ECS representative should observe the backhoe bucket being scrapped across the exposed rock surface to verify an unweathered rock surface is present.
- Concrete should be placed the same day the foundations are excavated to reduce degradation of the bearing surface due to exposure. Alternatively, a “mud mat” of lean concrete should be placed to protect the bearing surface.
- Disturbed, degraded or loose material should be removed from the excavation bottoms prior to concrete placement.

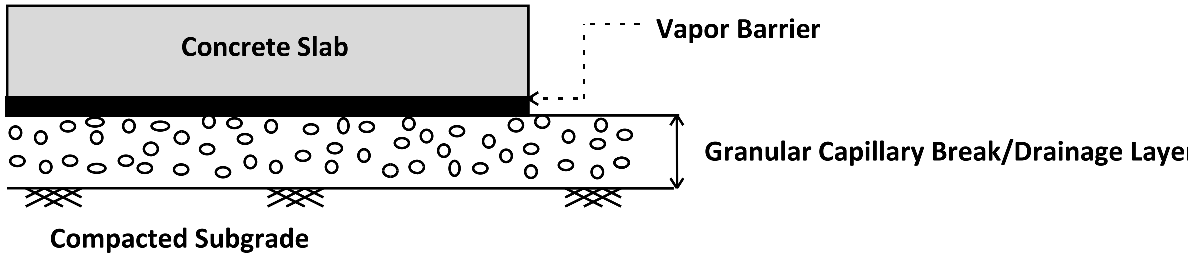
7.2 FLOOR SLABS

Recommended Slab Type:

- Grade supported floor slabs

Floor Subgrade Recommendations:

- Prepare subgrade in accordance with recommendations contained within this report.
- Subgrade proofrolled by an ECS representative and required improvements completed.
- Subgrade modulus for slab design: 100 pci.
- Place a minimum of 4 inches of well-graded crushed stone or angular sand base.
- Compact base material in accordance with the structural fill recommendations provided previously.
- Unless specifically approved otherwise, do not support floor slabs directly over open-graded coarse aggregate to avoid loss of concrete, increased concrete cracking during drying shrinkage, and puncture of the vapor barrier. If coarse aggregate is used as a drainage base, cap the coarse aggregate with a 2-inch (minimum) layer of well-graded aggregate (e.g., KYTC DGA).
- The following graphic depicts our soil-supported slab recommendations:



Notes:

(1) Drainage layer should consist of a minimum of 4 inches of well graded crushed stone or angular sand or open-graded coarse gravel. However, if open graded sone is selected then a minimum 2-inch layer of coarse aggregate with fines (e.g., KYTC DGA) should be used to cap the open graded stone.

(2) Subgrade compacted to 98% maximum dry density per ASTM D698.

Construction Guidelines:

- If a vapor barrier will be used, an adequate concrete design mix, placement, finishing, and curing techniques should be employed to reduce the potential for differential slab shrinkage, cracking, and curling.
- Special care must be taken to avoid puncturing the vapor barrier during construction. We recommend utilizing the ACI 302 guidelines for placement of the vapor barrier, manufactured sand layer, and concrete as a function of the construction sequence.
- Drying shrinkage and concrete curing methods frequently causes floor slab cracks. Control joints and saw cuts should be installed in accordance with ACI guidelines to control cracking.
- Slab joints should be doweled or keyed to allow rotation of the slab sections without localized vertical displacement.
- Penetrations of the floor slab by fixed objects, such as drains or piping, restrict shrinkage movement and must be isolated to reduce cracking potential.
- Slab-on-grade floor should be structurally isolated from foundation supported walls.
- Backfill along foundation excavations should be carefully controlled to reduce differential slab settlement.

7.3 SEISMIC DESIGN CONSIDERATIONS

- The 2018 Kentucky Building Code (KBC) requires site classification for seismic design based on the upper 100 feet of a soil profile. At least two methods are utilized in classifying sites, namely the shear wave velocity (vs) method and the Standard Penetration Resistance (N-value) method. The second method (N-value) was used in classifying this site.
- Based upon our interpretation of the subsurface conditions, the appropriate Seismic Site Classification is **"C"** as shown in the preceding table.

SEISMIC SITE CLASSIFICATION			
Site Class	**Soil Profile Name**	**Shear Wave Velocity, Vs, (ft./s)**	**N value (bpf)**
A	Hard Rock	Vs > 5,000 fps	N/A
B	Rock	2,500 < Vs ≤ 5,000 fps	N/A
C	Very dense soil and soft rock	1,200 < Vs ≤ 2,500 fps	>50
D	Stiff Soil Profile	600 ≤ Vs ≤ 1,200 fps	15 to 50
E	Soft Soil Profile	Vs < 600 fps	<15

Ground Motion Parameters:

- In addition to the seismic site classification noted above, ECS has determined the design spectral response acceleration parameters following the International Building Code (IBC) 2018 methodology. The Mapped Reponses were estimated from the OSHPD Seismic Design Map website (http://seismicmaps.org/). The design responses for the short (0.2-sec, S_{DS}) and 1-second period (S_{D1}) are noted at the right end of the following Table:

GROUND MOTION PARAMETERS [IBC 2018 Method]									
Period (sec)	**Mapped Spectral Response Accelerations (g)**		**Values of Site Coefficient for Site Class**		**Maximum Spectral Response Acceleration Adjusted for Site Class (g)**		**Design Spectral Response Acceleration (g)**		
0.2	S_S	0.193	F_a	1.2	$S_{MS}=F_aS_s$	0.231	$S_{DS}=2/3\ S_{MS}$	**0.154**	
1.0	S_1	0.102	F_v	1.698	$S_{M1}=F_vS_1$	0.173	$S_{D1}=2/3\ S_{M1}$	**0.115**	

- The Site Class definition should not be confused with the Seismic Design Category designation which the Structural Engineer typically assesses.

7.4 FLEXIBLE PAVEMENT DESIGN

Application:

- Primary driving lanes, parking areas or other locations where heavy vehicle or other equipment will not turn on a tight radius or be parked for extended periods of time.

General Comments:

- The limitations and recommendations associated with existing uncontrolled fill and high plasticity clays are described in more detail in **Section 6.0** and should be carefully understood and incorporated into construction planning.
- The pavement sections below are guidelines that may or may not comply with local jurisdictional minimums.

- If the traffic loads, Daily Equivalent 18-kip Axle Loads (DEALs), used in this report differ from the expected traffic loads onsite, ECS should be contacted to modify the pavement design.

FLEXIBLE DESIGN PARAMETERS	
Design Method	AASHTO Guide for Design of Pavement Structures (1993)
Daily Equivalent 18-KIP Axle Loads	7 (Light Duty) – Car Parking, Access, and Interior Lanes. 25 (Heavy Duty) – Drive lanes and entrances for cars, light trucks, and the occasional garbage truck.
Design Life	20 Years
California Bearing Ratio (CBR)	3 (Estimated)
Reliability	85%
Terminal Serviceability Index	2.0

RECOMMENDED FLEXIBLE PAVEMENT SECTIONS (1)			
Pavement Section	**Hot Mix Asphalt Wearing Surface**	**Hot Mix Asphalt Binder or Base**	**Granular Base Kentucky DGA**
Light Duty	1 inch	2 inches	9 inches
Heavy Duty	1 inch	3 inches	10 inches

Notes:

(1) It should be noted that although flexible pavement for the 20-year design period is structurally sound, an asphalt overlay is usually necessary after 7 to 12 years due to normal wear and exposure of the surfacing layer. In general, asphalt pavement should be sealed approximately 3 to 5 years to extend the life of the asphalt.

Subgrade Requirements:

- Prepare subgrade in accordance with recommendations contained within this report.
- Proofroll in the presence of an ECS representative and complete required improvements.
- Pavement subgrades sloped to facilitate drainage.

Drainage Requirements:

- Permit water movement beneath curbs at the subgrade level.
- Design catch basins to include finger drains at the granular base level.

Construction Guidelines

- Pavements should be constructed in accordance with the construction and material guidelines in the most recent edition of the Kentucky Transportation Cabinet's "Standard Specifications for Road and Bridge Construction."
- Granular base should be compacted in accordance with the structural fill recommendations provided in a previous section.
- In-place density, thickness, and gradation tests should be conducted by a ECS representative on the pavement components during construction to confirm compliance with project specifications.

7.5 RIGID PAVEMENT DESIGN

Application:

- Rigid pavements are adequate wherever flexible pavements can be used. Rigid pavements often provide better service for dumpster aprons, entranceways, or other areas where heavy trucks will turn on a tight radius or be parked for extended periods of time.

General Comments:

- The limitations and recommendations associated with existing uncontrolled fill and high plasticity clays are described in more detail in **Section 6.0** and should be carefully understood and incorporated into construction planning.
- The pavement sections below are guidelines that may or may not comply with local jurisdictional minimums.

RIGID PAVEMENT DESIGN PARAMETERS	
Design Method	ACI Guide for the Design and Construction of Concrete Parking Lots (ACI 330R-08)
Traffic Category	A (Light Duty): Car Parking, Access, and Interior Lanes C (Heavy Duty): Truck Parking, Exterior, and Entrance Lanes
Design Life	20 Years
California Bearing Ratio (CRR)	3 (Estimated)
Effective Subgrade Modulus	100 pci
Concrete Modulus of Rupture	500 psi

RECOMMENDED RIGID PAVEMENT SECTIONS		
Pavement Section	**Portland Cement Concrete**	**Granular Base Kentucky DGA**
Light Duty	5 inches	4 inches
Heavy Duty	7 inches	5 inches

Subgrade Requirements:

- Prepare subgrade in accordance with recommendations contained within this report.
- Proofroll in the presence of an ECS representative and complete required improvements.
- Pavement subgrades sloped to facilitate drainage.

Drainage Requirements:

- Permit water movement beneath curbs at the subgrade level.
- Design catch basins to include finger drains at the granular base level.

Concrete Recommendations:

- 4,000 pounds per square inch (psi) minimum 28-day compressive strength.
- 4 to 6 percent entrained air.

- Proper joint spacing to control shrinkage cracking.
- Dowels at construction joints to properly transfer loads between pavement sections.
- Control joints where concrete pavement abuts fixed structures or protrusions.

8.0 CLOSING

There are certain limitations inherent to geotechnical explorations and reports. These limitations are discussed below and in the **GBA "Important Information About Your Geotechnical Engineering Report"** in the **Appendix**. They should be fully considered prior to using the recommendations in this report.

Our geotechnical exploration identified the subsurface conditions that existed only at the locations and times that the borings were advanced. Given the natural variable characteristics of soil and rock, conditions may vary over short distances, change with time, or be affected by natural events, such as floods or earthquakes, or by human activity, such as past land use or new construction. As such, the information generated during our geotechnical exploration may not be representative of the entire conditions that may exist on the project site now or in the future. We use our professional judgment to render an opinion about the subsurface conditions that may exist in the areas of the site not specifically tested during our exploration based on our review of available field and laboratory data and our experience with similar subsurface conditions. However, the subsurface conditions encountered during construction may vary from the assumed conditions. Variations in the subsurface conditions between our borings and in unexplored areas of the site could affect our interpretations. Thus, it is important to retain ECS to provide construction monitoring services based on our involvement in the project, our knowledge about the site, and our knowledge relating to the assumptions and recommendations contained within this report.

The recommendations contained within this report are dependent on many factors, including, but not limited to, the project information provided by others and the specific conditions encountered during our exploration. If the project information contained within this report is incorrect or changed later or if the location or nature of the structures or facility components changes, ECS should be notified and given the chance to assess the impact of the changes. We cannot and do not accept responsibility or liability for problems that occur because we were not given the opportunity to properly assess changes to the project. The recommendations contained in this report must not be considered valid unless our firm reviews such changes and required modifications to our recommendations are verified in writing.

Our recommendations are dependent on several factors including, but not limited to, our review of project drawings and specifications prior to construction and observation of actual conditions during construction, including providing the required Special Inspections. We strongly recommend that ECS be retained to review pertinent portions of the project plans and specifications.

This report should be reproduced in its entirety only. Portions of this report should not be separated and used by others. It should be noted that this report was not prepared for the purpose of bid development and should not be used as such.

This geotechnical report is unique and was based on client needs and project requirements for the specific project described in this report. As such, no one other than who the report was intended and prepared for should rely on this report or the information contained within the report without first consulting with ECS. This report is not valid for any purpose or project except as described in this report.

This report and our recommendations were prepared using the generally accepted standards of geotechnical engineers practicing in this region. No warranty is express or implied.

APPENDIX

Site Location Diagram

Boring Location Plans

Karst Potential Diagram

Soil & Rock Classification

Boring Legend

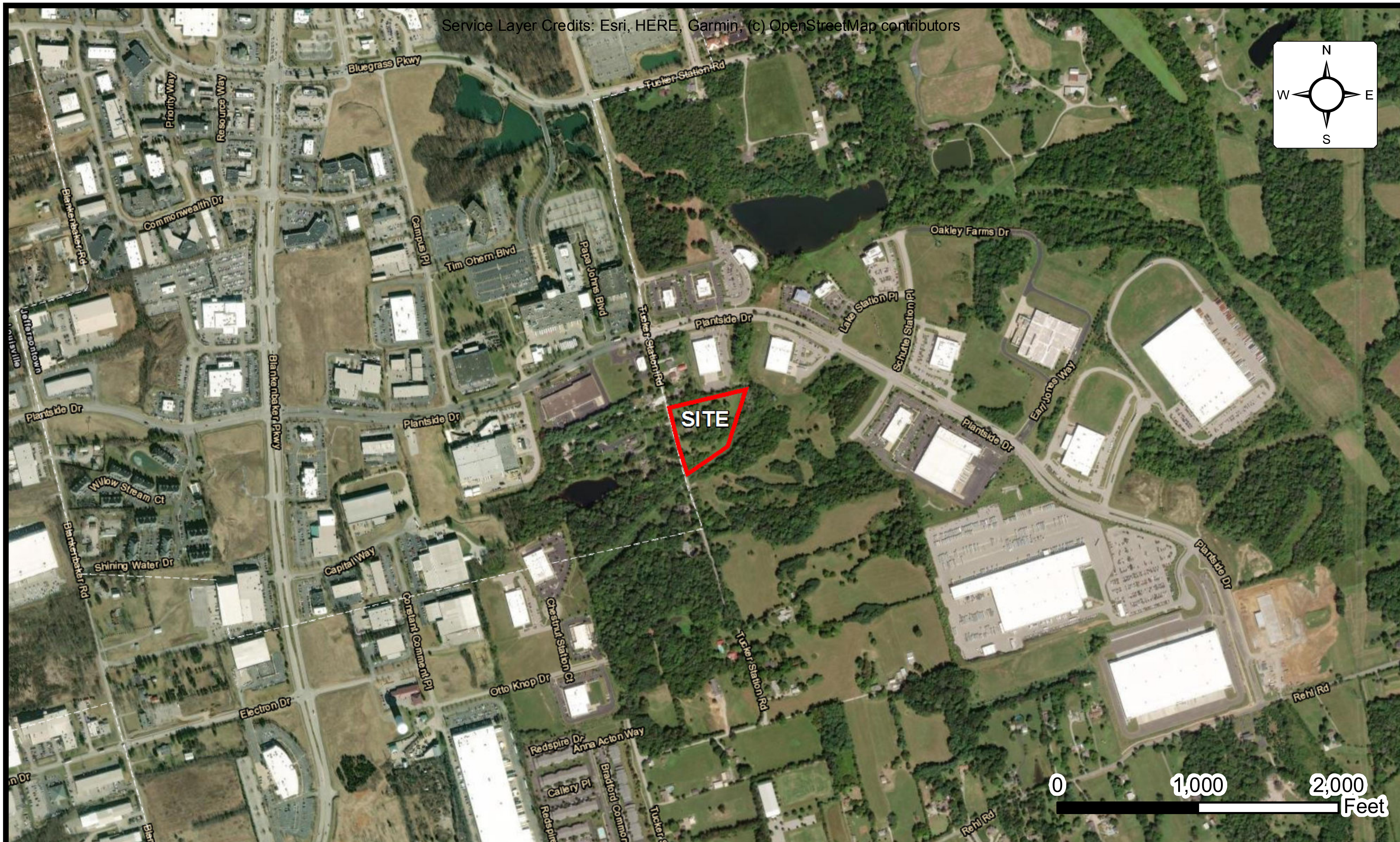
Boring Records

Boring Composite

Field Procedures

Laboratory Procedures

GBA "Important Information About Your Geotechnical Engineering Report"



Site Location Diagram
QUADRANT EXPANSION (QUAD 2)

12500 PLANTSIDE DRIVE, LOUISVILLE, KENTUCKY
QUADRANT INTERNATIONAL

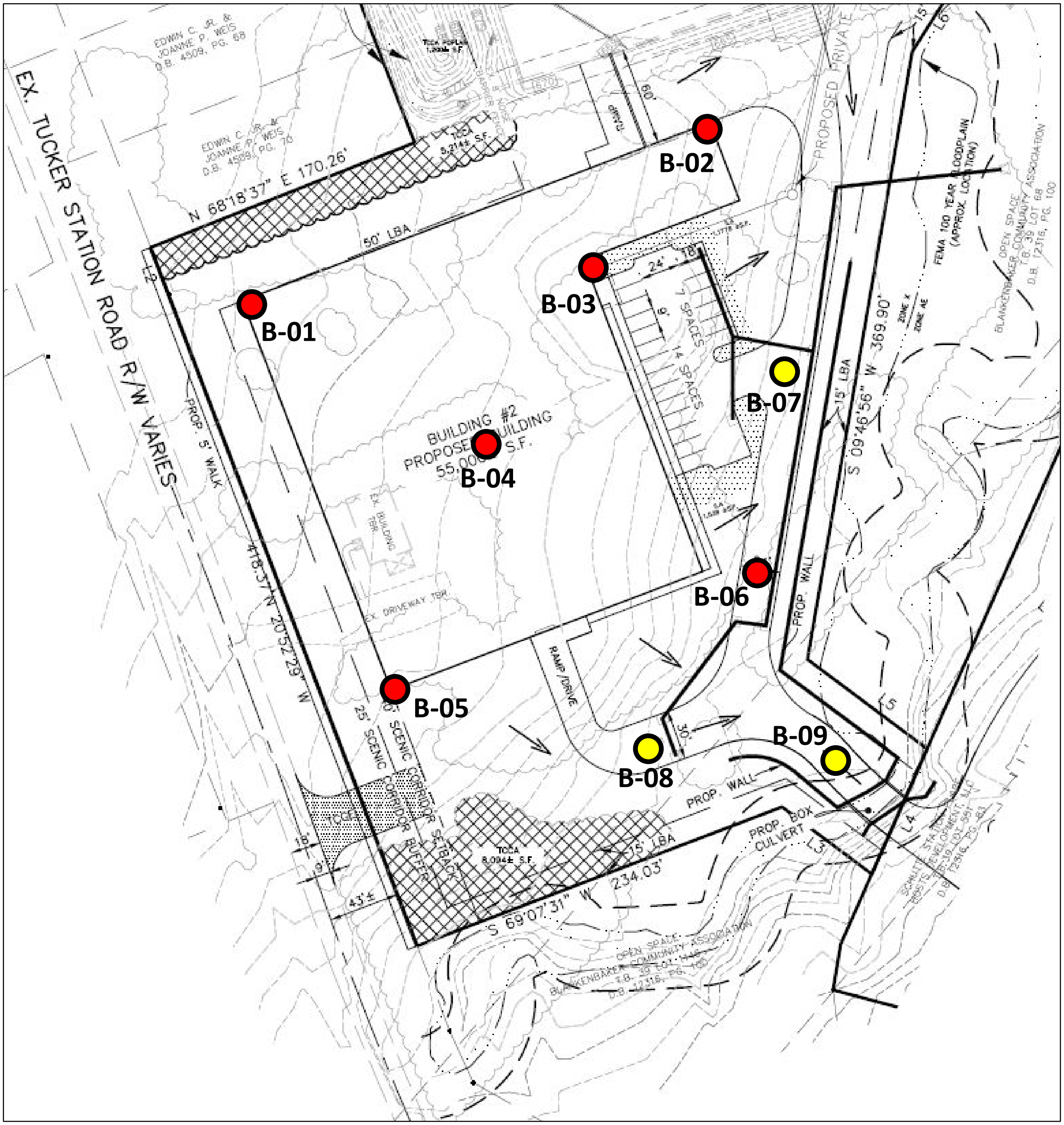
ENGINEER
S. ABDOLLAHIAN

SCALE
AS NOTED

PROJECT NO.
61:2769

SHEET
1 OF 1

DATE
6/15/2022



Boring in Building Areas (red circle) Boring in Pavement Areas (yellow circle)

Boring Location Plan
Quadrant Expansion (Quad 2)
12500 Plantside Drive
Louisville, Jefferson County, Kentucky 40299
ECS Project No. 61:2769

ECS Southeast, LLP
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Louisville, Kentucky 40299
Tel (502) 493-7100 Fax (502) 493-8190

Kentucky Geologic Map Information Service

June 7, 2022

1:9,028

0 0.1 0.2 0.4 mi
0 0.175 0.35 0.7 km

Kentucky Geological Survey

ECS Southeast, LLP

SOIL & ROCK CLASSIFICATION

SOIL CLASSIFICATION

MAJOR DIVISIONS			SYMBOLS	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS	Clean Gravels	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	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SAND AND SANDY SOILS	Clean Sands	SW	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sand, little or no fines
		Sands with fines	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE	SILTS AND CLAYS	Liquid Limit less than 50	ML	Inorganic silts, silty or clayey fine sands or clayey silts with slight plasticity
			CL	Inorganic clays of low to moderate plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS	Liquid Limit greater Than 50	MH	Inorganic silts, micaeceous or diatomaceous fine sand or silty soils
			CH	Inorganic clays of high plasticity
			OH	Organic clays of moderate to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT	Peat, humus, swamp soils with high organic contents

SOIL CONSISTENCY

SPT N: Standard Penetration Test N-Value N[1] – Manual Hammer (Rope & Pulley - 60% Efficiency) N[2] – Automatic Hammer (Free-Fall - 96% Efficiency)

COARSE GRAINED SOILS

SPT N[1]	SPT N[2]	Relative Density
0-4	0-3	Very loose
4-10	3-6	Loose
10-30	6-19	Medium dense
30-50	19-31	Dense
> 50	> 31	Very dense

FINE GRAINED SOILS

SPT N[1]	SPT N[2]	Field Identification
0-2	0-1	Very soft – Easily penetrated several inches by fist
3-4	2-3	Soft – Easily penetrated several inches by thumb
5-7	3-4	Firm – Can be penetrated several inches by thumb with moderate effort
8-15	5-9	Stiff – Readily indented by thumb but penetrated only with great effort
16-30	10-19	Very stiff – Readily indented by thumbnail
> 30	> 19	Hard – Indented with difficulty by thumbnail

SOIL PARTICLE SIZES

Description	Size Limits	Familiar Example
Boulder	12 inches or more	Larger than basketball
Cobble	3 - 12 inches	Orange to basketball
Coarse gravel	¾ - 3 inches	Grape to orange
Fine gravel	4.75 mm (No. 4 sieve) - ¾ inch	Pea to grape
Coarse sand	2-4.75 mm (No. 10 to 4 sieve)	Rock Salt
Medium sand	0.42-2 mm (No. 40 to 10 sieve)	Table Salt
Fine sand	0.075-0.42 mm (No. 200 to 40 sieve)	Powdered sugar
Silt/Clay/Fines	Less than 0.075 mm (No. 200)	Not visible to naked eye

RELATIVE PROPORTIONS

Description	Percent
Trace	1-5
Few	5-15
Little	15-30
Some	30-50
Mostly	50-100

ROCK CONTINUITY

Description	Core Recovery (%)
Incompetent	0-40
Competent	40-70
Fairly Continuous	70-90
Continuous	90-100

ROCK QUALITY DESIGNATION

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

ROCK BEDDING

Description	Thickness (in)
Parting	< 0.3
Band	0.3-2.5
Thin Bed	2.5-6.0
Medium bed	6.0-12.0
Thick bed	12.0-36.0
Massive	> 36.0

ROCK HARDNESS (Descriptions for rock core samples)

Description	Definition
Very soft	Can be broken with fingers
Soft	Can be scratched with fingernail; only edges can be broken with fingers
Moderately hard	Can be easily scratched with knife; cannot be scratched with fingernail
Hard	Difficult to scratch with knife; hard hammer blow to break specimen
Very hard	Cannot be scratched with knife; several hard hammer blows to break specimen

ROCK WEATHERING (Descriptions for rock core samples)

Description	Definition
Completely	Rock decomposed to soil; rock fabric and structure completely destroyed
Highly	Most minerals are decomposed; texture indistinct but fabric preserved; strength greatly reduced
Moderately	Discoloration throughout and weaker minerals decomposed; texture preserved but strength less than unweathered rock
Slightly	Discoloration around open fractures; strength preserved
Unweathered	No sign of decomposition

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BORING LEGEND

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf
			TOPSOIL	1.0							
			FILL	2.0							
			CLAY, low to moderate plasticity, (CL)	3.0							
			CLAY, moderate to high plasticity, (CH)	4.0							
5											
10											
15											
			Splitspoon Sample			16.0 - 17.0					
20											

Abbreviations
ATD - At the Time of Drilling

Notes
Dashed lines indicate an estimated or gradual strata change.

Solid lines indicate a more precise, measured depth value.

Comments

Scale - Proportional distance below the surface.

Elevation - Vertical distance above or below a benchmark.

Soil Symbol - Graphic representation of subsurface material.

Material Description - Account of encountered materials based on ASTM D-2488.

Depth - Distance below the surface to a strata as measured in the field.

Sample Type - Method for collecting soil or rock specimens.

Sample Depth - Collected specimen interval.

Recovery - Percentage of recovered sample material.

Standard Penetration Test Blows - Number of blows to drive a splitspoon sampler three 6" increments with a 140-lb. hammer falling 30".

N Value - Number of blows to drive the splitspoon the final foot. These blow counts have not been corrected for hammer efficiency or other applicable factors. The manual hammer, if used, has an estimated efficiency of 60%. The automatic hammer, if used, has an estimated efficiency of 96%.

Water Content - The weight of water divided by the weight of oven dried soil, expressed as a percentage.

Uc - Unconfined compressive strength.

Comments - Pertinent comments about the conditions encountered.

Remarks: Additional information about the surface, subsurface or other conditions that could impact the exploration results.

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Louisville, KY 40299

BORING RECORD

Project Name	**Quadrant Expansion (Quad 2)**			Boring No.	B-01
Location	**12500 Plantside Drive, Louisville, KY 40299**			Project No.	61:2769
Client	**Quadrant International**			Elevation	681 (a)
Driller	M. Reynolds	Rig Type	Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push	Hammer Type	Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD			Logged By	B. Hasanzadeh
				Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (5 inches)	0.4								
	680.0		CLAY, silty, brown with gray an tan mottling, low to moderate plasticity, stiff, moist, (CL), with trace to few black oxide nodules	1.5		0.0 - 1.5	100	2-3-3	6	23.9		
2.5			CLAY, silty, brown, tan brown, orange brown, high plasticity, stiff, moist to very moist, (CH), with few to little black oxide nodules - with some highly to completely weathered rock below approximately 2.5 feet	2.8		1.5 - 2.8	56	3-3-50/4"	50/4"	29.6		
	677.5		Boring Terminated at Direct Push Refusal									
5.0	675.0											
7.5	672.5											
10.0												

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	**Quadrant Expansion (Quad 2)**			Boring No.	B-02
Location	**12500 Plantside Drive, Louisville, KY 40299**			Project No.	61:2769
Client	**Quadrant International**			Elevation	666 (a)
Driller	M. Reynolds	Rig Type	Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push	Hammer Type	Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD			Logged By	B. Hasanzadeh
				Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (4 inches)	0.3								
	665.0		CLAY, silty, brown to tan brown with gray mottling, moderate plasticity, stiff to very stiff, dry to slightly moist, (CL), with trace to little black oxide nodules	1.5		0.0 - 1.5	100	2-4-6	10	19.7		
2.5			CLAY, silty, orange brown, high plasticity, stiff, slightly moist to moist, (CH), with few black oxide nodules			1.5 - 3.0	100	5-4-4	8	24.7		Liquid Limit: 77 Plastic Limit: 30 Plasticity Index: 47
	662.5											
5.0			- with some highly to completely weathered rock below approximately 5 feet	5.4		4.0 - 5.4	100	5-9-50/5"	50/5"			
			Boring Terminated at Direct Push Refusal									
	660.0											
7.5												
	657.5											
10.0												

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	**Quadrant Expansion (Quad 2)**	Boring No.	B-03
Location	**12500 Plantside Drive, Louisville, KY 40299**	Project No.	61:2769
Client	**Quadrant International**	Elevation	666 (a)
Driller	M. Reynolds — Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push — Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (4 inches)	0.2		0.0 - 0.3	100	50/4"	50/4"			
			CLAY, silty, tan brown, moderate plasticity, stiff, slightly moist, (CL), with some completely to highly weathered rock	0.5								
	665.0		Boring Terminated at Direct Push Refusal									
2.5												
	662.5											
5.0												
	660.0											
7.5												
	657.5											
10.0												

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	Quadrant Expansion (Quad 2)	Boring No.	B-04
Location	12500 Plantside Drive, Louisville, KY 40299	Project No.	61:2769
Client	Quadrant International	Elevation	673 (a)
Driller	M. Reynolds — Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push — Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (4 inches)	0.3								
	672.5		CLAY, silty, brown, low to moderate plasticity, moist, (FILL), with few black oxide nodules and trace rock fragments	0.9		0.0 - 1.5	100	2-3-3	6	21.0		
2.5	670.0		CLAY, silty, brown to tan brown, moderate plasticity, stiff to very stiff, slightly moist to moist, (CL), with trace to little black oxide nodules	3.5		1.5 - 3.0	100	5-5-6	11	19.7		
5.0	667.5		CLAY, silty, orange brown, high plasticity, very stiff, moist to very moist, (CH), with little black oxide nodules			4.0 - 5.5	100	5-6-8	14	24.6		Liquid Limit: 65 Plastic Limit: 27 Plasticity Index: 38
7.5	665.0		- orange brown and light gray, very moist, with little highly to completely weathered rock below approximately 7 feet	7.9		6.5 - 7.9	100	6-7-50/5"	50/5"	31.7		
10.0			Boring Terminated at Direct Push Refusal									

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	Quadrant Expansion (Quad 2)	Boring No.	B-05
Location	12500 Plantside Drive, Louisville, KY 40299	Project No.	61:2769
Client	Quadrant International	Elevation	673 (a)
Driller	M. Reynolds; Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push; Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (5 inches)									
	672.5		CLAY, silty, brown, low to moderate plasticity, stiff, moist, (CL), with trace to few black oxide nodules	0.4		0.0 - 1.5	100	2-2-3	5	20.5		
2.5			CLAY, silty, orange brown and gray, high plasticity, stiff to very stiff, moist, (CH), with few black oxide nodules	1.5		1.5 - 3.0	28	3-4-4	8	23.9		
5.0	670.0		- mostly highly to completely weathered rock below approximately 5 feet			4.0 - 5.4	100	5-7-50/5"	50/5"	28.1		
	667.5		Boring Terminated at Direct Push Refusal	5.4								
7.5	665.0											
10.0												

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	Quadrant Expansion (Quad 2)	Boring No.	B-06
Location	12500 Plantside Drive, Louisville, KY 40299	Project No.	61:2769
Client	Quadrant International	Elevation	657 (a)
Driller	M. Reynolds — Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push — Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (6 inches)	0.5								
			CLAY, silty, brown, low to moderate plasticity, firm, moist, (CL), with trace black oxide nodules and rootlets	1.9		0.0 - 1.5	100	0-1-3	4	21.2		
2.5	655.0		CLAY, silty, tan brown, orange brown, light gray, moderate to high plasticity, stiff to very stiff, slightly moist, (CH), with trace to few black oxide nodules			1.5 - 3.0	89	3-3-6	9	17.7		
5.0	652.5		- with highly to completely weathered rock below approximately 2.8 feet	5.3		4.0 - 5.3	73	13-26-50/3"	50/3"			
7.5	650.0		Boring Terminated at Direct Push Refusal									
10.0	647.5											

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	Quadrant Expansion (Quad 2)	Boring No.	B-07
Location	12500 Plantside Drive, Louisville, KY 40299	Project No.	61:2769
Client	Quadrant International	Elevation	658 (a)
Driller	M. Reynolds; Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push; Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (4 inches)	0.3								
	657.5		CLAY, silty, brown, orange brown, moderate plasticity, stiff, moist, (CL), with few black oxide nodules			0.0 - 1.5	100	2-3-4	7	25.8		
			- light gray between approximately 1.4 to 1.8 feet	1.8								
2.5	655.0		CLAY, silty, orange brown, moderate to high plasticity, very stiff to hard, moist, (CH), with trace to few black oxide nodules and trace chert fragments			1.5 - 3.0	100	6-5-6	11	27.0		
5.0	652.5		- orange brown and light gray, with little to some highly to completely weathered rock below approximately 4.5 feet			4.0 - 5.5	100	8-11-16	27			
				7.3		6.5 - 7.3	100	16-50/3"	50/3"			
7.5	650.0		Boring Terminated at Direct Push Refusal									
10.0												

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	**Quadrant Expansion (Quad 2)**	Boring No.	B-08
Location	**12500 Plantside Drive, Louisville, KY 40299**	Project No.	61:2769
Client	**Quadrant International**	Elevation	658 (a)
Driller	M. Reynolds — Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push — Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (4.5 inches)	0.4								
	657.5		CLAY, silty, brown, low to moderate plasticity, very soft to firm, moist to very moist, (CL), with trace to few black oxide nodules			0.0 - 1.5	100	2-2-2	4	23.7		
2.5			- brown, tan brown, gray, very moist, with few black oxide nodules below approximately 2 feet			1.5 - 3.0	100	2-1-0	1	33.9		
	655.0		- orange brown and light gray, with some to mostly highly to completely weathered rock below approximately 4.2 feet			4.0 - 4.8	100	6-50/3"	50/3"			
5.0			Boring Terminated at Direct Push Refusal	4.8								
	652.5											
7.5												
	650.0											
10.0												

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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BORING RECORD

Project Name	**Quadrant Expansion (Quad 2)**	Boring No.	B-09
Location	**12500 Plantside Drive, Louisville, KY 40299**	Project No.	61:2769
Client	**Quadrant International**	Elevation	655 (a)
Driller	M. Reynolds; Rig Type: Geo-Probe 7822DT	Started	6/08/2022
Drill Method	Direct Push; Hammer Type: Automatic	Completed	6/08/2022
Groundwater	Not encountered ATD	Logged By	B. Hasanzadeh
		Weather	70's - Clear

Scale, ft.	Elevation, ft.	Soil Symbol	Material Description and Classification	Depth, ft.	Sample Type	Sample Depth, ft.	Recovery, %	Standard Penetration Test Blows	N Value	Water Content, %	Uc, tsf	Comments
			TOPSOIL, (8 inches)	0.7								
			CLAY, silty, dark brown, gray brown, low to moderate plasticity, very soft to soft, moist to very moist, (CL), with trace to few black oxide nodules and rootlets			0.0 - 1.5	100	0-0-0	0	33.4		
2.5	652.5		- orange brown and light gray, mostly highly to completely weathered rock below approximately 2.4 feet	2.8		1.5 - 2.8	63	2-2-50/4"	50/4"	26.6		
			Boring Terminated at Direct Push Refusal									
5.0	650.0											
7.5	647.5											
10.0	645.0											

Remarks: (a) Ground surface elevations estimated to +/- 1- foot from Google Earth Imagery, dated 6/6/2020.

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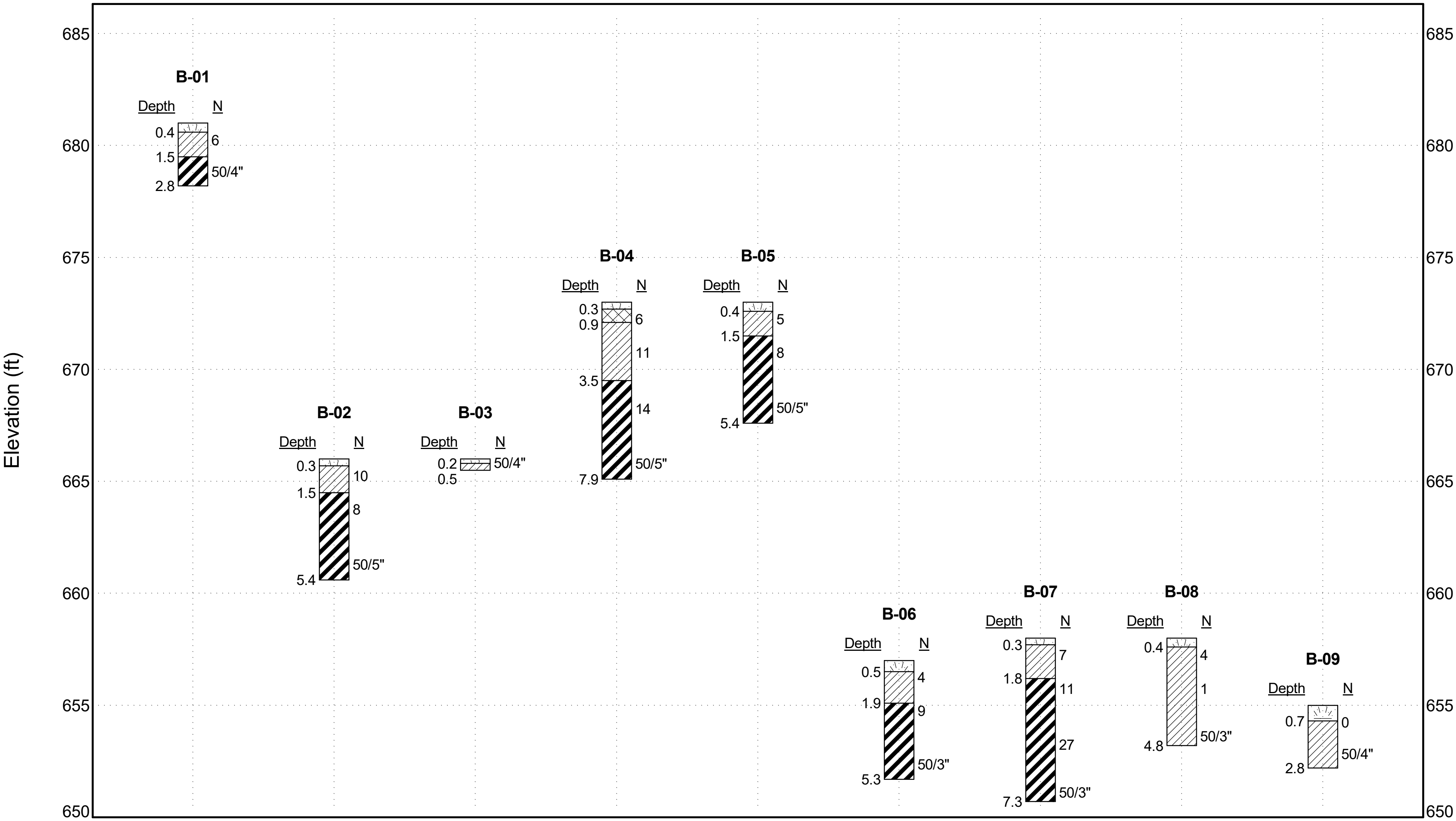
BORING COMPOSITE

CLIENT Quadrant International

PROJECT NUMBER 61:2769

PROJECT NAME Quadrant Expansion (Quad 2)

PROJECT LOCATION 12500 Plantside Drive, Louisville, KY 40299



BORING COMPOSITE 2769 BORING RECORDS.GPJ GEM ENGINEERING.GDT 6/15/22

Field Procedures

General

ECS conducts field sampling and testing procedures in general accordance with methods of the American Society for Testing Materials (ASTM) and widely accepted geotechnical engineering standards. A brief description of the procedures we utilize is provided in the following paragraphs.

Soil Borings (ASTM D-1452)

Soil borings are made with hollow stem augers or continuous augers which are mechanically advanced by a powered drill rig. At selected depths, soil samples are obtained with either a split-barrel sampler or a thin wall tube sampler. Soil borings are advanced to refusal, or to maximum depths as defined in our scope of work. The boring data, including sampling intervals, penetration resistances, soil classifications, and groundwater observations, are presented on the attached Boring Records.

Boring Locations and Elevations

Boring locations typically are selected by our project manager. The project manager establishes the boring locations in the field by pacing or measuring distances and estimating angles relative to existing site landmarks. When topographic plans of the site are provided, the project manager estimates the surface elevation of the boring locations using available information. Surveying to determine the locations and elevations of the borings is beyond the scope of typical geotechnical studies; therefore, the boring locations and elevations should be considered approximate.

Standard Penetration Test (SPT) Split-Barrel Samples (ASTM D-1586)

A split-barrel or "split spoon" is inserted into the borehole to obtain soil samples. The sampler is driven three, 6-inch increments with a 140-pound hammer falling from a height of 30 inches. The "standard penetration resistance" or "N-value" is the number of hammer blows required to drive the sampler the final 12 inches. The N-value, when properly evaluated, is an index of soil strength and/or density. Upon completion of each standard penetration test, the sampler is brought to the surface and the tube is opened to expose the recovered soil. Our project manager examines the sample, records the soil description and other pertinent information, and places a representative portion of the soil into a sealed container for transportation to our laboratory.

Water Level Readings

Water level readings are taken in each borehole upon the completion of drilling or excavation. In low permeability soils, such as silts and clays, the water level in the boreholes may take many hours to stabilize. Groundwater levels may be dependent upon recent rainfall activity and other site-specific factors. Since these conditions may change with time, the water level information presented on the Boring Records represents the conditions only at the time each measurement was taken.

Boring Records

Our interpretation of the conditions encountered at each location is indicated on the Boring Records, which are prepared from the observations of the ECS field engineer or geologist during drilling or excavation, our engineering review of the soil samples obtained, the results of laboratory testing on selected samples, and our experience with similar subsurface conditions. Soil descriptions are made using the Unified Soil Classification System and/or ASTM D-2488 as guides. The depths designating strata changes are estimations and only representative of depths at that specific boring location. In many geologic settings, the transition between strata is gradual. A Boring Legend, which defines the symbols and other pertinent information presented on the Boring Records, is provided with this report. The subsurface conditions indicated on our Boring Records represent only the conditions encountered at the specific boring location at the time of our exploration. The groundwater observations were made at the time of drilling and may vary with changes in the season and weather.

Refusal

Refusal is the term applied to material that cannot be penetrated with augers or has a standard penetration resistance exceeding 50 blows per 6-inch increment. Refusal may be encountered on continuous bedrock, discontinuous floaters, cemented soil, weathered rock, debris, buried structures, or other hard subsurface materials. Refusal materials can be evaluated only by obtaining a core of the material. This limitation must be considered when evaluating refusal depths where coring is not conducted.

Laboratory Procedures

General

Laboratory tests are generally conducted to satisfy one or more of the following objectives: (1) confirmation of visual-manual soil identification; (2) determination of index values used to estimate soil engineering properties (i.e., strength, compressibility, and permeability); or (3) direct measurement of specific soil properties. The tests selected for a given project are dependent on the subsurface conditions encountered, as well as specific project requirements, such as structural loads and planned grade changes. The results of laboratory tests conducted for this project are listed on the Boring Records, Laboratory Test Data Summary, or laboratory data curves in the Appendix. Brief descriptions of the test procedures are provided below.

Description and Identification of Soils (Visual-Manual Procedure) (ASTM D 2488)

The Visual-Manual Procedure provides a general guide to the engineering properties of soils and enables the engineer to apply experience to current situations. Samples obtained during the field exploration are examined and visually described and identified by a geotechnical engineer or geologist. The soils are typically identified according to predominant particle size (clay, silt, sand, etc.), consistency (based on apparent stiffness and the number of blows from standard penetration tests), color, moisture, and group symbol (CL, CH, SP, SC, etc.). Unless otherwise indicated, the soil descriptions in this report are based on the Visual-Manual Procedure.

Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D 2487)

The Visual-Manual Procedure described above is primarily qualitative. The Unified Soil Classification System (USCS) is used when precise soil classification is required. The USCS is based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index. Using these test results, the soil can be classified according to the Unified Classification System, which provides an index for estimating soil behavior.

Water (Moisture) Content of Soil (ASTM D 2216)

Moisture content is one of the most important index properties used in establishing a correlation between soil behavior and soil properties such as strength and compressibility. The moisture content, along with the liquid and plastic limits, are used to express the relative consistency or liquidity index of a soil. Increasing moisture contents typically reflect lower strengths for a given soil. The soil moisture content is the ratio, expressed as a percentage, of the mass of “pore” or “free” water in each mass of soil to the mass of the solid soil. Moisture content samples are taken from the sealed container obtained during the field exploration phase of a project. Each sample is weighed, and then placed in an oven set to $110^{o}C + 5^{o}$. Each sample remains in the oven until the free moisture evaporates. Each dried sample is removed from the oven, allowed to cool, and then weighed. The moisture content is computed by dividing the weight of evaporated water by the weight of the dry sample.

Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D 4318)

Depending upon the relative moisture content, a fine-grained soil may occur in a liquid, plastic, or solid state. In current usage, the liquid limit (LL) and plastic limit (PL) of a soil are referred to as the “Atterberg Limits”, which establish the approximate moisture contents at which the soil changes state. This test method is an integral part of several engineering classification systems to characterize the fine-grained fractions of soils. It is also used with other soil properties to correlate with engineering behavior such as compressibility, permeability, compactability, shrink-swell, and shear strength. The liquid limit is the moisture content at which a soil becomes sufficiently "wet" to behave as a heavy viscous fluid (i.e., transition from plastic to liquid state). It is defined as the moisture content at which the soil, when placed in a standard brass bowl, makes a 1/2-inch closure in a groove cut through the soil after the bowl is dropped 25 times at a specified height and rate. The plastic limit is the moisture content at which the soil begins to lose its plasticity (i.e., transition from plastic to semi-solid state). It is defined as the lowest moisture content at which the soil can be rolled into 1/8-inch diameter threads without crumbling. The plasticity index (PI) is the difference between the liquid limit and the plastic limit and is the range of moisture content over which a soil deforms as a plastic material.

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.***

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