Geotechnical Engineering Investigation

Folkston Treatment Plant Tank
Gowen Drive
Folkston, Charlton County, Georgia

March 15, 2016
Terracon Project No. ES165069

Prepared for:

P.C. Simonton & Associates, Inc.
Hinesville, Georgia

Prepared by:

Terracon Consultants, Inc.
Savannah, Georgia

March 15, 2016

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Re: Geotechnical Engineering Investigation
Folkston Treatment Plant Tank
Gowen Drive
Folkston, Charlton County, Georgia
Terracon Project No. ES165069

Dear Mr. Sack:

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. PES165069 dated February 15, 2016. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundation and pavement.

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

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

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TABLE OF CONTENTS

Section Page

APPENDICES

EXECUTIVE SUMMARY

This report presents the results of our Geotechnical Engineering Investigation for the proposed tank construction with ancillary buildings at a treatment plant located off Gowen Drive in Folkston, Charlton County, Georgia. The investigation included a field exploration program and engineering evaluation of the subsurface conditions and foundation recommendations. Based on the results of the subsurface exploration and analyses, we conclude the site is suitable for the proposed construction. The following geotechnical considerations were identified:

- In general, the subsurface soils consist of loose to medium dense silty sands in the upper 10 to 12 feet below ground surface (BGS), followed by dense to very dense silty sands to depths of about 28 to 29 feet BGS. A detailed discussion about the subsurface conditions is provided in **Section 3.1** of this report.
- Groundwater was encountered at depths of about 3 to 4 feet BGS at the time of field exploration. The groundwater level should be checked prior to construction to assess its effect on site work and other construction activities.
- Based on the settlement analyses, the proposed tank can be supported on a mat foundation system. We recommend hydrostatic testing be performed to check the integrity of the tank and also preload the loose / soft soils before the final connections of the piping. Please refer to **Section 4.0** for the discussion on hydrostatic testing.
- For the lightly loaded structures such as the pipeline and ancillary buildings, the shallow foundation system should be adequate after subgrade improvements using densification as discussed in **Section 4.2**.
- We anticipate some undercutting and backfilling may be required in isolated loose / soft areas under the footings to achieve stable subgrade. The extent and depth of undercut should be based on the subsurface conditions encountered during construction.
- Based on the information available, we understand the proposed development will consist of underground structure. Construction of the underground structure will require excavations to be performed with proper excavation support and dewatering. Please refer to **Section 4.5** for the discussion on excavation and earth support for the underground structure.
- For seismic design purposes, the subject site shall be classified as Site Class D in accordance with the International Building Code (IBC) 2012 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

Folkston Treatment Plant Tank
Gowen Drive
Folkston, Charlton County, Georgia

Terracon Project No. ES165069
March 15, 2016

1.0 INTRODUCTION

Terracon has completed the Geotechnical Engineering Investigation for the proposed tank construction with ancillary buildings at a treatment plant located off Gowen Drive in Folkston, Charlton County, Georgia. The investigation included a field exploration program and engineering evaluation of the subsurface conditions and foundation recommendations.

The subsurface conditions within the project site were explored with a total of four (4) Cone Penetration Test (CPT) soundings and four (4) hand auger borings. The CPT soundings were pushed to depths of about 14 to 31 feet below ground surface (BGS) until the penetration refusal was encountered. The hand auger borings were drilled to depths of about 5 feet BGS.

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

The purpose of our investigation was to explore and 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. PES165069) February 15, 2016:

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

2.0 PROJECT INFORMATION

Item	Description
Site location	The site is located off Gowen Drive in Folkston, Charlton County, Georgia. The following GPS coordinates provide the specific location of the site. Latitude: 30.8206°, Longitude: -82.0223°
Existing improvements	Existing treatment plant.
Current ground cover	Grassed area.
Existing topography	Relatively level.
Proposed Improvements	The proposed project will include the construction of tank above ground or in ground depending on conditions. Tanks will be 66 x 60 by 24 ft. deep. There will be ancillary buildings, underground infrastructure and roadways as well. However, the development plan is not available at this time.
Finished floor elevation	Not provided at this time.
Maximum loads	The proposed tank will be 66 x 60 by 24 ft. deep. **We estimated the tank floor load to be around 1,500 psf.** The loading information for the proposed ancillary buildings was not available at this time. We assumed the buildings to be lightly loaded. The following loading conditions were assumed for the settlement analyses. **Column Load**: 75 kips (assumed) **Wall Load**: 4 kips per lineal foot (assumed) **Building Slab Load**: 200 psf (assumed) If heavier structural loads are required, Terracon should be retained to perform further evaluation to determine if ground improvement or other type of foundation system is required to support the proposed structures.
Maximum allowable settlement	The following settlement criteria were assumed for the settlement analyses. Total settlement: 1 inch (assumed). Differential settlement: ½ inch over 40 feet (assumed).
Grading	We understand the site work will involve a minimal amount of cut and fill.

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 Bottom of Stratum (feet)	Material Encountered	Equivalent SPT N_{60}
Stratum 1	~ 0.5	Silty sands with grass roots (Topsoil).	--
Stratum 2	10 to 12	Loose to medium dense silty sands. (In CPT sounding C4, interbedded soft sandy clays were encountered at a depth of about 5 feet BGS.)	5 to 10
	28 to 29	Dense to very dense silty sands.	30 to 50+
Stratum 3	30 to 31	Soft to medium stiff sandy clays.	4 to 6
Stratum 4	31, end of sounding	Very dense silty sands.	50+

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** of this report. Stratification boundaries on the logs represent the approximate depth of changes in soil types; the transition between materials may be gradual.

3.2 Groundwater

Groundwater was encountered at depths of about 3 to 4 feet BGS at the time of field exploration. Mottling, which infers seasonal high groundwater, was encountered at depths of about 2.5 to 3 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 level should be checked prior to construction to assess its effect on site work and other construction activities.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

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

We performed settlement analyses using the assumed structural loads and the soil parameters derived from the CPT soundings. The loading information is discussed in **Section 2.0**. If heavier structural loads are required or if more stringent settlement criteria are required, Terracon should be retained to perform additional evaluation to determine if ground improvement measures or another foundation option is required.

Based on the results of our settlement analyses, the settlements were estimated to be less than 1 inch for the tank floor load of 1,500 psf. As such, we recommend the proposed tank be supported on a shallow, mat foundation system. We recommend at least 12 inches of stone be used as the subgrade to provide more uniform support of the mat foundation and to achieve subgrade stability.

From the CPT soundings, the subject site consists of loose to medium dense silty sands in the upper 10 to 12 feet BGS. The subject site has isolated areas (please see CPT sounding C4 log) where interbedded soft clayey soils exist at a depth of around 5 feet BGS. To minimize the effect of total settlement from the loose / soft soils, we recommend hydrostatic testing be performed to check the integrity of the tank and also to preload the loose / soft soils before the final connections of the piping.

The hydrostatic testing is carried out by filling the tank with water up to full capacity and measuring the consolidation settlements. The tank settlements should be monitored at least 8 points around the tank perimeter. The settlements of the tanks should be monitored periodically on a weekly basis until no further settlement is recorded. For planning purposes, the preloading should be performed for at least two weeks; however, the actual duration for preloading will depend on the results obtained from the settlement monitoring.

For lightly loaded structures such as the pipeline, the shallow foundation should be adequate, provided that the pipeline system is equipped with a sensor shut off system. We recommend some flexible connections be used between the tanks and pipelines to accommodate some differential settlements.

For the proposed ancillary buildings, we estimated the settlements to be less than 1 inch for assumed column load of 75 kips, assumed wall load of 4 kips / ft. and assumed slab load of 200 psf. With subgrade improvements using densification as discussed in **Section 4.2**, the proposed ancillary buildings can be supported on shallow foundation systems, resting on improved soils. We anticipate some undercutting and backfilling may be required in isolated loose/soft areas under the footings to achieve stable subgrade. The extent and depth of undercut should be based on the subsurface conditions encountered during construction.

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 construction area to intercept rain and surface water. We recommend a thorough field quality control program of proofrolling of the subgrade. The bottom of the excavation should be observed for potential unsuitable material or loose fill. Hand auger boring and dynamic cone penetration (DCP) testing may be performed to evaluate and confirm the subgrade conditions.

A net allowable bearing capacity of 2,000 pounds per square foot (psf) is recommended for shallow foundation design. The allowable bearing capacity may be increased by 1/3 for 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 at footing subgrade.

No topsoil, organic matter, stumps, undocumented fill, or other unsuitable materials should be left in place below any footings. All footings should bear on suitable natural soil, or on properly compacted structural fills. Compacted fill below any footings should be placed directly on suitable natural soil. We recommend Terracon be retained to test the footing subgrade during construction so that Terracon can provide additional recommendations to prepare the subgrade based on the conditions uncovered during the footing preparation.

4.2 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.

4.2.1 Site Drainage

We recommend an effective drainage system 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. The contractor should schedule the work according to the weather conditions and protect the subgrade from water damage.

4.2.2 Densification and Proofrolling

Prior to fill placement on the subgrade, the entire tank, building and pavement areas should be densified with a heavy-duty vibratory roller to achieve a uniform subgrade. 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 footing during subgrade preparation.

4.2.3 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. Hence, the soils to be used as structural fill should be free of organics, roots, or other deleterious materials. It should be non-plastic granular material containing less than 25 percent fines passing the No. 200 sieve. If necessary, soils with more than 25 percent fines may be used as fill in less critical areas under close control of moisture and compaction. In general, the onsite soils are suitable for structural fill, provided that objectionable materials are not present in the soils.

Areas to receive structural fills 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). The fill brought to the site 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.

4.3 Shallow Foundation System

4.3.1 Mat Foundation for the Proposed Tank

The proposed tank can be supported on a shallow, monolithic mat foundation system. The following sections present design recommendations and construction considerations for the shallow foundations for the proposed structures and related structural elements.

Foundation Design Recommendations

Description	Mat Foundation
Net allowable bearing pressure [1]	2,000 psf
Minimum dimensions	66 x 60 feet (dimension provided)
Minimum embedment below finished grade	12 inches
Approximate total settlement [2]	< 1 inch
Ultimate Coefficient of sliding friction [3]	0.32
Floor slab support	Compacted structural fill/inspected and tested natural ground [4]
Base course/capillary break [5]	12 inches of free draining granular material
Modulus of subgrade reaction	120 pounds per square inch per in (psi/in)

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the foundation 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 within the subsurface soil profile, the structural loading conditions, the embedment depth of the foundation, the thickness of compacted fill, and the quality of the earthwork operations.
3. Sliding friction along the base of the foundation will not develop where net uplift conditions exist.
4. 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 4.2** of this report.
5. The monolithic slab design should include a base course comprised of free-draining, compacted, granular material, at least 12 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 workability of the subgrade especially during rain periods.

4.3.2 Spread Footing Foundation for the Buildings

With the subgrade improvements using densification as discussed in **Section 4.2**, the proposed structures can be supported on a shallow, spread footing foundation system provided the structural loads are less than or equal to the assumed loads presented in **Section 2.0** of this report. The following sections present design recommendations and construction considerations for the shallow foundations for the proposed structures and related structural elements.

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	

6. 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.
7. The foundation settlement will depend upon the variations within 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.
8. 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 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 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 Geotechnical Engineer. If the soil conditions encountered differ significantly from those presented in this report, Terracon should be contacted to provide additional evaluation and supplemental recommendations.

4.3.3 Mat Foundation / 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 overnight or for an extended period of time.

We generally anticipate material suitable for the recommended design bearing pressure will be present at the bottom of the footings / slab. However, there is a possibility that isolated zones of soft or loose native soils could be encountered below footing / slab bearing level, even though field density tests are expected to be performed during fill placement operations. Therefore, it is important that the Geotechnical Engineer 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 / slab excavations, the excavations should be extended deeper to suitable soils and the footings / slab could bear directly on those soils at the lower level or on lean concrete backfill placed in the excavations. As an alternative, the footings / slab could also bear on properly compacted structural backfill extending down to the suitable soils. Over-excavation for compacted backfill placement below foundations should extend laterally beyond all edges of the foundation system at least 8 inches per foot of over-excavation depth below footing base elevation.

The over-excavation should be backfilled up to the foundation 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.

4.4 Floor Slabs for the Buildings

4.4.1 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 break[2]	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**

4.2 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 workability of the subgrade especially during rain periods.
3. The use of a vapor retarder should be considered beneath concrete slabs on grade that will be covered with wood, tile, carpet or other moisture sensitive or impervious coverings, or when the 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 use of sufficient control joints, appropriate reinforcing or other means.

4.4.2 Floor Slab Construction Considerations

Prior to 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 backfill placed beneath slabs should be compacted in accordance with recommendations outlined in **Section 4.2** 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 stone base and concrete.

4.5 Excavation and Earth Support for Underground Structure

Based on the information available, we understand the proposed development will include the construction of underground structure. However, no information is available at this time regarding the location and the depth of excavation for the proposed underground structure.

Construction of the underground structure will require excavations to be performed with proper excavation support and dewatering. The excavation should be performed with stable slopes at all sides or a temporary retaining wall or excavation support. Shoring may be required to support the temporary retaining structure in order to prevent collapse so that the construction can proceed.

If sloped open excavation is considered, the temporary slope can have an inclination of 2 horizontal to 1 vertical or flatter. If there is no space for the slope, a temporary sheet pile wall or a similar earth retaining structure should be constructed. The temporary shoring should be designed by an engineer retained by the contractor.

Based on the subsurface exploration at the site, we anticipate that the site excavations will largely encounter loose to medium dense silty sands in the upper 10 to 12 feet BGS, followed by dense to very dense silty sands to depths of about 28 to 29 feet BGS. The dense to very dense silty sands at depths below 10 to 12 feet BGS are suitable for foundation support for underground structures. If the proposed structure is located above 10 to 12 feet BGS, the loose to medium dense silty sands should be densified properly to support the structures on shallow foundation system, resting on improved subgrade.

It is anticipated that excavations for the proposed underground structure can be accomplished with conventional earthmoving equipment in the upper 10 to 12 feet BGS. However, the contractor should expect difficult soil conditions for deeper excavations below 10 to 12 feet BGS due to the presence of dense to very dense silty sands.

For the construction of underground structures, a permanent wall is required to provide lateral support. The temporary wall for excavation support and the permanent wall for underground structure should be properly designed to resist the lateral earth pressures exerted by the soils behind the wall and the loads adjacent to the wall. If placement of footings in permanent wall backfill is required, the resulting loads and their effects on the wall should be evaluated, and for the analysis, a structural engineer should be consulted. In order to avoid excessive lateral pressures on the walls, heavy compaction should not be operated within a minimum distance out from the wall, which is typically a distance equal to the height of the wall.

If the temporary retaining structures are required instead of the sloped open excavation as discussed above, the temporary retaining walls should be designed for earth pressures equal to those provided in **Table 4.5.1**. The lateral earth pressures provided in **Table 4.5.2** should be used to design permanent retaining walls.

Earth pressures are influenced by the structural design of the wall system, conditions of the wall restraint, construction methods and/or compaction and the strength of the materials being used. The recommended design lateral earth pressures provided in the table below do not include a factor of safety and do not provide hydrostatic pressures on the wall. Furthermore, if tieback anchors are used as part of the earth retaining system, the effect of clay layers and thin clay lenses should be considered in the development of the anchor resistance.

Table 4.5.1 Lateral Soil Pressure Coefficient for Temporary Wall Design for Excavation Support

Approximate Depth to Bottom of Stratum (feet)	**Material Type**	**Total Unit Weight**, (pcf)	**Active Earth Pressure Coefficient (k_a)**	**At-Rest Earth Pressure Coefficient (k_o)**	**Passive Earth Pressure Coefficient (k_p)**
10 to 12	Loose to medium dense silty sands.	115	0.36	0.53	2.77
28 to 29	Dense to very dense silty sands.	125	0.29	0.46	3.45
30 to 31	Soft to medium stiff sandy clays.	95	1.00	1.00	1.00
31, termination of soundings	Very dense silty sands.	125	0.29	0.46	3.45

Table 4.5.2 Lateral Soil Pressure Coefficient for Permanent Wall Design

Approximate Depth (feet)	**Material Type**	**Total Unit Weight**, (pcf)	**Active Earth Pressure Coefficient (k_a)**	**At-Rest Earth Pressure Coefficient (k_o)**	**Passive Earth Pressure Coefficient (k_p)**
Wall length (backfill placed against back of the retaining wall)	Granular backfill	120	0.33	0.50	3.00

The backfill placed against wall structures should consist of granular soils to reduce the hydrostatic pressure that could develop behind the wall. The granular backfill must extend out from the base of the wall at an angle of 45 degrees from the vertical.

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 infiltrating surface water behind the wall, a perimeter drain should be installed at the foundation level. The drain lines should be sloped to provide for gravity flow leading to a reliable discharge such as a stormwater drain and sump with pump system. The drain lines should be surrounded by a filter material to prevent the intrusion of fines.

4.6 Pavements

We understand that the proposed development will include paved drive and parking areas. This section presents thickness recommendations for asphalt concrete and Portland cement concrete pavements and general considerations for 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 were not available at this time. However, we anticipate that traffic loads will be produced primarily by automobile traffic, pickup trucks and a limited number of delivery and trash removal trucks.

Two pavement section alternatives have been provided. The light duty section is 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 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 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 site preparation procedures. Assuming the finished subgrade will be near the existing ground surface, the near surface soils are fine sands with silts to silty sands based on the hand auger borings. The fine sands with silts and the silty sands should have good drainage characteristics and are deemed suitable for subgrade support.

The proposed pavement areas may have isolated areas where clayey sands or sandy clays exist at the subgrade level. The clayey sands would have poor drainage characteristics and are not considered suitable for 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 Georgia Department of Transportation's (GDOT) 2001 edition of *Standard Specifications for Construction of Transportation Systems,* are included for the asphalt concrete sections.

4.6.1 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]	4	7	7
Graded aggregate base[2]	0	0	0
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. Graded aggregate base should conform to the GDOT material specification Section 815.
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 ingress of surface water into the subgrade soils. Proper surface and subgrade drainage system should be installed to avoid 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.

4.6.2 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
Asphalt Intermediate Course[1]	0	2	

Aggregate Base Course[1]	7	8	concentrated and repetitive loading areas, as concrete pavement, in general, performs better in these areas. Please refer to **Section 4.6.1** for the pavement section.
Total Pavement Section	**9**	**11 ½**	
Select fill[2] / improved subgrade[3]	24	24	

1. Asphalt concrete and base course materials should conform to the following GDOT material specifications.
   - Section 815 for Graded Aggregate
   - Section 828 for Hot Mix Asphalt Concrete Mixture. Surface course may use 9.5 mm Superpave for smooth surface in the light-duty section or 12.5 mm Superpave for the heavy-duty section. 19 mm and/or 25 mm Superpave is recommended for the intermediate course.
2. 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).
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 saturation of subgrade soils underneath the asphalt 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.

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 crushed stones, the pavement areas should be thoroughly proofrolled. For dumpster pads, the concrete pavement area should be large enough to support the container and the tipping axle of the refuse truck.

The above pavement recommendations are based on the assumption that no heavy duty trucks, such as construction dump trucks or similar maintenance vehicles, will use the facility. If the facility will be used by those heavy duty trucks, we recommend the concrete pavement be designed by the structural engineer based on the actual loads anticipated for the trucks and equipment.

4.6.3 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 high traffic areas that were rutted and disturbed and to 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.

4.6.4 Pavement and Subgrade Drainage

Poor subgrade drainage is the most common cause of pavement failure. Pavement should be sloped to provide rapid drainage of surface water. Water should not be allowed to pond on 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 moisture migration to subgrade soils. Subgrade drains should be installed at the bottom of the Graded Aggregate Base (GAB) level. The civil engineer should decide the placement of the subgrade drains to avoid saturation of pavement subgrade.

4.6.5 Pavement Maintenance

The performance of pavements will require regular maintenance. One key component of the maintenance is to minimize 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.

4.7 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) 2012 and ASCE 7-10. The seismic design parameters obtained based on IBC2012 and ASCE 7-10 are summarized in the table below. The design response spectrum curve, as presented in **Appendix B**, was developed based on the S_{DS} and S_{D1} values according to IBC2012 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}
30.8206° -82.0223°	D	0.127g	0.067g	1.600	2.400	0.135g	0.107g

- In general accordance with the 2012 International Building Code and ASCE 7-10.
- The 2012 IBC and ASCE 7-10 require a site soil profile determination extending a depth of 100 feet for seismic site classification. The current scope does not include 100 foot soil profile determination. Explorations for this project extended to a maximum depth of 31 feet and this seismic site class definition was provided in consideration of the overall soil conditions as well as the general geology of the area.

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

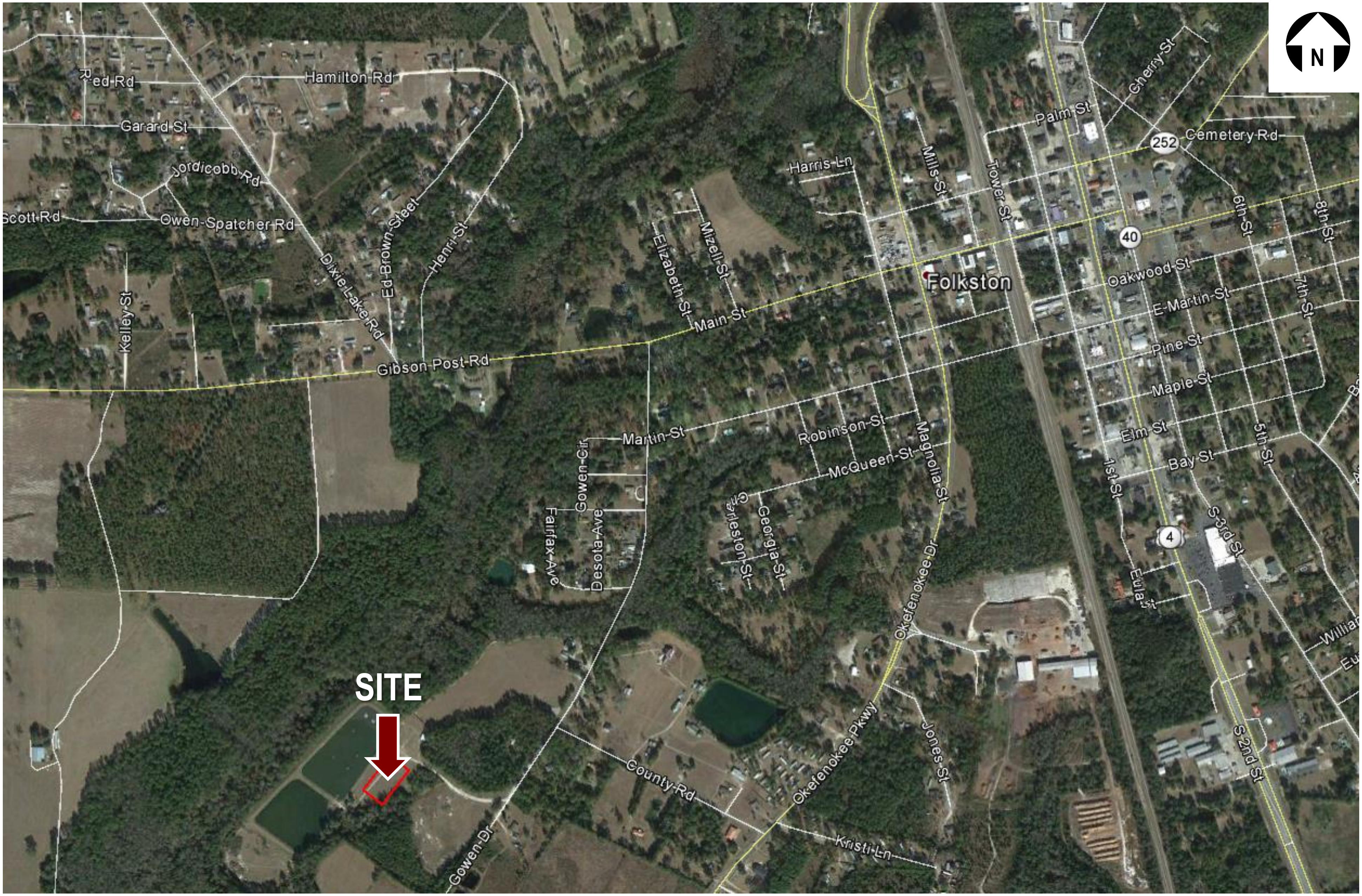
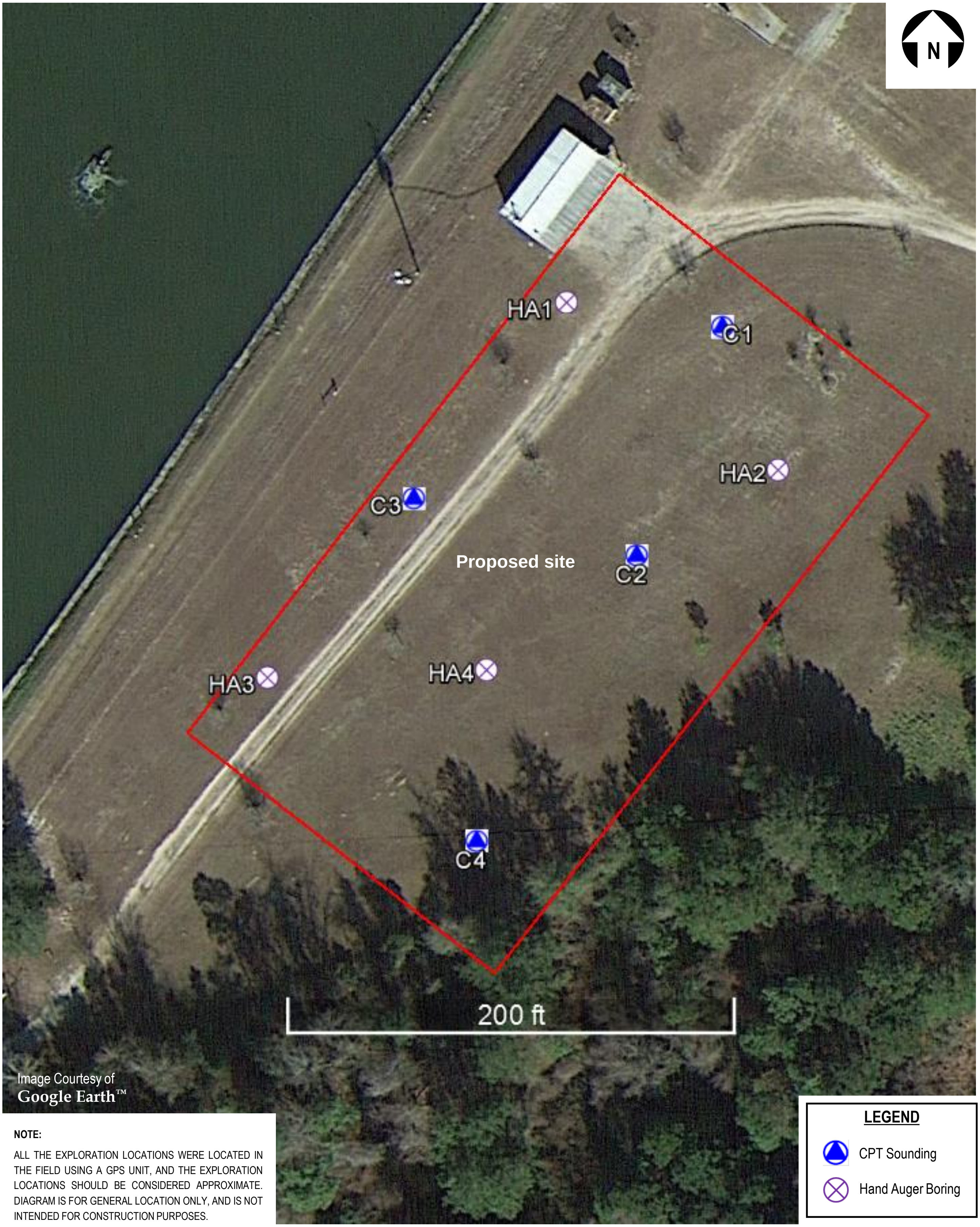


Image Courtesy of
Google Earth™

Project Manager: BG	Project No. ES165069	Terracon Consulting Engineers & Scientists	SITE LOCATION MAP	Exhibit:
Drawn by: BG	Scale: N.T.S.	2201 Rowland Avenue Savannah, Georgia 31404	Folkston Treatment Plant Tank	A-1
Checked by: GL	File Name: ES165069	Phone (912) 629 4000 Fax (912) 629 4001	Gowen Drive	
Approved by: GL	Date: 3/15/2016		Folkston, Charlton, Georgia	



NOTE:

ALL THE EXPLORATION LOCATIONS WERE LOCATED IN THE FIELD USING A GPS UNIT, AND THE EXPLORATION LOCATIONS SHOULD BE CONSIDERED APPROXIMATE. DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES.

Project Manager: BG	Project No. ES165069	Terracon Consulting Engineers & Scientists	EXPLORATION LOCATION PLAN
Drawn by: BG	Scale: AS SHOWN	2201 Rowland Avenue, Savannah, Georgia 31404	Folkston Treatment Plant Tank
Checked by: GL	File Name: ES165069	Phone (912) 629 4000 Fax (912) 629 4001	Gowen Drive
Approved by: GL	Date: 3/15/2016		Folkston, Charlton, Georgia

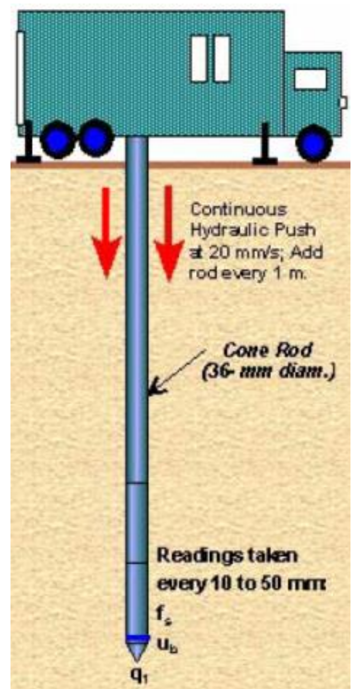
Exhibit: A-2

FIELD EXPLORATION DESCRIPTION

The locations of Cone Penetration Test (CPT) soundings and hand auger borings were discussed with the civil engineers prior to performing the field exploration and were located in the field using a hand-held GPS unit and in reference to the existing features. These test locations are shown in the Exploration Location Plan in **Exhibit A-2**, and they should be considered approximate. The test locations are not intended for construction purposes.

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 1½ and 2½ 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.



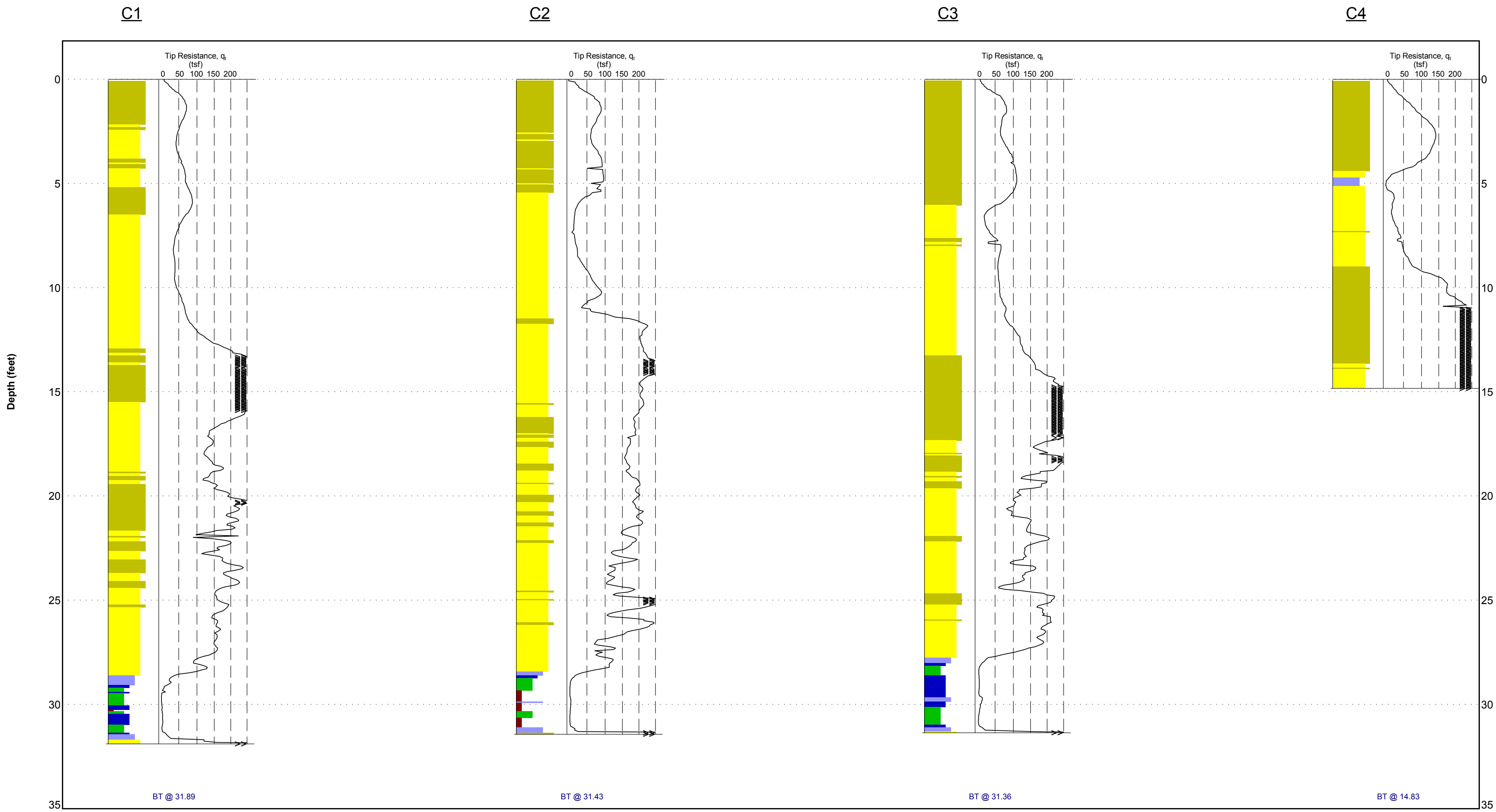
Source: FHWA NHI-06-088

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.

Hand Auger Boring

Hand auger boring was conducted in general accordance with ASTM D1452-80, 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.



Explanation

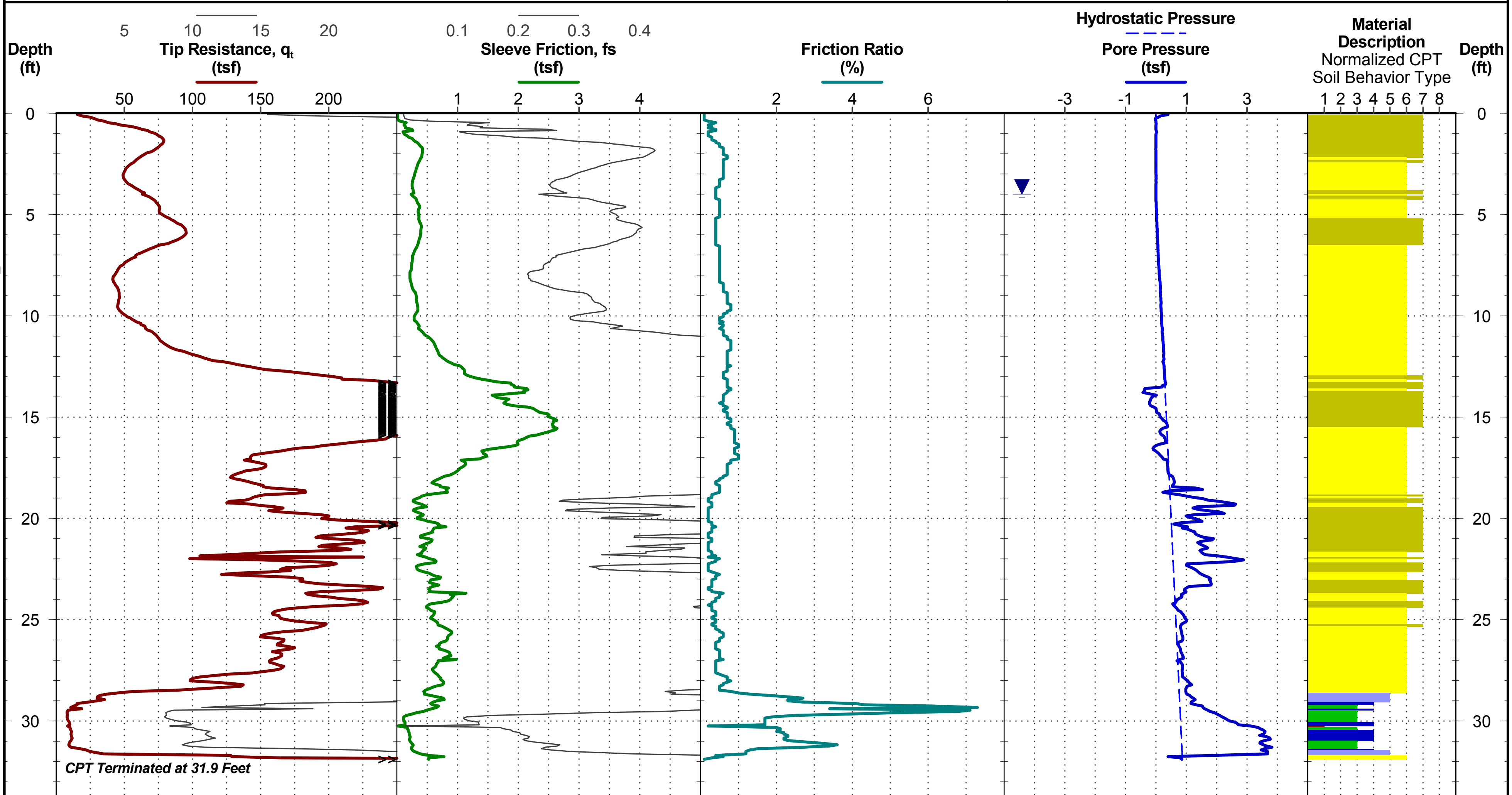
1 Sensitive, fine grained
2 Organic soils - clay
3 Clay - silty clay to clay
4 Silt mixtures - clayey silt to silty clay
5 Sand mixtures - silty sand to sandy silt
6 Sands - clean sand to silty sand
7 Gravelly sand to dense sand
8 Very stiff sand to clayey sand
9 Very stiff fine grained

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

Project Manager: BG	Project No.: ES165069	Terracon	**SUBSURFACE PROFILE**	EXHIBIT
Drawn by: BG	Scale: N.T.S.	2201 Rowland Avenue Savannah, Georgia	Folkston Treatment Plant Tank	A-4
Approved by: GL	File Name: ES165069	PH. 912-629-4000 FAX. 912-629-4001	Gowen Drive	
Date: 3/15/2016			Folkston, Charlton, Georgia	

CPT LOG NO. C1

PROJECT: Folkston Treatment Plant Tank	**CLIENT:** P.C. Simonton & Associates, Inc. Hinesville, Georgia	**TEST LOCATION:** See Exhibit A-2
SITE: Folkston, Georgia		



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	Probe no. 4675	Terracon	CPT Started: 3/1/2016	CPT Completed: 3/1/2016
4 ft estimated water depth (used in normalizations and correlations; see Appendix B)		2201 Rowland Avenue Savannah, Georgia	Rig: Pagani TG73-200	Operator: RF
			Project No.: ES165069	Exhibit: A-5-1

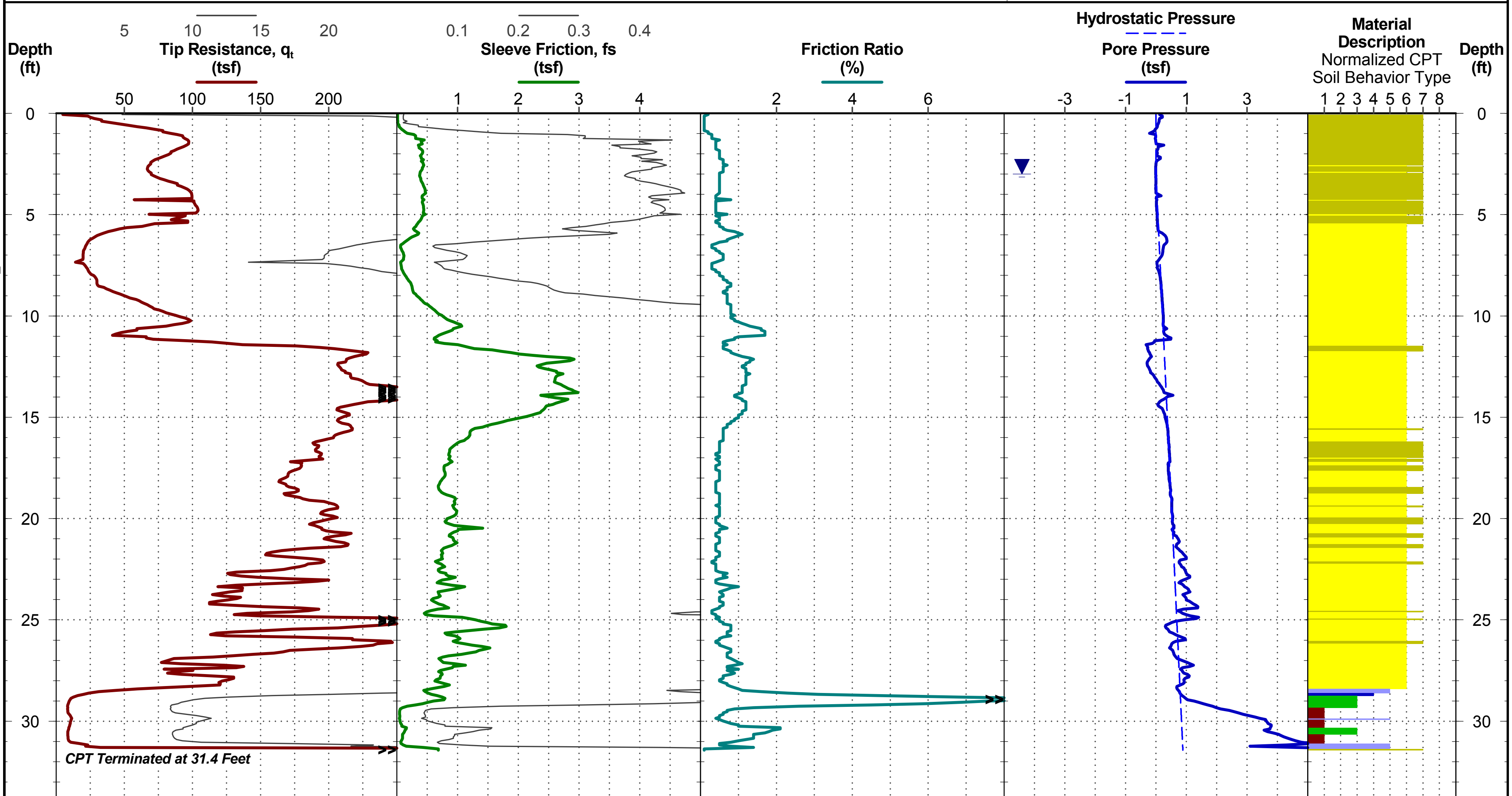
CPT LOG NO. C2

PROJECT: Folkston Treatment Plant Tank

CLIENT: P.C. Simonton & Associates, Inc.
Hinesville, Georgia

TEST LOCATION: See Exhibit A-2

SITE: Folkston, Georgia



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 3 ft estimated water depth (used in normalizations and correlations; see Appendix B)	Probe no. 4675	Terracon 2201 Rowland Avenue Savannah, Georgia	CPT Started: 3/1/2016 Rig: Pagani TG73-200 Project No.: ES165069
			CPT Completed: 3/1/2016 Operator: RF Exhibit: A-5-2

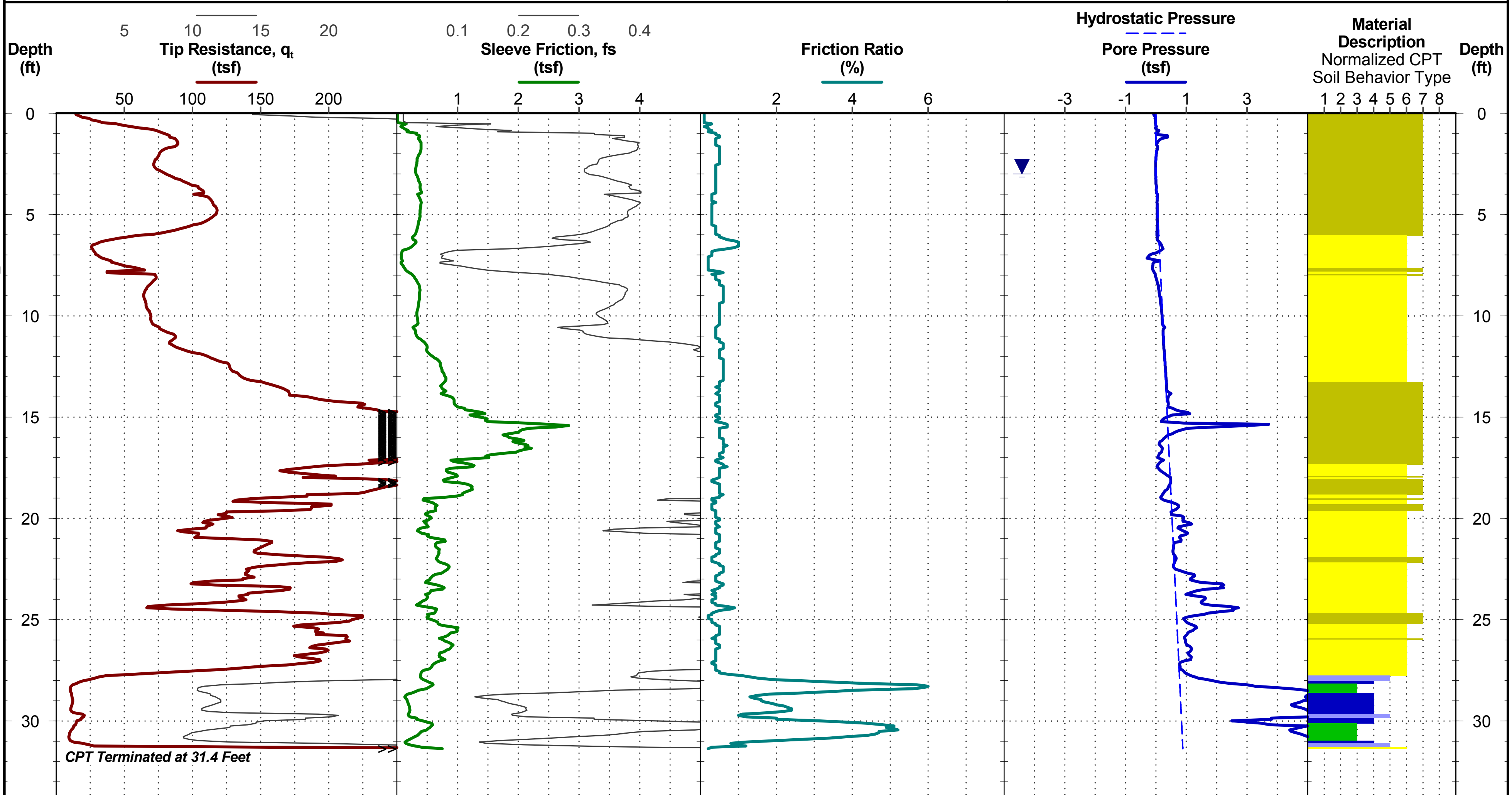
CPT LOG NO. C3

PROJECT: Folkston Treatment Plant Tank

CLIENT: P.C. Simonton & Associates, Inc.
Hinesville, Georgia

TEST LOCATION: See Exhibit A-2

SITE: Folkston, Georgia



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

▼ 3 ft estimated water depth
(used in normalizations and correlations; see Appendix B)

Probe no. 4675

Terracon
2201 Rowland Avenue
Savannah, Georgia

CPT Started: 3/1/2016	CPT Completed: 3/1/2016
Rig: Pagani TG73-200	Operator: RF
Project No.: ES165069	Exhibit: A-5-3

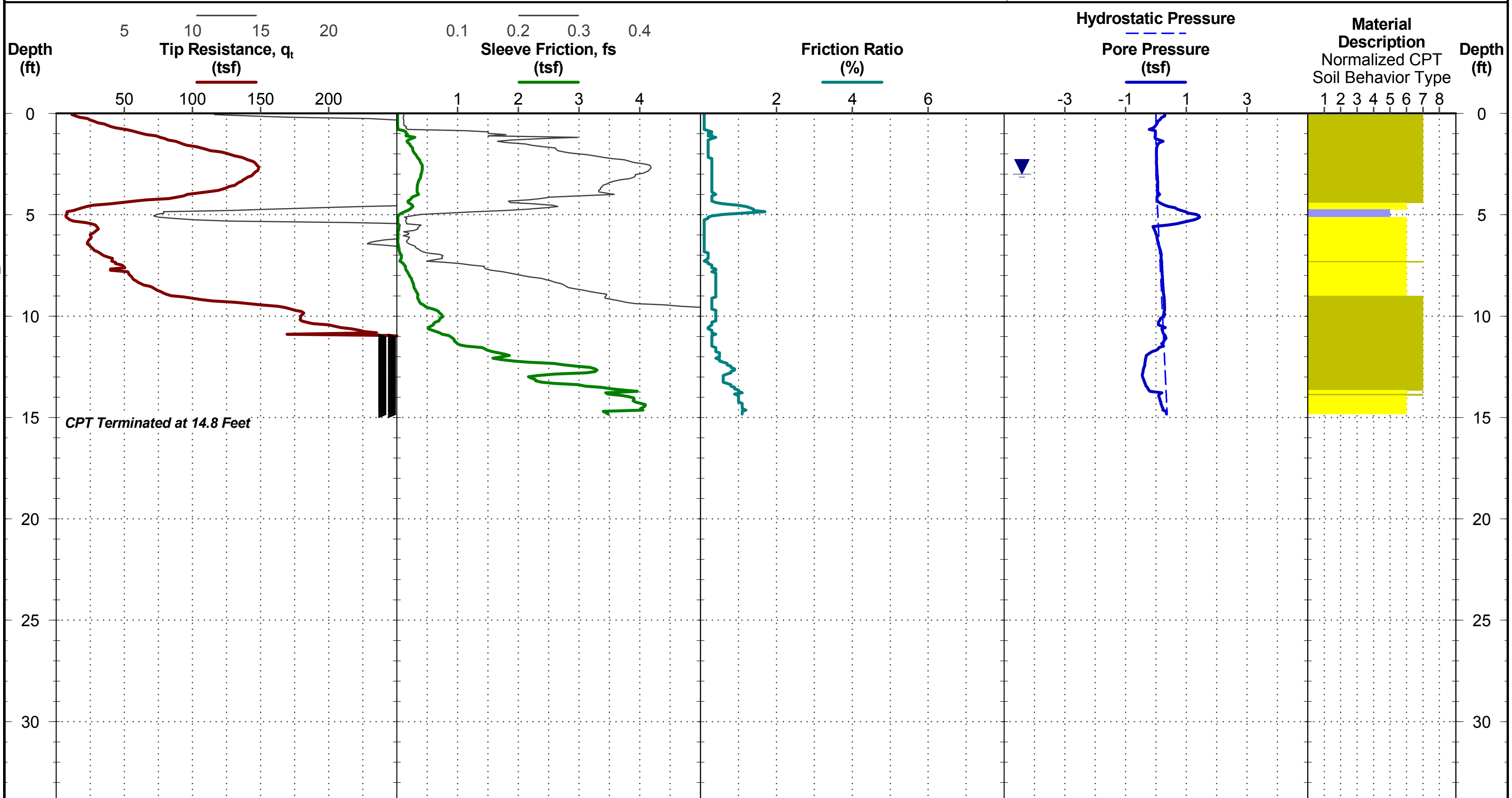
CPT LOG NO. C4

PROJECT: Folkston Treatment Plant Tank

CLIENT: P.C. Simonton & Associates, Inc.
Hinesville, Georgia

TEST LOCATION: See Exhibit A-2

SITE: Folkston, Georgia



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

▼ 3 ft estimated water depth
(used in normalizations and correlations; see Appendix B)

Probe no. 4675

2201 Rowland Avenue
Savannah, Georgia

CPT Started: 3/1/2016	CPT Completed: 3/1/2016
Rig: Pagani TG73-200	Operator: RF
Project No.: ES165069	Exhibit: A-5-4

Hand Auger Boring Log

Project Name: Folkston Treatment Plant Tank
Project No.: ES165069
Project Location: Folkston, Charlton County, Georgia

HA1		
Depth Below Grade (inch)	**Material Description**	**USCS Classification**
0 to 4	Brown silty SAND with grass roots (Topsoil).	SM
4 to 12	Brown silty SAND.	SM
12 to 60	Gray and light orange fine SAND.	SP
Groundwater @ 48" BGS	**Mottling @ 38" BGS**	

HA2		
Depth Below Grade (inch)	**Material Description**	**USCS Classification**
0 to 6	Brown silty SAND with grass roots (Topsoil).	SM
6 to 12	Brown silty SAND.	SM
12 to 28	Light brown fine SAND with silt.	SP-SM
28 to 60	Gray and orange fine SAND.	SP
Groundwater @ 36" BGS	**Mottling @ 36" BGS**	

HA3		
Depth Below Grade (inch)	**Material Description**	**USCS Classification**
0 to 3	Brown silty SAND with grass roots (Topsoil).	SM
3 to 24	Brown silty SAND.	SM
24 to 60	Gray and light orange fine SAND.	SP
Groundwater @ 42" BGS	**Mottling @ 38" BGS**	

HA4		
Depth Below Grade (inch)	**Material Description**	**USCS Classification**
0 to 6	Brown silty SAND with grass roots (Topsoil).	SM
6 to 24	Brown silty SAND.	SM
24 to 60	Gray and orange fine to coarse SAND.	SP
Groundwater @ 36" BGS	**Mottling @ 32" BGS**	

Note: BGS = Below Ground Surface

APPENDIX B
SUPPORTING INFORMATION

Seismic Design Parameters Based on IBC2012 Code and ASCE 7-10 Standard

Terracon Project Name: Folkston Treatment Plant Tank

Terracon Project Number: ES165069

Site Location: Folkston, Charlton County, Georgia

Latitude : 30.8206°

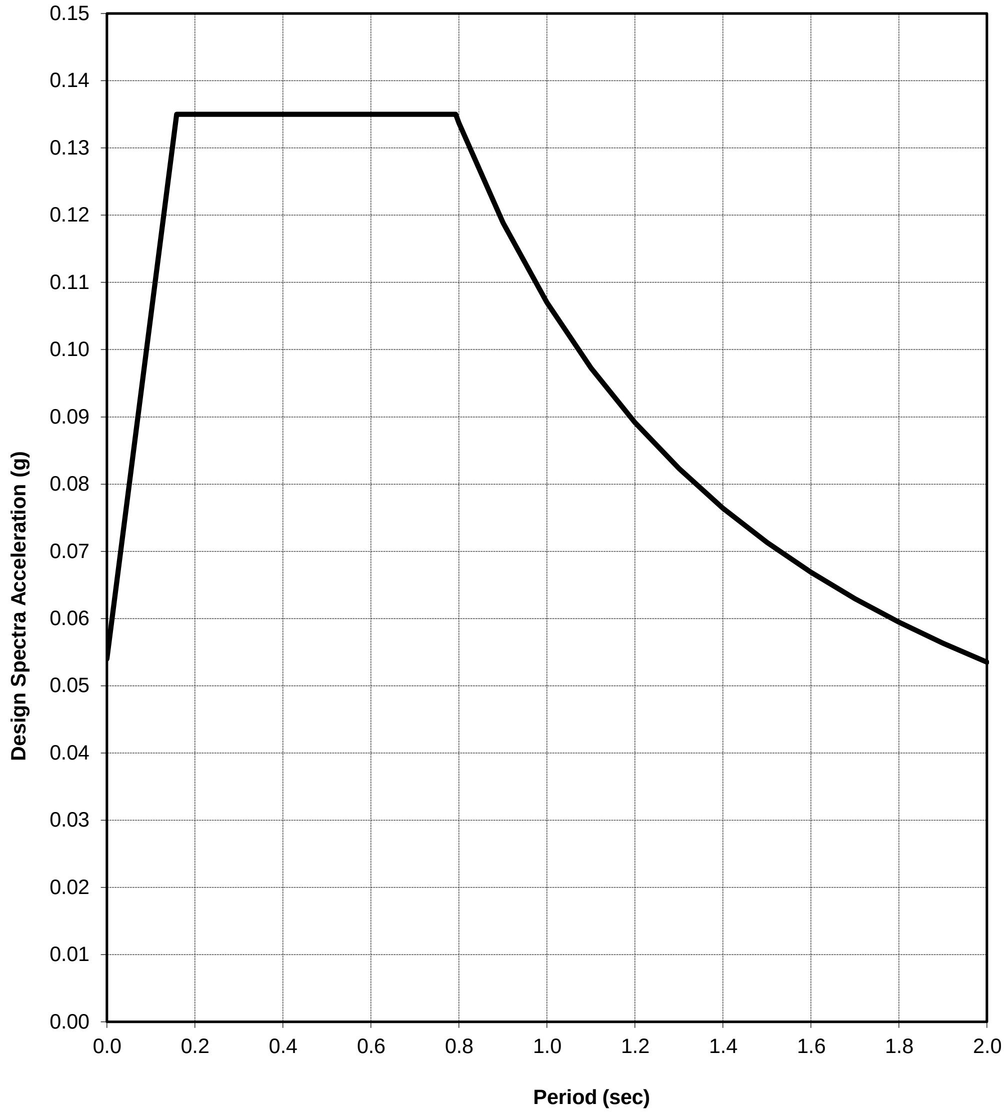
Longitude : -82.0223°

Site Class: D

Design Response Spectrum for the Site Class

S_s	0.127	S_1	0.067
F_a	1.600	F_v	2.400
S_{MS}	0.203	S_{M1}	0.160
S_{DS}	0.135	S_{D1}	0.107

	Period (sec)	Sa (g)
	0.000	0.054
T_0	0.159	0.135
	0.200	0.135
T_S	0.793	0.135
T	0.800	0.134
	0.900	0.119
	1.000	0.107
	1.100	0.097
	1.200	0.089
	1.300	0.082
	1.400	0.076
	1.500	0.071
	1.600	0.067
	1.700	0.063
	1.800	0.059
	1.900	0.056
	2.000	0.054



GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING		GROUNDWATER		FIELD TESTS	
	Auger		Groundwater Initially Encountered	(HP)	Hand Penetrometer
	Split Spoon		Groundwater Level After a Specified Period of Time	(T)	Torvane
	Shelby Tube		Static Groundwater Level After a Specified Period of Time	(b/f)	Standard Penetration Test (blows per foot)
	Macro Core		No Groundwater Observed	(PID)	Photo-Ionization Detector
	No Recovery		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.	(OVA)	Organic Vapor Analyzer
	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.

STENGTH 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

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

GRAIN SIZE TERMINOLOGY

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

RELATIVE PROPORTIONS OF FINES

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

PLASTICITY DESCRIPTION

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

Terracon

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
Coarse Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[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]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[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 / Liquid limit - not dried < 0.75	OL	Organic clay[K,L,M,N]
					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 / Liquid limit - not dried < 0.75	OH	Organic clay[K,L,M,P]
					Organic silt[K,L,M,Q]
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

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

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

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

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

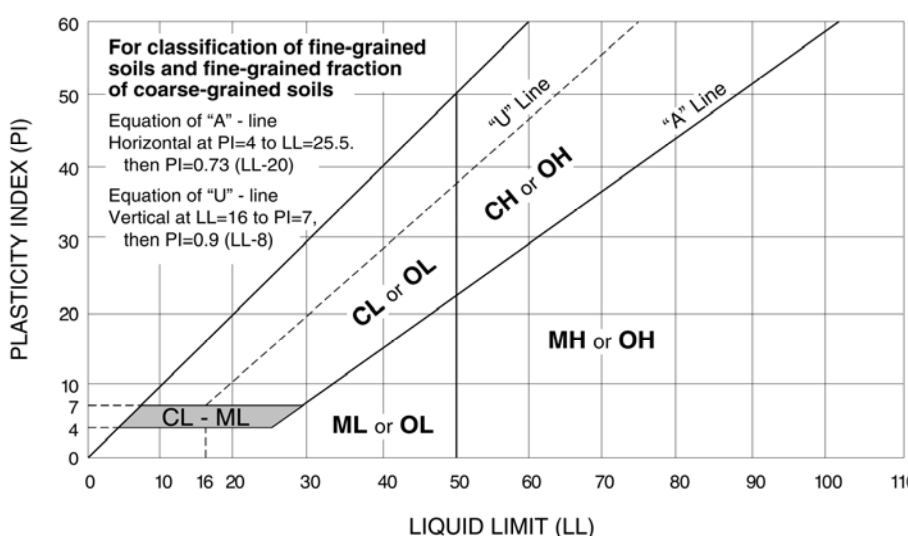


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Exhibit B-3

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, fs
Frictional force acting on the sleeve divided by its surface area

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

To be reported per ASTM D7400, if collected:

Shear Wave Velocity, Vs
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, Su
$Su = Q_t \times \sigma'_{V0}/N_{kt}$
N_{kt} is a geographical factor (shown on Su plot)

Sensitivy, St
$St = (q_t - \sigma_{V0}/N_{kt}) \times (1/fs)$

Effective Friction Angle, ϕ'
ϕ' (1) $= \tan^{-1}(0.373[\log(q_t/\sigma'_{V0}) + 0.29])$
ϕ' (2) $= 17.6 + 11[\log(Q_t)]$

Unit Weight
$UW = (0.27[\log(FR)]+0.36[\log(q_t/atm)]+1.236) \times UW_{water}$
σ_{V0} is taken as the incremental sum of the unit weights

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

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

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

Elastic Modulus, Es (assumes $q/q_{ultimate} \sim 0.3$, i.e. FS = 3)
Es (1) $= 2.6\psi G_0$
where $\psi = 0.56 - 0.33\log Q_{t,clean\ sand}$
Es (2) $= G_0$
Es (3) $= 0.015 \times 10^{(0.55Ic + 1.68)}(q_t - \sigma_{V0})$
Es (4) $= 2.5q_t$

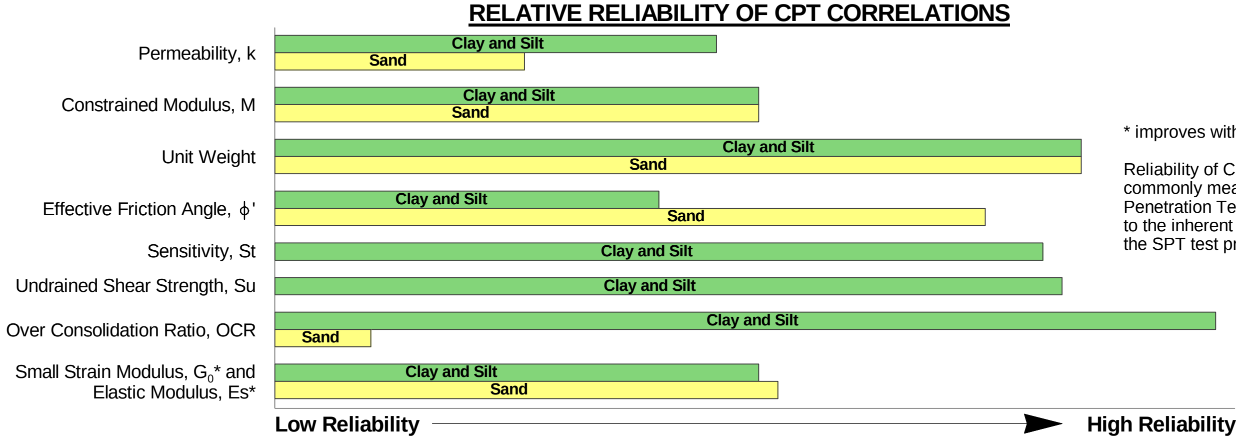
Constrained Modulus, M
$M = \alpha_M(q_t - \sigma_{V0})$
For Ic > 2.2 (fine-grained soils)
$\alpha_M = Q_t$ with maximum of 14
For Ic < 2.2 (coarse-grained soils)
$\alpha_M = 0.0188 \times 10^{(0.55Ic + 1.68)}$

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

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



* improves with seismic Vs measurements

Reliability of CPT-predicted N_{60} values as commonly measured by the Standard Penetration Test (SPT) is not provided due to the inherent inaccuracy associated with the SPT test procedure.

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

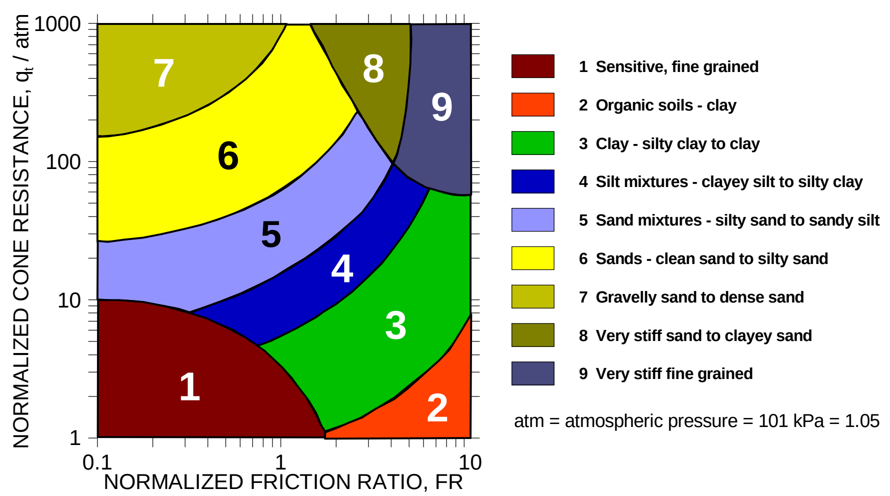
Estimated - Depth to water interpolated by the practitioner using pore pressure measurements in coarse grained soils and known site conditions

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 (fs), 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.



atm = atmospheric pressure = 101 kPa = 1.05 tsf

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Schmertmann, J.H., (1970). "Static Cone to Compute Static Settlement over Sand," *Journal of the Soil Mechanics and Foundations Division*, 96(SM3), 1011-1043.

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Exhibit B-4