

Geotechnical Engineering Investigation

**May River High School Building Addition
601 New Riverside Road
Bluffton, South Carolina**

June 24, 2019
Terracon Project No. HG195008

Prepared for:

Ward Edwards Engineering
Bluffton, South Carolina

Prepared by:

Terracon Consultants, Inc.
Savannah, Georgia

Offices Nationwide
Employee-Owned

Established in 1965
terracon.com

Terracon

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

June 24, 2019

Ward Edwards Engineering
P.O. Box 381
Bluffton, South Carolina 29910

Attn: Mr. Heath Duncan, P.E.
Vice President & Senior Project Manager
P: (843) 837 5250
E: hduncan@wardedwards.com

Re: Report of Geotechnical Engineering Investigation

May River High School Building Addition
601 New Riverside Road
Bluffton, South Carolina
Terracon Project No. HG195008

Dear Mr. Duncan:

Terracon Consultants, Inc. (Terracon) has completed the Geotechnical Engineering Investigation for the above-referenced project. The services were performed in general accordance with our proposal No. PHG195008. This report presents the findings of the subsurface exploration and provides geotechnical recommendations for the proposed construction.

We appreciate the opportunity to be of service to you. Should you have any questions concerning this report or if we may be of further service, please contact us at your convenience.

Sincerely,

Terracon Consultants, Inc.



Biraj Gautam, P.E.
Project Geotechnical Engineer

A handwritten signature in black ink, appearing to read "Guoming Lin".

Guoming Lin, Ph.D., P.E., D.GE.
Senior Principal

cc: 1 – Client (PDF)



Terracon Consultants, Inc. 379 Browns Cove Road, Ste.C Ridgeland, South Carolina 29936
P (843) 258 7070 F (843) 258-7070 terracon.com



TABLE OF CONTENTS

Section	Page
EXECUTIVE SUMMARY	i
1.0 INTRODUCTION	1
2.0 PROJECT INFORMATION	2
3.0 SUBSURFACE CONDITIONS	2
3.1 Typical Profile	2
3.2 Groundwater	3
4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION	4
4.1 Geotechnical Considerations	4
4.2 Demolition/Removal of Existing Structures.....	5
4.3 Earthwork.....	5
4.3.1 Site Drainage	5
4.3.2 Densification and Proofrolling	6
4.3.3 Fill Material Consideration	6
4.4 Spread Footing Foundations	7
4.4.1 Spread Footing Design Recommendations	7
4.4.2 Spread Footing Construction Considerations	8
4.5 Floor Slabs.....	9
4.5.1 Floor Slab Design Recommendations	9
4.5.2 Floor Slab Construction Considerations.....	9
4.6 Lateral Earth Pressure Considerations.....	10
4.7 Pavements.....	11
4.7.1 Flexible (Asphalt) Pavement Design Recommendations	13
4.7.2 Rigid (Concrete) Pavement Design Recommendations	14
4.7.3 Pavement Construction Considerations.....	15
4.7.4 Pavement and Subgrade Drainage.....	15
4.7.5 Pavement Maintenance	15
4.8 Seismic Considerations	16
4.8.1 Liquefaction Potential	16
4.8.2 Seismic Design Parameters	16
5.0 GENERAL COMMENTS	16

APPENDICES

APPENDIX A: FIELD EXPLORATION

Exhibit A-1	Site Location Map
Exhibit A-2	Exploration Location Plan
Exhibit A-3	Field Exploration Description
Exhibit A-4	CPT Sounding Cross Section
Exhibit A-5	CPT Sounding Log
Exhibit A-6	Hand Auger Boring Log

APPENDIX B: SUPPORTING INFORMATION

Exhibit B-1	Seismic Design Parameters
Exhibit B-2	Liquefaction Analysis Result
Exhibit B-3	CPT General Notes
Exhibit B-4	General Notes
Exhibit B-5	Unified Soil Classification System

EXECUTIVE SUMMARY

This report presents the results of our Geotechnical Engineering Investigation for the proposed wing addition to the existing building located at May River High School in Bluffton, South Carolina. Our investigation included a field exploration program, an engineering evaluation of the subsurface conditions, and a foundation recommendation. Based on the results of our subsurface exploration and analyses, the following geotechnical considerations were identified:

- In general, the subsurface profile consists of medium dense to dense sands in the upper 4 to 6 feet below ground surface (BGS), followed by mainly soft to stiff sandy clays to approximately 13 feet BGS. Below the soft to stiff clays, medium dense sands exist to approximately 26 to 27 feet BGS, which are then followed by mostly stiff clays to the termination of sounding at approximately 39 feet BGS.
- The groundwater depths were measured in the CPT sounding at approximately 6 to 12 feet at the time of our field exploration.
- Based on our settlement analyses with the assumed loads discussed in **Section 2.0**, the proposed building can be supported on a shallow foundation system after the subgrade has been improved by densification or undercut and backfill. The need and depth of undercut and backfill can be determined in the field during construction.
- **Please note** the type of foundation system required to support the proposed structures will depend upon the structural loads, development plan, and the foundation performance requirements. Terracon should be retained to perform additional evaluation if the structural loads are significantly different from those used in our settlement analyses.
- A net allowable bearing capacity of 2,000 pounds per square foot (psf) is recommended for shallow foundation design after achieving a stable subgrade. The allowable bearing capacity may be increased by 1/3 for transient wind load and seismic load conditions.
- For the seismic design, Terracon classifies the subject site as Site Class D in accordance with the International Building Code IBC (2015) and ASCE 7-10 Section 11.4.2.

This summary should be used in conjunction with the entire report for design purposes. It should be recognized that details were not included or fully developed in this section, and **the report must be read in its entirety** for a comprehensive understanding of the items and recommendations contained herein. The section titled **GENERAL COMMENTS** should be read for an understanding of the report's limitations.

GEOTECHNICAL ENGINEERING INVESTIGATION

May River High School Building Addition

601 New Riverside Road
Bluffton, South Carolina

Terracon Project No. HG195008
June 24, 2019

1.0 INTRODUCTION

Terracon Consultants (Terracon) has completed our Geotechnical Engineering Investigation for the proposed wing addition to the existing building located at May River High School in Bluffton, South Carolina. The general location of the project site and its vicinity are shown on the Site Location Map in **Exhibit A-1, Appendix A**.

The investigation included a field exploration program and engineering evaluation of the subsurface conditions and foundation recommendations. The subsurface conditions within the proposed expansion area were explored with a total of three Cone Penetration Test (CPT) soundings and three Hand Auger (HA) borings. The CPT soundings were pushed to depths of approximately 34 to 39 feet below ground surface (BGS), with the HA borings drilled to approximately 5 feet BGS.

A detailed presentation of the subsurface soils encountered at each sounding and borehole location during our site exploration can be found in the CPT sounding and the HA boring logs included in **Appendix A** of this report, along with a site location map and an exploration location plan.

The purpose of our investigation is to evaluate the existing subsurface conditions at the project site and develop conclusions and geotechnical recommendations for the proposed construction. The following study was conducted in accordance with our scope of services outlined in our proposal (Proposal No. PHG195008) dated April 8, 2019:

- | | |
|------------------------------|--------------------------------------|
| ■ subsurface soil conditions | ■ groundwater conditions |
| ■ site preparation | ■ foundation design and construction |
| ■ pavement recommendations | ■ seismic considerations |

2.0 PROJECT INFORMATION

Item	Description
Site location	The site is May River High School located at 601 New Riverside Road, Bluffton, South Carolina. Latitude: 32.2171 °, Longitude: -80.9718°
Current ground cover	Grassed area.
Existing topography	Relatively level.
Proposed Improvements	The proposed project will include a new wing addition to the existing building.
Finished floor elevation	Not provided at this time but assumed to be FFE of the adjacent buildings.
Maximum loads	The structural loading information has not been made available at this time. We assumed the following loads in our settlement analyses. Wall Load: 5 kips / ft. (assumed) Column Load: 75 kips (assumed) Building Slab Load: 200 psf (assumed) Note: If the structural loading is significantly different from those used in our settlement analyses, Terracon should be retained for further analyses.
Maximum allowable settlement	Total settlement: 1 inch (assumed). Differential settlement: ½ inch over 40 feet or between columns (assumed).
Grading	It is anticipated that the site work will involve minimal cut / fill (less than 2 feet) during the site preparation.

Should any of the above information or assumptions be inconsistent with the planned construction, Terracon should be informed so that modifications to this report can be made as necessary.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

Based on the results of the field exploration program, we developed a generalized soil profile to represent the soil conditions of the project site, and they can be generalized as follows:

Description	Approximate Depth to Stratum Bottom from Existing Grade (feet)	Soil Classification based on CPT Soundings	Consistency / Relative Density
Stratum 1	0.5*	Silty sands with grass roots.	n/a

Description	Approximate Depth to Stratum Bottom from Existing Grade (feet)	Soil Classification based on CPT Soundings	Consistency / Relative Density
Stratum 2	4 to 6	Silty sands	Medium dense to dense
Stratum 3	13	Sandy clays, with interbedded medium dense silty/clayey sands at various depths.	Soft to stiff
Stratum 4	17	Silty sands.	Medium dense
Stratum 5	26 to 27	Sandy clays.	Soft to medium stiff
Stratum 6 (varying soils)	29	Silty sands	Dense
		Sandy clays, with interbedded medium dense silty sands.	Stiff
Stratum 7	34 to 39	Sandy clays.	Stiff
Stratum 8	39.5, end of exploration	Silty sands.	Dense

***Please note** the depth / thickness of topsoil will vary, depending upon the near-surface soil disturbance during the site grading.

Details of subsurface conditions encountered at each sounding and boring location are presented in the individual CPT sounding and hand auger boring logs in **Appendix A**. Stratification boundaries on the logs represent the approximate depth of changes in soil types; the transition between materials may be gradual.

3.2 Groundwater

The groundwater depths were measured in the CPT sounding at approximately 6 to 12 feet at the time of our field exploration. We used a Slope Indicator® water level meter upon the completion of the CPT sounding tests to obtain the groundwater depths.

Groundwater was not encountered in any of the 5-foot Hand Auger (HA) borings at the time of our field exploration. Mottling which infers seasonal high groundwater level was determined in all HA borings at approximately 3 to 5 feet BGS.

It should be noted that groundwater levels tend to fluctuate with seasonal and climatic variations, as well as with construction activities. As such, the possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project. The groundwater table should be checked prior to construction to assess its effect on site work and other construction activities.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

The following evaluation and recommendations are based upon our understanding of the proposed construction and the results from our field exploration. If the above-described project conditions are incorrect or changed after this report, or subsurface conditions encountered during construction are significantly different from those reported, Terracon should be notified and these recommendations must be re-evaluated to make appropriate revisions.

4.1 Geotechnical Considerations

The subsurface conditions at this site are suitable for the proposed construction. The generalized soil profile is presented in **Section 3.1**.

The structural loading and the site grading plan of the proposed building have not been available at this time. We assume the building will have the column, the wall and the slab loads not exceeding 75 kips, 5 kips/ft. and 200 psf, respectively. We anticipate the proposed site will have minimal cut/fill (less than 2 feet) during site preparation.

If heavier structural loads are required than those discussed above, or if the site will receive significantly more fill, Terracon should be retained to perform the additional evaluation.

We performed the settlement analyses at each sounding location using the soil parameters derived from the CPT soundings and the structural loads discussed above. We estimated the settlement to be less than 1 inch for the column load of 75 kips, for the wall load of 5 kips/ft. and for the slab load of 200 psf.

As such, after the subgrade has been improved by densification, the proposed building can be supported on a shallow foundation system, resting on the improved subgrade. However, we anticipate some undercutting and backfilling may be required in isolated areas with loose / soft soils under the footings to achieve stable subgrade.

We recommend a thorough field quality control program of proofrolling of the subgrade. The bottom of the excavation should be observed for potentially unsuitable material. Hand auger boring and dynamic cone penetration (DCP) testing can be performed to evaluate and confirm the subgrade conditions.

The subgrade soils may lose some of their strengths when rain and surface water infiltrates into them. We recommend an effective drainage system in the proposed addition area to intercept rain and surface water.

A net allowable bearing capacity of 2,000 pounds per square foot (psf) is recommended for the shallow foundation design. The allowable bearing capacity may be increased by 1/3 for the transient wind load and seismic load conditions. Terracon should be retained to confirm and test the subgrade during construction to provide more specific recommendations on subgrade repair based on the conditions encountered at the footing subgrade.

During the site preparation, no topsoil, organic matter, stumps, undocumented fill, or other unsuitable materials should be left in place below footings, slab, and pavement. All foundations should bear on the suitable natural soil, or on properly compacted structural fill. Compacted fill below any foundation should be placed directly on suitable natural soil.

We recommend Terracon be retained to test the foundation subgrade during construction so that we can provide additional recommendations to prepare the subgrade based on the conditions uncovered during the subgrade preparation.

4.2 Demolition/Removal of Existing Structures

There are existing structures within the proposed building addition. We anticipate the existing structures will be demolished to accommodate the proposed construction. The demolition of the existing structure will leave old foundations and utilities at the site. These old foundations and utilities should be removed from the building areas. Any voids from the removal should be repaired by backfilling with compacted fill. The inert materials such as aggregate and concrete can be stockpiled for reuse as engineering fill, if desired. The crushed materials should be tested for gradation and impurity contents before its use.

4.3 Earthwork

The site work conditions will be largely dependent on the weather conditions and the contractor's means and methods in controlling surface drainage and protecting the subgrade. Site preparation should include clearing, stripping and grubbing of roots, removal of objectionable materials, and debris disposal. The site preparation should also include the installation of site drainage system, subgrade preparation, densification, and proofrolling. The following paragraphs present our considerations and recommendations for the site and subgrade preparation.

4.3.1 Site Drainage

An effective drainage system should be installed prior to site preparation and grading activities to intercept surface water and to improve overall shallow drainage. The drainage system may consist of perimeter ditches supplemented with parallel ditches and swales.

Pumping equipment should be prepared if the above ditch system cannot effectively drain water away from the site, especially during the rainy season. The site should be graded to shed water and avoid ponding over the subgrade.

4.3.2 Densification and Proofrolling

Prior to fill placement on the subgrade, the entire building and pavement areas should be densified with a heavy-duty static roller to achieve a uniform subgrade. **The contractor should take necessary precaution to avoid damages to the adjacent structures from the vibration of the equipment.**

The subgrade should be thoroughly proofrolled after the completion of densification. Proofrolling will help detect any isolated soft or loose areas that "pump", deflect or rut excessively, and also densify the near-surface soils for floor slab support.

A loaded tandem axle dump truck, capable of transferring a load in excess of 20 tons, should be utilized for this operation. Proofrolling should be performed under the Geotechnical Engineer's observation. Areas, where pumping, excessive deflection or rutting is observed after successive passes of the proofrolling equipment, should be undercut, backfilled and then properly compacted. It is anticipated that some amount of subgrade undercutting may be required under the foundation during subgrade preparation.

4.3.3 Fill Material Consideration

Structural fill should be placed over a stable or stabilized subgrade. The properties of the fill will affect the performance of the footings and the floor slabs. The soils to be used as structural fill should be free of organics, roots, or other deleterious materials. It should be a non-plastic granular material containing less than 25 percent fines passing the No. 200 sieve.

Based on the findings from our HA borings, the proposed site mostly consists of silty sands in the upper 2 to 5 feet BGS. The silty sands are generally considered suitable for structural fill, provided that the soils are free of roots, organics or other foreign materials.

Areas to receive structural fill should be placed in thin (8 to 10 inches loose) lifts and compacted to a minimum of 95 percent of the soil's Modified Proctor maximum dry density (ASTM D-1557). If import fill is required, the fill should be within 3 percent (wet or dry) of the optimum moisture content and should meet the properties as described above.

Some manipulation of the moisture content (such as wetting, drying) will be required during the filling operation to obtain the required degree of compaction. The manipulation of the moisture content is highly dependent on weather conditions and site drainage conditions.

Therefore, the contractor should prepare both dry and wet fill materials to obtain the specified compaction during grading. A sufficient number of density tests should be performed to confirm the required compaction of the fill material.

4.4 Spread Footing Foundations

After the subgrade has been improved by densification or undercut and backfill as discussed in **Section 4.1**, the proposed structures can be supported on a shallow, spread footing foundation system, provided that the proposed structure will not exceed the loads included in **Section 2.0** and the structure has a criteria of allowable settlement of 1.0 inch or greater. The following sections present design recommendations and construction considerations for the shallow foundations for the proposed structures and related structural elements.

4.4.1 Spread Footing Design Recommendations

Description	Column	Wall
Net allowable bearing pressure ¹	2,000 psf	2,000 psf
Minimum dimensions	24 inches	12 inches
Minimum embedment below finished grade	18 inches	12 inches
Approximate total settlement ²	<1 inch	<1 inch
Estimated differential settlement	<1 inch between columns	<1/2 inch over 40 feet
Ultimate Coefficient of sliding friction ³	0.32	

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. It assumes any unsuitable fill or soft soils, if encountered, will be replaced with compacted structural fill.
2. The foundation settlement will depend upon the variations in the subsurface soil profile, the structural loading conditions, the embedment depth of the footings, the thickness of compacted fill, and the quality of the earthwork operations. Footings should be proportioned to reduce differential settlements. Proportioning on the basis of equal total settlement is recommended; however, proportioning to relative constant dead-load pressure will also reduce differential settlement between adjacent footings.
3. Sliding friction along the base of the footing will not develop where net uplift conditions exist.

The design bearing pressure may be increased by one-third when considering total loads that include the wind or seismic conditions. The weight of the foundation concrete below grade may be neglected in dead load computations.

Footings, foundations, and masonry walls should be reinforced as necessary to reduce the potential for the distress caused by differential foundation movement. The use of joints at openings or other discontinuities in masonry walls is recommended.

Foundation excavations should be observed by the Terracon. If the soil conditions encountered differ significantly from those presented in this report, Terracon should be contacted to provide additional evaluation and supplemental recommendations.

4.4.2 Spread Footing Construction Considerations

The bottom of all foundation excavations should be free of water and loose soil and rock prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance.

Care should be taken to prevent wetting or drying of the bearing materials during construction. Extremely wet or dry material or any loose or disturbed material in the bottom of the footing excavations should be removed before foundation concrete is placed.

If the soils at bearing level become excessively dry, disturbed or saturated, the affected soil should be removed prior to placing concrete. A lean concrete mud-mat should be placed over the bearing soils if the excavations must remain open for an extended period of time.

Regarding the construction of footings, we generally anticipate material suitable for the recommended design bearing pressure will be present at the bottom of the footings. However, there is a possibility that isolated zones of soft or loose native soils could be encountered below footing bearing level, even though field density tests are expected to be performed during fill placement operations.

Therefore, it is important that Terracon be retained to observe, test, and evaluate the bearing soil prior to placing reinforcing steel and concrete to determine if additional footing excavation or other subgrade repair is needed for the design loads.

If unsuitable bearing soils are encountered in footing excavations, the excavations should be extended deeper to suitable soils and the footings could bear directly on those soils at the lower level or on lean concrete backfill placed in the excavations.

As an alternative, the footings could also bear on properly compacted structural backfill extending down to the suitable soils. Over-excavation for compacted backfill placement below footings should extend laterally beyond all edges of the footings at least 8 inches per foot of over-excavation depth below footing base elevation.

The over-excavation should be backfilled up to the footing base elevation with well-graded granular material placed in lifts of 6 inches or less in loose thickness and compacted to at least 95 percent of the material's maximum dry density as determined by the Modified Proctor test (ASTM D-1557).

No. 57 stone is recommended in lieu of structural fill when the volume of excavation is relatively small, re-compaction of the fill is difficult or the weather conditions or construction schedule becomes a controlling factor.

4.5 Floor Slabs

4.5.1 Floor Slab Design Recommendations

Item	Description
Floor slab support	Compacted structural fill / inspected and tested natural ground ¹ .
Modulus of subgrade reaction	120 pounds per square inch per in (psi / in) for point loading conditions.
Base course/capillary break²	4 inches of free draining granular material.
Vapor barrier	Project Specific ³ .
Structural considerations	Floor slabs should be structurally separated from columns and walls to allow relative movements ⁴ .

1. Because the existing ground may have been filled or disturbed previously, we recommend the subgrade be inspected and tested with proofrolling after the topsoil is stripped as outlined in **Section 4.3** of this report.
2. The floor slab design should include a base course comprised of free-draining, compacted, granular material, at least 4 inches thick. The granular subbase may be graded aggregate base (GAB) or sands containing less than 5 percent fines (material passing the #200 sieve). GAB subbase can also help improve the workability of the subgrade especially during rain periods.
3. The use of a vapor retarder should be considered beneath concrete slabs on the grade that will be covered with wood, tile, carpet or other moisture sensitive or impervious coverings, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer should refer to ACI 302 and / or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.
4. Floor slabs should be structurally independent of any building footings or walls to reduce the possibility of floor slab cracking caused by differential movements between the slab and foundation. Where floor slabs are tied to perimeter walls or turn-down slabs to meet structural or other construction objectives, our experience indicates that any differential movement between the walls and slabs will likely be observed in adjacent slab expansion joints or floor slab cracks that occur beyond the length of the structural dowels. The structural engineer should account for this potential differential settlement through the use of sufficient control joints, appropriate reinforcing or other means.

4.5.2 Floor Slab Construction Considerations

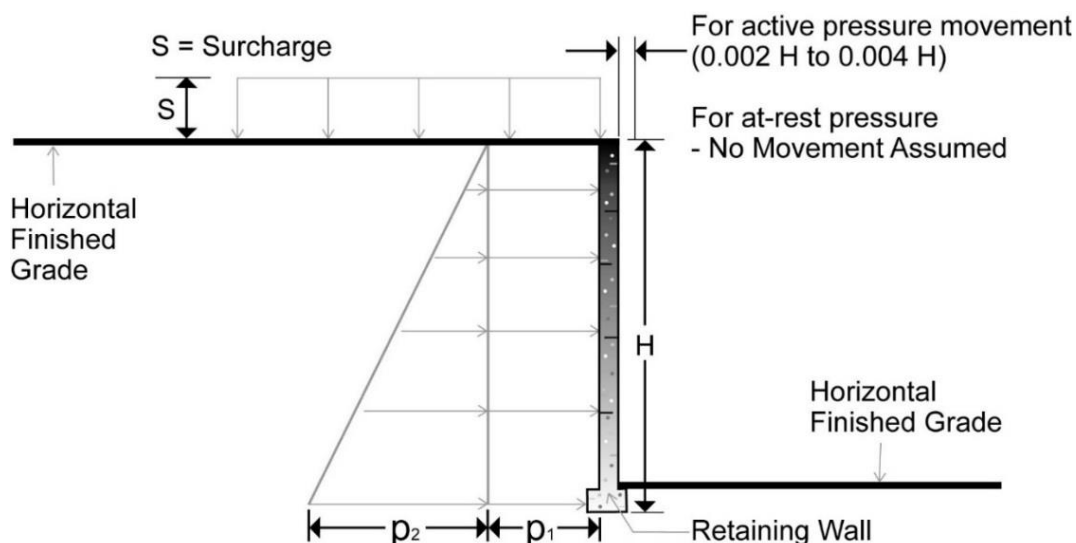
Prior to the construction of grade supported slabs, varying levels of remediation may be required to reestablish stable subgrades within slab areas due to construction traffic, rainfall, disturbance, desiccation, etc. As a minimum, the following measures are recommended:

- The interior trench backfills placed beneath slabs should be compacted in accordance with recommendations outlined in **Section 4.4** of this report.
- All floor slab subgrade areas should be moisture conditioned and properly compacted to the recommendations in this report immediately prior to placement of the concrete.

4.6 Lateral Earth Pressure Considerations

The foundation walls with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to those indicated in the following table. The earth pressure parameters are recommended based on the structural fills specified in **Section 4.4**.

Earth pressures will be influenced by the structural design of the walls, conditions of wall restraint, methods of construction and/or compaction and the strength of the materials being restrained. Two wall restraint conditions are shown. Active earth pressure is commonly used for the design of free-standing cantilever retaining walls and assumes wall movement. The "at-rest" condition assumes no wall movement. The recommended design lateral earth pressures do not include a factor of safety or possible hydrostatic pressure on the walls.



Earth Pressure Coefficients

Earth Pressure Conditions	Coefficient for Backfill Type	Equivalent Fluid Density (pcf)	Surcharge Pressure, p_1 (psf)	Earth Pressure, p_2 (psf)
Active (K_a)	Granular - 0.33	40	$(0.33)S$	$(40)H$
At-Rest (K_o)	Granular - 0.46	55	$(0.46)S$	$(55)H$
Passive (K_p)	Granular - 3.00	360	---	---

Applicable conditions to the above include:

- For active earth pressure, wall must rotate about base, with top lateral movements of about $0.002 H$ to $0.004 H$, where H is wall height
- For passive earth pressure to develop, wall must move horizontally against the fill to mobilize resistance
- Uniform surcharge, where S is surcharge pressure
- In situ soil backfill weight a maximum of 115 pcf
- Horizontal backfill, compacted between 95 percent of modified Proctor maximum dry density
- Loading from heavy compaction equipment or dynamic loading not included
- No hydrostatic pressures acting on wall
- No safety factor included in soil parameters

Backfill placed against structures should consist of granular soils. The granular backfill must extend out from the base of the wall at an angle of at least 45 and 60 degrees from vertical for the active and passive cases, respectively. To calculate the resistance to sliding, a value of 0.35 should be used as the ultimate coefficient of friction between the footing and the underlying soil. We recommend the friction between the soils and sides of grade beams and footings be ignored due to the shallow depth of grade beams and footings.

Depending on the depth of excavation and long-term groundwater conditions, the unbalanced hydrostatic pressure may be considered in the design of the retaining wall. To control hydrostatic pressure behind the wall, we recommend that a drain be installed at the foundation wall with a collection pipe leading to a reliable discharge such as a stormwater drain. If this is not possible, hydrostatic pressure should be added to the lateral earth pressures recommended above. These pressures do not include the influence of surcharge, equipment or floor loading, which should be added. Heavy equipment should not operate within a distance closer than the exposed height of retaining walls to prevent lateral pressures more than those provided.

4.7 Pavements

This section presents thickness recommendations for asphalt concrete and Portland cement concrete pavements and general considerations for the pavement construction. Pavement thickness design is dependent upon:

- The traffic loads including traffic pattern and the service life of the pavement;
- Subgrade conditions including soil strength and drainage characteristics;
- Paving material characteristics;

- Climatic conditions of the region.

Traffic patterns and anticipated loading conditions have not been made available at this time. We anticipate traffic loads will be produced primarily by automobile traffic, pickup trucks and a limited number of delivery and trash removal trucks.

We have provided two pavement section alternatives: light-duty and heavy-duty sections. The light-duty section is constructed for the areas that receive only car traffic. The heavy-duty section assumes car traffic and 10 delivery vehicles per day and 5 trash removal trucks per week. If heavier traffic loading is expected, this office should be provided with the anticipated traffic loading information and allowed to review these pavement sections.

A design life of 20 years was assumed to develop the total traffic used in thickness design. However, as typical for pavement, some maintenance repairs are typically required for a period of 7 to 10 years.

For the pavement support, the subgrade conditions can often be the overriding factor in pavement performance. The subgrade conditions will depend on the in-situ soils at the subgrade level, characteristics of fill material for the subgrade, as well as the site preparation procedures.

Assuming the finished subgrade will be near the existing ground surface, based on the Hand Auger (HA) borings, the near surface soils are mostly silty sands. The silty sands are generally considered suitable for the subgrade support.

If, during construction, clayey sands or sandy clays are encountered at the subgrade level, the upper (2) feet of the subgrade should be replaced with relatively clean sands with percent fines less than 15 percent. A California Bearing Ratio (CBR) value of 8 has been estimated based on the in-situ soils at the site, and typical imported fills available in this area.

Climatic conditions are considered in the design subgrade support value listed above and in the paving material characteristics. Recommended paving material characteristics, taken from the South Carolina Department of Transportation's (SCDOT) Standard Specifications for Highway Construction, 2007 edition are included for the asphalt and concrete sections.

4.7.1 Flexible (Asphalt) Pavement Design Recommendations

Material	Minimum Section Thickness (inch)		
	Light-Duty Section	Heavy-Duty Section	
	Auto Parking	Access Road for Delivery / Trash Collection Vehicles	Concentrated and Repetitive Loading Areas (e.g. Dumpster pad, truck delivery docks and ingress / egress aprons)
Asphalt Surface Course ¹	2	1 ½	We recommend concrete pavement sections for concentrated and repetitive loading areas, as concrete pavement, in general, performs better in these areas. Please refer to Section 4.7.2 for the pavement section.
Asphalt Intermediate Course ¹	0	2	
Graded Aggregate Base Course ¹	7	8	
Total Pavement Section	9	11 ½	
Select fill ² / improved subgrade ³	24	24	

1. Subgrade, base, and pavement construction operations and materials should meet the minimum requirements of the South Carolina Department of Transportation's (SCDOT) Standard Specifications for Highway Construction, 2007 edition. The Aggregate Base Course should be compacted to 100% of its Modified Proctor as determined by AASHTO T-180. The Asphalt Concrete should be compacted to at least 95% of the maximum unit weight, as determined by the Marshall Mix Design Procedures.
2. The select fill should be relatively clean sands with percent fines less than 15% and should be compacted to a minimum of 95% of the soil's Modified Proctor maximum dry density (ASTM D-1557).
3. If SP or SP-SM or SM soils exist at the proposed subgrade elevation extending to a depth at least 24 inches below the proposed subgrade level, the in-situ soils can replace the select fill and the subgrade should be improved using densification as discussed in **Section 4.3**.

Notes:

- Proper surface and subgrade drainage system should be installed to avoid the saturation of subgrade soils underneath the asphalt pavements and should be designed to maintain the groundwater at least 2 feet below the top of the subgrade.
- We anticipate some subgrade soil undercutting and backfilling with suitable structural fill will be required if unstable subgrade soils are encountered during the subgrade preparation. The use of geogrid (Tensar BX1100 or equivalent) may be necessary to help reduce the depth of undercut to achieve stability if the unstable subgrade soils extend to greater depths. The need for geogrid and/or the need for undercutting and backfilling should be determined in the field during subgrade preparation.

4.7.2 Rigid (Concrete) Pavement Design Recommendations

Material	Minimum Section Thickness (inch)		
	Light-Duty Section	Heavy-Duty Section	
	Auto Parking	Access Road for Delivery / Trash Collection Vehicles	Concentrated and Repetitive Loading Areas (e.g. Dumpster pad, truck delivery docks and ingress / egress aprons)
Concrete ¹	5	7	8
Graded aggregate base ²	4	4	4
Select fill ³ / improved subgrade ⁴	24	24	24

1. The concrete should be air entrained and have a minimum compressive strength of 4,000 psi after 28 days of lab curing per ASTM C-31.
2. The graded aggregate base should conform to the SCDOT material specification Section 305.
3. The select fill should be relatively clean sands with percent fines less than 15%. The fill material should be compacted to a minimum of 95% of the soil's Modified Proctor maximum dry density (ASTM D-1557).
4. If SP or SP-SM or SM soils exist at the proposed subgrade elevation extending to a depth at least 24 inches below the proposed subgrade level, the in-situ soils can replace the select fill and the subgrade should be improved using densification as discussed in **Section 4.3**.

Notes:

- Concrete joints should be sealed properly to avoid the ingress of surface water into the subgrade soils. Proper surface and subgrade drainage system should be installed to avoid the saturation of subgrade soils underneath the concrete pavements. The site drainage should be designed to maintain the groundwater at least 2 feet below the top of the subgrade.
- Some subgrade soil undercutting and backfilling with suitable structural fill will be required if unstable subgrade soils are encountered during subgrade preparation. The use of geogrid (Tensar BX1100 or equivalent) may be necessary to help reduce the depth of undercut to achieve stability if the unstable subgrade soils extend to greater depths. The need for geogrid and/or the need for undercutting and backfilling should be determined in the field during subgrade preparation.

For the pavements subject to concentrated and repetitive heavy loading conditions such as container parks, truck delivery docks and ingress/egress aprons, we recommend Portland cement concrete pavement with a minimum thickness of 8 inches. The concrete pavement can be poured over compacted granular subgrade (sand) or on at least 4 inches of the graded aggregate base (GAB stone).

We emphasize the use of the stone base under the pavement even though the stone base is not part of the pavement structural design. Based on our experience, the stone base can be significantly help improve the constructability during construction especially in rainy seasons. Furthermore, the stone base will help maintain subgrade stability and support when the subgrade is wet due to the rise of groundwater or infiltration of surface water through the pavement joints

or cracks. The stone base enhances pavement constructability condition during construction and long-term performance. We recommend the use of stone base be considered based on the cost benefit analysis.

The above rigid and flexible pavement sections represent the minimum design thicknesses and, as such, periodic maintenance should be anticipated. Prior to the placement of the subbase (compacted structural fill), the pavement areas should be thoroughly proofrolled.

4.7.3 Pavement Construction Considerations

Pavement subgrades prepared early in the project should be carefully evaluated as the time for pavement construction approaches. We recommend the pavement areas be rough graded and then thoroughly proofrolled with a loaded tandem-axle dump truck.

Particular attention should be paid to the high traffic areas that were rutted and disturbed and to the areas where backfilled trenches are located. Areas where unsuitable conditions are located should be repaired by removing and replacing the materials with properly compacted fill.

After proofrolling and repairing subgrade deficiencies, the entire subgrade should be scarified to a depth of 12 inches, and uniformly compacted to at least 95% of the materials' modified Proctor maximum dry density.

4.7.4 Pavement and Subgrade Drainage

Poor subgrade drainage is the most common cause of pavement failure. Pavement should be sloped to provide a rapid drainage of surface water. Water should not be allowed to pond on the pavement surface or adjacent to the pavement which would saturate the subgrade soils and weaken the subgrade support. We recommend the site drainage be designed to maintain the groundwater at least two (2) feet below the top of the subgrade.

Pavement subgrade drainage should be installed surrounding the areas anticipated for frequent wetting or having poor natural drainage, such as landscaped islands, along curbs and gutters and around drainage structures.

All landscaped areas in or adjacent to pavements should be sealed to reduce the moisture migration to subgrade soils. Subgrade drains should be installed with the pipe bottom at least two (2) feet below the top of the select fill. The civil engineer should decide the placement of the subgrade drains to avoid the saturation of pavement subgrade.

4.7.5 Pavement Maintenance

The performance of pavements will require regular maintenance. One key component of the maintenance is to minimize the infiltration of water into the pavement base and subgrade. Preventive maintenance should include crack and joint sealing and patching, as well as overall

surface sealing and overlay. Additional engineering observation and evaluation is recommended prior to any major maintenance.

4.8 Seismic Considerations

4.8.1 Liquefaction Potential

We performed a liquefaction potential analysis for the site to evaluate the stability of the soils. Ground shaking at the foundation of structures and liquefaction of the soil under the foundation are the principal seismic hazards identified for the design of earthquake-resistant structures. Our estimates of liquefaction induced settlements from the geometric mean maximum considered earthquake (MCE_G) are close to 1 inch.

Actual liquefaction settlement at the site would be highly dependent on the magnitude and distance from the source during the design earthquake event. In the event of an earthquake, the structure may sustain some damage that should be repairable. The above-estimated magnitude of settlement should not cause the structure to collapse. As such, it would not be necessary to use special ground improvement measures to mitigate the risk of liquefaction for the proposed structure.

4.8.2 Seismic Design Parameters

Based on the findings from the field exploration and our knowledge of the local geological formation in the project area, the site can be classified as Site Class D in accordance with International Building Code (IBC) 2015 and ASCE 7-10. The seismic design parameters obtained based on IBC2015 and ASCE 7-10 are summarized in the following table. The design response spectrum curve, as presented in **Appendix B**, was developed based on the S_{DS} and S_{D1} values according to IBC2015 and ASCE 7-10.

Summary of Seismic Design Parameters

Site Location (Lat. – Long.)	Site Classification	S_s	S_1	F_a	F_v	S_{DS}	S_{D1}
32.2171° -80.9718°	D	0.362g	0.133g	1.511	2.267	0.364g	0.202g

- The Site Class for this site was determined based on the soil properties to the maximum exploration depth and estimated soil properties below the maximum exploration depth to 100 feet based on our experience with the geologic conditions of the site area in accordance with the 2015 IBC and ASCE 7-2010.

5.0 GENERAL COMMENTS

Terracon should be consulted to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations

in the project design and specifications. Terracon should also be retained to provide observation and testing services during grading, excavation, foundation construction and other earth-related construction phases of the project.

The analyses and recommendations presented in this report are based upon the data obtained from the explorations performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between exploration locations, across the site, or may be caused due to the modifying effects of construction or weather. Bear in mind that the nature and extent of such variations may not become evident until construction has started or until construction activities have ceased.

If variations do appear, Terracon should be notified immediately so that further evaluation and supplemental recommendations can be provided. The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, and bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or hazardous conditions. If the owner is concerned about the potential for such contamination or pollution, please advise so that additional studies may be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project and site discussed, and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. Site safety, excavation support and dewatering requirements are the responsibility of others.

In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes, and then either verifies or modifies the conclusions of this report in writing.

APPENDIX A

Field Exploration

- § Exhibit A-1 Site Location
- § Exhibit A-2 Exploration Plan
- § Exhibit A-3 Field Exploration Description
- § Exhibit A-4 CPT Cross-Section Log
- § Exhibit A-5 CPT Sounding Log
- § Exhibit A-6 Hand Auger Boring Log



Image Courtesy of
Google Earth™

Project Manager:	BG
Drawn by:	DL
Checked by:	GL
Approved by:	GL

Project No.	HG195008
Scale:	N.T.S
File Name:	HG195008
Date:	06/24/2019

Terracon
Consulting Engineers & Scientists

2201 Rowland Avenue Savannah, Georgia 31404
Phone (912) 629 4000 Fax (912) 629 4001

SITE LOCATION MAP

May River High School Addition
601 New Riverside Road
Bluffton, South Carolina

Exhibit

A-1

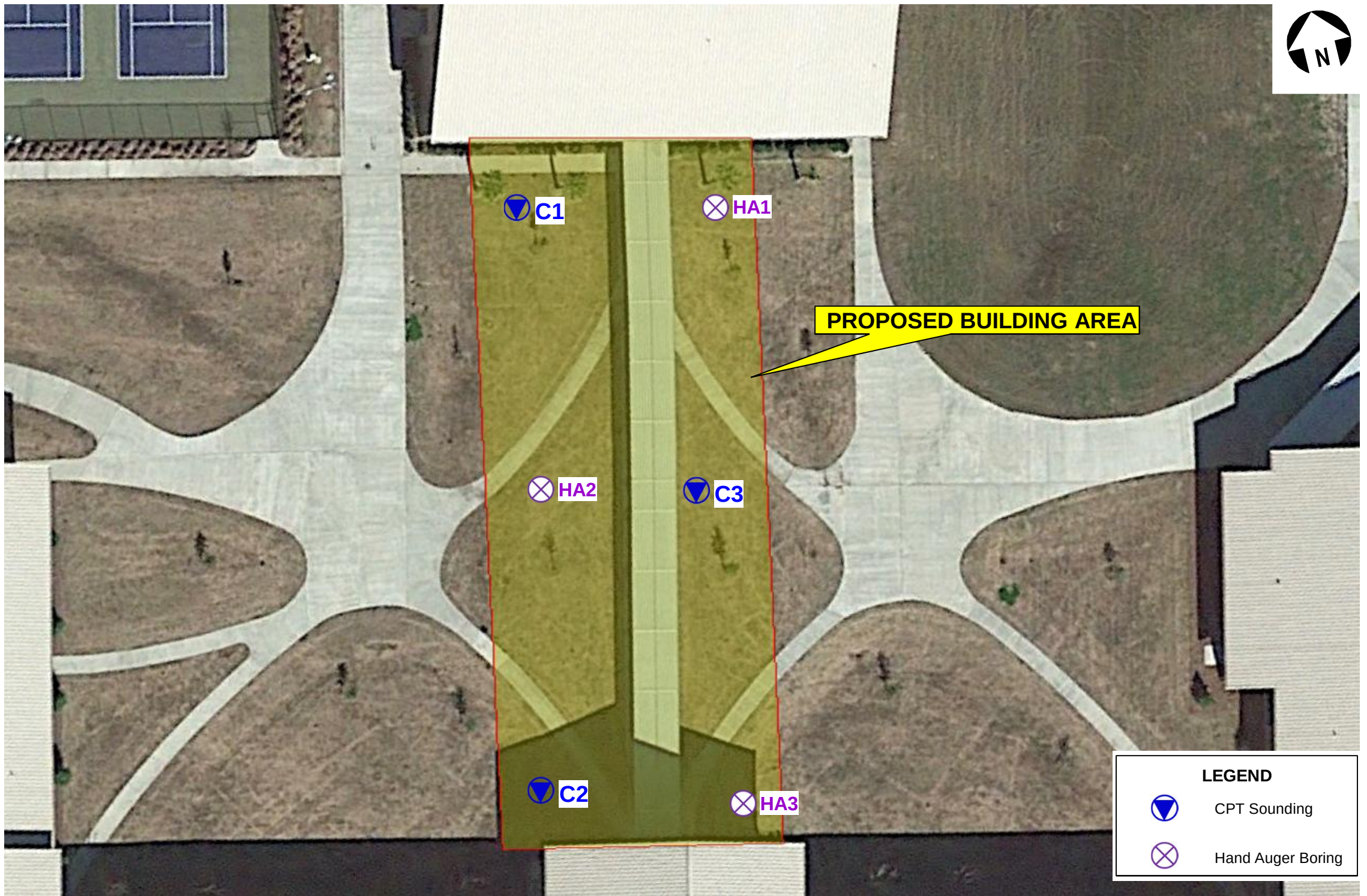


Image Courtesy of
Google Earth™

Project Manager: BG	Project No. HG195008	 2201 Rowland Avenue Savannah, Georgia 31404 Phone (912) 629 4000 Fax (912) 629 4001	EXPLORATION LOCATION MAP May River High School Addition 601 New Riverside Road Bluffton, South Carolina	Exhibit: A-2
Drawn by: DL	Scale: N.T.S.			
Checked by: GL	File Name: HG195008			
Approved by: GL	Date: 06/24/2019			

Field Exploration Description

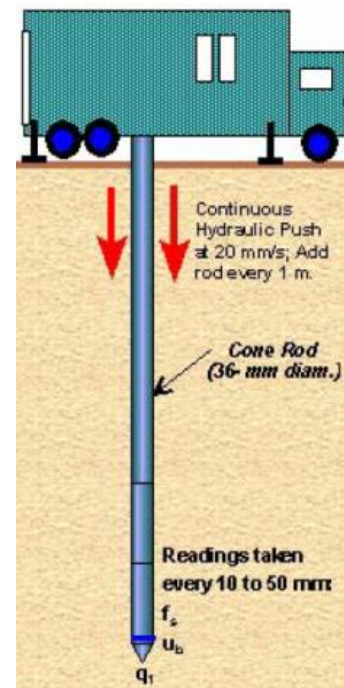
The locations of the Cone Penetration Test (CPT) soundings and the Hand Auger (HA) borings were determined by Terracon based on the proposed plan and located in the field using a hand-held GPS unit and in reference to the existing site features. These locations are shown on the Exploration Location Plan and should be considered approximate.

Cone Penetration Testing

The CPT hydraulically pushes an instrumented cone through the soil while nearly continuous readings are recorded to a portable computer. The cone is equipped with electronic load cells to measure tip resistance and sleeve resistance and a pressure transducer to measure the generated ambient pore pressure. The face of the cone has an apex angle of 60° and an area of 10 cm^2 . Digital data representing the tip resistance, friction resistance, pore water pressure, and probe inclination angle are recorded about every 2 centimeters while advancing through the ground at a rate between $1\frac{1}{2}$ and $2\frac{1}{2}$ centimeters per second. These measurements are correlated to various soil properties used for geotechnical design. No soil samples are gathered through this subsurface investigation technique.

CPT testing is conducted in general accordance with ASTM D5778 "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils."

Upon completion, the data collected were analyzed and processed by the project engineer.

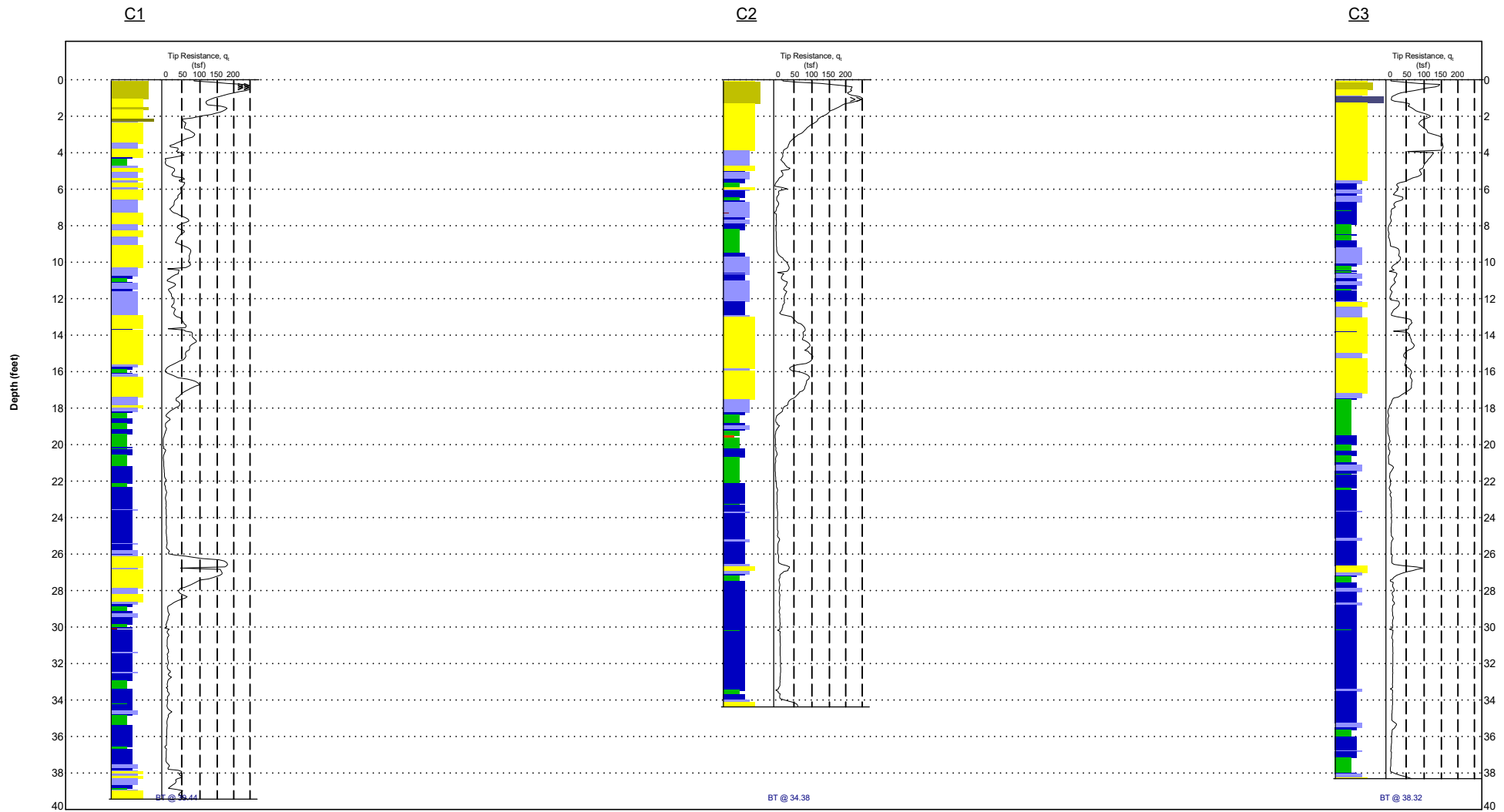


Source: FHWA NHI-06-088

Hand Auger Borings

Hand auger borings were conducted in general accordance with ASTM D 1452-80, Standard Practice for Soil Investigation and Sampling by Auger Borings. In this test, hand auger borings are drilled by rotating and advancing a bucket auger to the desired depths while periodically removing the auger from the hole to clear and examine the auger cuttings. The soils were classified in accordance with ASTM D2488.

THIS TEST RECORD IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. 11X17 CPT FENCE HG195008 MARY RIVER HIGH S.GPJ FENCE PROJECT 1-30-13.GPJ 6/10/19



Explanation



NOTES:
See Exhibit for orientation of soil profile.
See General Notes in Appendix C for symbols and soil classifications.
Soils profile provide for illustration purposes only.
Soils between borings may differ
AR - Auger Refusal
BT - Boring Termination

Project Manager: BG
Drawn by: BG
Approved by: GL
Date: 6/24/2019

Project No.: HG195008
Scale: N.T.S.
File Name: ES195008

Terracon
379 Browns Cove Rd Ste C
Ridgeland, SC
PH.843-258-7070 FAX. 843-258-7070

SUBSURFACE PROFILE

May River High School Building Addition
New Riverside Road
Bluffton, South Carolina

EXHIBIT

A-4

CPT LOG NO. C1

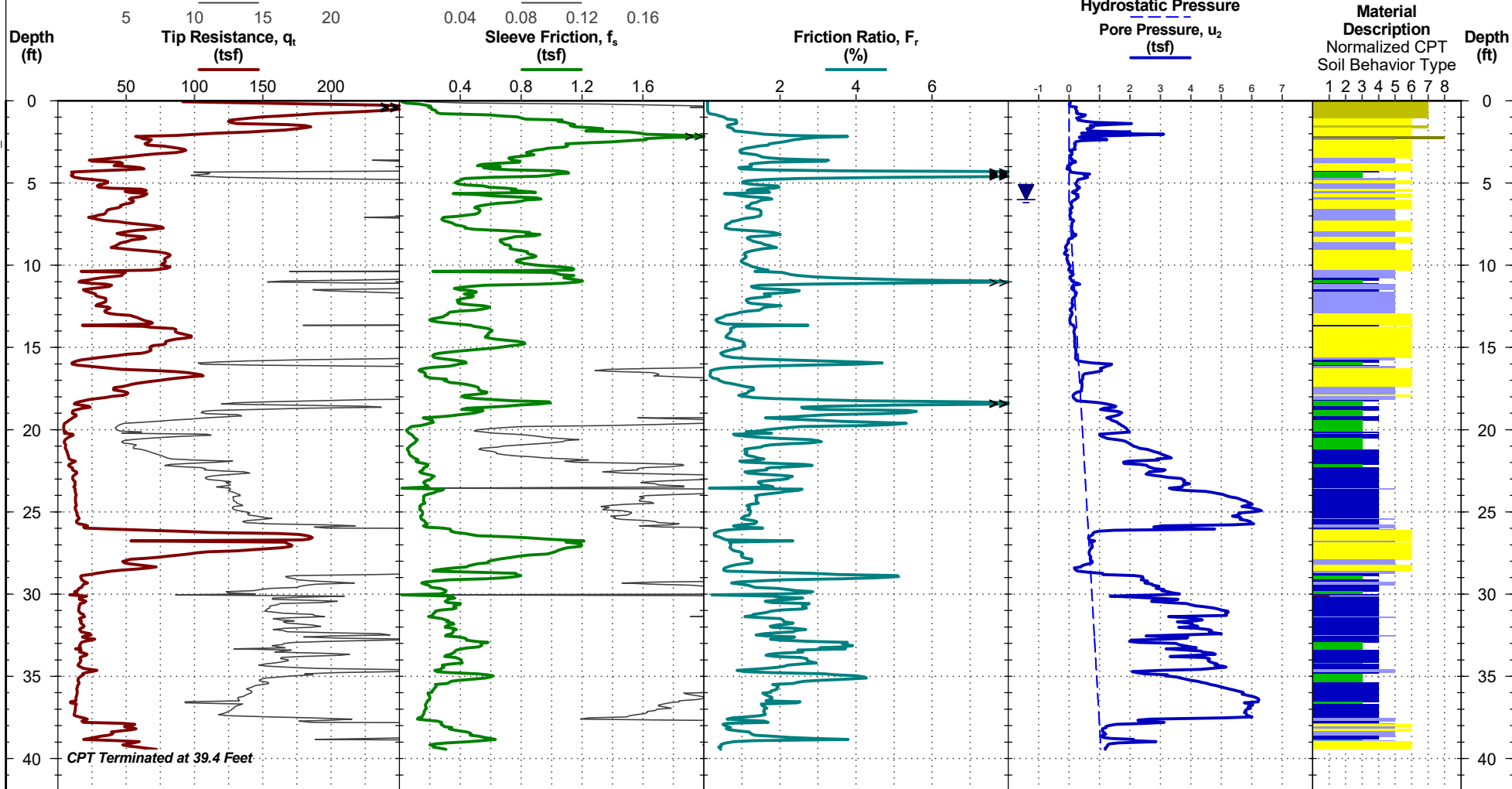
Page 1 of 1

PROJECT: May River High School Building Addition

CLIENT: Ward Edwards Engineering
Bluffton, SC

TEST LOCATION: See Exhibit A-2

SITE: New Riverside Rd
Bluffton, South Carolina



See Exhibit A-3 for description of field procedures.
See Appendix B for explanation of symbols and abbreviations.

CPT sensor calibration reports available upon request.

- 1 Sensitive, fine grained
- 2 Organic soils - clay
- 3 Clay - silty clay to clay
- 4 Silt mixtures - clayey silt to silty clay
- 5 Sand mixtures - silty sand to sandy silt
- 6 Sands - clean sand to silty sand
- 7 Gravelly sand to dense sand
- 8 Very stiff sand to clayey sand
- 9 Very stiff fine grained

WATER LEVEL OBSERVATION

6 ft measured water depth
(used in normalizations and correlations;
see Appendix B)

Probe no. 5207 with net area ratio of .866
U2 pore pressure transducer location
Manufactured by Geotech A.B.; calibrated 4/1/2019
Tip and sleeve areas of 10 cm² and 150 cm²
Ring friction reducer with O.D. of 1.875 in

Terracon
379 Browns Cove Rd Ste C
Ridgeland, SC

CPT Started: 5/31/2019

Rig: Pagani TG73-200

Project No.: HG195008

CPT Completed: 5/31/2019

Operator: JM

Exhibit: A-5-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CPT REPORT: HG195008 MARY RIVER HIGH S.GPJ TERRACON_DATATEMPLATE.GDT 6/4/19

CPT LOG NO. C2

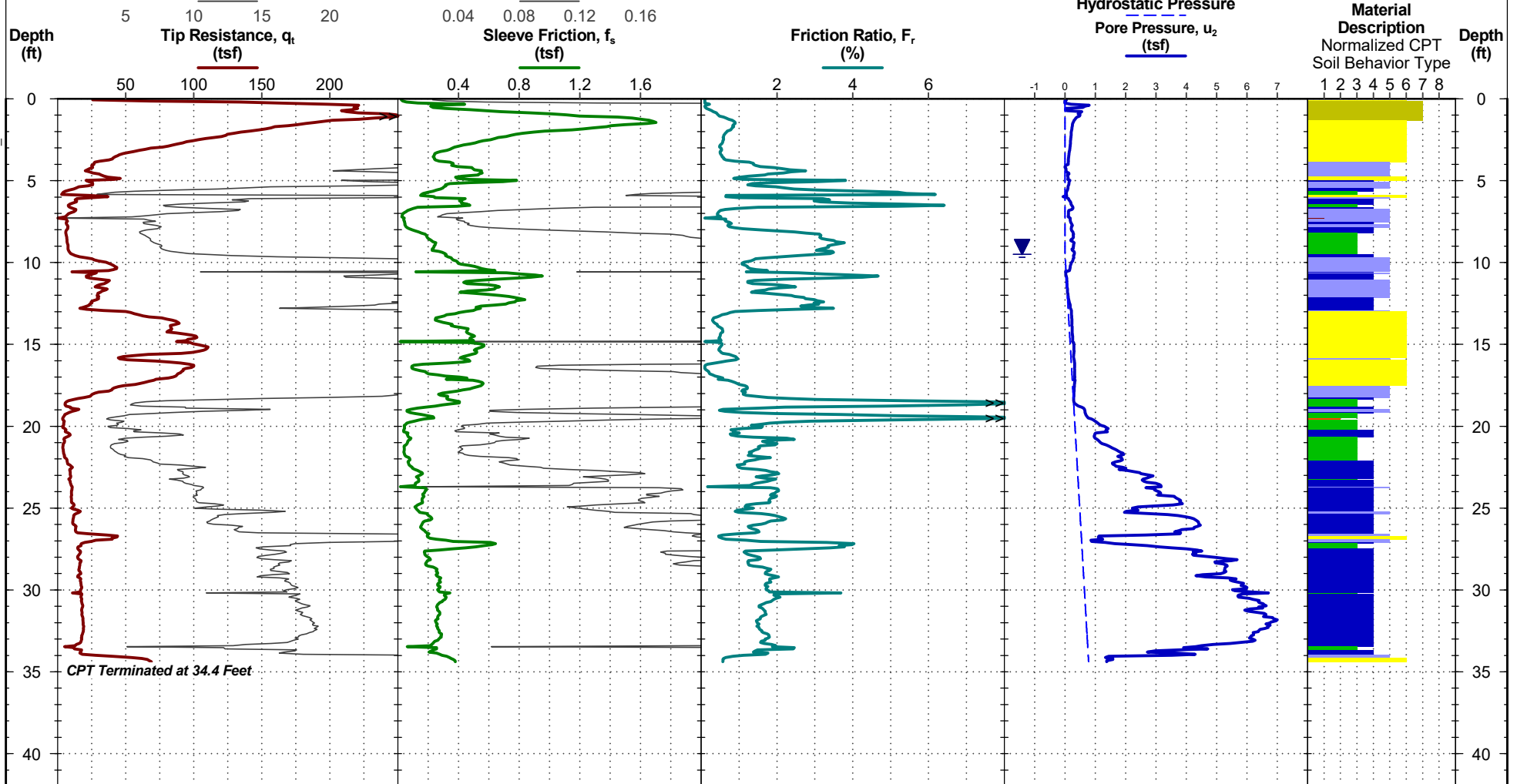
Page 1 of 1

PROJECT: May River High School Building Addition

CLIENT: Ward Edwards Engineering
Bluffton, SC

TEST LOCATION: See Exhibit A-2

SITE: New Riverside Rd
Bluffton, South Carolina



See Exhibit A-3 for description of field procedures.

See Appendix B for explanation of symbols and abbreviations.

CPT sensor calibration reports available upon request.

- 1 Sensitive, fine grained
- 2 Organic soils - clay
- 3 Clay - silty clay to clay
- 4 Silt mixtures - clayey silt to silty clay
- 5 Sand mixtures - silty sand to sandy silt
- 6 Sands - clean sand to silty sand
- 7 Gravelly sand to dense sand
- 8 Very stiff sand to clayey sand
- 9 Very stiff fine grained

WATER LEVEL OBSERVATION

9.5 ft measured water depth
(used in normalizations and correlations;
see Appendix B)

Probe no. 5207 with net area ratio of .866
U2 pore pressure transducer location
Manufactured by Geotech A.B.; calibrated 4/1/2019
Tip and sleeve areas of 10 cm² and 150 cm²
Ring friction reducer with O.D. of 1.875 in

Terracon
379 Browns Cove Rd Ste C
Ridgeland, SC

CPT Started: 5/31/2019

Rig: Pagani TG73-200

Project No.: HG195008

CPT Completed: 5/31/2019

Operator: JM

Exhibit: A-5-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CPT REPORT HG195008 MARY RIVER HIGH S.GPJ TERRACON_DATATEMPLATE.GDT 6/4/19

CPT LOG NO. C3

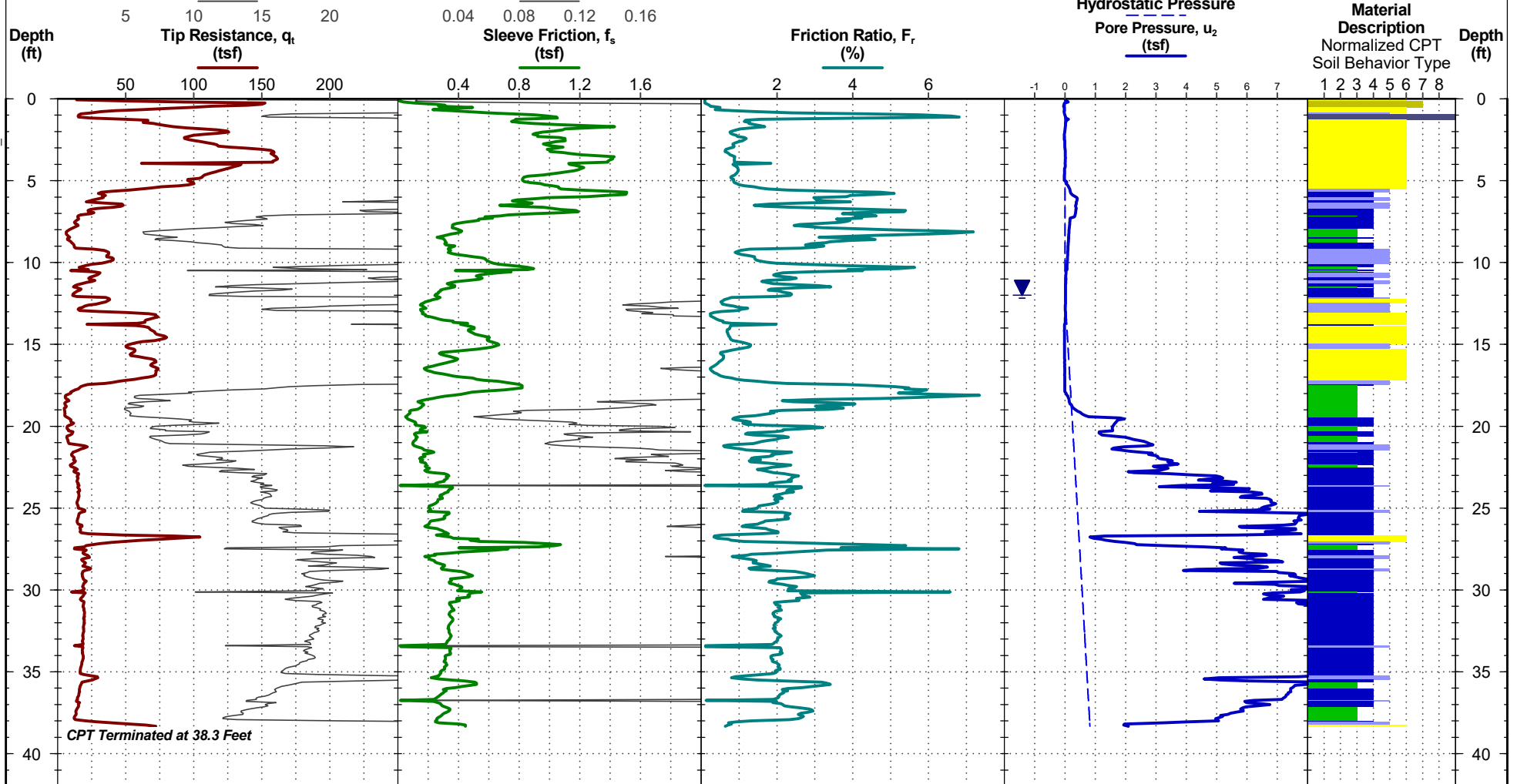
Page 1 of 1

PROJECT: May River High School Building Addition

CLIENT: Ward Edwards Engineering
Bluffton, SC

TEST LOCATION: See Exhibit A-2

SITE: New Riverside Rd
Bluffton, South Carolina



See Exhibit A-3 for description of field procedures.

See Appendix B for explanation of symbols and abbreviations.

CPT sensor calibration reports available upon request.

- 1 Sensitive, fine grained
- 2 Organic soils - clay
- 3 Clay - silty clay to clay
- 4 Silt mixtures - clayey silt to silty clay
- 5 Sand mixtures - silty sand to sandy silt
- 6 Sands - clean sand to silty sand
- 7 Gravelly sand to dense sand
- 8 Very stiff sand to clayey sand
- 9 Very stiff fine grained

WATER LEVEL OBSERVATION

12 ft measured water depth
(used in normalizations and correlations;
see Appendix B)

Probe no. 5207 with net area ratio of .866
U2 pore pressure transducer location
Manufactured by Geotech A.B.; calibrated 4/1/2019
Tip and sleeve areas of 10 cm² and 150 cm²
Ring friction reducer with O.D. of 1.875 in

Terracon
379 Browns Cove Rd Ste C
Ridgeland, SC

CPT Started: 5/31/2019

Rig: Pagani TG73-200

Project No.: HG195008

CPT Completed: 5/31/2019

Operator: JB

Exhibit: A-5-3

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CPT REPORT: HG195008 MARY RIVER HIGH S.GPJ TERRACON_DATATEMPLATE.GDT 6/4/19

Hand Auger Boring Log



Project Name: May River High School Building Addition

Project No.: HG195008

Project Location: Bluffton, South Carolina

HA1			
Depth Below Grade (in)	Material Description	Moisture	USCS Classification
0 to 8	Dark brown fine silty SAND.	Dry	SM
8 to 35	Brown / gray fine silty SAND.	Dry	SM
35 to 48	Dark brown fine silty SAND with organics (pine straw / roots).	Dry	SM
48 to 55	Dark gray / gray / brown sandy CLAY.	Moist	CL
55 to 60	Gray / dark gray fine silty SAND.	Moist	SM
No Groundwater encountered.		Mottling noted @ 55" BGS.	

HA2			
Depth Below Grade (in)	Material Description	Moisture	USCS Classification
0 to 24	Dark brown fine silty SAND.	Dry	SM
24 to 38	Dark brown SILT with sand and organics (pine straw / roots).	Moist	ML
38 to 48	Dark gray / gray / brown sandy CLAY.	Moist	CL
48 to 60	Gray / light gray fine silty SAND.	Moist	SM
No Groundwater encountered.		Mottling noted @ 38" BGS.	

HA3			
Depth Below Grade (in)	Material Description	Moisture	USCS Classification
0 to 5	Dark brown fine silty SAND.	Dry	SM
5 to 38	Light brown / gray / brown fine silty SAND with clay.	Dry	SM
38 to 60	Gray / dark brown fine silty SAND with organics (roots, pine straw, and wood chips).	Dry	SM
No Groundwater encountered.		Mottling noted @ 38" BGS.	

Note: BGS = Below Ground Surface

APPENDIX B

Supporting Documents

- § Exhibit B-1 Seismic Parameters Design Graph
- § Exhibit B-2 Liquefaction Analysis Results
- § Exhibit B-3 CPT General Notes
- § Exhibit B-4 General Notes
- § Exhibit B-5 Unified Soil Classification System

Seismic Design Parameters Based on IBC2015 Code and ASCE 7-10 Standard

Terracon Project Name: May River High School Building Addition

Terracon Project Number: HG195008



Site Location: Bluffton, South Carolina

Latitude : 32.2171°

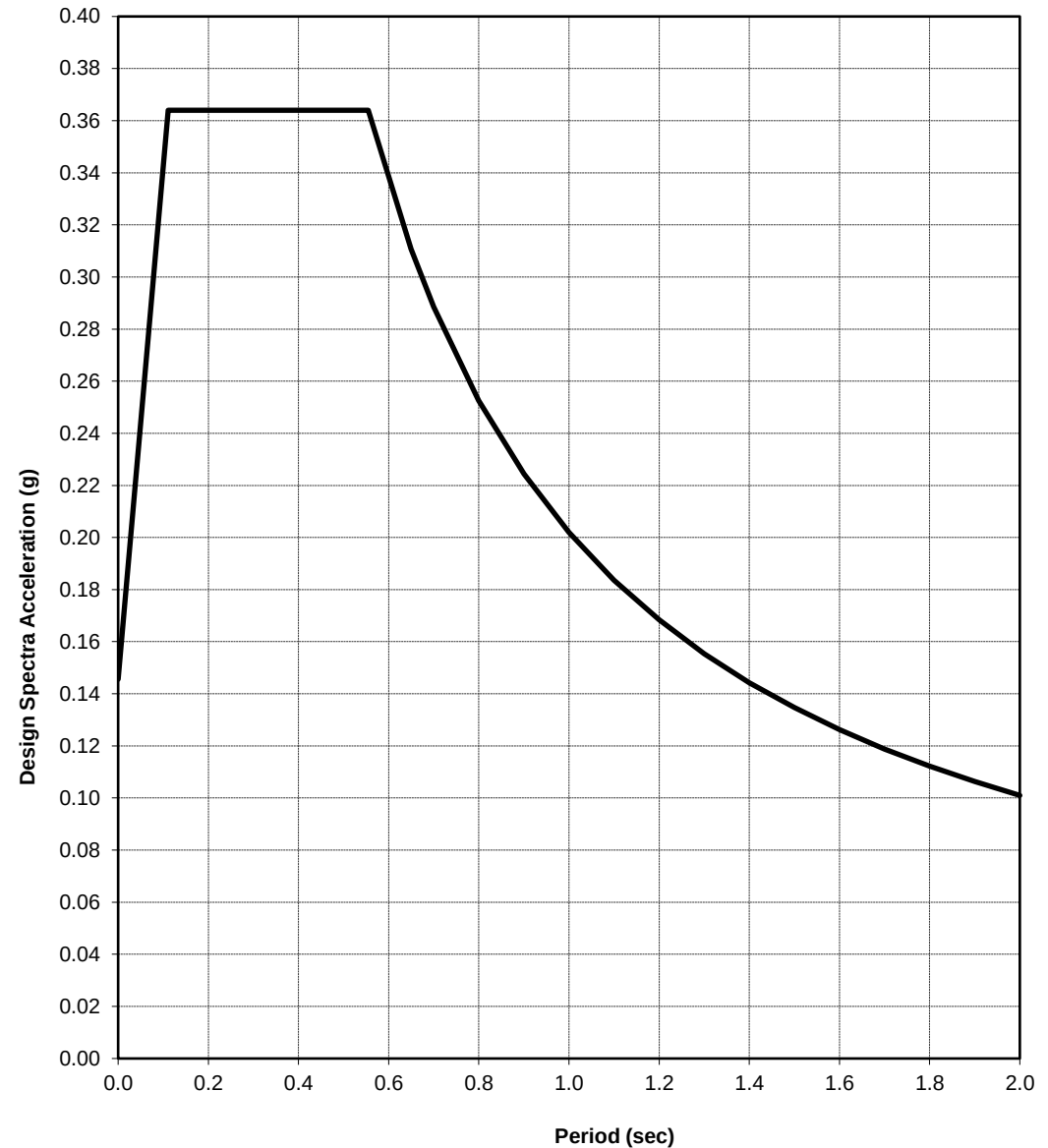
Longitude : -80.9718°

Site Class: D

Design Response Spectrum for the Site Class

S_s 0.362	S_1 0.133
F_a 1.511	F_v 2.267
S_{MS} 0.546	S_{M1} 0.302
S_{DS} 0.364	S_{D1} 0.202

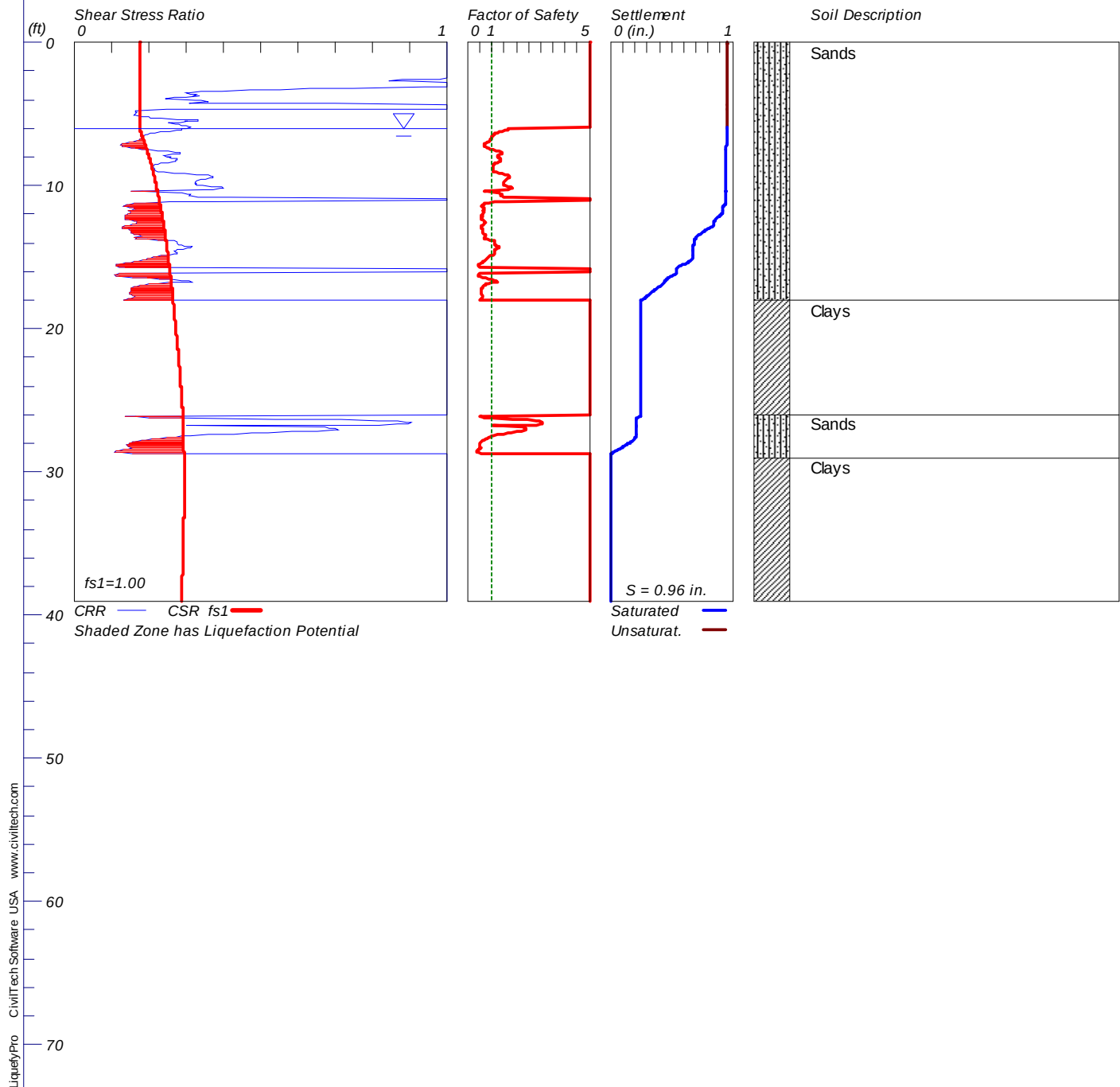
	<u>Period (sec)</u>	<u>S_a (g)</u>
	0.000	0.146
T_0	0.111	0.364
	0.200	0.364
T_s	0.555	0.364
T	0.650	0.311
	0.700	0.289
	0.800	0.253
	0.900	0.224
	1.000	0.202
	1.100	0.184
	1.200	0.168
	1.300	0.155
	1.400	0.144
	1.500	0.135
	1.600	0.126
	1.700	0.119
	1.800	0.112
	1.900	0.106
	2.000	0.101



May River High School Building Addition

Hole No.=C1 Water Depth=6 ft

Magnitude=7.3
Acceleration=0.273g



CPT GENERAL NOTES

DESCRIPTION OF MEASUREMENTS AND CALIBRATIONS

To be reported per ASTM D5778:

Uncorrected Tip Resistance, q_c
Measured force acting on the cone divided by the cone's projected area

Corrected Tip Resistance, q_t
Cone resistance corrected for porewater and net area ratio effects
 $q_t = q_c + U2(1 - a)$

Where a is the net area ratio, a lab calibration of the cone typically between 0.70 and 0.85

Pore Pressure, U1/U2
Pore pressure generated during penetration
U1 - sensor on the face of the cone
U2 - sensor on the shoulder (more common)

Sleeve Friction, f_s
Frictional force acting on the sleeve divided by its surface area

Normalized Friction Ratio, FR
The ratio as a percentage of f_s to q_t , accounting for overburden pressure

To be reported per ASTM D7400, if collected:

Shear Wave Velocity, V_s
Measured in a Seismic CPT and provides direct measure of soil stiffness

DESCRIPTION OF GEOTECHNICAL CORRELATIONS

Normalized Tip Resistance, Q_t
 $Q_t = (q_t - \sigma_{v0}) / \sigma'_{v0}$

Over Consolidation Ratio, OCR
OCR (1) = $0.25(Q_t)^{1.25}$
OCR (2) = $0.33(Q_t)$

Undrained Shear Strength, S_u
 $S_u = Q_t \times \sigma'_{v0} / N_k$
 N_k is a geographical factor (shown on S_u plot)

Sensitivity, St
 $St = (q_t - \sigma_{v0} / N_k) \times (1 / f_s)$
Effective Friction Angle, ϕ'
 $\phi' (1) = \tan^{-1}(0.373[\log(q_t / \sigma'_{v0}) + 0.29])$
 $\phi' (2) = 17.6 + 11[\log(Q_t)]$

Unit Weight
 $UW = (0.27[\log(FR)] + 0.36[\log(q_t / \text{atm})] + 1.236) \times UW_{\text{water}}$
 σ_{v0} is taken as the incremental sum of the unit weights

SPT N_{60}
 $N_{60} = (q_t / \text{atm}) / 10^{(1.1268 - 0.2817k)}$

Soil Behavior Type Index, I_c
 $I_c = [(3.47 - \log(Q_t))^2 + (\log(FR) + 1.22)^2]^{0.5}$

Small Strain Modulus, G_0
 $G_0 = \rho V_s^2$

Elastic Modulus, E_s (assumes $q / q_{\text{ultimate}} \sim 0.3$, i.e. $FS = 3$)
 $E_s (1) = 2.6 \psi G_0$
where $\psi = 0.56 - 0.33 \log Q_{t, \text{clean sand}}$
 $E_s (2) = G_0$
 $E_s (3) = 0.015 \times 10^{(0.55I_c + 1.68)} (q_t - \sigma_{v0})$
 $E_s (4) = 2.5 q_t$

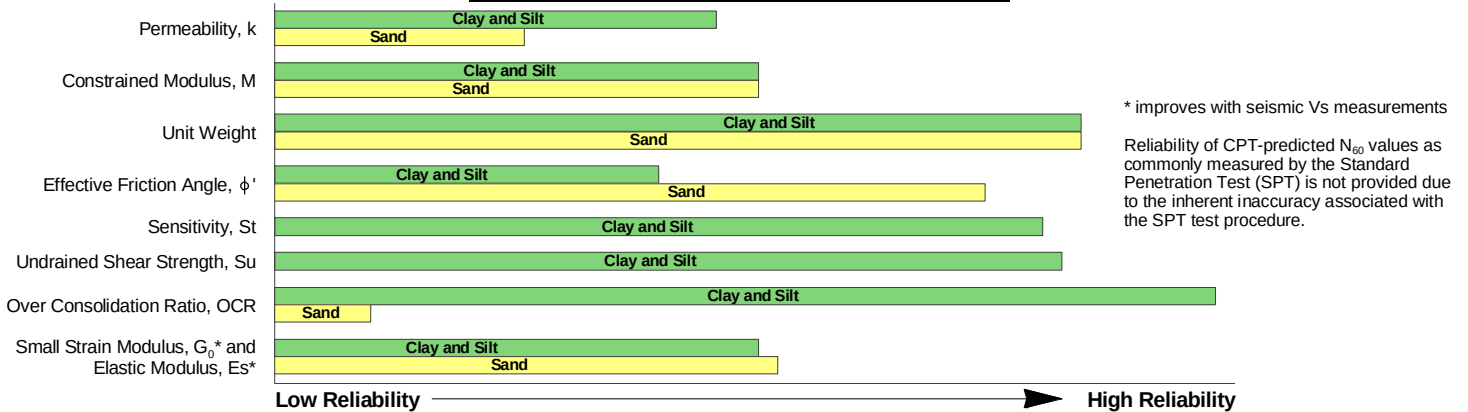
Constrained Modulus, M
 $M = \alpha_M (q_t - \sigma_{v0})$
For $I_c > 2.2$ (fine-grained soils)
 $\alpha_M = Q_t$ with maximum of 14
For $I_c < 2.2$ (coarse-grained soils)
 $\alpha_M = 0.0188 \times 10^{(0.55I_c + 1.68)}$

Hydraulic Conductivity, k
For $1.0 < I_c < 3.27$ $k = 10^{(0.952 - 3.04I_c)}$
For $3.27 < I_c < 4.0$ $k = 10^{(-4.52 - 1.37I_c)}$

REPORTED PARAMETERS

CPT logs as provided, at a minimum, report the data as required by ASTM D5778 and ASTM D7400 (if applicable). This minimum data include tip resistance, sleeve resistance, and porewater pressure. Other correlated parameters may also be provided. These other correlated parameters are interpretations of the measured data based upon published and reliable references, but they do not necessarily represent the actual values that would be derived from direct testing to determine the various parameters. The following chart illustrates estimates of reliability associated with correlated parameters based upon the literature referenced below.

RELATIVE RELIABILITY OF CPT CORRELATIONS



WATER LEVEL

The groundwater level at the CPT location is used to normalize the measurements for vertical overburden pressures and as a result influences the normalized soil behavior type classification and correlated soil parameters. The water level may either be "measured" or "estimated."

Measured - Depth to water directly measured in the field

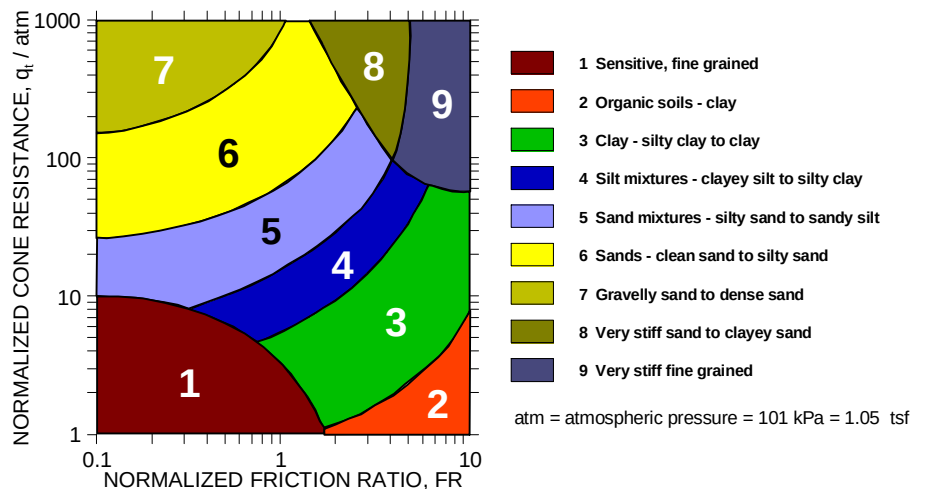
Estimated - Depth to water interpolated by the practitioner using pore pressure measurements in coarse grained soils and known site conditions

While groundwater levels displayed as "measured" more accurately represent site conditions at the time of testing than those "estimated," in either case the groundwater should be further defined prior to construction as groundwater level variations will occur over time.

CONE PENETRATION SOIL BEHAVIOR TYPE

The estimated stratigraphic profiles included in the CPT logs are based on relationships between corrected tip resistance (q_t), friction resistance (f_s), and porewater pressure (U2). The normalized friction ratio (FR) is used to classify the soil behavior type.

Typically, silts and clays have high FR values and generate large excess penetration porewater pressures; sands have lower FRs and do not generate excess penetration porewater pressures. Negative pore pressure measurements are indicative of fissured fine-grained material. The adjacent graph (Robertson et al.) presents the soil behavior type correlation used for the logs. This normalized SBT chart, generally considered the most reliable, does not use pore pressure to determine SBT due to its lack of repeatability in onshore CPTs.



REFERENCES

- Kulhavy, F.H., Mayne, P.W., (1997). "Manual on Estimating Soil Properties for Foundation Design," Electric Power Research Institute, Palo Alto, CA.
Mayne, P.W., (2013). "Geotechnical Site Exploration in the Year 2013," Georgia Institute of Technology, Atlanta, GA.
Robertson, P.K., Cabal, K.L. (2012). "Guide to Cone Penetration Testing for Geotechnical Engineering," Signal Hill, CA.
Schmertmann, J.H., (1970). "Static Cone to Compute Static Settlement over Sand," *Journal of the Soil Mechanics and Foundations Division*, 96(SM3), 1011-1043.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING			GROUNDWATER		Groundwater Initially Encountered	FIELD TESTS	(HP)	Hand Penetrometer
	Auger	Split Spoon			Groundwater Level After a Specified Period of Time		(T)	Torvane
					Static Groundwater Level After a Specified Period of Time		(b/f)	Standard Penetration Test (blows per foot)
	Shelby Tube	Macro Core			No Groundwater Observed		(PID)	Photo-Ionization Detector
				<p>Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.</p>			(OVA)	Organic Vapor Analyzer
	No Recovery	Rock Core						
								
	Ring Sampler							

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS	RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance Includes gravels, sands and silts.		CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
	Descriptive Term (Density)	Std. Penetration Resistance (blows per foot)	Descriptive Term (Consistency)	Undrained Shear Strength (kips per square foot)	Std. Penetration Resistance (blows per foot)
	Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
	Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
	Medium Dense	10 - 29	Medium-Stiff	0.50 to 1.00	5 - 7
	Dense	30 - 50	Stiff	1.00 to 2.00	8 - 14
	Very Dense	> 50	Very Stiff	2.00 to 4.00	15 - 30
			Hard	above 4.00	> 30

RELATIVE PROPORTIONS OF SAND AND GRAVEL

<u>Descriptive Term(s) of other constituents</u>	<u>Percent of Dry Weight</u>
Trace	< 15
With	15 - 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

<u>Descriptive Term(s) of other constituents</u>	<u>Percent of Dry Weight</u>
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

<u>Descriptive Term(s) of other constituents</u>	<u>Percent of Dry Weight</u>
Trace	< 5
With	5 - 12
Modifier	> 12

PLASTICITY DESCRIPTION

<u>Term</u>	<u>Plasticity Index</u>
Non-plastic	0
Low	1 - 10
Medium	11 - 30
High	> 30

Terracon

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests^A

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^A					Soil Classification	
					Group Symbol	Group Name ^B
Coarse Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines ^C	Cu ≥ 4 and 1 ≤ Cc ≤ 3 ^E	GW	Well-graded gravel ^F	
			Cu < 4 and/or 1 > Cc > 3 ^E	GP	Poorly graded gravel ^F	
		Gravels with Fines More than 12% fines ^C	Fines classify as ML or MH	GM	Silty gravel ^{F,G,H}	
			Fines classify as CL or CH	GC	Clayey gravel ^{F,G,H}	
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines ^D	Cu ≥ 6 and 1 ≤ Cc ≤ 3 ^E	SW	Well-graded sand ^I	
			Cu < 6 and/or 1 > Cc > 3 ^E	SP	Poorly graded sand ^I	
		Sands with Fines More than 12% fines ^D	Fines classify as ML or MH	SM	Silty sand ^{G,H,I}	
			Fines Classify as CL or CH	SC	Clayey sand ^{G,H,I}	
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line ^J	CL	Lean clay ^{K,L,M}	
			PI < 4 or plots below "A" line ^J	ML	Silt ^{K,L,M}	
		organic	Liquid limit - oven dried	< 0.75	OL	Organic clay ^{K,L,M,N}
			Liquid limit - not dried		Organic silt ^{K,L,M,O}	
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay ^{K,L,M}	
			PI plots below "A" line	MH	Elastic Silt ^{K,L,M}	
		organic	Liquid limit - oven dried	< 0.75	OH	Organic clay ^{K,L,M,P}
			Liquid limit - not dried		Organic silt ^{K,L,M,Q}	
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat	

^ABased on the material passing the 3-in. (75-mm) sieve

^BIf field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

^CGravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

^DSands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

$$^E Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

^FIf soil contains $\geq 15\%$ sand, add "with sand" to group name.

^GIf fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

^HIf fines are organic, add "with organic fines" to group name.

^IIf soil contains $\geq 15\%$ gravel, add "with gravel" to group name.

^JIf Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

^KIf soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

^LIf soil contains $\geq 30\%$ plus No. 200 predominantly sand, add "sandy" to group name.

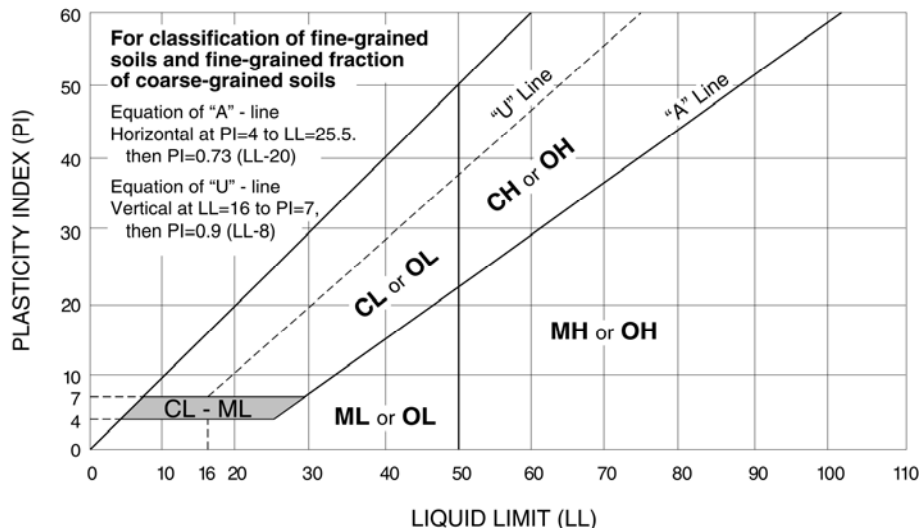
^MIf soil contains $\geq 30\%$ plus No. 200, predominantly gravel, add "gravelly" to group name.

^N $PI \geq 4$ and plots on or above "A" line.

^O $PI < 4$ or plots below "A" line.

^P PI plots on or above "A" line.

^Q PI plots below "A" line.



Terracon

Exhibit B-5