REPORT OF PRELIMINARY GEOTECHNICAL EXPLORATION

Marion County Industrial Park

Marion County, South Carolina
S&ME Project No. 1633-12-186

Prepared By:

S&ME

1330 Highway 501 Business
Conway, South Carolina 29526

August 29, 2012
August 29, 2012

Reference: Report of Preliminary Geotechnical Exploration
Marion County Industrial Park
Marion County, South Carolina
S&ME Project No. 1633-12-186

S&ME, Inc. has completed the preliminary geotechnical exploration for the referenced project after receiving authorization to proceed on July 23, 2012. Our exploration was conducted in general accordance with our Proposal No. 1634-0083-11a, dated April 5, 2012.

The purpose of this exploration was to evaluate general subsurface conditions at the site as they relate to general commercial/industrial development, to satisfy portions of the South Carolina Department of Commerce’s Site Certification Program. This report characterizes the general surface and subsurface conditions of the site, offers preliminary recommendations regarding site preparation, suitability of on-site soils for use in construction and potential foundation types. The recommendations contained herein are not valid for design without the confirmation of an additional design level subsurface investigation after the locations of proposed structures, pavements and general site features are determined.

PROJECT INFORMATION

We are familiar with this site having performed a due diligence assessment of approximately 230 acres of the now 360-acre site in 2005. We have also performed geotechnical explorations within the southeast and west portions of the site for industrial development projects under consideration in the past. Our current exploration associated with this report was conducted within the approximately 130 acres of land that has been added to the project site to supplement previous site explorations.
The subject property is comprised of approximately 360 acres, located north of U.S. Highway 76, and is bisected by U.S. Highway 501, in Marion County, South Carolina as shown in Figure 1 of Appendix A. The site generally consists of wooded land with some agricultural or open fields interspersed throughout the property.

EXPLORATION PROCEDURES

Field Exploration
On August 2 through 8, 2012, representatives of S&ME, Inc. visited the site. Using the information provided, we performed the following tasks:

- We performed a site walkover, observing features of topography, existing structures, ground cover, and surface soils at the project site.

- We established six cone penetration test (CPT) sounding locations spread widely throughout the site. The approximate sounding locations are shown on the test location sketch included as Figure 2 in Appendix A.

- Each of the CPT soundings was advanced to a depth of about 30 feet.

- Direct push samples were obtained from each of the sounding locations between depths of approximately 0 to 4 feet. The samples were transported to the laboratory for further observation.

A description of the field tests performed during the exploration as well as the CPT sounding logs are attached in Appendix B.

Laboratory Testing
After the recovered soil samples were brought to our laboratory, a geotechnical professional examined each sample to estimate its distribution of grain sizes, plasticity, organic content, moisture condition, color, presence of lenses and seams, and apparent geologic origin in general accordance with ASTM D 2488, “Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)”.

The resulting classifications are presented on the sounding logs, included in Appendix B. Similar soils were grouped into representative strata on the logs. The strata contact lines represent approximate boundaries between soil types. The actual transitions between soil types in the field are likely more gradual in both the vertical and horizontal directions than those which are indicated on the logs.

SURFACE CONDITIONS
Currently the northwest, southeast, and northeast portions of the site are heavily wooded with dense underbush. The southwest and the northeast portions of the site bordering US Highway 501 appear to be utilized as cultivated agricultural fields. The southeast portion of the site was observed to be wet and appeared to be low-lying areas. A man-made pond was observed between two agricultural fields which border US Highway 501.
Ground surface elevations were not surveyed at the CPT sounding locations for the purposes of this report. From visual observation, the site appears to be relatively level to gently sloping. Organic topsoil and plowzone was encountered at all of the test locations, ranging from about 8 to 18 inches in thickness. Thicker zones of topsoil and rootmat may be encountered in parts of the site that were not explored, and in wooded portions of the site.

**SUBSURFACE CONDITIONS**

**Local Geology**

The site is located in the Coastal Plain Physiographic Region of South Carolina. A review of local geologic mapping indicates that the site area likely lies within an outcrop area of the Bear Bluff Formation (Tb), typically inter-layered terrestrial clays, silts, sands, and shell beds laid down during the Upper Pliocene Epoch approximately 1.8 to 2.4 million years ago.

These materials weathered in place and have formed a mantle of clays and sands anticipated to be approximately 20 to 30 feet thick which overlie less weathered, much older, calcareous soils below. The surface has been reworked by erosional processes over geologic time, and the limestone residuum has been masked by deposits of loose to dense sands or stiff to very stiff clays and silts. The upper contact of the lower sands may be irregular due to localized scouring and redeposition of the overlying clays. Soils below approximately 20 to 30 feet are mapped as Cretaceous-age sediments of the Pee Dee Formation (Kpd). While not penetrated by our CPT soundings, soils below the Pee Dee Formation, are mapped as Cretaceous-age sediments of the Donoho Creek Formation (Kdc).

**USDA Soil Survey Information**

USDA Soils Conservation Service soils mapping for Marion County indicates the sands and loamy sands described in Table 1, as the general soil series composition at the site. Soil map units are also described in terms of some relevant engineering properties or in terms of relative suitability for use in land development. High water elevations are generally given for the winter and spring months (November through April).

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Depth to Seasonal GWT (feet)</th>
<th>Permeability</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coxville fine sandy loam</td>
<td>0 – 2½</td>
<td>Moderately slow</td>
<td>Nearly level slopes</td>
</tr>
<tr>
<td>Dothan loamy fine sand</td>
<td>3½ – 4</td>
<td>Moderately slow</td>
<td>0 to 2 percent slopes 2 to 6 percent slopes</td>
</tr>
<tr>
<td>Duplin fine sandy loam</td>
<td>2½ – 3½</td>
<td>Moderately slow</td>
<td>0 to 2 percent slopes</td>
</tr>
<tr>
<td>Goldsboro loamy fine sand</td>
<td>2 – 3</td>
<td>Moderate</td>
<td>0 to 2 percent slopes</td>
</tr>
</tbody>
</table>
Interpreted Subsurface Profiles

The generalized subsurface conditions at the site are described below. For more detailed descriptions and stratifications at a test location, the respective sounding logs should be reviewed in Appendix B. Two subsurface cross-sectional profile of the site soils are attached in Appendix A as Figures 3 and 4. The cross-section orientations in plan view are shown on Figure 2. These cross-sections are given to provide a general representation of the subsurface conditions encountered at widely-spaced locations across the site.

The strata indicated in the profiles are characterized in the following section. Note that the profiles are not to scale. The subsurface profiles were prepared for illustrative purposes only. Subsurface stratifications may be more gradual than indicated, and conditions may vary between test locations.

Soils encountered by each of the soundings presented on the profile were grouped into four general strata, based on estimated physical properties derived from the CPT data, and the recovered near-surface samples. The strata encountered are labeled I through IV on the soil profiles to allow their properties to be systematically described.

**Stratum I: Upper Soft Clays and Loose Clayey Sands**

Underlying the surficial topsoil and plowzone layers, an upper stratum of clays and clayey sands was encountered to depths ranging from about 4 to 7 feet. These soils consisted of clayey sands, and sandy lean clays, were moist to wet, and were predominately brown, tan, orange, red, and gray in color.

The soils of Stratum I exhibited sleeve stresses ranging from less than 0.1 to about 2.6 tsf. The tip stresses in these soils ranged from less than 10 to about 60 tsf. The soil typically exhibited tip stresses ranging from 10 to 30 tsf, which is consistent with very loose to loose clayey sands, and soft to stiff clays.

**Stratum II: Intermediate Stiff Clays and Medium Dense Clayey Sands**

Beneath Stratum I, beginning at depths of 4 to 7 feet, a stratum of clayey soils was encountered to depths ranging from about 6 to 10 feet. These soils exhibited sleeve stresses ranging from 0.5 to 5.7 tsf. The tip stresses in these soils ranged from 15 to 160 tsf, but typically were around 15 to 45 tsf, which is consistent with medium dense sands, and firm to very stiff clays and silts.

**Stratum III: Intermediate Dense Sands (Bear Bluff Formation)**

Beneath Stratum II, beginning at depths of 6 to 10 feet, a stratum of sandy soils was encountered to depths ranging from about 17 to 22 feet. These soils exhibited sleeve stresses ranging from less than 0.1 to 2.2 tsf. The tip stresses in these soils ranged from 15 to about 245 tsf, but typically were around 75 to 125 tsf, which is consistent with medium dense to dense sands.
Stratum IV: Lower Dense Silty Sands and Stiff Sandy Silts (Pee Dee Formation)

Underlying Stratum III, a layer of silty sands and sandy silts was encountered beginning at depths ranging from 17 to 22 feet, and extending to a depth of about 30 feet. All of the soundings were terminated within this stratum at a depth of about 30 feet. These soils exhibited sleeve stresses ranging from less than 0.1 to 6.8 tsf. Although the tip stresses in these soils ranged from less than 10 to about 375 tsf, the majority of the soil exhibited tip stresses ranging from 30 to 80 tsf, which is consistent with medium dense sands and stiff to hard silts and clays.

A soft clay seam approximately 1 to 3½ feet thick was encountered within this stratum between the depths of 19 to 23½ feet at test locations C-1, C-2, and C-6. These soils exhibited sleeve stresses ranging from less than 0.1 to 1.4 tsf. The tip stresses in these soils ranged from less than 10 to 40 tsf, but typically were around 10 to 20 tsf, which is consistent with soft to stiff silts and clays.

Subsurface Water

Water levels within the CPT soundings were measured at the time of our exploration to range from about 3 to 5 feet below the existing ground surface. Subsurface water levels may fluctuate seasonally at the site, being influenced by rainfall variation and other factors. Site construction activities can also influence water elevations.

PRELIMINARY SEISMIC CONSIDERATIONS

Seismic induced ground shaking at the foundation is the effect taken into account by seismic-resistant design provisions of the 2006 International Building Code (IBC). Other effects, including soil liquefaction, are not addressed in building codes but must also be considered.

Liquefaction of saturated, loose, cohesionless soils occurs when they are subject to earthquake loading that causes the pore pressures to increase, and effective overburden stresses to decrease, to the point where large soil deformation or even transformation from a solid to a liquid state results.

We performed a liquefaction analysis based on the design earthquake prescribed by the 2006 edition of the International Building Code (IBC 2006), the “simplified procedure” as presented in Youd et al. (2001), and recent research concerning the liquefaction resistance of aged sands (Hayati & Andrus, 2008; Andrus et al. 2009; Hayati & Andrus, 2009). Our analysis was based upon a peak ground surface acceleration of 0.22g.

The sands encountered at this site do not appear likely to undergo widespread liquefaction in the event of the design earthquake. Our qualitative assessment was based on the relatively high overall density, the amount of fines of these soils, and their apparent geologic age. These soils are not historically recorded to have experienced liquefaction in previous earthquakes.

To help evaluate the consequences of liquefaction, we have computed the Liquefaction Potential Index (LPI), which is an empirical tool used to evaluate the potential for
liquefaction to cause damage. The LPI considers the factor of safety against liquefaction, the depth to the liquefiable soils, and the thickness of the liquefiable soils to compute an index that ranges from 0 to 100. An LPI of 0 means there is no risk of liquefaction; an LPI of 100 means the entire profile is expected to liquefy. The level of risk is generally defined below.

- \( LPI < 5 \) – surface manifestation and liquefaction-induced damage not expected.
- \( 5 \leq LPI \leq 15 \) – moderate liquefaction with some surface manifestation possible.
- \( LPI > 15 \) – severe liquefaction and foundation damage is likely.

The LPI for this site was less than 1, indicating that the liquefaction risk is low, and the potential for liquefaction does not appear to constitute a seismic hazard.

Based on our previous work performed at the site and our knowledge of the general geologic profile of this area, it appears a Seismic Site Class of D will be available over a large portion of the site. However, we recommend further seismic testing and evaluations be performed once specific structure locations are determined.

CONCLUSIONS AND RECOMMENDATIONS

The preliminary conclusions and recommendations included in this section are based on the project information outlined previously and the data obtained during our exploration. The recommendations provided below are preliminary in nature and should be considered as such. When the final site layout is determined, S&ME, Inc. should be retained to complete a design-grade geotechnical exploration.

Site Preparation and Earthwork

Stripping depths will likely be about 8 to 18 inches over the majority of the site. In drainage features, or within heavily wooded areas of the site, stripping depths may be greater.

Fine-grained, sandy lean clays (CL) were encountered by our soundings in the upper soil profile at the site. These soils may pump, rut and become unstable under construction equipment when they are wet, and may be difficult to dry out once they become wet. These unfavorable conditions will be exacerbated during periods of wet weather. To help reduce the impact of water on site grading, we recommend ditching be installed around the site perimeter prior to starting grading. Drainage by ditching may also need to be performed to remove potential near-surface lenses of perched groundwater. This will reduce the potential for damage to the subgrade during earthwork operations and should help stabilize the subgrade. Perched water can likely be controlled during mass grading by excavating open ditches and/or constructing underdrains that discharge toward lower elevations.

On-Site Fill Suitability

Based upon our interpretation of CPT sounding data, correlations between Robertson Soil Behavior Types and Unified Soil Classification System Soil Types, and the previous explorations performed at the site, highly variable soil types appear to be present within
the subsurface profile. Soil types encountered within the subsurface profile include poorly graded sands (SP), poorly graded sands with silt or clay (SP-SM, SP-SC), silty sands (SM), clayey sands (SC), sandy lean clays and silts (CL, ML), and high plasticity silts and clays (MH, CH). Excluding high plasticity silts and clays (MH, CH), the remaining soil types are typically suitable for reuse as structural fill, based on our past experience. Moisture conditioning may be required after excavation before these soils are suitable for placement and compaction.

Some of the soils that classify as sandy lean clays or silts (CL, ML) or clayey sands (SC) may be less preferred for reuse as fill than other soils of lower fines content. While these clayey soils do contain some sandy material, they often contain a large enough percentage of fines to induce cohesive behavior, especially under wet conditions, and are difficult to dry. Although these soils are not ideal for use as fill material, our experience suggests that contractors have been able to use this type of material when given enough time and suitable weather conditions to properly dry and compact the soils. Drying can typically be facilitated by disk ing and scarifying soils repeatedly during favorable weather conditions.

It should be noted that there may a potential for proposed borrow areas to be overexcavated to obtain access to the deeper sandy soils of Stratum III. Because they are below the water table, the deeper sandy soils will likely need to be stockpiled and allowed to drain prior to use as structural fill. The overexcavated borrow areas could then be backfilled with the clayey soils to the design elevation if this approach appears practical for the project.

**Preliminary Fill Placement and Compaction Recommendations**

Where fill soil is required, structural fill within building pads and parking areas must be compacted throughout to the degree of compaction determined necessary during the final design-grade geotechnical exploration. Compacted soils should be stable and must not exhibit pumping or rutting under equipment traffic. Loose lifts of fill should be no more than 8 inches in thickness prior to compaction. Structural fill should extend at least 10 feet from the edge of building and parking areas before either sloping or being allowed to exhibit a lower level of compaction.

**Potential Foundation Types**

The soil profiles encountered appear generally suitable for development for light to medium industrial use, considering static loading. The use of shallow foundations for support of column loads up to about 100 kips would likely be feasible for typical light to medium industrial structural column configurations, provided footings are properly constructed and settlements of up to about one inch can be tolerated. Area loads imposed by new fill placement, floor slab loads, stacked materials, large vessels or tanks can likely be supported by mat or strip footings, provided that several inches of settlement can be withstood by the structure, or possibly in conjunction with ground improvement which may consist of the following general techniques.
Surcharging.

- Removing and stockpiling the native material, scarifying and densifying the subgrade in place, replacing the stockpiled material in 8-inch loose lifts after properly moisture-conditioning it, and compacting each lift.

- Densifying the existing subgrade at the surface to achieve a stable condition, and overexcavate footings.

Once building locations are established, test soundings and/or borings should be conducted within each building footprint prior to design of foundations.

Groundwater and Surface Runoff Control
Depending on proposed site grades, seasonal fluctuations and other factors, groundwater may be encountered within 3 to 5 feet of the existing ground surface elevations, as indicated on the sounding logs. Due to the highly variable nature of the subsurface water levels in the site vicinity, groundwater may also be encountered in areas of the site not tested in this preliminary subsurface investigation.

If perched water or groundwater is encountered during grading, ditching will be necessary to provide a stable bearing surface for foundations or pavements. In areas where machine pits may be constructed, ditching or excavation of sumps and pumping may be necessary to control potential perched water conditions. Capacity of sediment or detention ponds may also be limited in areas where shallow groundwater is encountered. In areas of proposed construction where shallow groundwater is encountered, it may be desirable to raise site grades to help reduce the impact of groundwater on construction.

During normal rainfall periods, ditching or other provisions for drainage should be provided prior to stripping and grading in low areas. If subsurface water or infiltrating surface water is not properly controlled during construction, the subgrade soils that will support foundations, as well as pavements or floor slabs, may be damaged. Furthermore, construction equipment mobility may be impaired. The design and installation of permanent underdrainage systems may be required to reduce the potential impact of shallow subsurface water, and should be further evaluated during the design phase of development.

Grade Slab Support and Construction
It is likely that grade slabs may be supported upon properly prepared existing soils or borrow soils.

- Soils similar to those penetrated by the soundings will generally provide adequate support to soil-supported slabs, assuming proper preparation, moisture control, and compaction of the subgrade for static load conditions.
• A capillary break of at least 4 inches of granular soils or crushed stone placed below floor slabs will be required. Granular soils proposed for use should have less than 5 percent fines (silt and clay).

• We recommend that a vapor barrier be installed to limit moisture infiltration into finished space, or other areas where moisture infiltration will potentially cause problems. The vapor barrier should be placed below the capillary break material.

Pavement Subgrade Preparation
In their current condition, the surface soils of Stratum I (clays and clayey sands) appear to be typically unsuitable for direct support of pavements. One option would be to stabilize the clay soils using lime or cement stabilization. A second option is to partially undercut the clayey soils and replace them with sand material exhibiting a higher support value, possibly in conjunction with installation of geogrid.

Drainage of subgrade material plays an important role in the performance of pavement sections. Site preparation should allow for drainage that results in groundwater elevations being maintained at least 2 feet below the top of the pavement section. Laboratory California Bearing Ratio (CBR) testing should be performed upon representative soil samples of each soil type during the design geotechnical exploration. This is to establish the relationship between relative compaction and CBR for the existing soils, and to develop recommendations for pavement section design and construction.

RECOMMENDATION FOR ADDITIONAL WORK
It was not within the scope of this preliminary report to explore areas of proposed structures or pavements. A design-grade geotechnical report should be performed, which should include an exploration program designed by the geotechnical engineer, including Standard Penetration Test (SPT) borings or Cone Penetration Test (CPT) soundings with seismic design considerations within the areas of any proposed structures and pavements. The exploration program should also include laboratory testing to evaluate engineering properties of subsurface soils and facilitate development recommendations for design and construction.

LIMITATIONS OF REPORT
This report has been prepared in accordance with generally accepted geotechnical engineering practice for specific application to this project. The conclusions and recommendations in this report are based on the applicable standards of our practice in this geographic area at the time this report was prepared. No other warranty, express or implied, is made.

The analyses and recommendations submitted herein are based, in part, upon the data obtained from the subsurface exploration. The nature and extent of variations of the soils at the site to those encountered at our test locations will not become evident until construction. If variations appear evident, then we will re-evaluate the recommendations of this report. In the event that any changes in the nature, design, or location of the
development are planned, the conclusions and recommendations contained in this report will not be considered valid unless the changes are reviewed and conclusions modified or verified in writing by the submitting engineers.

Assessment of site environmental conditions; sampling of soils, ground water or other materials for environmental contaminants; identification of jurisdictional wetlands, rare or endangered species, geological hazards, potential air quality and noise impacts, seismic considerations, or seismic site class determination were beyond the scope of this geotechnical exploration.

**CLOSURE**

S&ME appreciates this opportunity to work with you, as your geotechnical engineering consultant. If you should have any questions concerning this preliminary geotechnical report, please do not hesitate to contact us.

Very truly yours,
S&ME, Inc.

Christopher M. Douton, P.E.
Project Engineer

Thomas C. Still, P.E.
Senior Engineer

Attachments: Appendix A  
Appendix B
APPENDIX A

SITE VICINITY PLAN

TEST LOCATION PLAN

INTERPRETED SUBSURFACE PROFILES
SITE VICINITY MAP
Marion County Industrial Park
Marion County, South Carolina

SCALE: 1" = 1 mile
SOURCE: ESRI 2010
DRAWN BY: CMD
DATE: August, 2012
JOB NO. 1633-12-186

1
FIGURE NO.

SUBJECT PROPERTY
34.2 / -79.353
The depicted stratigraphy is shown for illustrative purposes only and is not warranted. Separations between different strata may be gradual and likely vary considerably from those shown. Profiles between nearby borings have been estimated using reasonable engineering care and judgment. The actual subsurface conditions will vary between boring locations.
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**SUBSURFACE PROFILE - B-B'**

**PROJECT:** Marion County Industrial Park  
**LOCATION:** Marion, South Carolina  
**FIGURE:** 4

**FACING NORTHEAST**

**STRATUM I:** UPPER SOFT CLAYS & LOOSE CLAYEY SANDS  
**STRATUM II:** INTERMEDIATE STIFF CLAYS & MEDIUM DENSE CLAYEY SANDS  
**STRATUM III:** INTERMEDIATE DENSE SANDS (BEAR BLUFF FORMATION)  
**STRATUM IV:** LOWER DENSE SILTY SANDS AND STIFF SANDY SILTS (PEE DEE FORMATION)
APPENDIX B

SUMMARY OF EXPLORATION PROCEDURES

CPT SOIL CLASSIFICATION LEGEND

CPT SOUNDING LOGS
SUMMARY OF EXPLORATION PROCEDURES

The American Society for Testing and Materials (ASTM) publishes standard methods to explore soil, rock and ground water conditions in Practice D-420-98, “Standard Guide to Site Characterization for Engineering Design and Construction Purposes.” The boring and sampling plan must consider the geologic or topographic setting. It must consider the proposed construction. It must also allow for the background, training, and experience of the geotechnical engineer. While the scope and extent of the exploration may vary with the objectives of the client, each exploration includes the following key tasks:

- Reconnaissance of the Project Area
- Preparation of Exploration Plan
- Layout and Access to Field Sampling Locations
- Field Sampling and Testing of Earth Materials
- Laboratory Evaluation of Recovered Field Samples
- Evaluation of Subsurface Conditions

The standard methods do not apply to all conditions or to every site. Nor do they replace education and experience, which together make up engineering judgment. Finally, ASTM D 420 does not apply to environmental investigations.

RECONNAISSANCE OF THE PROJECT AREA

Where practical, we reviewed available topographic maps, county soil surveys, reports of nearby investigations and aerial photographs when preparing the boring and sampling plan. Then we walked over the site to note land use, topography, ground cover, and surface drainage. We observed general access to proposed sampling points and noted any existing structures.

Checks for Hazardous Conditions - State law requires that we notify the Palmetto Utility Protection Service (PUPS) before we drill or excavate at any site. PUPS is operated by the major water, sewer, electrical, telephone, CATV, and natural gas suppliers of South Carolina. PUPS forwarded our location request to the participating utilities. Location crews then marked buried lines with colored flags within 72 hours. They did not mark utility lines beyond junction boxes or meters. We checked proposed sampling points for conflicts with marked utilities, overhead power lines, tree limbs, or man-made structures during the site walkover.

SOUNDINGS AND SAMPLING

Electronic Cone Penetrometer (CPT) Soundings

CPT soundings consist of a conical pointed penetrometer which is hydraulically pushed into the soil at a slow, measured rate. Procedures for measurement of the tip resistance and side friction resistance to push generally follow those described by ASTM D-5778, “Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils.”
A penetrometer with a conical tip having a 60 degree apex angle and a cone base area of 10 cm$^2$ was advanced into the soil at a constant rate of 20 mm/s. The force on the conical point required to penetrate the soil was measured electronically every 50 mm penetration to obtain the cone resistance $q_c$. A friction sleeve is present on the penetrometer immediately behind the cone tip. The force exerted on the sleeve was measured electronically at a minimum of every 50 mm penetration and divided by the surface area of the sleeve to obtain the friction sleeve resistance value $f_s$. A pore pressure element mounted immediately behind the cone tip was used to measure the pore pressure induced during advancement of the cone into the soil.

**CPT Soil Stratification**

Using ASTM D-5778 soil samples are not obtained. Soil classification was made on the basis of comparison of the tip resistance, sleeve resistance and pore pressure values to values measured at other locations in known soil types, using experience with similar soils and exercising engineering judgment.

Plots of normalized tip resistance versus friction ratio and normalized tip resistance versus penetration pore pressure were used to determine soil classification (Soil Behavior Type, SBT) as a function of depth using empirical charts developed by P.K. Robertson (1990). The friction ratio soil classification is determined from the chart in the appendix using the normalized corrected tip stress and the normalized corrected tip stress and the normalized friction ratio.

At some depths, the CPT data fell outside of the range of the classification chart. When this occurred, no data was plotted and a break was shown in the classification profile. This occasionally occurred at the top of a penetration as the effective vertical stress is very small and commonly produced normalized tip resistances greater than 1000.

To provide a simplified soil stratigraphy for general interpretation and for comparison to standard boring logs, a statistical layering and classification system was applied the field classification values. Layer thicknesses were determined based on the variability of the soil classification profile, based upon changes in the standard deviation of the SBT classification number with depth. The average SBT number was determined for each successive 6-inch layer, beginning at the surface. Whenever an additional 6-inch increment deviated from the previous increment, a new layer was started, otherwise, this material was added to the layer above and the next 6-inch section evaluated. The soil behavior type for the layer was determined by the mean value for the complete layer.

**Refusal to CPT Push**

Refusal to the cone penetrometer equipment occurred when the reaction weight of the CPT rig was exceeded by the thrust required to push the conical tip further into the ground. At that point the rig tended to lift off the ground. Refusal may have resulted from encountering hard cemented or indurated soils, soft weathered rock, coarse gravel, cobbles or boulders, thin rock seams, or the upper surface of sound continuous rock. Where fills are present, refusal to the CPT rig may also have resulted from encountering buried debris, building materials, or objects.
**Direct Push Samples**

Soil samples were obtained in the CPT soundings at selected depths using a Vertek direct push sampler. The soil sampler consists of a 1.4 inch ID stainless steel tube which is hydraulically pushed to the desired depth with the CPT equipment. The cone tip is retracted into the sample barrel by a lanyard lowered through the push rods. Once the tip is released, the lanyard is removed and the sampler advanced into the soil. The probe forces the sample into a clear plastic sleeve through a core catcher. The probe is then retracted, bringing the filled plastic sleeve to the surface. The recovered sleeve is then capped and transported to the laboratory for further evaluation.

**Subsurface Water Level Determination**

CPT penetration pore pressures include the *in-situ equilibrium pore pressure*, controlled by the local ground water regime, and the *excess pore pressure*, generated by insertion of the probe. In clays and silts, penetration is essentially undrained and recorded pore pressures significantly exceed in-situ equilibrium pore pressures. In sands and gravels, penetration is essentially drained and recorded pore pressures are essentially equal to the in-situ equilibrium pore pressure. The piezometric surface, defined as the point of zero equilibrium pore pressure, was obtained by plotting in-situ equilibrium pore pressure vs. depth using only pore pressure data from sand or gravel soils. Where possible, derived piezometric surface was verified by tape measurement through the sounding opening after removal of the CPT rod and before collapse of the soils.

**Examination of Recovered Soil Samples**

Soil and field records were reviewed in the laboratory by the geotechnical professional. Soils were classified in general accordance with the visual-manual method described in ASTM D 2488, “*Standard Practice for Description and Identification of Soils (Visual-Manual Method)*”.
FIELD TESTING PROCEDURES

Cone Penetrometer Test (CPT) Sounding

The cone penetrometer test soundings (ASTM D 5778) were performed by hydraulically pushing an electronically instrumented cone penetrometer through the soil at a constant rate. As the cone penetrometer tip was advanced through the soil, nearly continuous readings of point stress, sleeve friction and pore water pressure were recorded and stored in the on-site computers. Using theoretical and empirical relationships, CPT data can be used to determine soil stratigraphy and estimate soil properties and parameters such as effective stress, friction angle, Young’s Modulus and undrained shear strength.

The consistency and relative density designations, which are based on the cone tip resistance, \( q_t \) for sands and cohesive soils (silts and clays) are as follows:

<table>
<thead>
<tr>
<th>SANDS</th>
<th>SILTS AND CLAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone Tip Resistance, ( q_t ) (tsf)</td>
<td>Relative Density</td>
</tr>
<tr>
<td>&lt;20</td>
<td>Very Loose</td>
</tr>
<tr>
<td>20 – 40</td>
<td>Loose</td>
</tr>
<tr>
<td>40 – 120</td>
<td>Medium Dense</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>120 – 200</td>
<td>Dense</td>
</tr>
<tr>
<td>&gt;200</td>
<td>Very Dense</td>
</tr>
</tbody>
</table>

CPT Correlations

References are in parenthesis next to the appropriate equation.

**General**

\( p_a \) = atmospheric pressure (for unit normalization)  
\( q_t \) = corrected cone tip resistance (tsf)  
\( f_s \) = friction sleeve resistance (tsf)  
\( R_f = 100\% \cdot \frac{f_s}{q_t} \)  
\( u_2 \) = pore pressure behind cone tip (tsf)  
\( u_0 \) = hydrostatic pressure  
\( B_q = \frac{(u_2-u_0)/(q_t-\sigma_v)}{\sigma_v} \)  
\( Q_t = \frac{(q_t-\sigma_v)}{\sigma_v} \)  
\( F_r = 100\% \cdot \frac{f_s}{(q_t-\sigma_v)} \)  
\( I_c = \{(3.47-\log Q_t)^2+(\log F_r+1.22)^2\}^{0.5} \)

\[ N_{60} = \frac{(q_t/p_a)}{[8.5(1-I_c/4.6)]} \]  (6)

## CPT Soil Classification Legend

<table>
<thead>
<tr>
<th>Zone</th>
<th>Qc/N</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Sensitive, Fine Grained</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Organic Soils - Peats</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>Clays - Clay to Silty Clay</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Silt Mixtures - Clayey Silt to Silty Clay</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Sand Mixtures - Silty Sand to Sandy Silt</td>
</tr>
<tr>
<td>6</td>
<td>4.5</td>
<td>Sands - Clean Sand to Silty Sand</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Gravelly Sand to Sand</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Very Stiff Clay to Clayey Sand*</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>Very Stiff, Fine Grained*</td>
</tr>
</tbody>
</table>

(*) Heavily Overconsolidated or Cemented

## Robertson's Soil Behavior Type (SBT), 1990

<table>
<thead>
<tr>
<th>Group #</th>
<th>Description</th>
<th>Ic</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sensitive, fine grained</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Organic soils - peats</td>
<td></td>
<td>3.60</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>Clays - silty clay to clay</td>
<td>2.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Silt mixtures - clayey silt to silty clay</td>
<td>2.60</td>
<td>2.95</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sand mixtures - silty sand to sandy silt</td>
<td>2.05</td>
<td>2.60</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sands - clean sand to silty sand</td>
<td>1.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Gravelly sand to dense sand</td>
<td>N/A</td>
<td></td>
<td>1.31</td>
</tr>
<tr>
<td>8</td>
<td>Very stiff sand to clayey sand (High OCR or cemented)</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Very stiff, fine grained (High OCR or cemented)</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soil behavior type is based on empirical data and may not be representative of soil classification based on plasticity and grain size distribution.

## Relative Density and Consistency Table

<table>
<thead>
<tr>
<th>Cone Tip Stress, qt (tsf)</th>
<th>Relative Density</th>
<th>Cone Tip Stress, qt (tsf)</th>
<th>Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 20</td>
<td>Very Loose</td>
<td>Less than 5</td>
<td>Very Soft</td>
</tr>
<tr>
<td>20 - 40</td>
<td>Loose</td>
<td>5 - 15</td>
<td>Soft to Firm</td>
</tr>
<tr>
<td>40 - 120</td>
<td>Medium Dense</td>
<td>15 - 30</td>
<td>Stiff</td>
</tr>
<tr>
<td>120 - 200</td>
<td>Dense</td>
<td>30 - 60</td>
<td>Very Stiff</td>
</tr>
<tr>
<td>Greater than 200</td>
<td>Very Dense</td>
<td>Greater than 60</td>
<td>Hard</td>
</tr>
</tbody>
</table>
Marion County Industrial Park
Marion, South Carolina
S&ME Project No: 1633-12-186

Cone Penetration Test
C-2

Date: Aug. 8, 2012
Estimated Water Depth: 3.5 ft
Rig/Operator: CPT Track Rig/M. Cox

Total Depth: 29.9 ft
Termination Criteria: Target Depth
Cone Size: 1.75

Depth (ft)
0 5 10 15 20 25

Tip Resistance
$q_t$ (tsf)

Sleeve Friction
$f_s$ (tsf)

Pore Pressure
$u_d$, $u_s$ (tsf)

Friction Ratio
$R_f$ (%)

Equivalent
$N_{eq}$

$SBT_{fr}$
MAI = 4

Depth (ft)
0 5 10 15 20 25

Very Stiff Fine Grained Soils
Sands-Clean Sand to Silty Sand
Clays-Clay to Silty Clay
Sand Mixtures-Silty Sand to Sandy Silt

Electronic Filename: G08G1205C.DAT
**Cone Penetration Test**

**Marion County Industrial Park**
Marion, South Carolina
S&ME Project No: 1633-12-186

**Date:** Aug. 8, 2012  
**Estimated Water Depth:** 3.5 ft  
**Rig/Operator:** CPT Track Rig/M. Cox

**Total Depth:** 30.0 ft  
**Termination Criteria:** Target Depth  
**Cone Size:** 1.75

**Depth (ft):**
- 0
- 5
- 10
- 15
- 20
- 25

**Tip Resistance (tsf):**
- 80
- 160
- 240
- 320

**Sleeve Friction (tsf):**
- 2
- 4
- 6
- 8

**Pore Pressure (tsf):**
- 0
- 5
- 10
- 15

**Friction Ratio (%):**
- 2
- 4
- 6
- 8

**Equivalent N<sub>ae</sub>**

**SBT<sub>fr</sub>**  
MAI = 4

**Depth (ft):**
- 0
- 5
- 10
- 15
- 20
- 25

**Soil Layers:**
- Very Stiff Fine Grained Soils
- Sands-Clean Sand to Silty Sand
- Sand Mixtures-Silty Sand to Sandy Silt
- Silt Mixtures-Clay Silt to Silty Clay
- Sand Mixtures-Silty Sand to Sandy Silt

---

**Electronic Filename:** G08G1206C.DAT
Cone Penetration Test

Marion County Industrial Park
Marion, South Carolina
S&ME Project No: 1633-12-186

Date: Aug. 8, 2012
Estimated Water Depth: 3 ft
Rig/Operator: CPT Track Rig/M. Cox

Total Depth: 29.9 ft
Termination Criteria: Target Depth
Cone Size: 1.75

Depth (ft) vs Tip Resistance (q_t (tsf)), Sleeve Friction (f_s (tsf)), Pore Pressure (u_s (tsf)), Friction Ratio (R_f (%)), Equivalent N_e, and Depth (ft) over a range of 0 to 29.9 ft. The soil types indicated include Very Stiff Clay to Clayey Sand, Very Stiff Fine Grained Soils, Clayey to Silty Clay, Clean Sand to Silty Sand, Sand Mixtures-Silty Sand to Sandy Silt, and Soils. The estimated water depth is 3 ft, and the rig/operator is CPT Track Rig/M. Cox. The total depth is 29.9 ft, and the termination criteria is target depth with a cone size of 1.75.
Cone Penetration Test

Date: Aug. 8, 2012
Estimated Water Depth: 4.5 ft
Rig/Operator: CPT Track Rig/M. Cox

Total Depth: 29.9 ft
Termination Criteria: Target Depth
Cone Size: 1.75

Depth (ft)

<table>
<thead>
<tr>
<th>Tip Resistance</th>
<th>Sleeve Friction</th>
<th>Pore Pressure</th>
<th>Friction Ratio</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_t$ (tsf)</td>
<td>$f_s$ (tsf)</td>
<td>$u_1$ (tsf)</td>
<td>$R_f$ (%)</td>
<td>$N_{eq}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
</tbody>
</table>

$S_{BT_{fr}}$ MAI = 4

Electronic Filename: G08G1202C.DAT

Marion County Industrial Park
Marion, South Carolina
S&ME Project No: 1633-12-186
C-6