N61165.AR.003083
CNC CHARLESTON
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FUEL DISTRIBUTION SYSTEM CONTAMINATION ASSESSMENT REPORT ZONE G
VOLUME 2 OF 3 APPENDICES A AND B CNC CHARLESTON SC
9/10/1998
ENSAFE INC.

ZONE G
FUEL DISTRIBUTION SYSTEM
CONTAMINATION ASSESSMENT REPORT
NAVBASE CHARLESTON
NORTH CHARLESTON, SOUTH CAROLINA

Volume II of III
Appendix A and B

CTO-029
Contract Number: N62467-89-D-0318

Prepared for:

Department of the Navy
Southern Division
Naval Facilities Engineering Command
North Charleston, South Carolina

Prepared by:

EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962

September 10, 1998
Revision: 0

Appendix A

Fuel Distribution System
CPT Logs

CONE PENETRATION TESTING WITH SOIL ELECTRICAL CONDUCTIVITY MEASUREMENTS, AND SOIL SAMPLING
ZONE G, CHARLESTON NAVAL BASE
CHARLESTON, SOUTH CAROLINA

Prepared for:

EnSafe/Allen and Hoshall
2114 Airport Blvd.
Pensacola, Florida 32504

Prepared by:

STRATIGRAPHICS
The Geotechnical Data Acquisition Corporation
439 Taylor Avenue
Glen Ellyn, Illinois 60137
Phone: (630) 790-4610

December, 1996
96-110-230

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1.0 INTRODUCTION

STRATIGRAPHICS, The Geotechnical Data Acquisition Corporation, performed geo-environmental penetrometer exploration in Zone G of the Charleston Naval Base in Charleston, South Carolina. Cone Penetration Test with soil Electrical Conductivity measurements (CPT-EC) soundings were performed to provide indirect data on site stratigraphy for evaluation by Ensafe/Allen and Hoshall (Ensafe). Penetrometer soil samples were also collected for Ensafe's evaluation of Site geochemical characteristics.

Exploration work was performed during the period of September 11 to October 6, 1996, and totaled 16 days of field work. Sixty one CPT-EC soundings were performed for a total of 611.1 ft of data. Sounding depths ranged from 6.3 to 31.1 ft. Fifty one soil samples were collected from depths ranging from 2.7 to 14.7 ft.

This final report includes all CPT-EC sounding logs, interpreted sounding logs, tabulations of recorded data and correlated geotechnical parameters for each location. A summary of the sampling program is included in this report as Table 1. Capabilities and aspects of penetrometer exploration techniques are included in the main body of the report, both for this specific study and for penetrometer uses in general. Detailed discussions of geotechnical data correlation are included in Appendix A.

2.0 PENETROMETER EQUIPMENT AND DATA ACQUISITION

2.1 Procedure The Cone Penetration Test (CPT) consists of smoothly pushing a small diameter, instrumented probe (penetrometer) deep into the ground while a computer data acquisition system analyzes the soil response to penetration (Figure 1a). The CPT penetrometer models a foundation pile under failure load conditions. CPT data are used to develop continuous, high resolution profiles of in situ soil conditions rapidly, accurately and economically.

The soil resistance to penetration, acting on the tip and along the sides of the penetrometer, is measured during CPT. CPT soil resistance measurements are accurate and repeatable, and allow the evaluation of stratigraphy and various geotechnical parameters. Performance of CPT is specified by ASTM Standard D3441.

A pressure transducer is added to the CPT penetrometer to acquire hydrogeologic data (Saines and others, 1989) and is called a Piezometric Cone Penetration Test (CPTU). A soil electrical conductivity sensor is added to the penetrometer (CPTU-EC) to acquire geotechnical, hydrogeological and qualitative geochemical data (Strutynsky and others, 1991). Penetrometer samplers can be used for direct sampling (Strutynsky and Sainey, 1990).

The penetrometer is mounted on a string of sounding rods. A hydraulic ram is used to push the penetrometer into the ground at a constant rate of 4 ft per minute. Electronic signals from downhole sensors are transmitted by a cable, strung through the sounding rods, to a computer data acquisition and display system.

Measurements are monitored in real time for immediate definition of subsurface conditions. The downhole equipment is steam cleaned during retrieval at the end of a test. Open hole is grouted using a bentonite clay grout. A closed circuit television system is used for observation of the rod string during operations.

A 3 axle truck is used to carry the penetrometer system. Truck weight and ballast serve to counteract the thrust of the hydraulic ram. The enclosed work area allows all-weather operations. Field computers, samplers, electrical power, lighting, compressed air, steam cleaner, grout pump, water tank and spare parts are all included within the penetrometer truck, providing for self-contained operations.

No borehole is required during penetrometer operations because penetrometers are directly thrust into the soil from the ground surface. Pressures of up to 2 million pounds per square foot can be applied to the tip of the penetrometer for penetration of most soils finer than medium gravel. Asphalt pavements can usually be penetrated by penetrometer methods without predrilling.

Site disturbance is reduced since no borehole cuttings or drilling fluids are generated during penetrometer operations. Personnel exposure to possibly contaminated soil is significantly less than exposures during drilling and sampling operations. Penetrometer downhole equipment is readily decontaminated by steam cleaning during retrieval, when contaminated soils are encountered.

Four to thirteen hundred feet of CPT, without time dependent piezometric, gamma or induced fluorescence measurements, can be performed in one day, depending on site access. Depths of more than 180 ft can be achieved, depending on site stratigraphy.

An un-instrumented prepunch tool can be used to push aside subsurface obstructions. Where soils are exceptionally dense or gravelly and prevent the use of instrumented penetrometers, the prepunch tool can be used to probe the subsurface. Information obtained using the prepunch tool can be similar to that obtained during mechanical (Dutch) cone testing, especially where friction on the sounding rods is minimal.

STRATIGRAPHICS has also developed techniques where dynamic driving can be used in conjunction with the thrust of the hydraulic ram to aid in penetration of very dense or gravelly soils. Dynamic driving can be used during prepunching or sampling activities.

2.1.1 Signal Conditioning and Recording CPT data are acquired using a 16 bit (resolution of 1 part in 32,768) analog to digital data logger and field computer. Test data are displayed on screen allowing for real-time evaluation subsurface conditions. Field sounding logs are provided at the end of each test. Data are recorded for data processing and long term storage.

2.2 Soil Shear Resistance Measurements The resistance of a soil to penetration is measured on the tip and along the sides of the CPT penetrometer. The conical tip of the penetrometer has a projected cross-sectional area of 15 square centimeters (2.3 square inches), and a diameter of 1.7 inches. The soil resistance acting on the cone tip reflects the deep bearing capacity of a soil, and is termed cone end bearing or tip resistance.

The sliding friction between the soil and the penetrometer is measured along a cylindrical sleeve mounted just behind the cone tip. The sleeve has a surface area of 200 square centimeters (31.0 square inches), a length of 5.8 inches, and a diameter just slightly larger than the cone tip. The measurement of soil friction acting on the sleeve is termed friction sleeve or sleeve resistance.

Two strain gage loadcells are used to measure the tip and sleeve resistances (Strutynsky and others, 1985). The tip measurement has a layer detection limit of about a 2 to 4 inches and has an accuracy of about +/- 0.5 TSF. The sleeve measurement has a resolution of about 6 inches and an accuracy of about +/- 0.07 TSF.

2.3 Piezometric Measurements A miniature pressure transducer is used to measure the soil water pressure response to penetration simultaneously with the tip and sleeve measurements. The CPTU piezometric measurement has a layer detection limit of about 1 inch and an accuracy of about +/- 0.5 ft of water head pressure.

The volumetric distortion of a soil caused by the advance of the penetrometer generates a localized water pressure field. Generated pressures dissipate almost instantaneously in soils of high permeability and thus equilibrium water pressures are measured during CPTU in coarse sands and gravels. In medium or low permeability soils, the generated water pressure requires a significant amount of time to dissipate (Saines and others, 1989). Excess (above or below ambient) water pressures are measured during CPTU in soils of medium or lower permeability.

The dissipation of generated water pressure can be recorded as a function of time during pauses in the penetration process and is termed a dissipation test. If the pauses are long enough for all generated water pressures to dissipate, multiple potentiometric surface measurements can be obtained in a single CPTU sounding. The dissipation test also can be used to estimate soil hydraulic conductivity and consolidation characteristics.

2.3.1 Piezometer Saturation The CPTU piezometer filter is saturated with an incompressible liquid so instantaneous responses (zero lag time) are achieved during testing. High saturation levels are indicated by sharp responses at interfaces and immediate regeneration of excess water pressure after pauses in penetration.

Low saturation levels leading to poor results can be caused by inadequate equipment preparation, soil suction, or filter damage on coarse soil particles. Clogging of piezometric filters by clay particles also can lead to poor results. Loss of filter saturation or clogged filters are beyond the control of the equipment operator. Thus, the piezometric measurements can be less repeatable than the tip and sleeve measurements.

2.4 Electrical Conductivity and Thermal Measurements A CPTU-EC penetrometer including tip, sleeve, piezometric, temperature, and electrical conductivity (EC) sensors can be used to simultaneously acquire geotechnical, hydrogeological and qualitative geochemical information. Soil EC is measured using a two electrode array (Figure 1b) mounted on the penetrometer tip. A 3 kHz alternating current is applied to the array to control polarization and contact resistance effects. Soil EC is computed based on voltages induced across the array and a reference resistor. The EC measurement has a resolution of about 0.75 inches.

A thermistor is mounted inside the penetrometer to measure temperature. Significant frictional heating occurs when advancing the penetrometer through sandy soils. By pausing during the penetration process, generated heat will dissipate and the penetrometer will reach thermal equilibrium with the soil. The accuracy of soil temperature measurements is about 0.5 degrees C.

2.5 Natural Gamma Measurements A CPTU-ECG penetrometer incorporating cone, friction, piezometric, soil electrical conductivity and natural gamma (G) sensors can be used to simultaneously acquire geotechnical, hydrogeological, qualitative geochemical and radiological information. Gamma measurements can be used in lithologic interpretation, as clay strata typically have a greater content of naturally occurring radionuclides than sand strata. The presence of radionuclide contamination can also be detected using gamma logging.

2.6 Induced Fluorescence A CPTU-ECG-IF penetrometer incorporating cone, friction, piezometric, soil electrical conductivity, natural gamma, and downhole Induced Fluorescence (IF) sensors can be used to simultaneously acquire geotechnical, hydrogeological, qualitative and quantitative geochemical and radiological information.

The IF system consists of a sapphire window in the penetrometer, and a fiber-optics cable strung alongside the penetrometer instrumentation cable. An ultra-violet light is transmitted through the window, into the adjacent soil. If the soil contains compounds, such as petroleum hydrocarbons, that fluoresce, the resulting light is guided uphole through the fiber optics cable for analysis.

The intensity of the returned light can be related to the concentration of downhole contamination. By monitoring the fluorescent light emissions at different wavelengths, a signature pictogram (wavelength-emission intensity) is generated, which allows fingerprinting of particular contaminants.

2.7 Penetrometer Geometry The CPT penetrometer external geometry is specified by ASTM standards. Differences in penetrometer internal design can lead to some variability in response between penetrometers of different manufacture, especially in very soft clays. CPTU and CPTU-EC details are not specified by ASTM due to the recent development of these test procedures.

The CPTU measurement of generated water pressure is depends on external filter geometry. Measurements of equilibrium water pressures after pauses in the penetration process are not sensitive to geometry, and reflect undisturbed conditions.

CPTU piezometric filters are typically mounted on either the cone tip or just ahead of the friction sleeve. Each position has advantages and disadvantages. Measurements taken with the cone tip filter are at a maximum and show high resolution of thin soil seams. The cone tip filter is more prone to damage on coarse soil particles than the friction sleeve filter.

Negative pressures are often measured in dense, silty or clayey sands and hard clays when using the friction sleeve filter. These low pressures are caused by soil elastic rebound (expansion) as the soil moves from the intensely loaded region beneath the cone tip to the less loaded region next to the friction sleeve. Soil expansion can induce large suction forces on the friction sleeve filter, which then can often result in decreased filter saturation levels.

Site characteristics and data usage determine which piezometric filter geometry is appropriate for use. The piezometric filter is placed at the friction sleeve position on the CPTU-EC penetrometer. Generally good results can be obtained using this geometry when proper equipment preparation techniques are observed.

2.8 Downhole Equipment Decontamination The rod string is retrieved through a rod washer mounted at the bottom of the hydraulic ram assembly. The rod washer is pressurized by the rig steam cleaner. Rubber seals control water leakage from around the sounding rods. Waste water can be pumped to storage for disposal. About 1/2 gallon of water is generated for every 10 ft of rod decontaminated.

2.9 Grouting of Open Hole The STRATIGRAPHICS grouting system is used to seal open hole. As penetrometers are being advanced, a bentonite grout is pumped into the annular space between the 1.5 inch diameter sounding rods and the soil formed by the passage of the 1.72 inch diameter penetrometer. A bypass valve is opened and additional grout is pumped to seal the hole during downhole equipment retrieval. About 3/4 gallons of grout are required to seal every 10 ft of open hole.

Pressure grouting during sounding advance controls cross-contamination between different strata. The grout decreases the contact of downhole equipment with contaminated soil. The grout also can decrease friction on the sounding rods, which allows deeper penetration capabilities. Grout levels are checked after hole completion; additional grout is added to account for penetration of grout into permeable strata.

3.0 PENETROMETER SAMPLING EQUIPMENT

Groundwater, soil gas, and soil samplers are deployed in the same manner as CPTU-EC penetrometers. Good sample isolation is achieved because no open hole exists during penetrometer operations.

3.1 Groundwater Sampler The STRATIGRAPHICS groundwater sampler is a shielded wellpoint sampler of heavy construction. The shield prevents contamination of the sampler while penetrating soils above the sampling depth. After shield retraction, groundwater flows under in situ pressure conditions, through a 20 inch long screen, and up into the 350 ml sample barrel. The sampler is retrieved to pour off the sample and for decontamination. Small diameter pumps can be used with the sampler to acquire large volumes of sample. The sampler is deployed with heavy wall penetrometer sounding rod. The STRATIGRAPHICS sampler can be deployed in any soil capable of being penetrated by the CPTU-EC penetrometer.

A small diameter water pressure transducer can be lowered into the sampler after deployment. The transducer allows the measurement of the sample inflow rate. Analysis of this data can provide another means of estimating soil hydraulic conductivities. If equilibrium conditions are allowed to occur, a measurement of the static water pressure head can be obtained during groundwater sampling.

3.2 Soil Gas Sampler The STRATIGRAPHICS soil gas sampler consists of a sealed slide assembly mounted on the heavy wall penetrometer sounding rods. The slide is opened, and a cavity is created in the soil, by pulling back the rod string during sampling. The slide can be closed, and the rod string advanced to a greater depth, to allow multiple sampling events during a single rod trip.

A fitting is placed over the top of the sounding rods to seal the hollow rod string. Tubing is run from the fitting to an onboard vacuum system. A vacuum box can be used to inflate Tedlar bags for gas sample containment. Analytical equipment can be mounted in line with the tubing to allow real time analysis. The sampler, rod string and tubing are purged before sampling.

3.3 Soil Samplers Fixed piston samplers are used to obtain soil samples during penetrometer exploration. The STRATIGRAPHICS, MOSTAP 35 and MOSTAP 2-meter samplers are deployed using the heavy wall penetrometer sounding rods. A piston, locked into the tip of the barrel to prevent soil from entering the sampler prematurely, is released at the sampling depth. The barrel is then advanced to the bottom of the sampling interval. The soil enters the liners within the barrel and is retained by a core catcher. The sampler is retrieved to remove the sample and for sampler decontamination.

A modified MOSTAP 35 sampler is used to obtain 1 inch diameter samples as long as 2 meters (78 inches). This sampler incorporates a PVC liner and a nylon stocking to allow retrieval of such a long sample. As the sample enters the sampler, it is encased in the nylon stocking. The stocking lessens soil friction around on the sample as it enters the PVC liner. At the end of the 2 meter run, the sampler is rotated to twist shut the stocking, helping retain the sample within the sampler barrel.

4.0 PIEZOMETER INSTALLATION TECHNIQUES

Penetrometer methods can be used to install piezometers for water level measurements, slug testing, groundwater sampling, and for remediation activities, such as sparging and soil vapor extraction (SVE). Various installation techniques are available (Saines and others, 1989). Proprietary, low volume change piezometers also can be installed using penetrometer equipment. These piezometers are often used for long term water pressure measurements during geotechnical projects.

4.1 PVC Standpipe PVC piezometers can be installed using either of two techniques. The simplest is to lower 3/4 inch PVC screen and riser into the open hole left after penetrometer retrieval. Installation and material costs are very low for this technique. A drawback is that caving sands or squeezing clays can limit the depth to which the PVC pipe can be lowered.

PVC piezometers also can be installed using a steel casing pushed to depth. The steel casing is sealed with an expendable tip, which prevents soil from entering the casing during deployment. The PVC screen and risers are lowered into the casing, after it has been pushed to the required depth. The steel casing is withdrawn, leaving the expendable tip and PVC piezometer in place.

4.2 Steel Wellpoint Pipe piezometers can be installed using penetrometer techniques. An exceptionally tight seal between the risers and the formation results from directly pushing the piezometer into the ground. Wellpoints are available in galvanized and stainless steel materials. Risers can be made from stainless steel, galvanized steel or black iron pipe.

5.0 DATA REDUCTION

est data are monitored as the soundings are performed. Data are recorded on hard disk and may consist of: depth, time, tip and sleeve resistance, generated water pressure, temperature, and soil electrical conductivity. Data are processed for final reporting using an in-house computer system. Before final reporting, data pass a quality control review. Routine checking of proper equipment performance is conducted in the field. Office review helps assure that data quality is maintained throughout the study.

Several parameters can be computed to enhance data correlation:

friction ratio, FR (in %):

$$FR = fs/qc * 100 \qquad \text{(Eq. 1); and}$$

pore pressure ratio, Bq (dimensionless):

$$Bq = (U-Ue)/(qc-Sv) \qquad \text{(Eq. 2);}$$

where: fs is the measured friction sleeve resistance, in TSF;
qc is the measured cone end bearing resistance, in TSF;
U is the measured generated pore water pressure, in TSF;
Ue is the measured or estimated equilibrium pore water pressure, in TSF; and
Sv is the total soil overburden pressure, in TSF.

Measured data and correlated parameters are presented in a graphical sounding log format for each sounding; numerical data are tabulated at 0.5 ft intervals. Digital data are available on request.

CPTU dissipation test data are recorded as a function of time during pauses in the penetration process. The CPTU dissipation data can be normalized using the following equation:

normalized dissipation level, U* (dimensionless):
(Ut - Ue) / (U0 - Ue) (Eq. 3);

where: Ut is the excess pore water pressure at time t, in TSF;
Ue is the measured or estimated equilibrium, undisturbed pore water pressure (in situ pore water pressure before penetrometer insertion), in TSF; and
U0 is the excess pore water pressure at time equal to zero, at the start of the dissipation test, in TSF

The normalized dissipation level is plotted versus the logarithm of time. In homogeneous soils, the plot takes the shape of a reverse S-curve, beginning at 1.0 at zero time (at the instant the penetration process is stopped) and falling to 0.0 when equilibrium pressures are achieved. Boundary effects in interbedded deposits can cause deviation from this ideal.

Estimates of the horizontal coefficient of soil consolidation can be calculated (Baligh and Levadoux, 1980) using:

Ch (in cm**2/sec) = (r**2*T)/t Eq. 4a.

Estimates of soil hydraulic conductivity in the horizontal direction can be calculated using:

kh (in cm/s) = ((r**2*T)/t)*RR*(Gw/(2.3*Sv')) Eq. 4b;

where: r is the penetrometer radial dimension at the plane of the piezometric filter, equal to 2.2 cm for the friction sleeve filter and 1.9 cm for the cone tip filter;
T is a dimensionless time factor at the 50% normalized dissipation level, equal to 5.5 for the friction sleeve filter and 3.8 for the cone tip filter;
t is the measured time, in seconds, at which the normalized dissipation level is 50%;
RR is a dimensionless soil compressibility parameter;
Gw is the unit weight of water, in kg/cm***3; and
Sv' is the effective soil vertical overburden pressure, in kg/cm**2.

CPTU dissipation test data are individually presented in graphical plots and are summarized in tabular form.

6.0 GENERAL DATA EVALUATION

<u>6.1 Sounding Log</u> The CPTU-EC sounding logs provide high resolution information on subsurface conditions. Soil layering is often highly apparent. Soil relative strength and saturation levels can also be evaluated. Zones of anomalous soil electrical conductivity can readily be identified. Lateral continuity of conditions can be developed by overlaying adjacent sounding logs on a light table and comparing layer characteristics for similarities. Two and three dimensional data visualization software programs are also being used with CPTU-EC data to evaluate site conditions.

<u>6.2 Soil Type Classification</u> Correlations between penetrometer data and soil classification have been developed from geotechnical bearing capacity theory and a relational database on adjacent CPT soundings and drilled boreholes (Douglas and Olsen, 1981). A CPT soil classification chart based on cone tip resistance and friction ratio is presented in Appendix A.

The CPT tip resistance increases exponentially with soil grain size. For example, tip resistance in dense sands ranges from about 100 to 400 tons per square foot (TSF), while tip resistance in a stiff clay ranges from about 5 to 15 TSF. The friction ratio (Section 5.0) is also used for indication of soil type. The friction ratio increases with the fines content and compressibility of a soil. The friction ratio is less than about 1% in a sand and greater than about 3% in a clay.

Correlated CPT soil classifications reflect the soil shear resistance to penetration. Soil shear resistance is not entirely controlled by grain size distribution. However, correlated CPT classifications generally agree with classifications based on grain size distribution methods, such as the Unified Soil Classification System (USCS).

The generated water pressure measurement may be useful for classification of saturated soils. No excess (above or below equilibrium) water pressures are measured during CPTU in soils of high permeability. Penetration of coarse sand and gravel occurs under drained loading conditions, and equilibrium pressures are measured during penetration. The pore pressure ratio (Section 5.0) is zero in high permeability soils.

For saturated soils of permeability less than about 1*10E-2 cm/sec, undrained loading with significant excess water pressure generation occurs during CPTU. Positive excess water pressures are generally measured during penetration of silt or clay soils when using either the cone tip or friction sleeve filter penetrometer (Section 2.7). Pore pressure ratios of fine grained soils typically range from about 0.4 to 1.0.

Positive excess water pressures are also usually measured in dense, silty or clayey sands when using the cone tip filter penetrometer, with pore pressure ratios from about 0 to 0.3. Due to geometric effects (Section 2.7), negative pressures are usually measured in dense, silty or clayey sands, sandy silts, or hard sandy clays with the friction sleeve filter penetrometer. Thus, it is important to note which type of piezometer geometry was used during a study. The CPTU-EC penetrometer uses a friction sleeve piezometric filter.

<u>6.3 Potentiometric Surfaces</u> Equilibrium water pressures are measured during penetrometer advance in saturated, coarse sands and gravels. Measurements of equilibrium water pressures can be obtained during CPTU in lower permeability soils by pausing during the penetration process and allowing generated water pressures to dissipate to equilibrium conditions.

<u>6.4 Soil Saturation</u> Soil saturation can be evaluated by inspection of the CPTU sounding log. Atmospheric (zero) pressure is measured during CPTU in unsaturated soils. Hydrostatic pressures are measured in saturated, high permeability soils. Significant water pressures are generated in saturated, low permeability soils due to penetrometer advance. Decreased levels of water pressure generation can be indicative of partially saturated soils. Decreased water pressure generation also may occur in organic soils due to the high compressibility of organic soil particles and the presence of biogenic gases, such as methane and hydrogen sulfide.

<u>6.5 Soil Hydraulic Conductivity</u> Excess water pressures are generated by penetrometer advance in saturated soils with permeability of less than about 1*10E-2 cm/sec. These pressures can be allowed to dissipate during pauses in the penetration process. The CPTU dissipation test is somewhat similar to a falling head slug test and can be used to estimate soil hydraulic conductivity in the horizontal direction.

Very high water pressures can be generated in low permeability soils by penetrometer advance. The large water pressure changes require soil compressibility (storage) effects to be included in analyses. The CPTU tip resistance provides an index of soil compressibility for these computations (Section 5.0).

6.6 Soil Electrical Conductivity Behavior Soil electrical conductivity (EC) is controlled by the conductance of the soil particles and the fluid occupying the soil pore spaces. The ratio between pore fluid and aggregate soil-pore fluid electrical conductivity is termed the formation factor (Archie, 1942).

Clay minerals can be electrically conductive due to adsorbed water and ionic electrical charges on the clay platelets. Clay conductance depends on mineralogy, porosity and pore fluid characteristics. Sand grains are typically non-conductive, so granular soil conductance is primarily dependent on the conductance of pore fluids. The following factors affect granular soil EC:

Pore fluids Pore fluids play the major role in sand EC. A dry sand has low conductance since both the sand grains and the air in the pore space have very little electrical conductance. Sands saturated with conductive liquids, such as brine or landfill leachates, have high electrical conductivity. Hydrocarbon pore fluids decrease sand EC because of their low conductance.

Saturation Soil saturation has a pronounced effect on soil EC, as conductance increases with water saturation. Low saturation is associated with low EC.

Porosity The low porosity of a dense sand results in less pore fluid available for electrical conductance and thus lower EC; the high porosity of a loose sand is associated with higher EC. Formation factors vary as an inverse function of porosity, from about 3 at high porosity to about 4.5 at low porosity.

Clay content The addition of as little as 5% clay to a sand can significantly increase soil electrical conductance (Windle, 1977).

Gravel Interference The high resolution of the STRATIGRAPHICS CPTU-EC electrode array makes measurements sensitive to soil grain size. Two behaviors can occur when penetrating gravelly soils. One can occur when a large particle is crushed against an electrode, masking it from the pore fluids, which results in very low EC values. This can result in false positive interpretations of hydrocarbon products.

An opposite behavior is observed in gravel deposits which contain few fine grained, intersticial soils. The resolution of the EC measurement is so high that electrical conductance paths are often entirely within the pore fluid of the coarse grained soil. In this situation, high EC values are measured, more closely reflecting pore fluid EC, rather than the soil EC.

EC Evaluation EC data are evaluated for qualitative geochemical characteristics in conjunction with piezometric data and soil types. Anomalous zones possibly indicative of contaminants can be directly sampled for quantitative chemical analysis.

Vadose Zone Low or zero EC values are measured in dry sandy soils. Increased EC in sands above the water table may indicate moisture infiltration. Low EC data in silty or clayey soils can be anomalous as fine grained soils often retain significant amounts of moisture within their pore spaces, creating good conditions for electrical conductance. Thus, low EC values in silty or clayey soils in the vadose zone may indicate hydrocarbon contamination.

Elevated EC values in the vadose zone may be associated with elevated salt content, buried metals and rusted metal objects, flyash and cinders, among others. Elevated salt content is often due to nearby use of road de-icing compounds.

Saturated Soils Low EC values in saturated soils can be indicative of anomalous geochemistry. In particular, depressed EC zones immediately at the water table may be associated with floating (LNAPL) compounds. Very low EC zones at interfaces between aquifers and aquitards may be associated with either floating (LNAPL) or sinking (DNAPL) compounds. Gravel interference must be considered when evaluating depressed EC zones in saturated soils.

Elevated EC values in saturated soils can be due to increased soil clay content or to increased dissolved salts in the ground water. Increased clay contents are evaluated based on the CPTU-EC piezometric data and soil type information. Zones of elevated EC immediately above an aquiclude may be associated with groundwater of increased density due to dissolved salts, such as a brine.

6.7 CPT-SPT Correlation Since many geoscientists are familiar with drilling and split spoon sampling methods of exploration, CPT data have been correlated with the SPT N-value. The SPT N-value is defined by ASTM to be the number of blows of a 140 lb hammer, dropped 30 inches, required to drive a 2 inch outside diameter sampler 12 inches into the bottom of the borehole, after an initial seating drive of 6 inches. Correlations of CPT to the crude SPT have been based on numerical modeling of the two penetration processes and on side by side comparisons (Douglas and others, 1981). Details on CPT-SPT correlations are included in Appendix A.

7.0 OPTIONAL GEOTECHNICAL DATA CORRELATION

CPT data have been correlated with soil type, drained friction angle, undrained shear strength, relative density, and SPT blowcounts, among others. A correlation scheme including tip resistance and friction ratio has proved most useful for evaluating CPT data using computer techniques.

Correlation of CPT data with other parameters has been developed using: 1) comparisons between CPT data and results of other in situ and laboratory tests in adjacent boreholes; 2) CPT testing on large scale soil samples of known composition; and 3) geotechnical bearing capacity and cavity expansion theory. Site specific information can be used to fine tune correlations. Additional information on correlation techniques, including overburden pressure normalization, test drainage conditions and recommended practices, is presented in Appendix A.

8.0 PROGRAM RESULTS

Acquired data are presented following the report text and consist of: 1) CPT-EC sounding logs with lithologic evaluation; 2) data presentation CPT-EC sounding logs; and 3) tabulations of correlated geotechnical parameters, including soil classifications.

It should be noted that the computerized correlations of soil types and other geotechnical properties were generated using a global rather than site specific data base. Use of site specific data was beyond the scope of this study.

SOUNDING NUMBER	SOUNDING DATE	SOUNDING TYPE	DEPTH, FEET
CP-001	09/12/96	CPT-EC	4.1
CP-002	09/12/96	CPT-EC	4.1
CP-003	09/12/96	CPT-EC	4.0
CP-004	09/12/96	CPT-EC	4.2
CP-005	09/12/96	CPT-EC	10.2
CP-006	09/12/96	CPT-EC	4.0
CP-007	09/12/96	CPT-EC	4.6
CP-008	09/13/96	CPT-EC	7.2
CP-009	09/13/96	CPT-EC	4.3
CP-010	09/16/96	CPT-EC	4.3
CP-011	09/16/96	CPT-EC	10.1
CP-012	09/16/96	CPT-EC	10.2
CP-013	09/16/96	CPT-EC	4.6
CP-014	09/16/96	CPT-EC	6.0
CP-015	09/17/96	CPT-EC	5.1
CP-016	9/16/96	CPT-EC	6.2
CP-017	09/17/96	CPT-EC	4.2
CP-019	09/17/96	CPT-EC	4.8
CP-020	09/17/96	CPT-EC	6.3
CP-021	09/17/96	CPT-EC	10.5
CP-024	09/17/96	CPT-EC	6.3
CP-033	09/19/96	CPT-EC	10.5
CP-035	09/19/96	CPT-EC	10.4
CP-037	09/20/96	CPT-EC	16.1
CP-039	09/20/96	CPT-EC	17.1

CP-040	09/20/96	CPT-EC	16.3
CP-042	09/22/96	CPT-EC	17.0
CP-043	09/22/96	CPT-EC	14.9
CP-045	09/22/96	CPT-EC	24.8
CP-046	09/22/96	CPT-EC	20.5
CP-046A	10/03/96	CPT-EC	31.1
CP-047	09/22/96	CPT-EC	14.8
CP-048	09/22/96	CPT-EC	20.5
CP-049	09/22/96	CPT-EC	20.4
CP-050	09/23/96	CPT-EC	14.9
CP-054	09/23/96	CPT-EC	14.9
CP-059	09/24/96	CPT-EC	7.5
CP-062	09/24/96	CPT-EC	14.7
CP-063	09/24/96	CPT-EC	15.4
CP-066	09/25/96	CPT-EC	15.0
CP-070	09/30/96	CPT-EC	15.8
CP-074	10/01/96	CPT-EC	15.1
CP-078	10/01/96	CPT-EC	10.6
CP-079	10/01/96	CPT-EC	15.0
CP-081	10/02/96	CPT-EC	20.0
CP-085	10/02/96	CPT-EC	14.9
CP-087	10/02/96	CPT-EC	10.7
CP-088	10/02/96	CPT-EC	14.7
CP-090	10/03/96	CPT-EC	10.4
CP-091	10/03/96	CPT-EC	10.7
CP-092	10/03/96	CPT-EC	14.9
CP-093	10/03/96	CPT-EC	10.6
CP-094	10/03/96	CPT-EC	14.6
CP-095	10/03/96	CPT-EC	14.9
CP-096	10/03/96	CPT-EC	11.5
CP-097	10/03/96	CPT-EC	14.9
CP-100	10/03/96	CPT-EC	14.9

CP-104	10/04/96	CPT-EC	14.7
CP-106	10/04/96	CPT-EC	7.9
CP-111	10/05/96	CPT-EC	10.7
CP-114	10/05/96	CPT-EC	10.0

9.0 STATEMENT OF LIMITATIONS

Subsurface information was gathered only at the sounding locations. Extrapolation of sounding data to develop stratigraphic continuity is conjectural. Actual site conditions between sounding locations may differ.

Computer correlation of penetrometer data with other parameters was performed using generalized charts rather than on site specific information. Site specific correlation work based on results of detailed laboratory testing was beyond the scope of this project. Evaluation of soil saturation levels and potentiometric surfaces is only representative of conditions encountered during the field program. Seasonal variation must be expected.

Data gathering for this study was attempted to be performed in general accordance with accepted procedures and practices. Correlation of penetrometer data with other parameters is empirical and should not be considered as the exact equivalent of laboratory testing. STRATIGRAPHICS shall not be responsible for another's interpretation of the information obtained for this study.

10.0 REFERENCES

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FIGURES AND TABULATIONS

TABLE 1
SUMMARY OF SAMPLING
Zone G
Charelston Naval Base, South Carolina

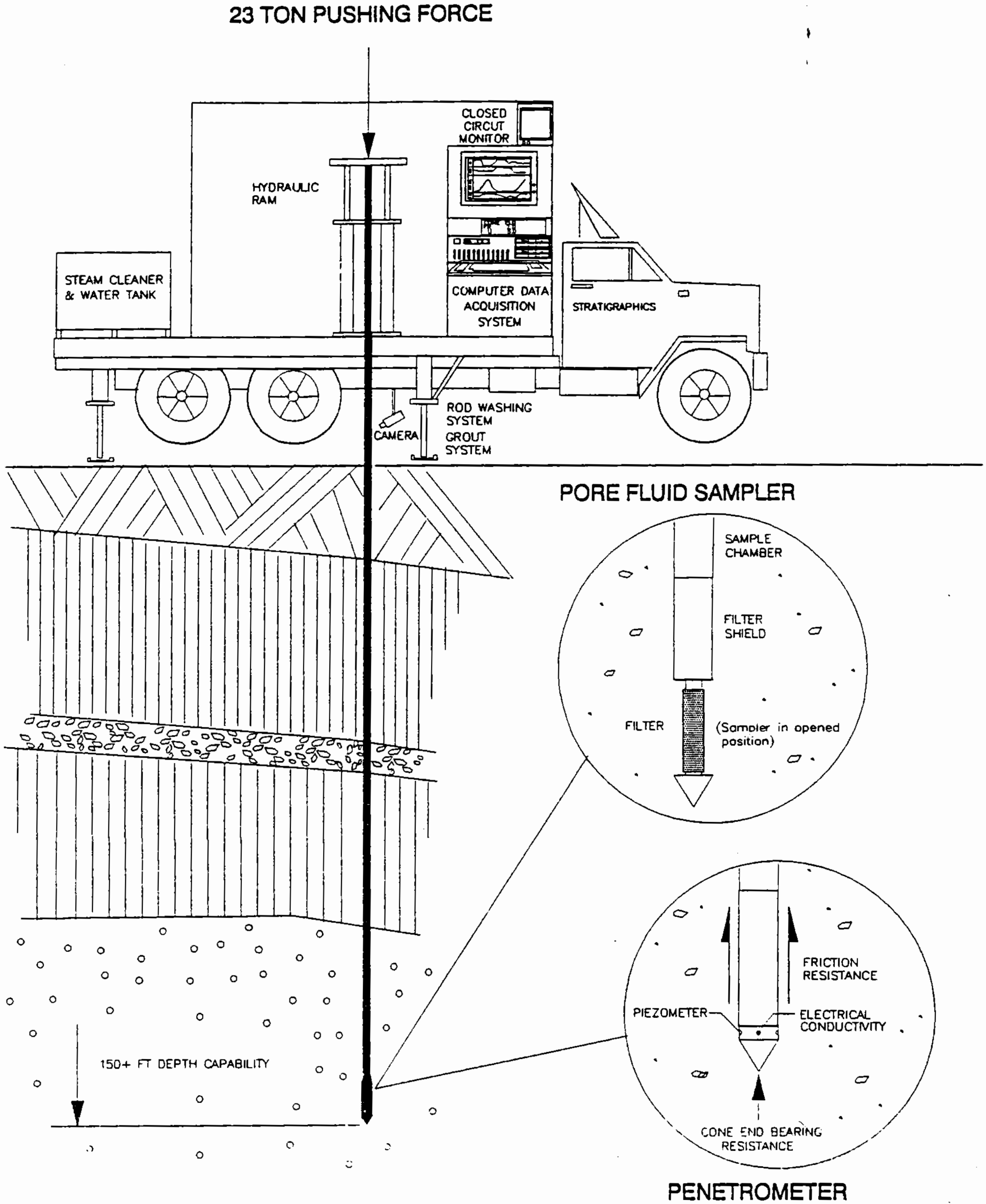
SAMPLE NUMBER	DATE SAMPLED	SAMPLER TYPE	DEPTH INTERVAL (in feet)	EQUILIBRIUM WATER LEVEL (Depth below ground surface, in feet)	COMMENTS
SS-FDS068	09/30/96	STRATIGRAPHICS soil sampler	7.7 - 9.3		
SS-FDS069	09/30/96	STRATIGRAPHICS soil sampler	6.3 - 8.2		
SS-FDS070	09/30/96	STRATIGRAPHICS soil sampler	7.3 - 9.2		
SS-FDS071	09/30/96	STRATIGRAPHICS soil sampler	7.2 - 9.2		
SS-FDS072	10/01/96	STRATIGRAPHICS soil sampler	7.3 - 9.3		
SS-FDS073	10/01/96	STRATIGRAPHICS soil sampler	7.3 - 8.9		
SS-FDS074	10/01/96	STRATIGRAPHICS soil sampler	8.9 - 10.7		
SS-FDS075	10/01/96	STRATIGRAPHICS soil sampler	7.7 - 9.4		
SS-FDS076	10/01/96	STRATIGRAPHICS soil sampler	6.3 - 8.1		
SS-FDS077	10/01/96	STRATIGRAPHICS soil sampler	6.7 - 9.2		
SS-FDS078	10/01/96	STRATIGRAPHICS soil sampler	7.1 - 9.1		
SS-FDS079	10/01/96	STRATIGRAPHICS soil sampler	4.7 - 6.7		
SS-FDS080	10/01/96	STRATIGRAPHICS soil sampler	6.2 - 8.0		
SS-FDS081	10/02/96	STRATIGRAPHICS soil sampler	7.4 - 9.4		
SS-FDS082	10/02/96	STRATIGRAPHICS soil sampler	5.7 - 7.3		
SS-FDS083	10/02/96	STRATIGRAPHICS soil sampler	6.0 - 7.6		
SS-FDS084	10/02/96	STRATIGRAPHICS soil sampler	7.0 - 9.0		
SS-FDS084A	10/02/96	STRATIGRAPHICS soil sampler	9.0 - 11.6		
SS-FDS085	10/02/96	STRATIGRAPHICS soil sampler	4.9 - 6.9		
SS-FDS086	10/02/96	STRATIGRAPHICS soil sampler	4.7 - 6.7		

TABLE 1
SUMMARY OF SAMPLING
Zone G
Charelston Naval Base, South Carolina

SAMPLE NUMBER	DATE SAMPLED	SAMPLER TYPE	DEPTH INTERVAL (in feet)	EQUILIBRIUM WATER LEVEL (Depth below ground surface, in feet)	COMMENTS
SS-FDS087	10/02/96	STRATIGRAPHICS soil sampler	3.8 - 5.4		
SS-FDS087A	10/02/96	STRATIGRAPHICS soil sampler	7.7 - 9.7		
SS-FDS088	10/02/96	STRATIGRAPHICS soil sampler	8.7 - 10.6		
SS-FDS089	10/02/96	STRATIGRAPHICS soil sampler	6.7 - 8.4		
SS-FDS090	10/03/96	STRATIGRAPHICS soil sampler	2.7 - 4.3		
SS-FDS091	10/03/96	STRATIGRAPHICS soil sampler	8.9 - 10.7		
SS-FDS092	10/03/96	STRATIGRAPHICS soil sampler	5.7 - 7.7		
SS-FDS093	10/03/96	STRATIGRAPHICS soil sampler	5.8 - 7.5		
SS-FDS094	10/03/96	STRATIGRAPHICS soil sampler	4.7 - 6.4		
SS-FDS094A	10/03/96	STRATIGRAPHICS soil sampler	6.4 - 8.4		
SS-FDS095	10/03/96	STRATIGRAPHICS soil sampler	4.7 - 6.7		
SS-FDS096	10/03/96	STRATIGRAPHICS soil sampler	4.8 - 6.5		
SS-FDS097	10/03/96	STRATIGRAPHICS soil sampler	6.7 - 8.5		
SS-FDS097A	10/03/96	STRATIGRAPHICS soil sampler	8.5 - 10.5		
SS-FDS098	10/03/96	STRATIGRAPHICS soil sampler	8.7 - 10.5		
SS-FDS099	10/03/96	STRATIGRAPHICS soil sampler	8.7 - 10.5		
SS-FDS100	10/04/96	STRATIGRAPHICS soil sampler	5.7 - 7.7		
SS-FDS100A	10/04/96	STRATIGRAPHICS soil sampler	12.7 - 14.7		
SS-FDS101	10/04/96	STRATIGRAPHICS soil sampler	8.7 - 10.3		
SS-FDS102	10/04/96	STRATIGRAPHICS soil sampler	8.9 - 10.7		

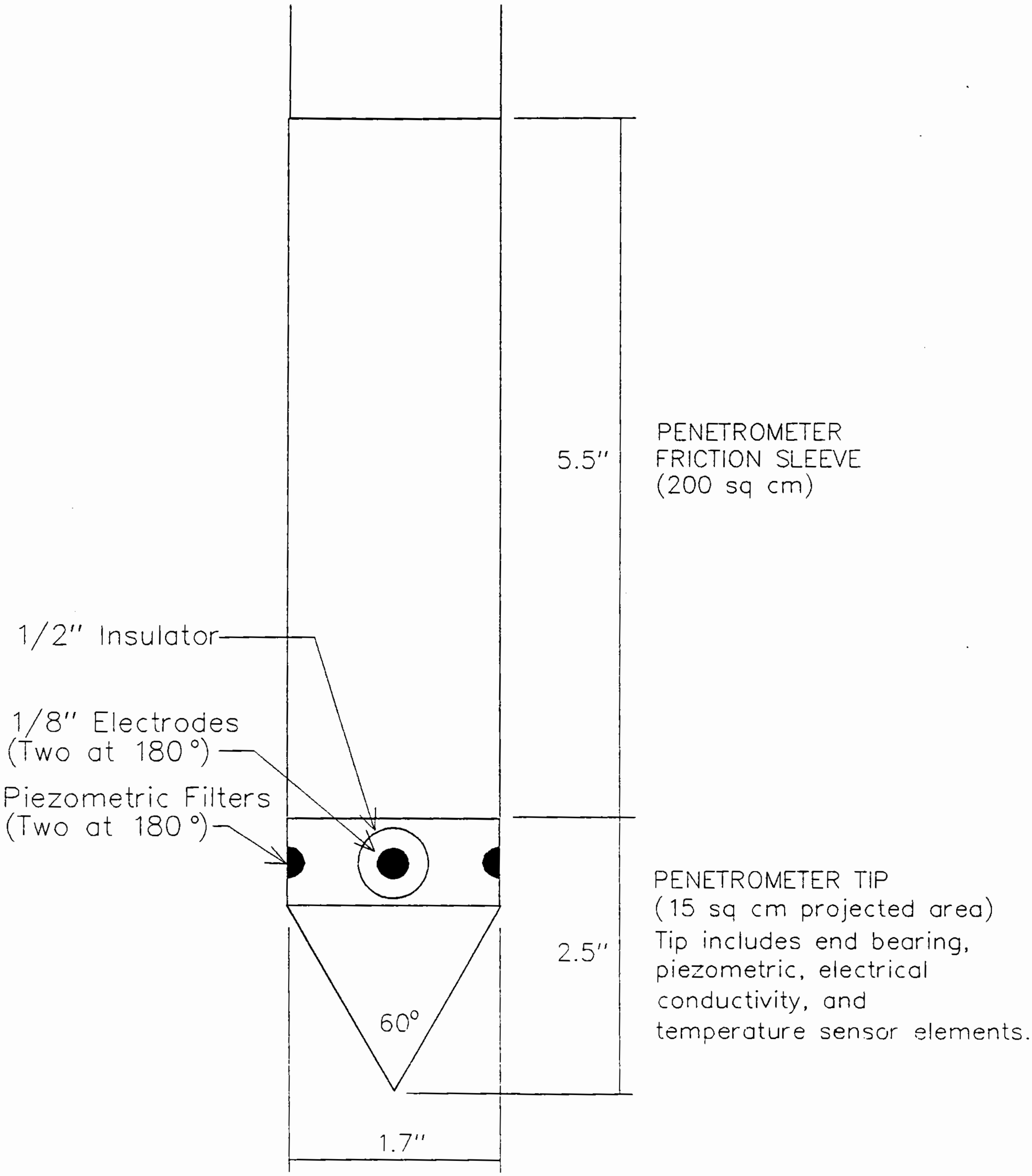
TABLE 1
SUMMARY OF SAMPLING
Zone G
Charelston Naval Base, South Carolina

SAMPLE NUMBER	DATE SAMPLED	SAMPLER TYPE	DEPTH INTERVAL (in feet)	EQUILIBRIUM WATER LEVEL (Depth below ground surface, in feet)	COMMENTS
SS-FDS103	10/04/96	STRATIGRAPHICS soil sampler	9.0 - 10.8		
SS-FDS104	10/04/96	STRATIGRAPHICS soil sampler	3.7 - 5.7		
SS-FDS104A	10/04/96	STRATIGRAPHICS soil sampler	8.7 - 11.4		
SS-FDS104B	10/04/96	STRATIGRAPHICS soil sampler	9.3 - 11.0		
SS-FDS105	10/04/96	STRATIGRAPHICS soil sampler	3.7 - 6.0		
SS-FDS106	10/04/96	STRATIGRAPHICS soil sampler	6.8 - 8.6		
SS-FDS107	10/04/96	STRATIGRAPHICS soil sampler	5.9 - 7.9		
SS-FDS108	10/04/96	STRATIGRAPHICS soil sampler	5.8 - 7.7		
SS-FDS109	10/05/96	STRATIGRAPHICS soil sampler	6.7 - 8.4		
SS-FDS110	10/05/96	STRATIGRAPHICS soil sampler	6.8 - 8.9		
SS-FDS111	10/05/96	STRATIGRAPHICS soil sampler	5.7 - 7.7		
SS-FDS112	10/05/96	STRATIGRAPHICS soil sampler	4.7 - 6.7		
SS-FDS113	10/05/96	STRATIGRAPHICS soil sampler	4.7 - 6.7		
SS-FDS114	10/05/96	STRATIGRAPHICS soil sampler	2.7 - 4.7		
SS-FDS115	10/05/96	STRATIGRAPHICS soil sampler	2.7 - 5.5		



PENETROMETER SUBSURFACE EXPLORATION SYSTEM

STRATIGRAPHICS



NOTE:

1. All dimensions approximate.

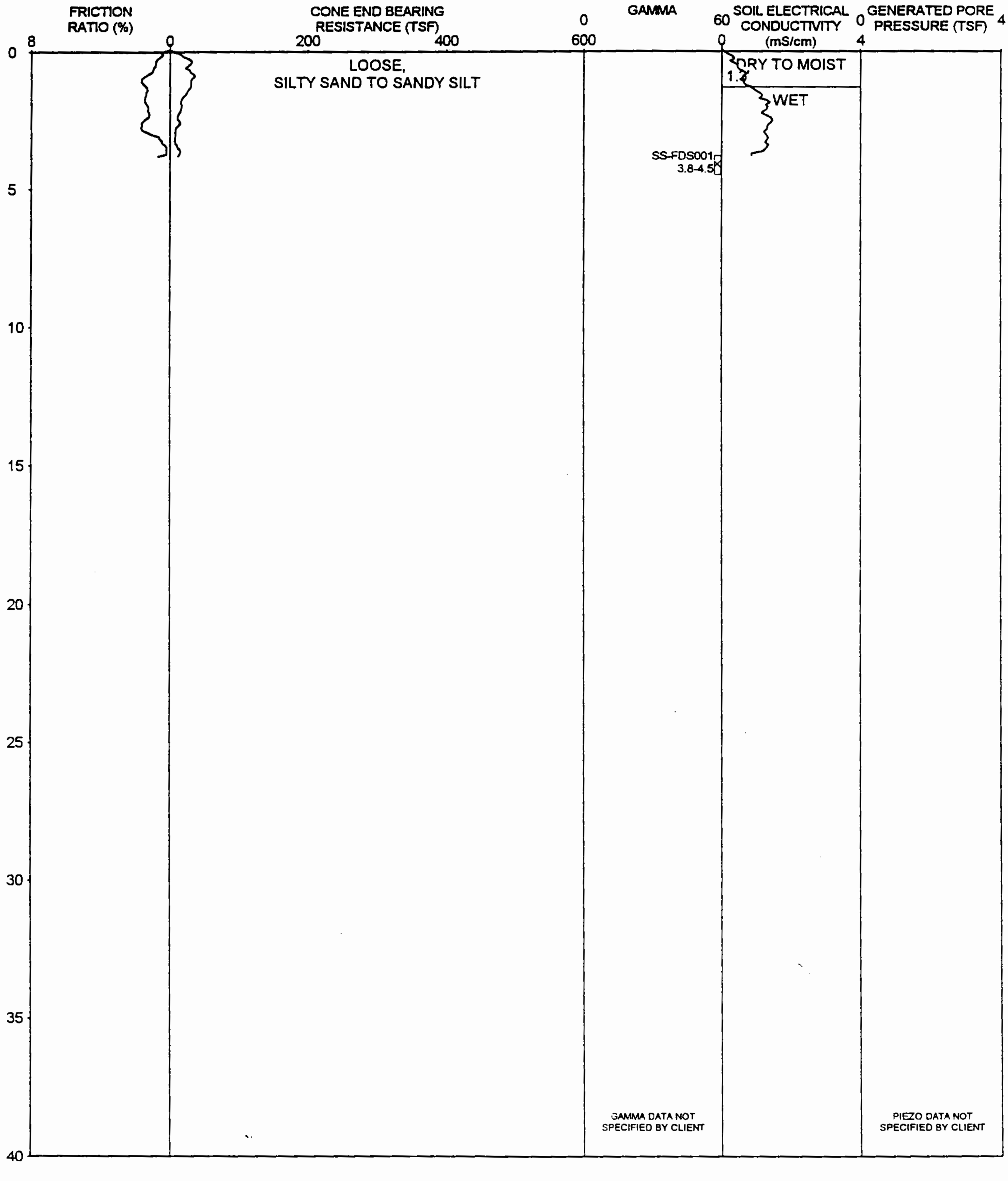
STRATIGRAPHICS

PENETROMETER FOR CPTU-EC TESTING

Figure 1a

[redacted]

INTERPRETED CPT-EC LOG

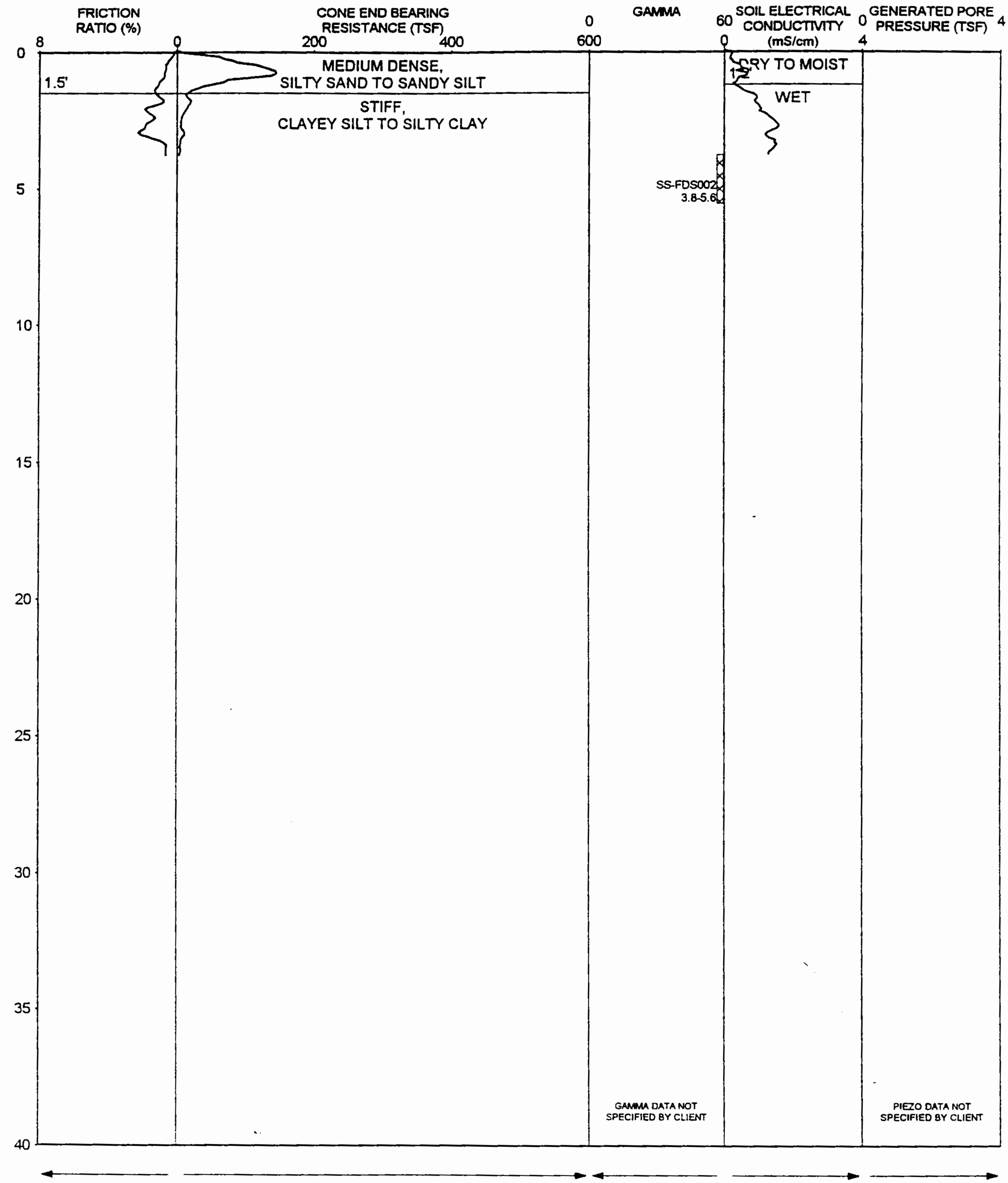


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base, S.C.
PROJECT NUMBER: 96-110-230

DATE: 09/12/96
SOUNDING NUMBER: CPFDS001

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base, S.C.
PROJECT NUMBER: 96-110-230

DATE: 09/12/96
SOUNDING NUMBER: CPFDS002

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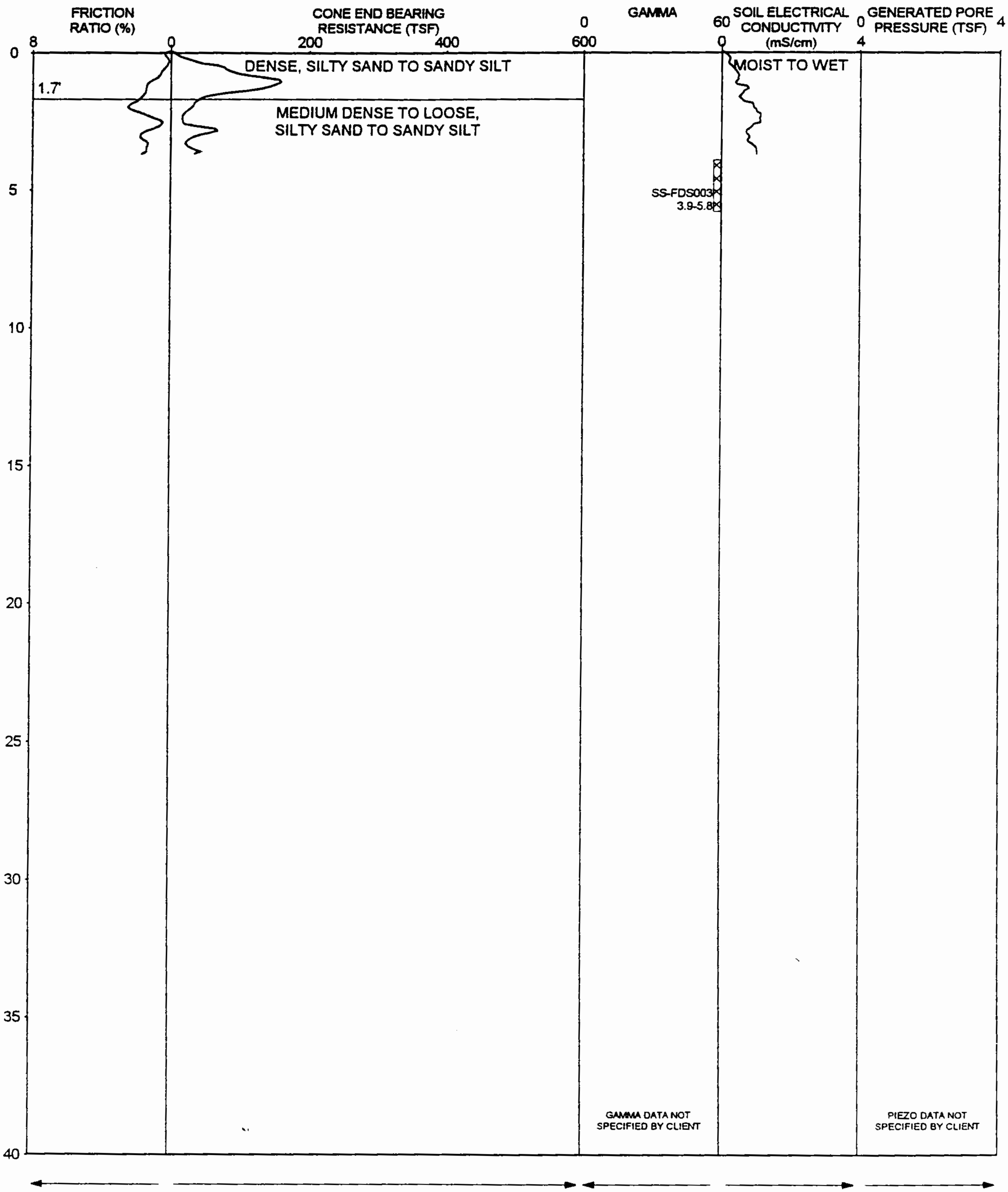

STRATIGRAPHICS

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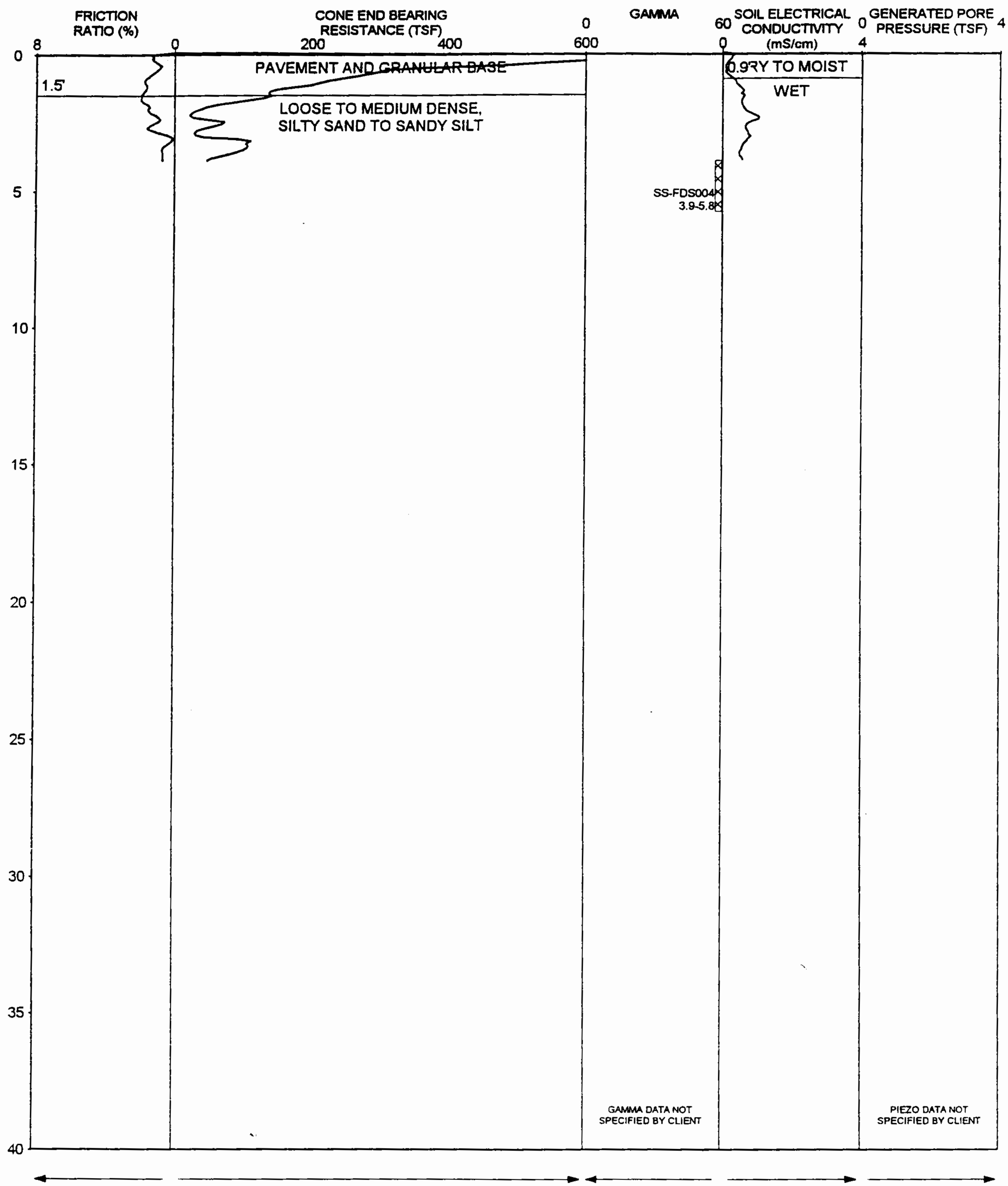
PROJECT NUMBER: 96-110-230 SOUNDING NUMBER: CPFDS003

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C
PROJECT NUMBER: 96-110-230

DATE: 09/12/96
SOUNDING NUMBER: CPFDS004

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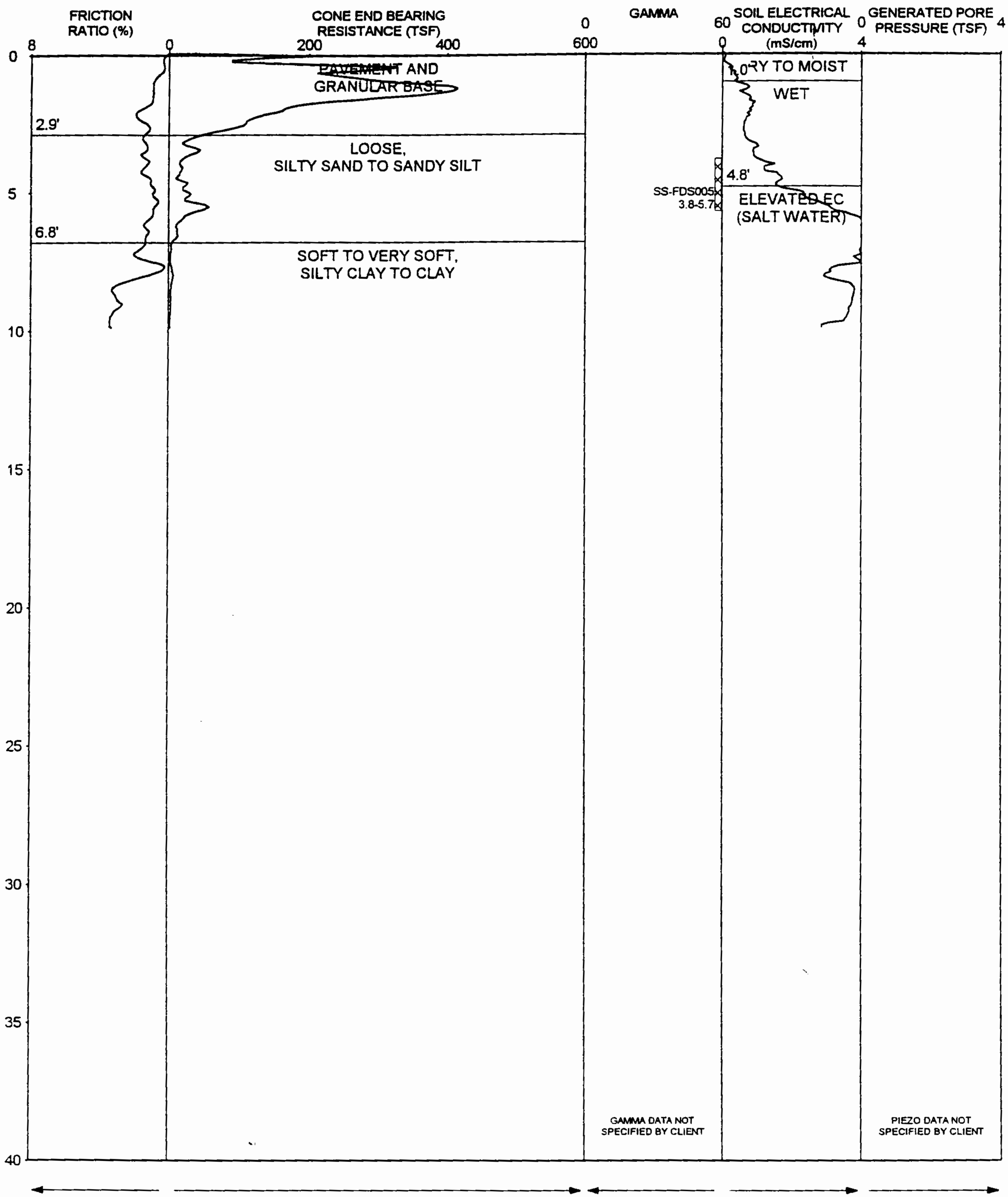

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C
PROJECT NUMBER: 96-110-230

DATE: 09/12/96
SOUNDING NUMBER: CPFDS005

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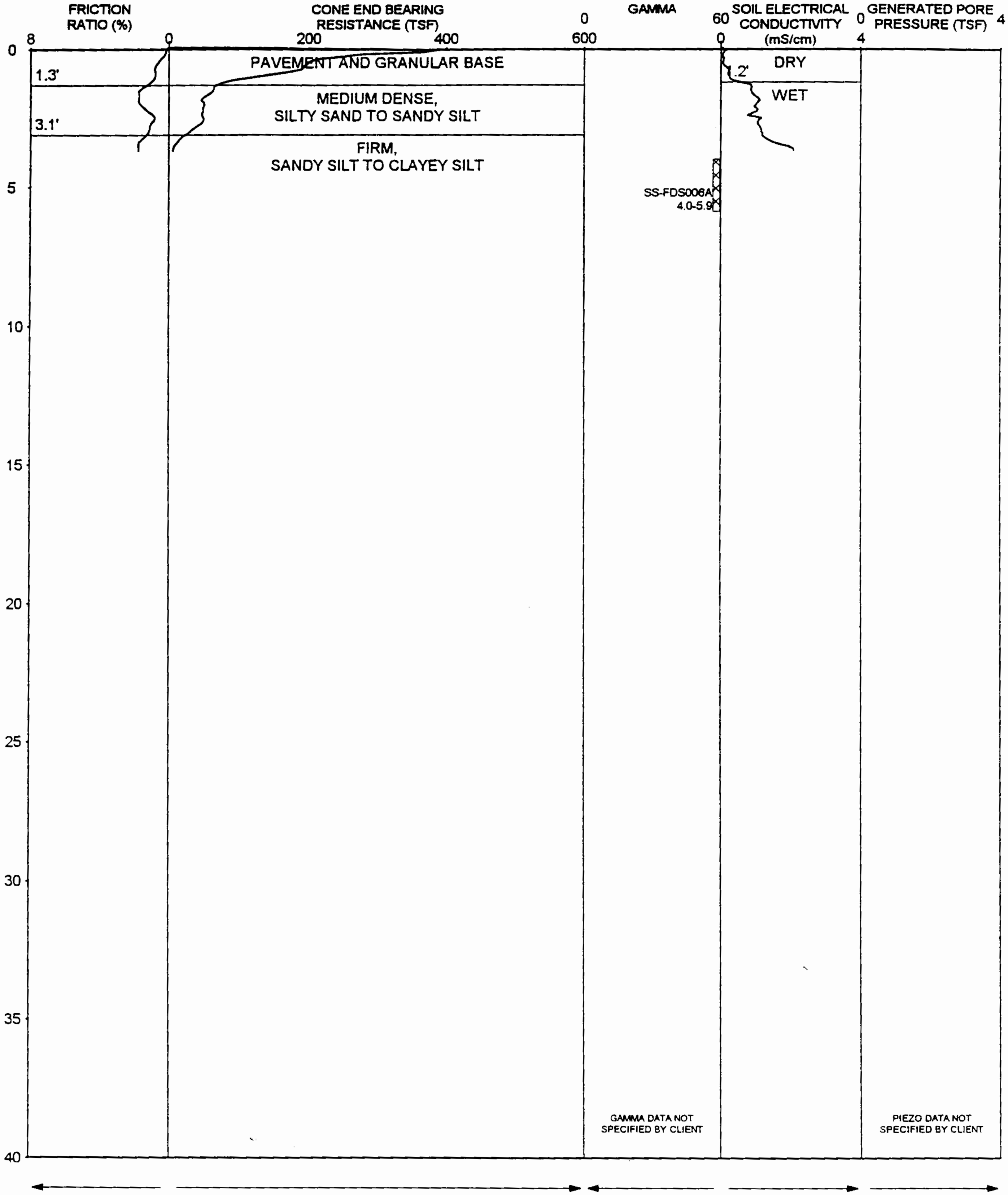

STRATIGRAPHICS

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PROJECT NUMBER: 96-110-230

DATE: 09/12/96

SOUNDING NUMBER: CPFDS006

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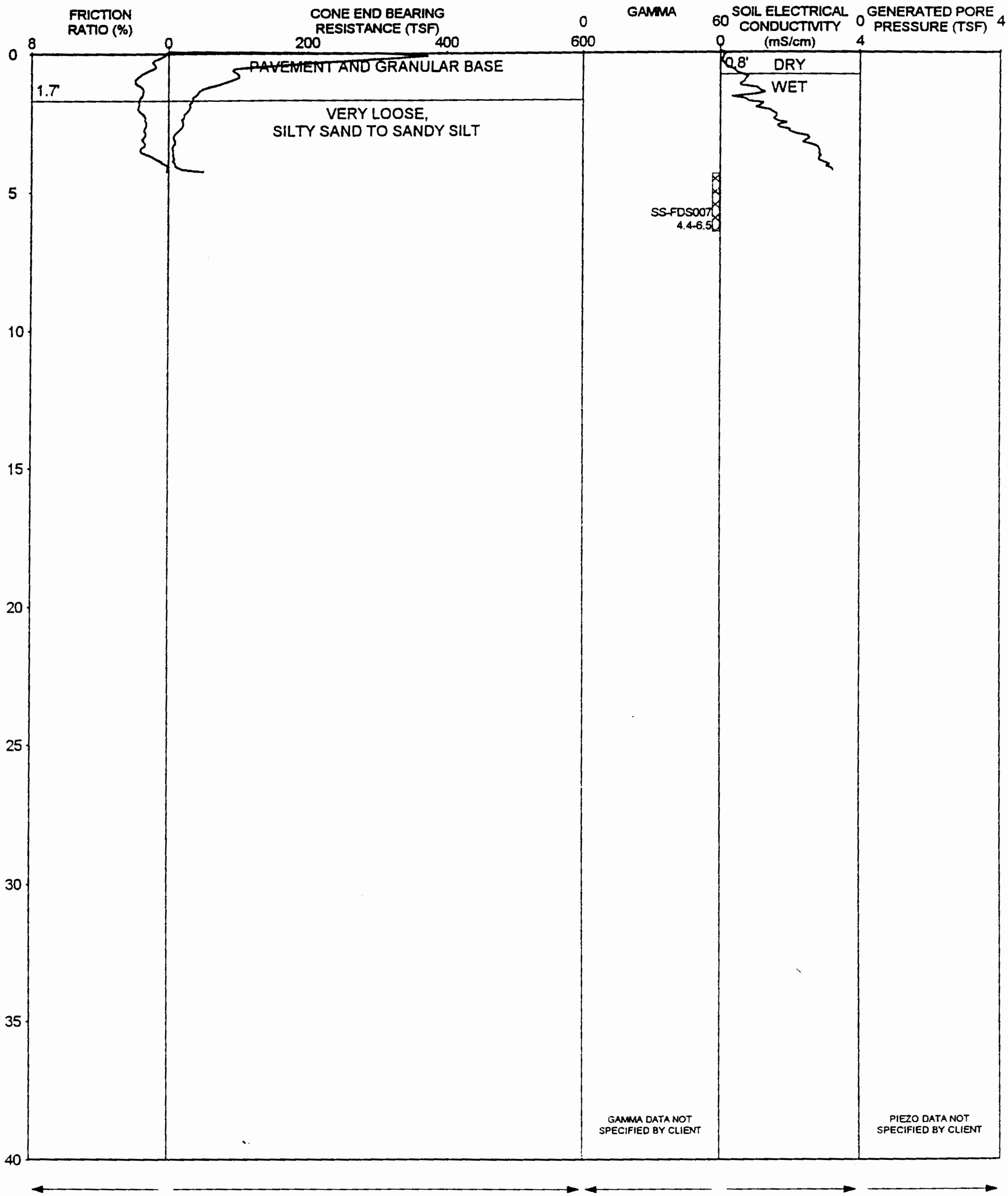

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C

DATE: 09/12/96

PROJECT NUMBER: 96-110-230

SOUNDING NUMBER: CPFDS007

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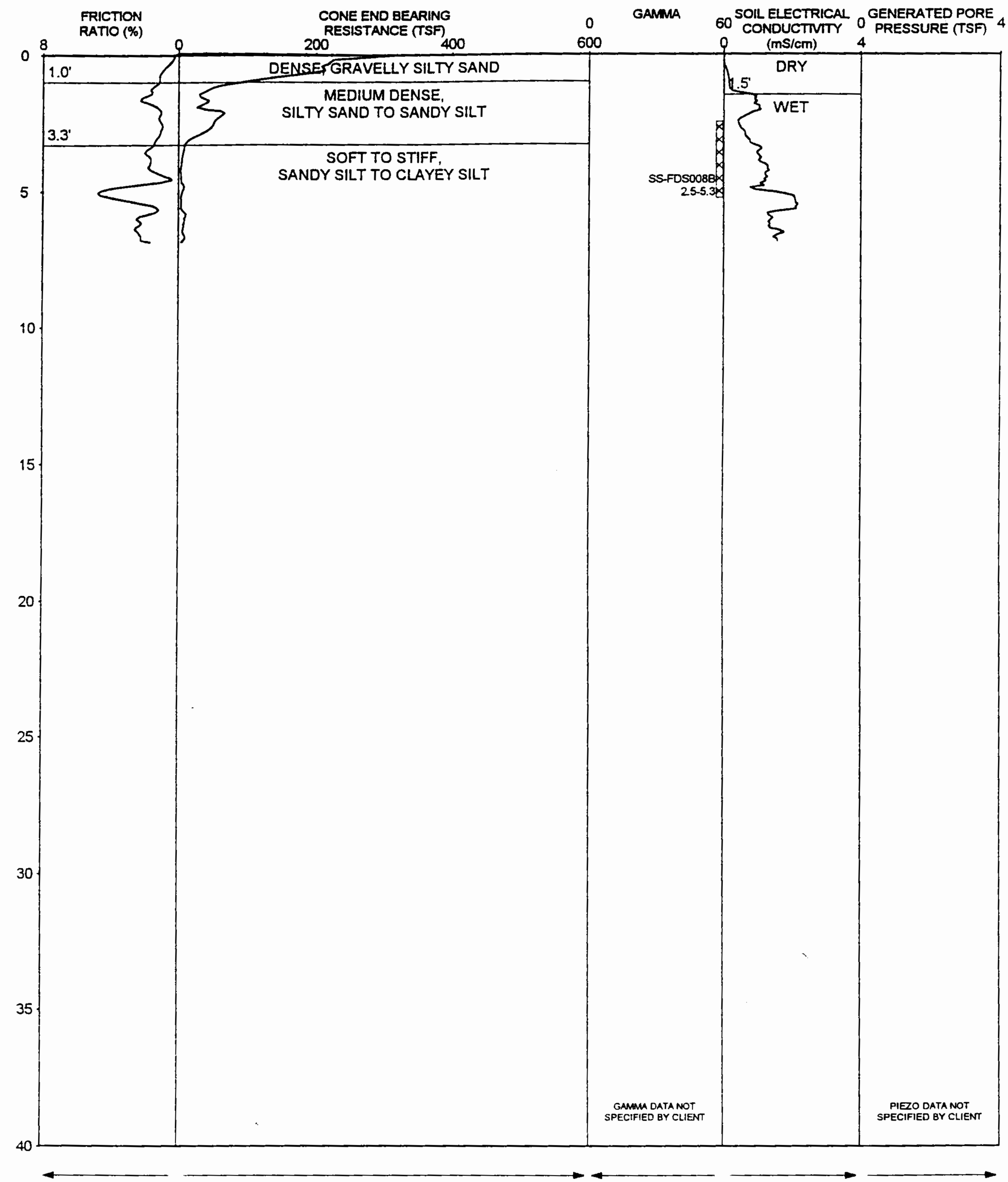

STRATIGRAPHICS

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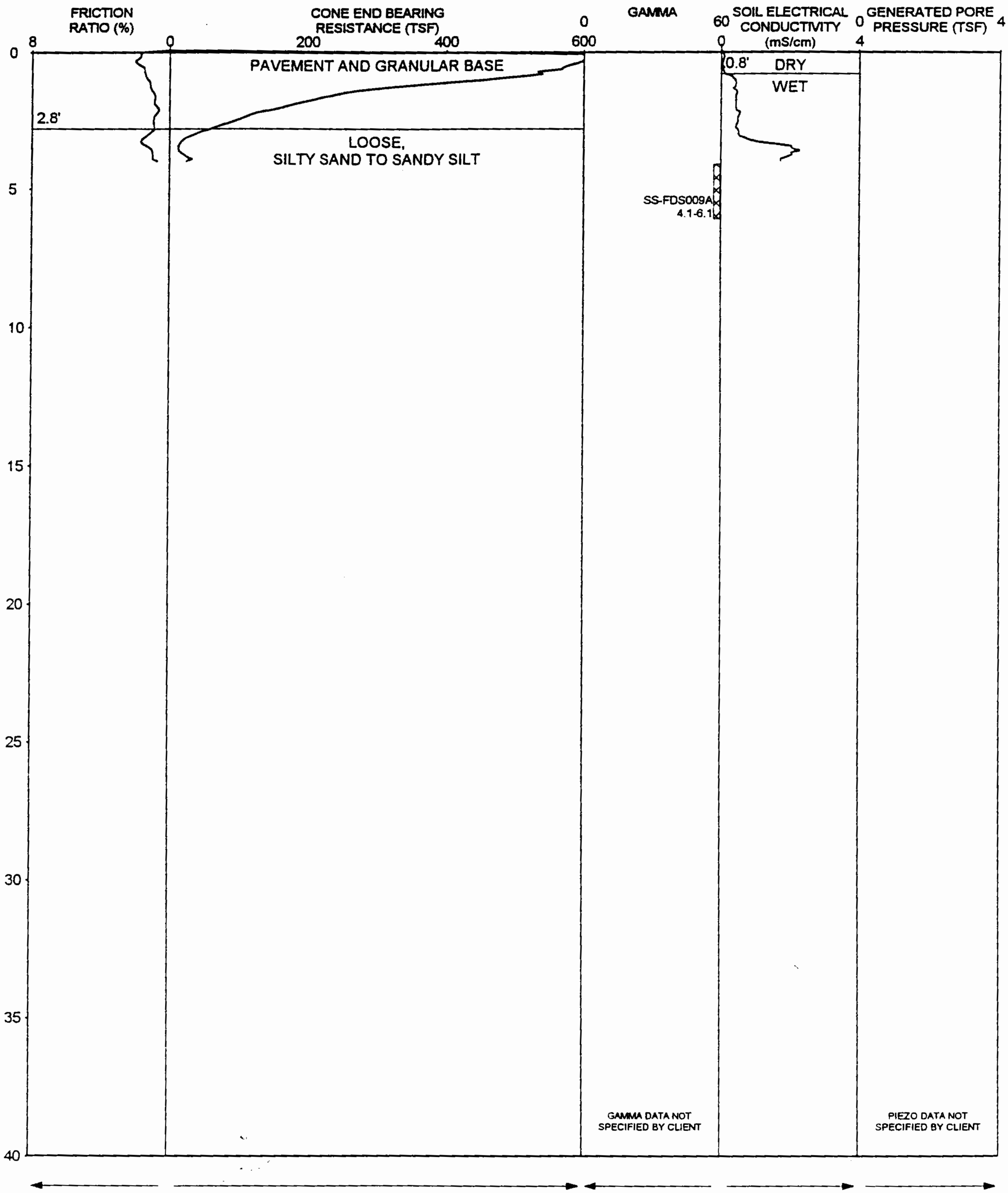
DATE: 09/13/96

PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CPFDS008

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

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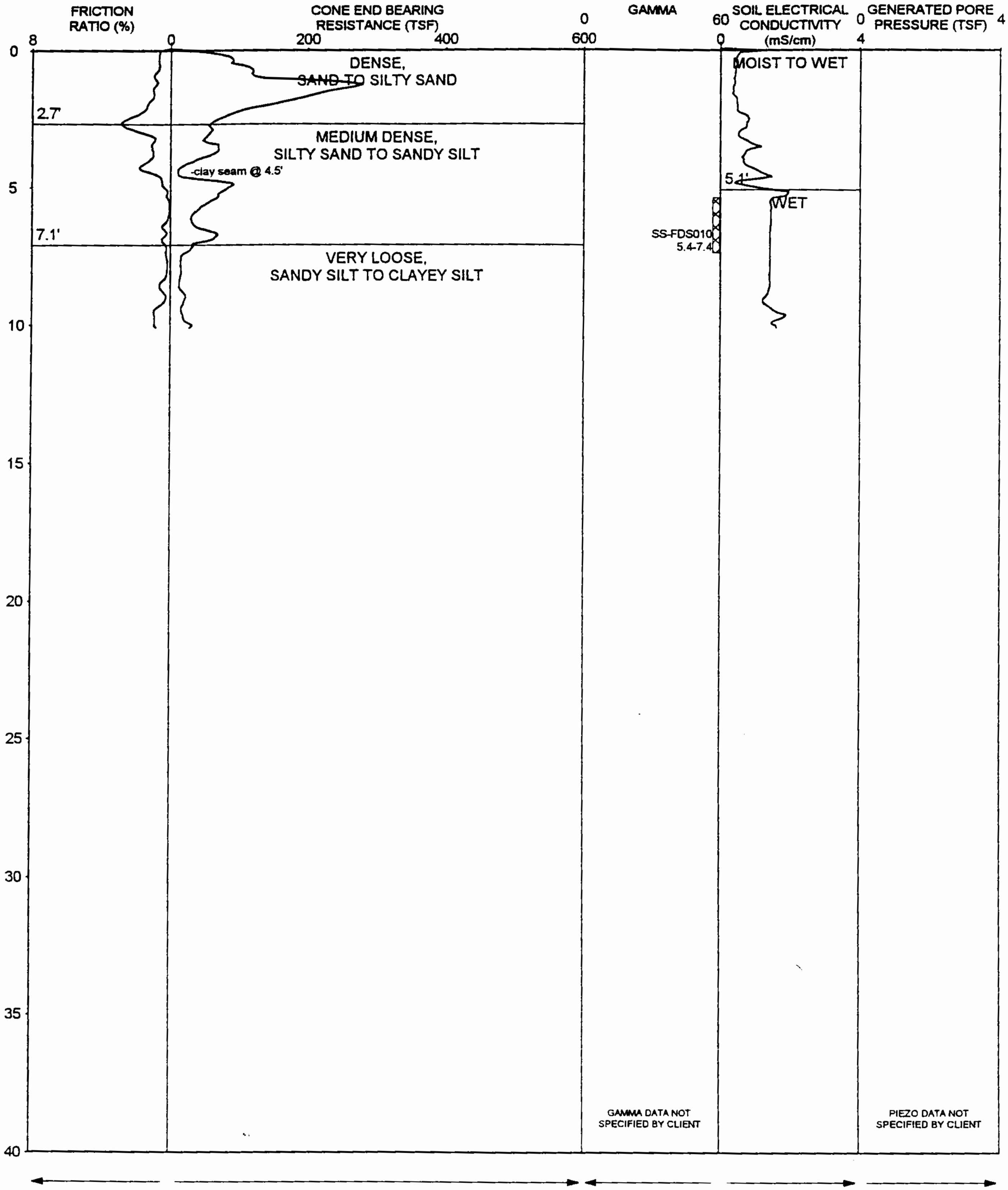
DATE: 09/13/96
PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CPFDS009

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

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PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CPFDS010

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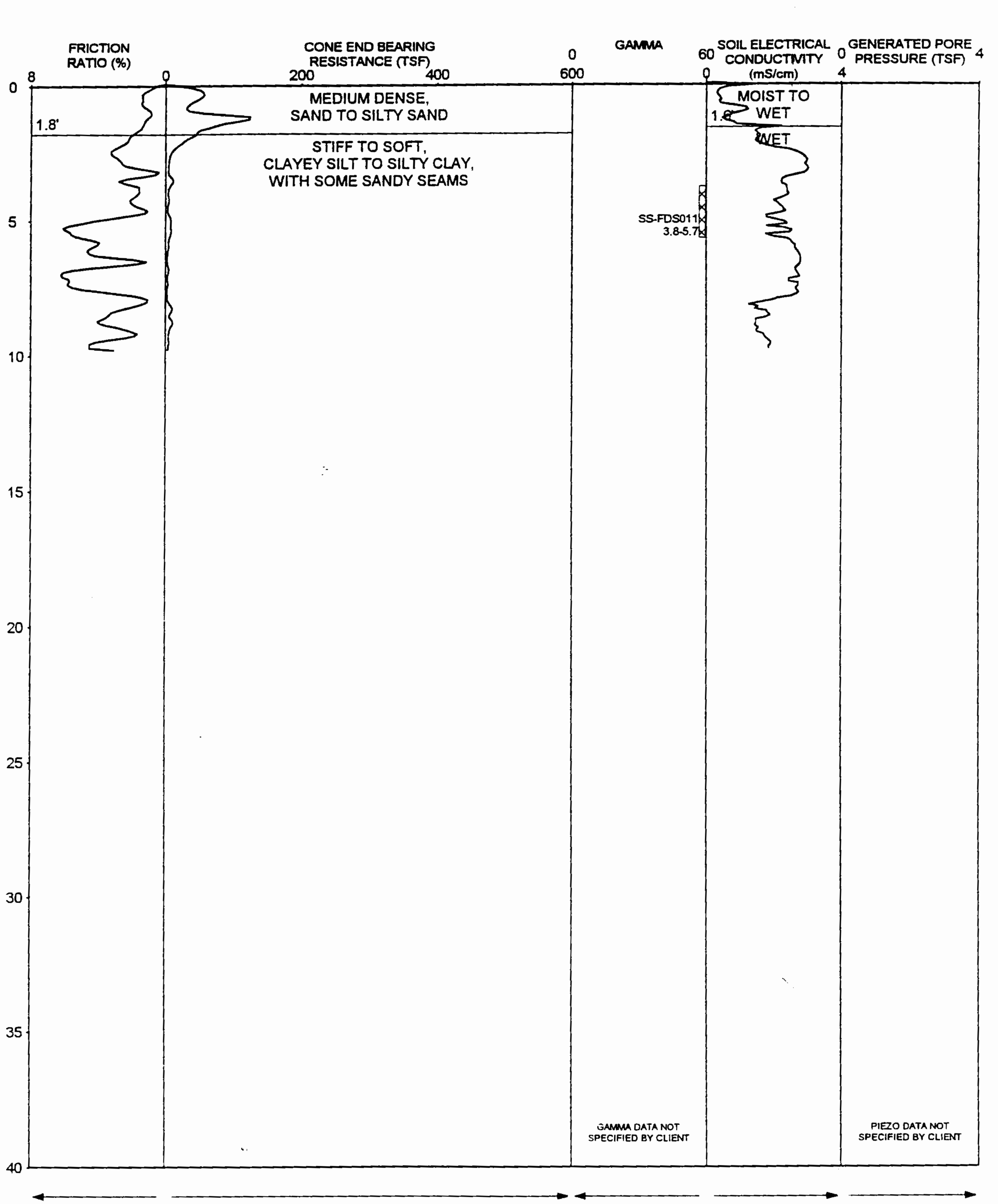

STRATIGRAPHICS

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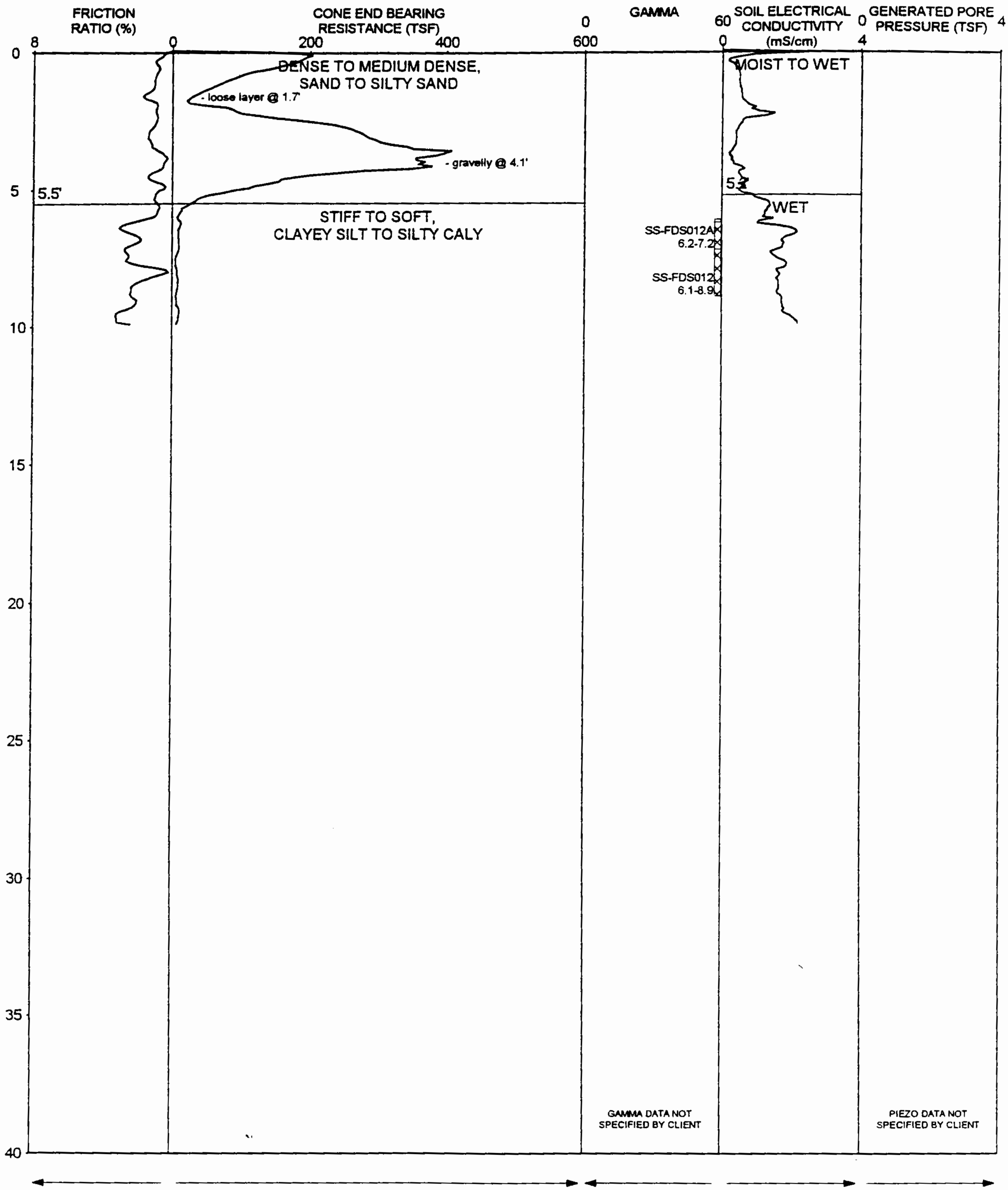
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP011

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base | DATE: 09/16/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CPFDS012

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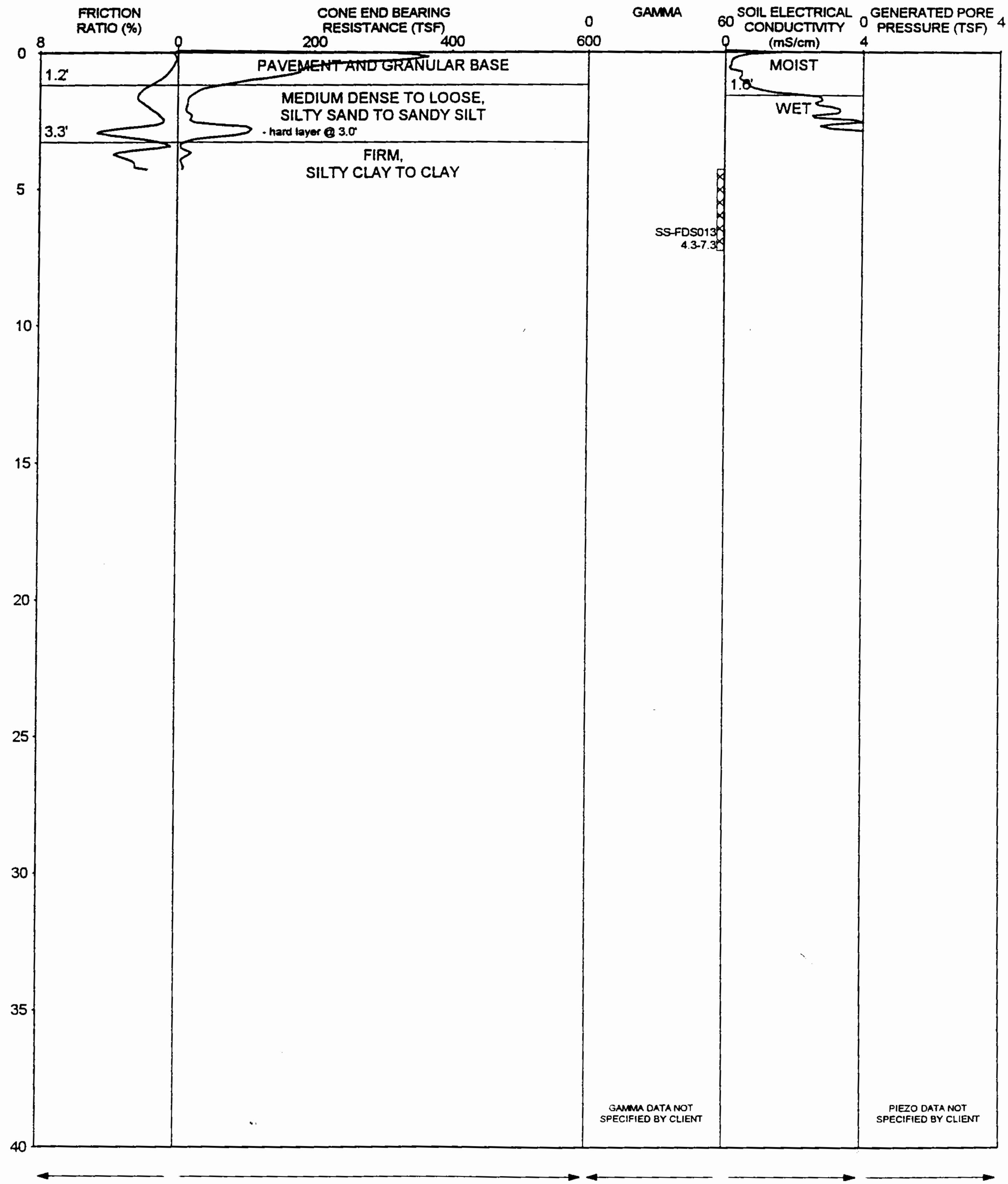

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP013

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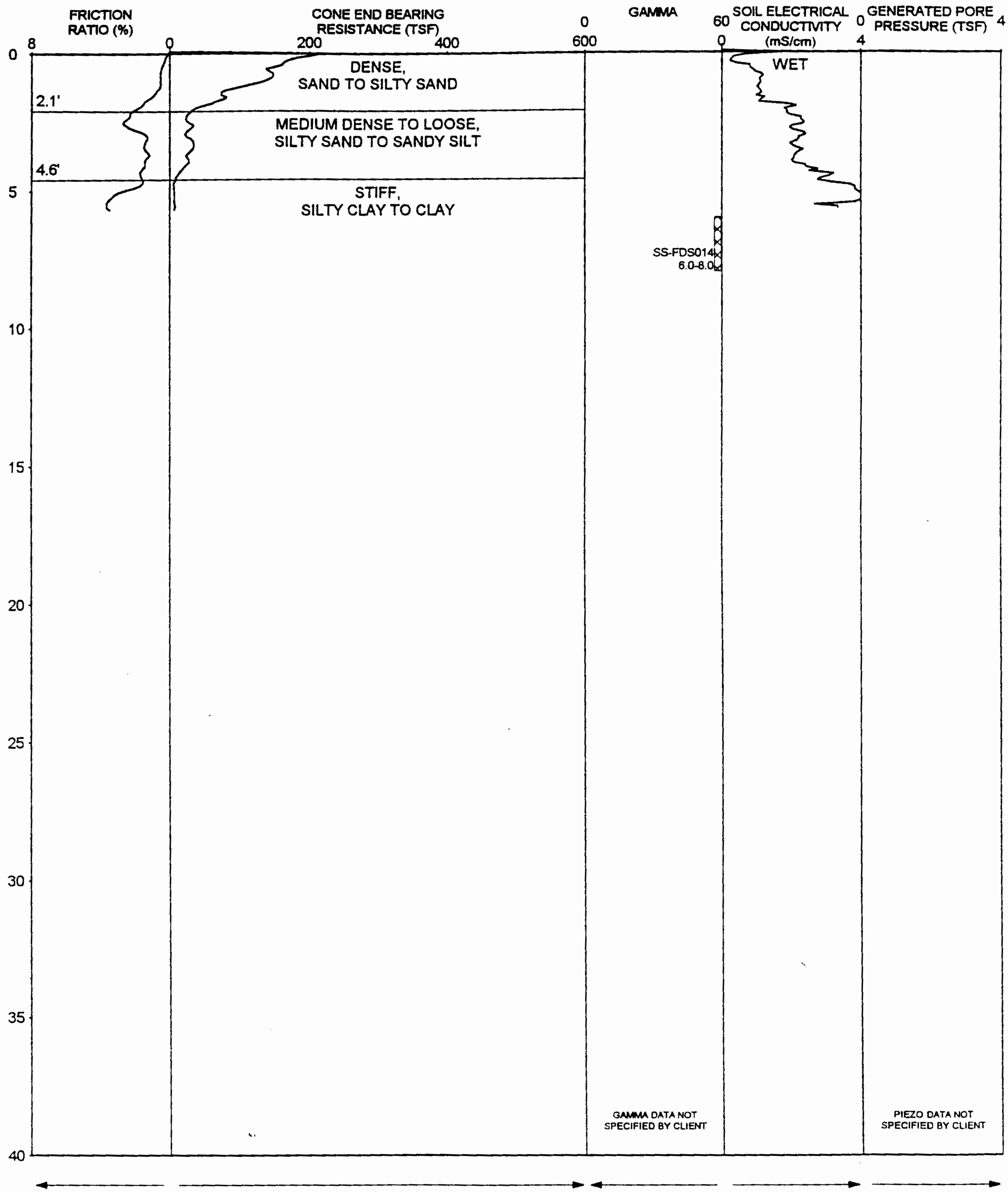

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP014

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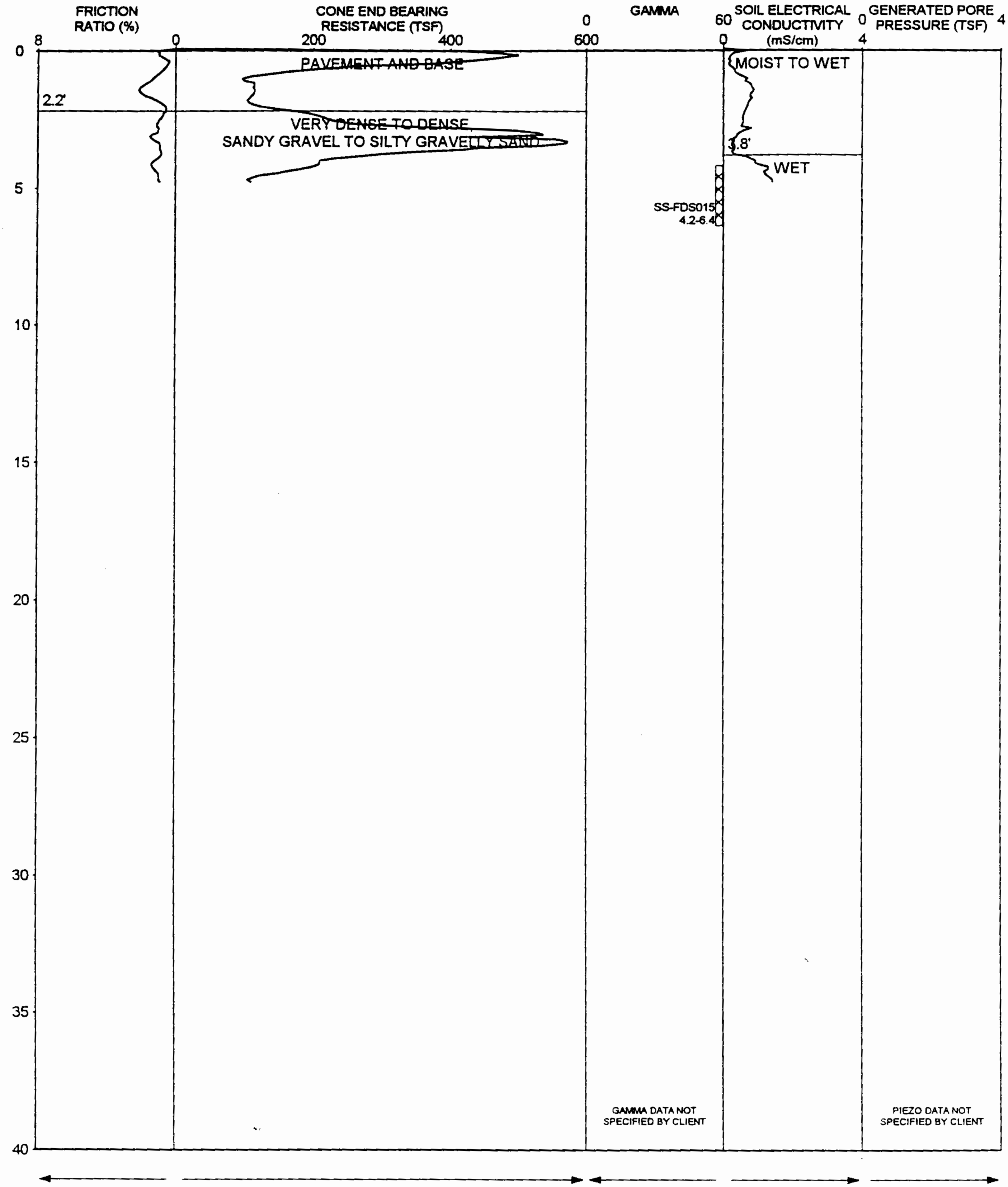

STRATIGRAPHICS

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PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP015

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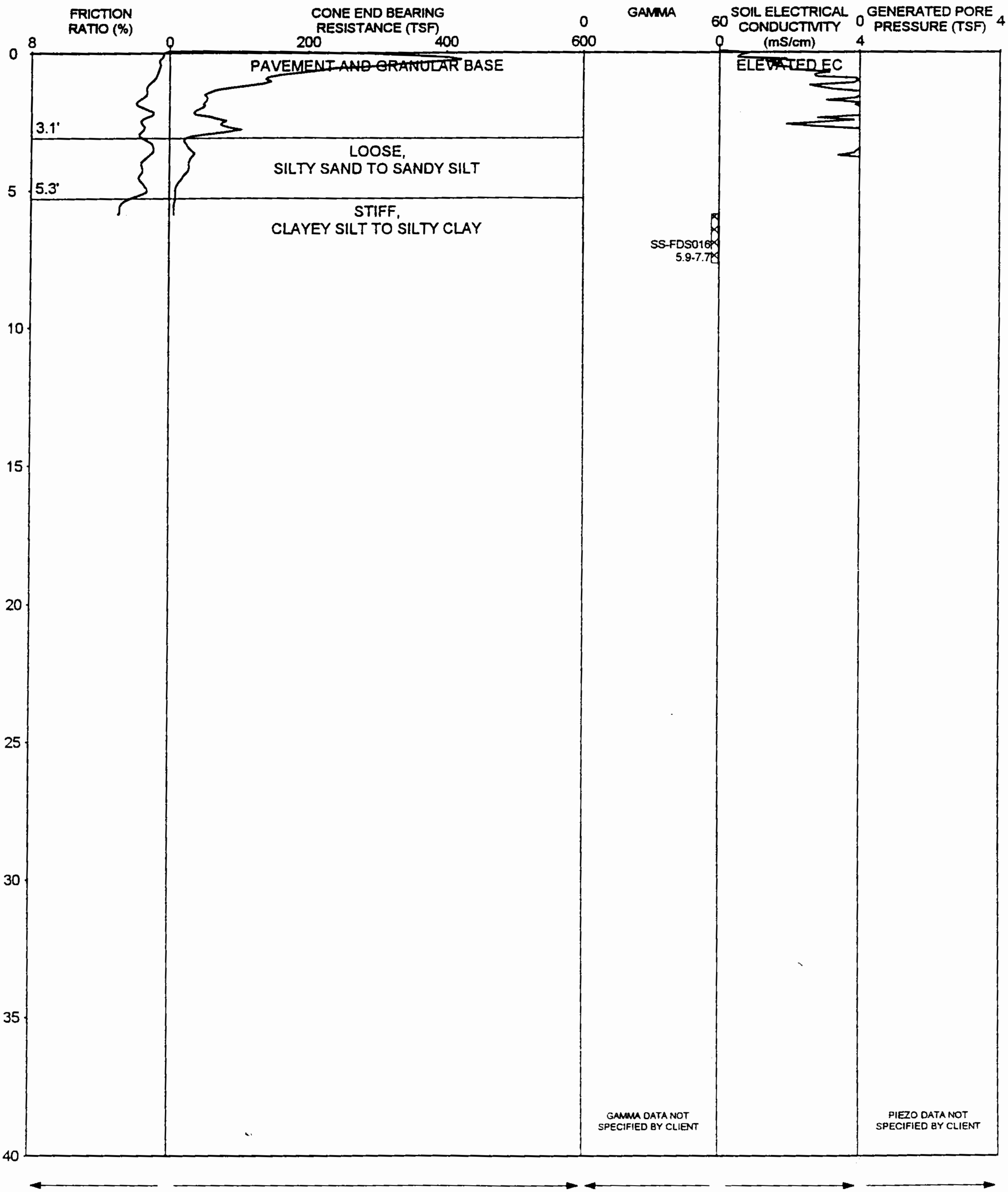
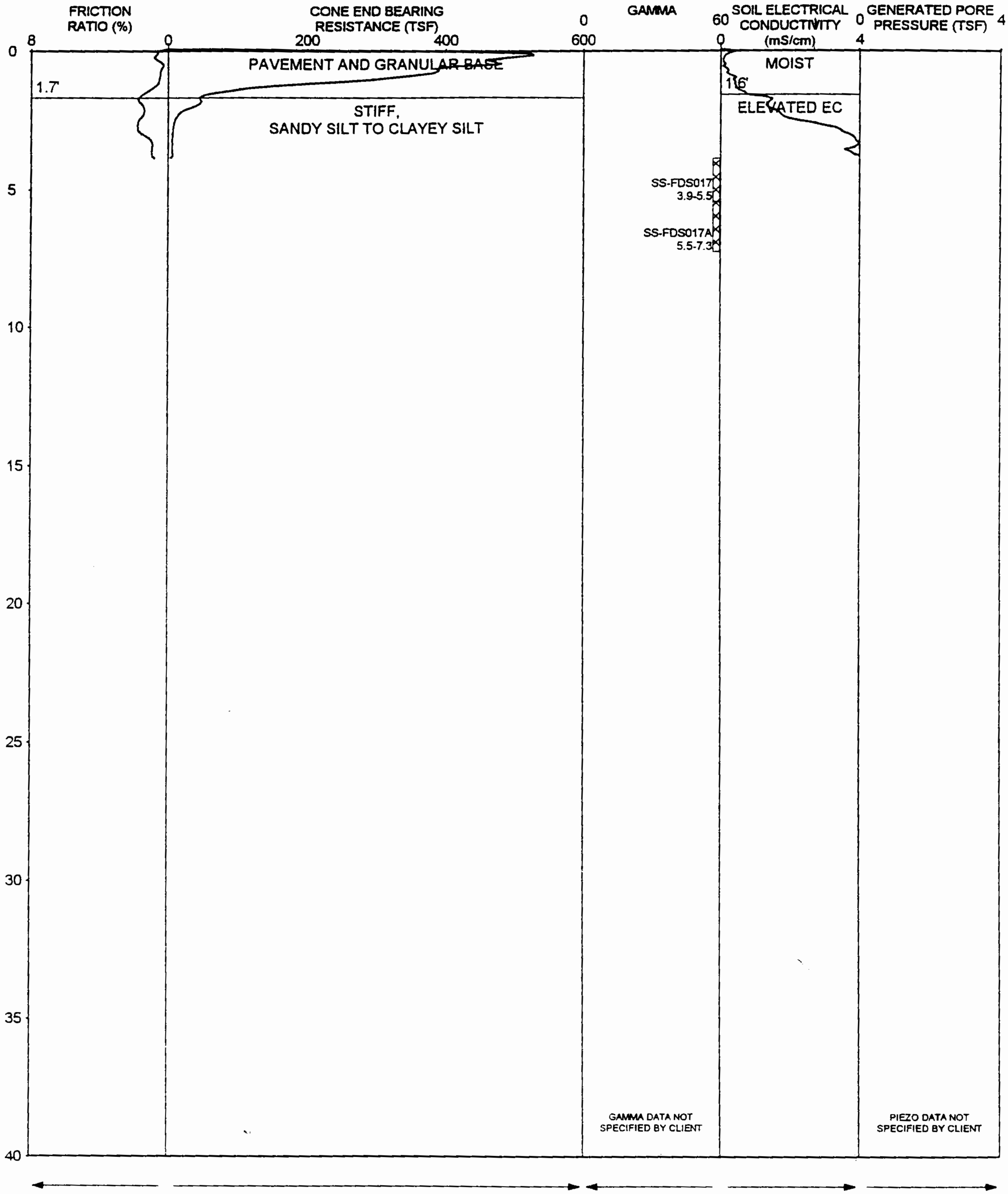


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base | DATE: 09/16/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CP016

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

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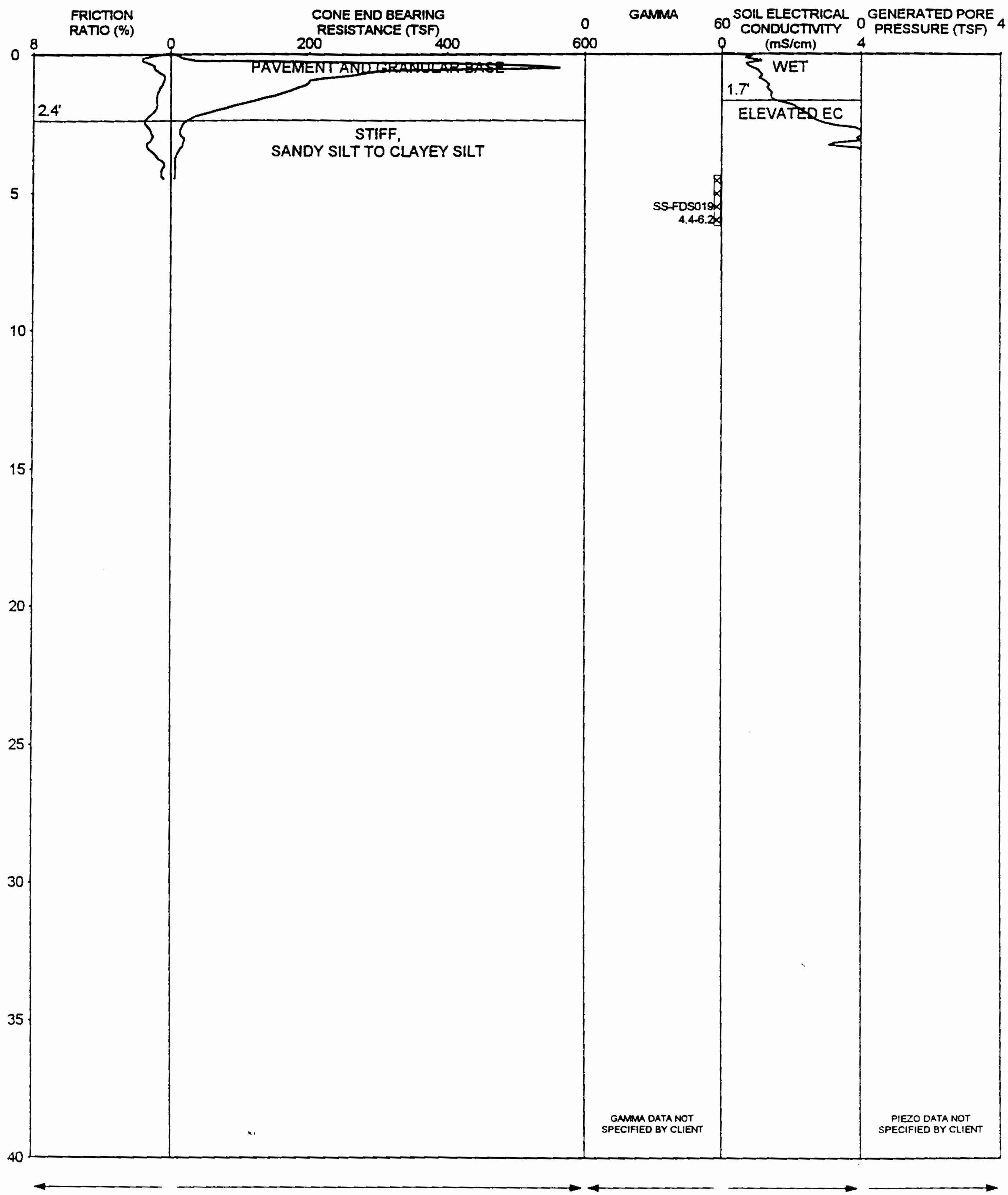
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP017

INTERPRETED CPT-EC LOG

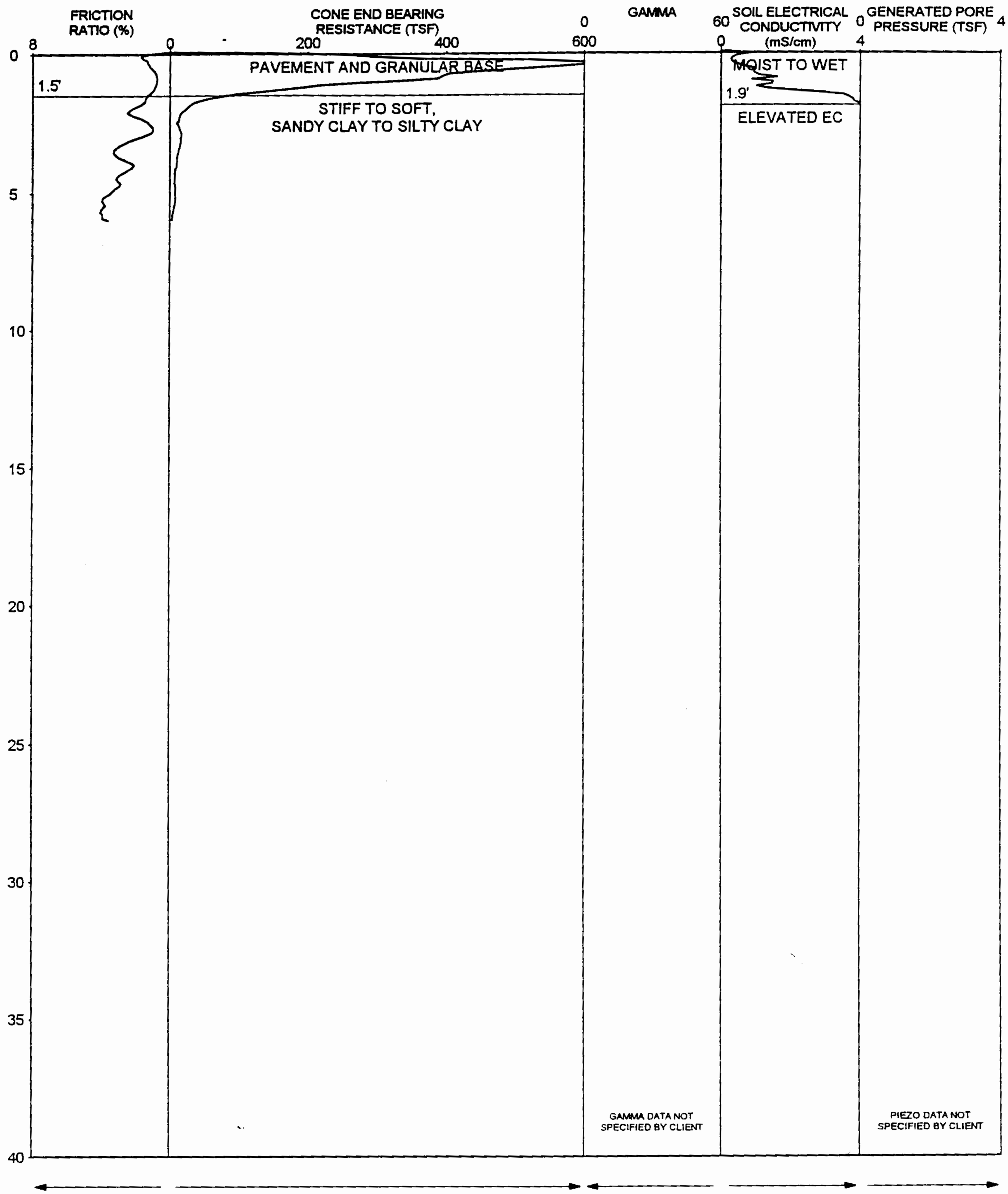


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP019

INTERPRETED CPT-EC LOG

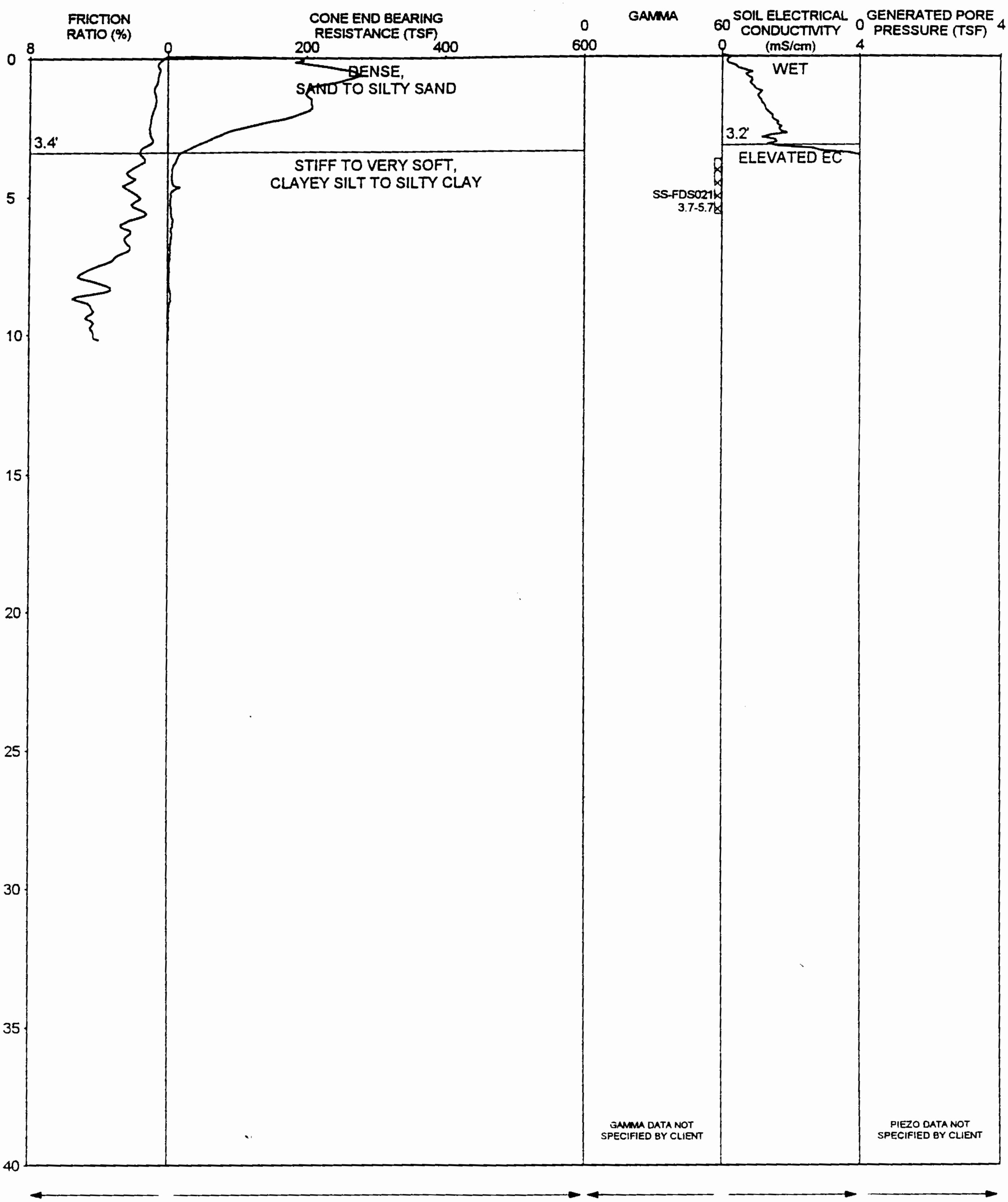


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP020

INTERPRETED CPT-EC LOG

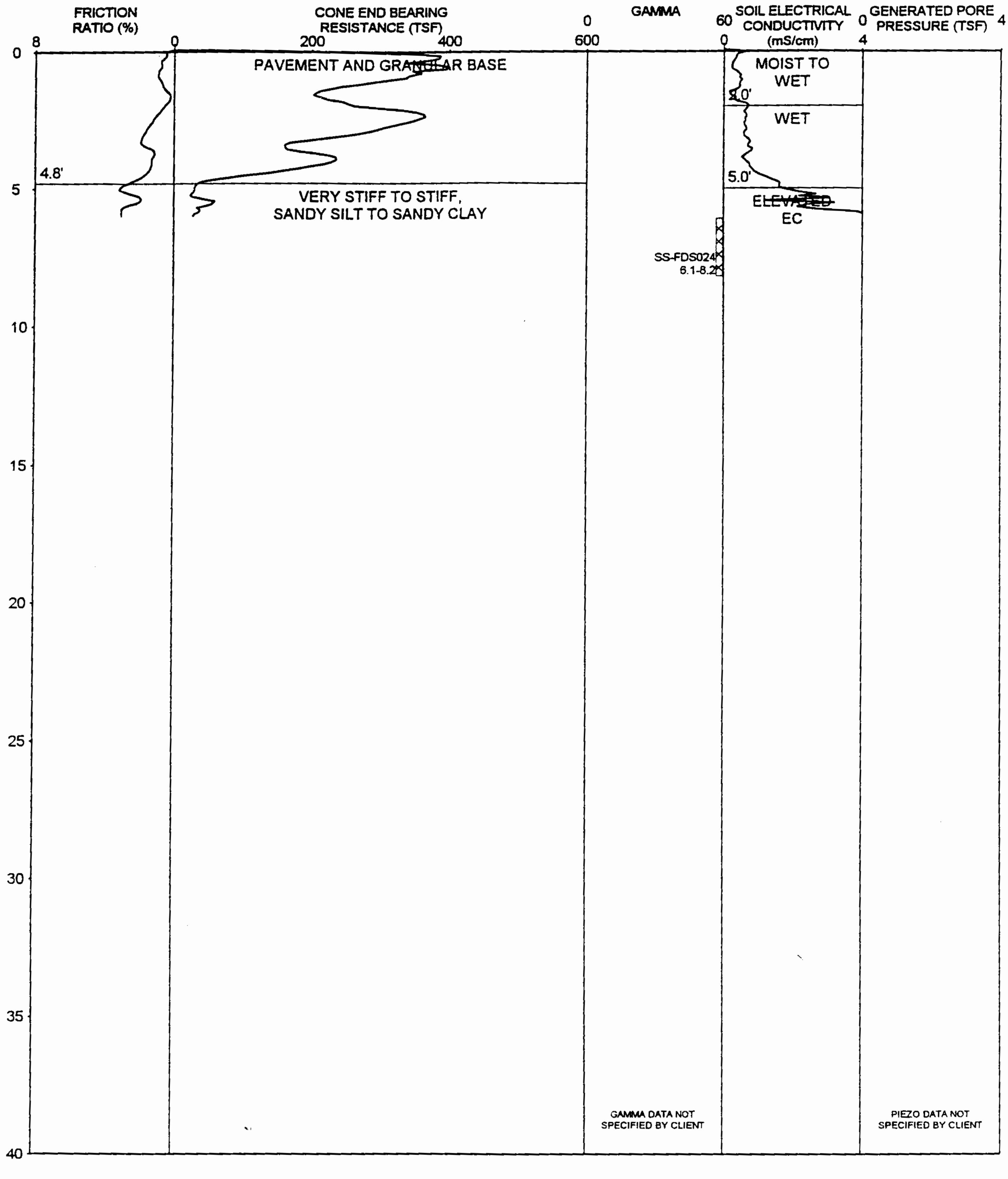


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP021

INTERPRETED CPT-EC LOG

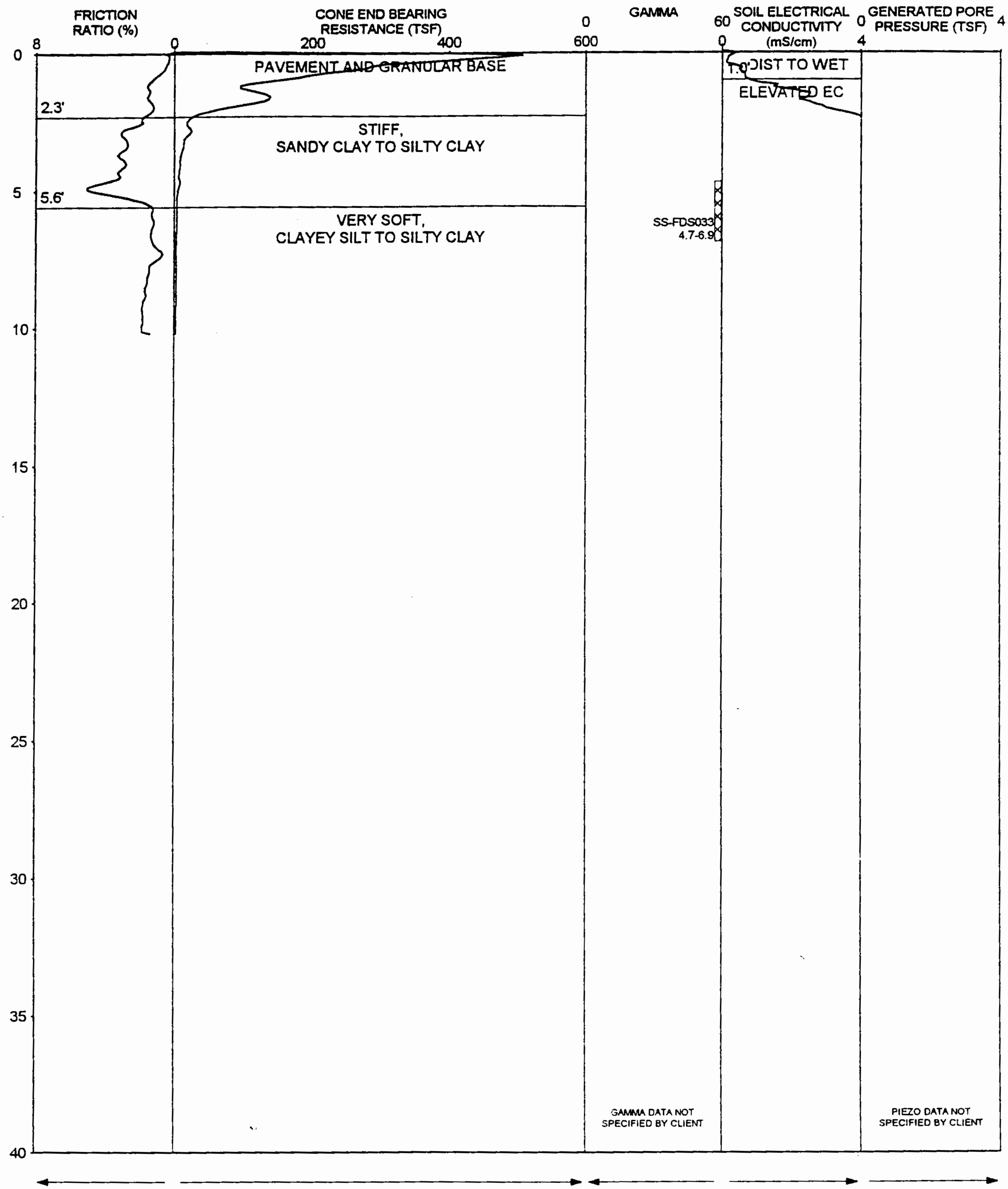


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base | DATE: 09/17/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CP024

INTERPRETED CPT-EC LOG

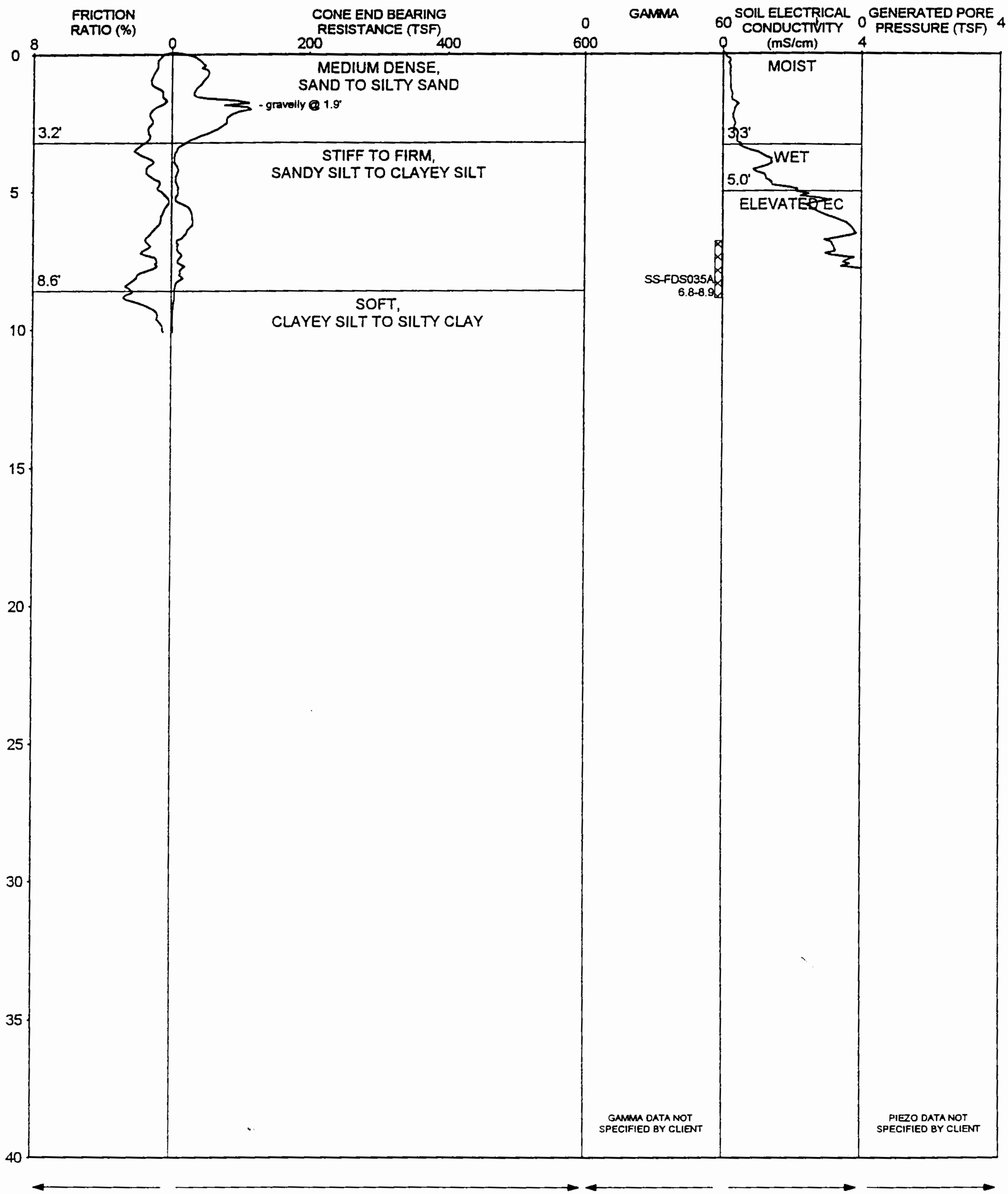


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/19/96
SOUNDING NUMBER: CP033

INTERPRETED CPT-EC LOG

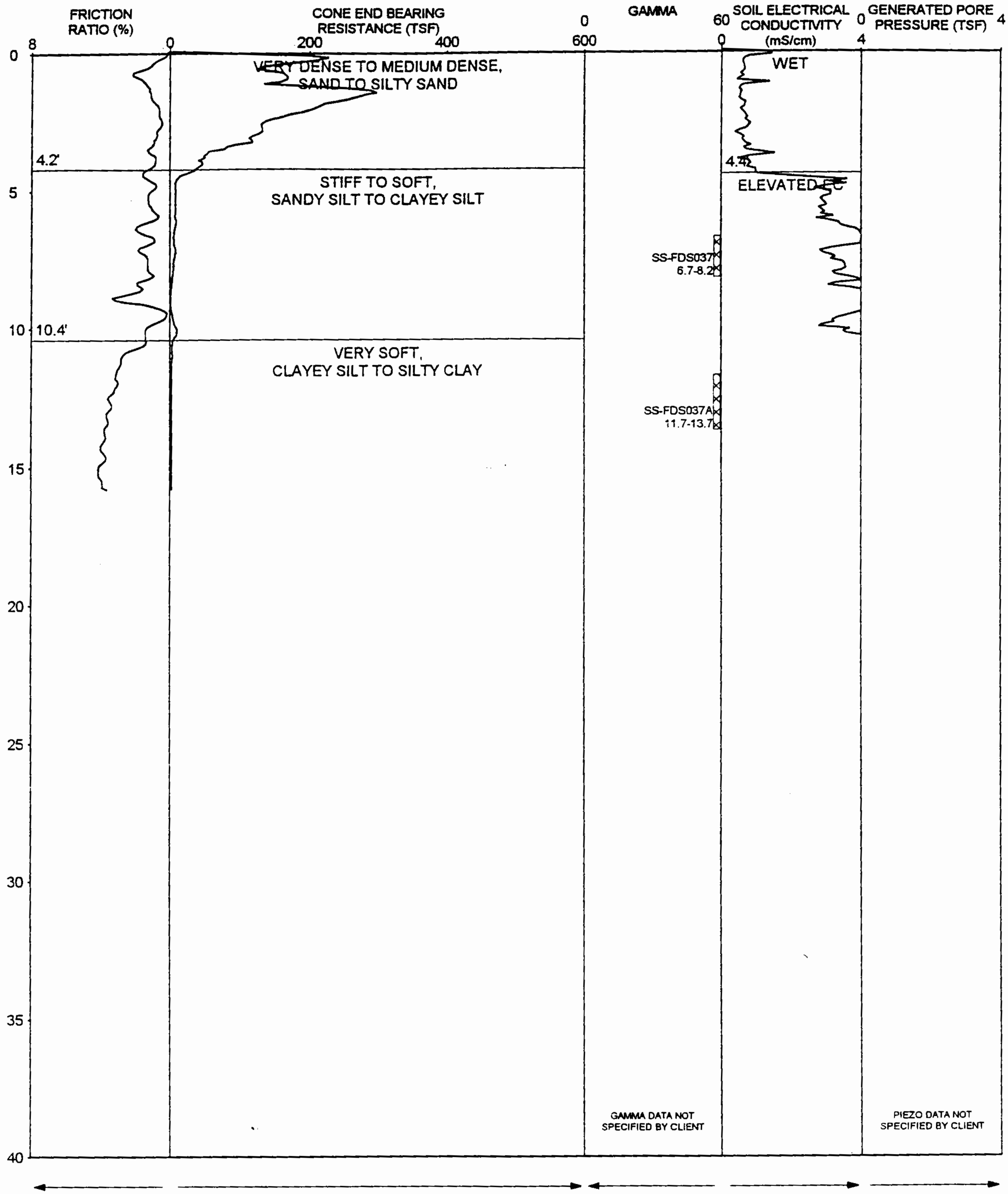


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/19/96
SOUNDING NUMBER: CP035

INTERPRETED CPT-EC LOG

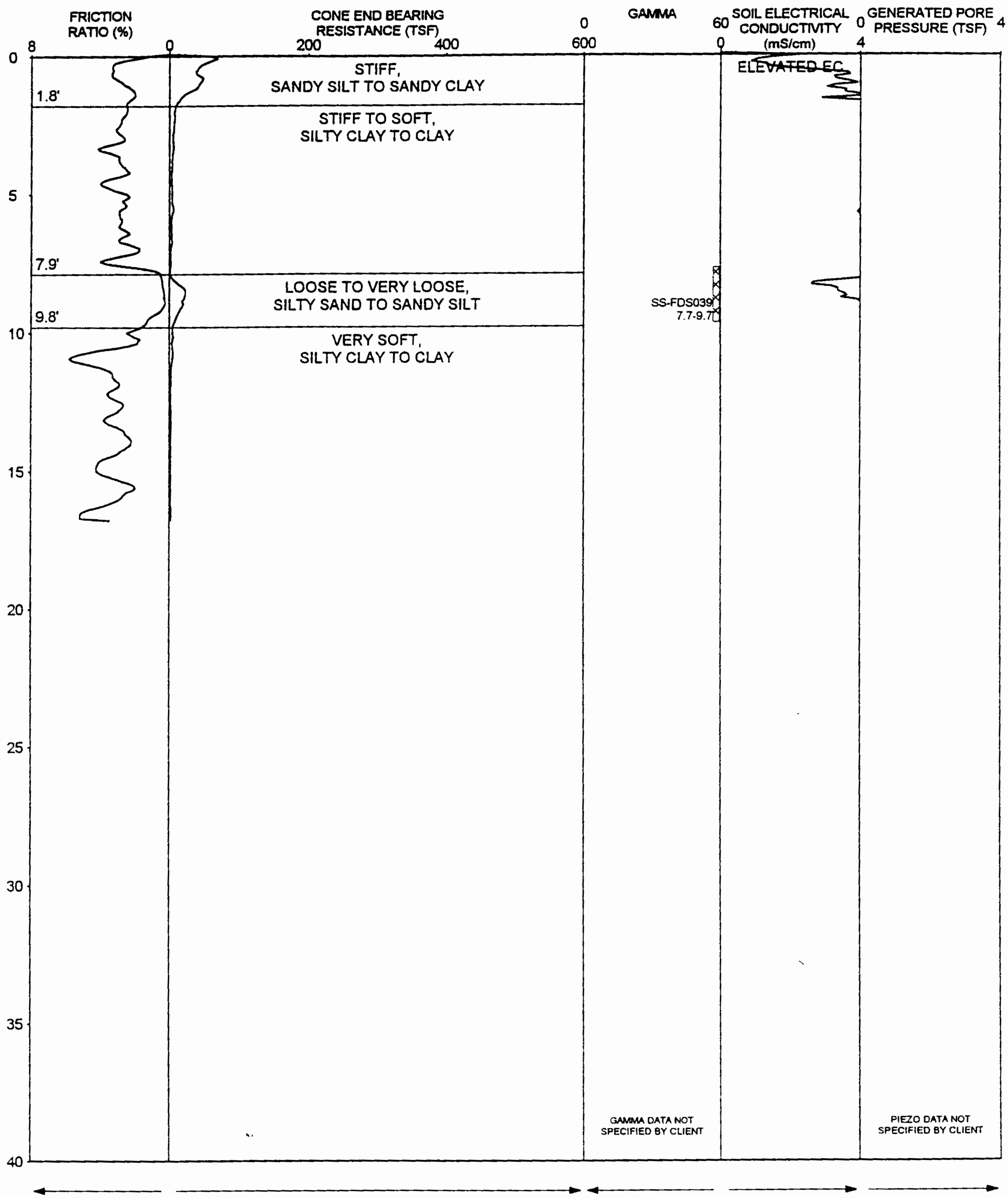


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/20/96
SOUNDING NUMBER: CP037

INTERPRETED CPT-EC LOG

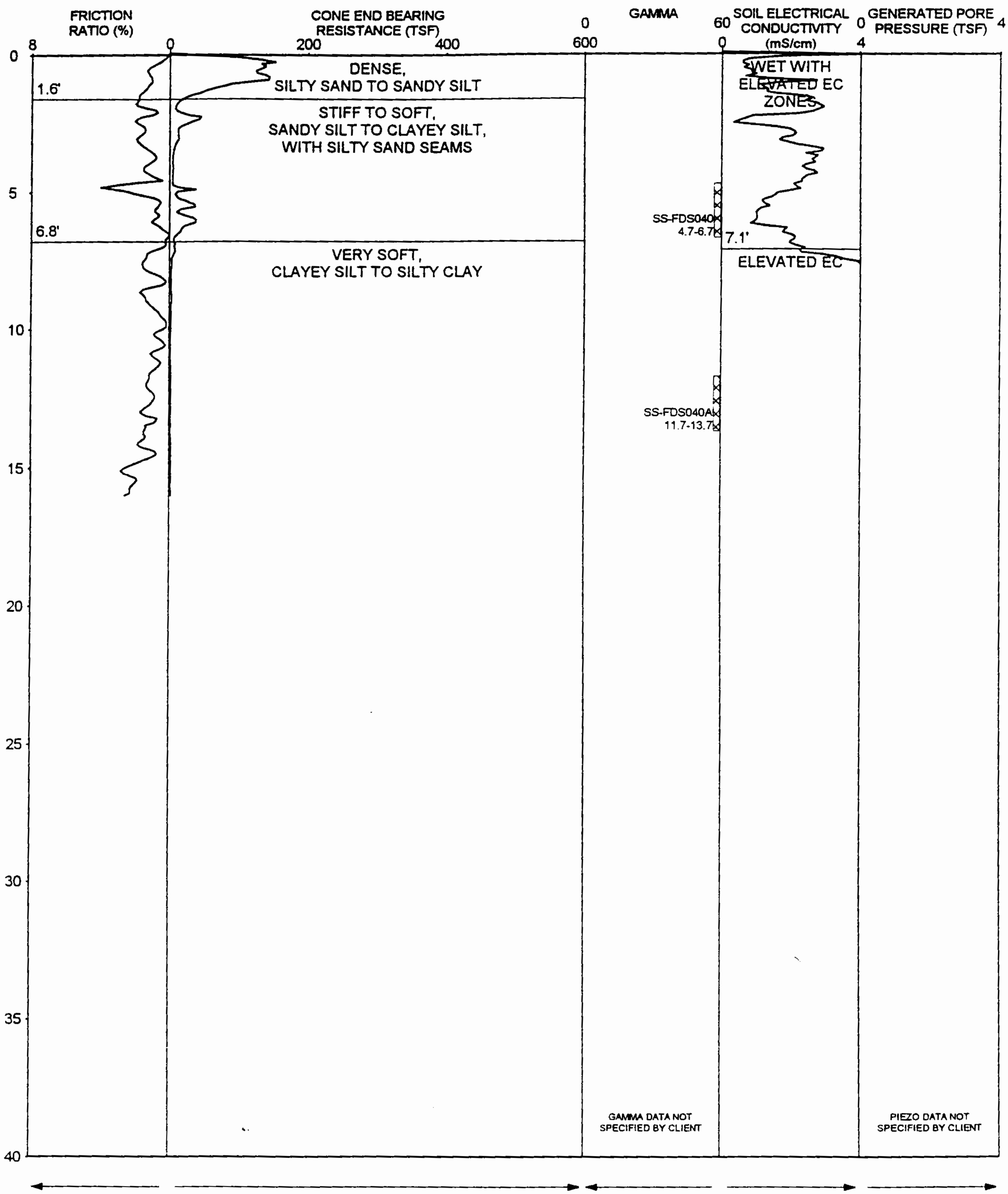


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/20/96
SOUNDING NUMBER: CP039

INTERPRETED CPT-EC LOG

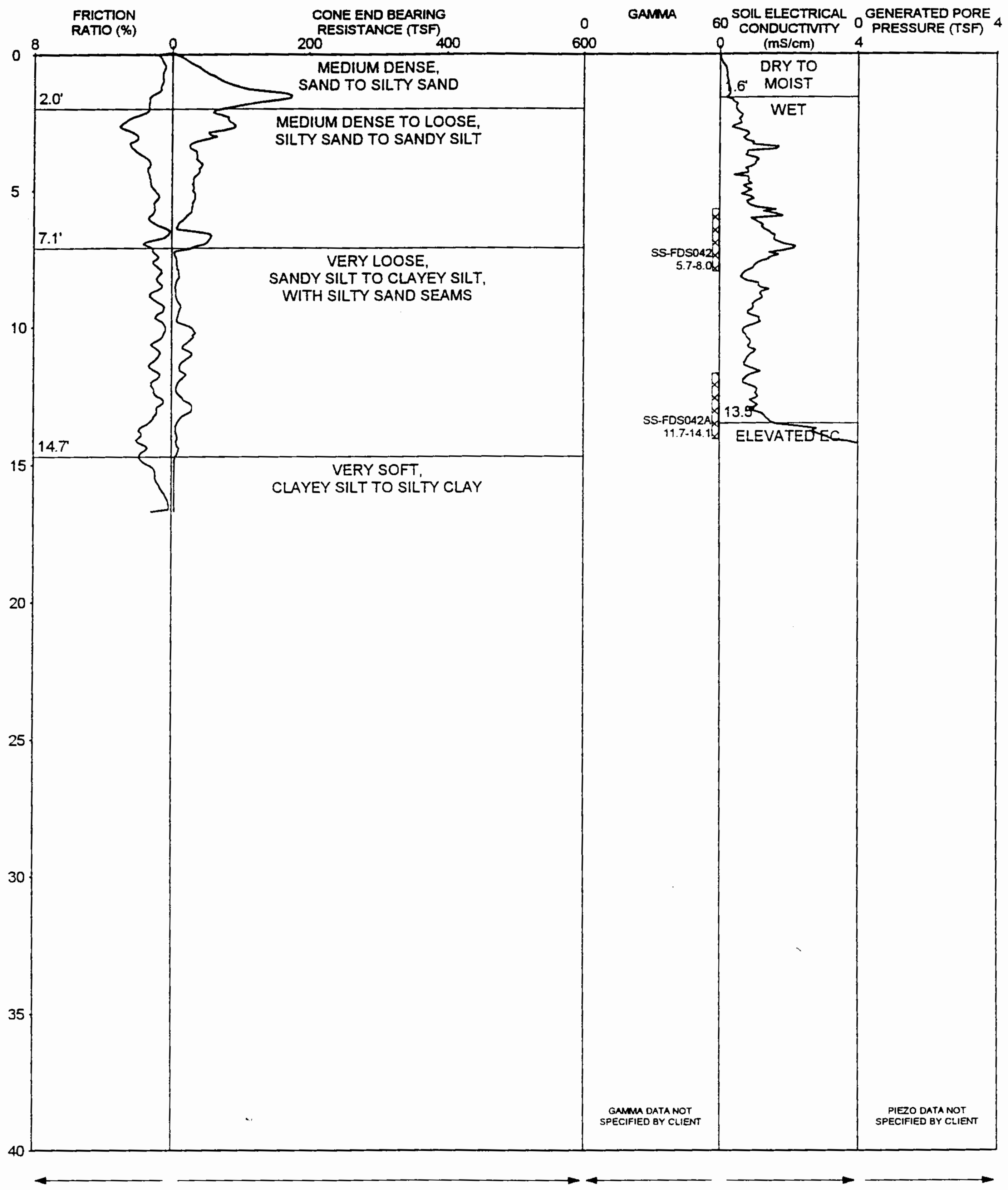


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/20/96
SOUNDING NUMBER: CP040

INTERPRETED CPT-EC LOG

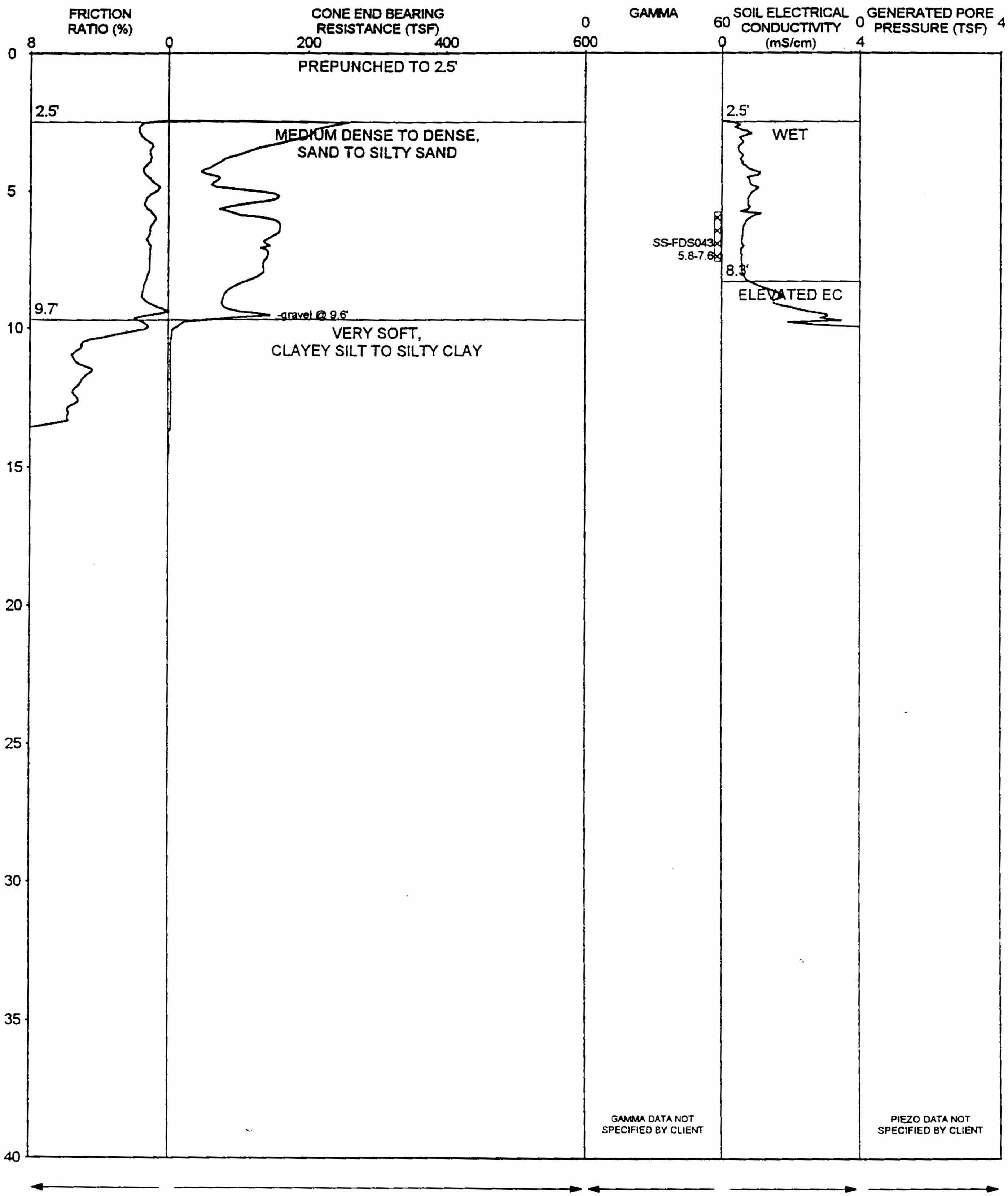


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP042

INTERPRETED CPT-EC LOG

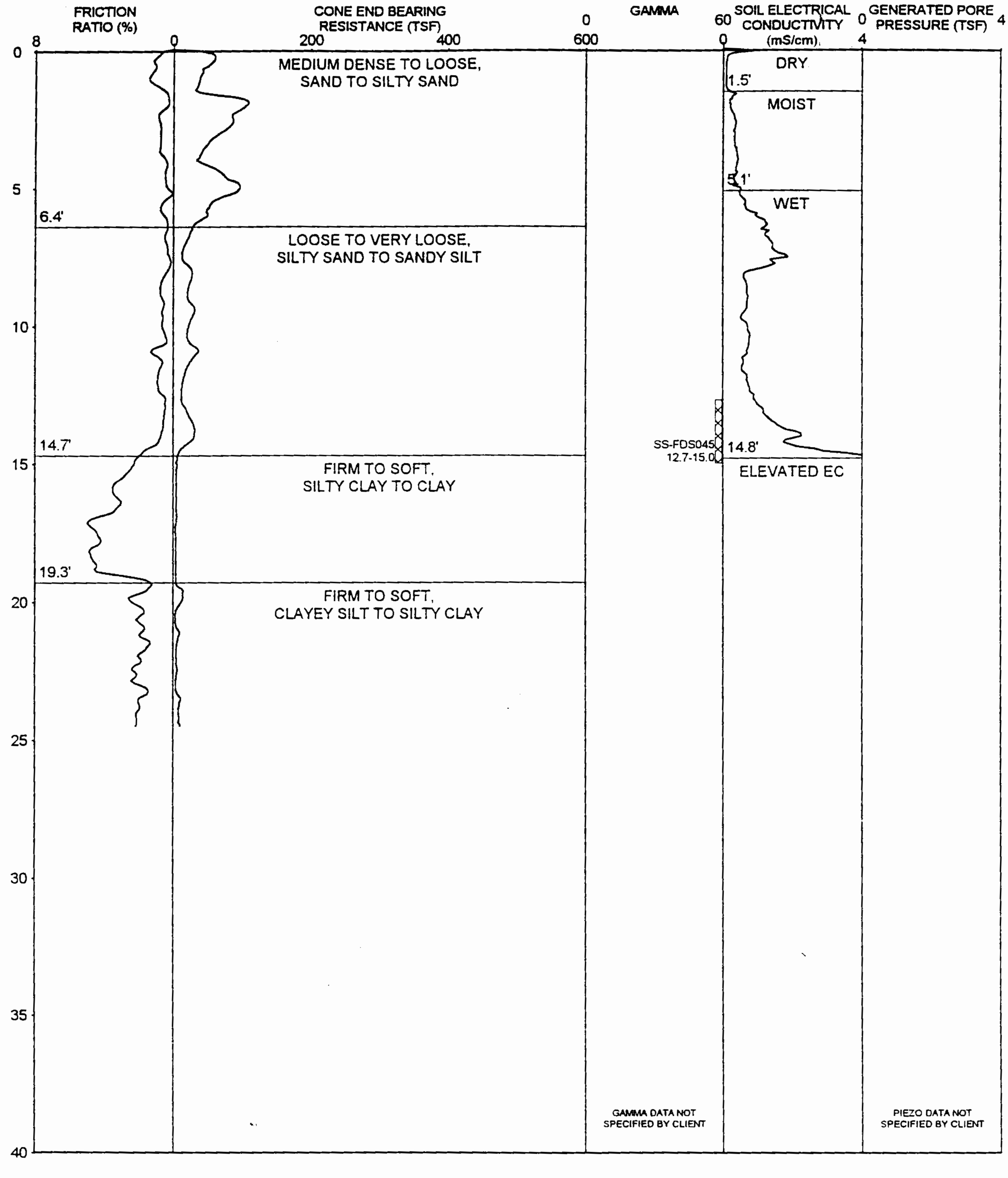


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP043

INTERPRETED CPT-EC LOG

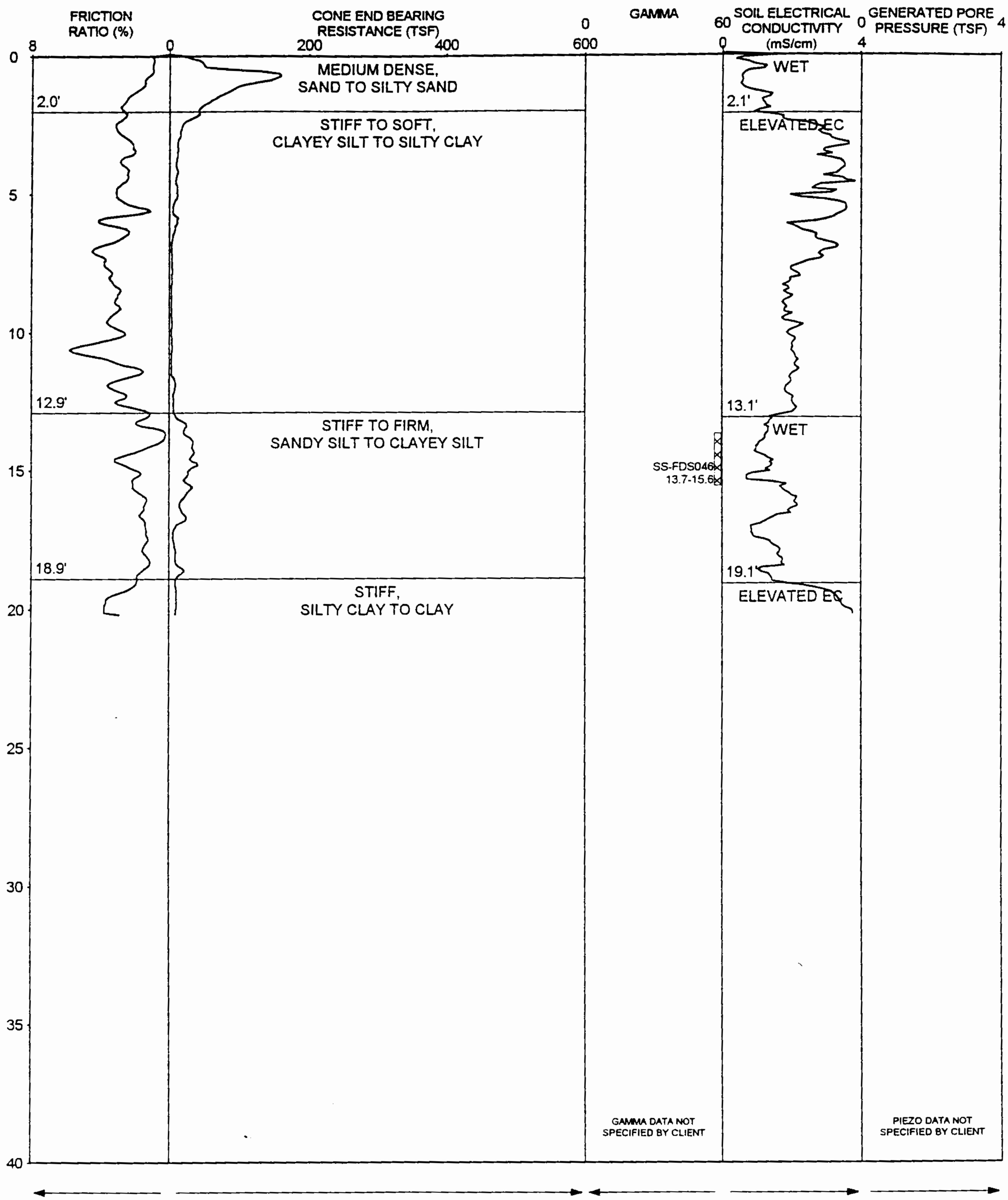


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP045

INTERPRETED CPT-EC LOG

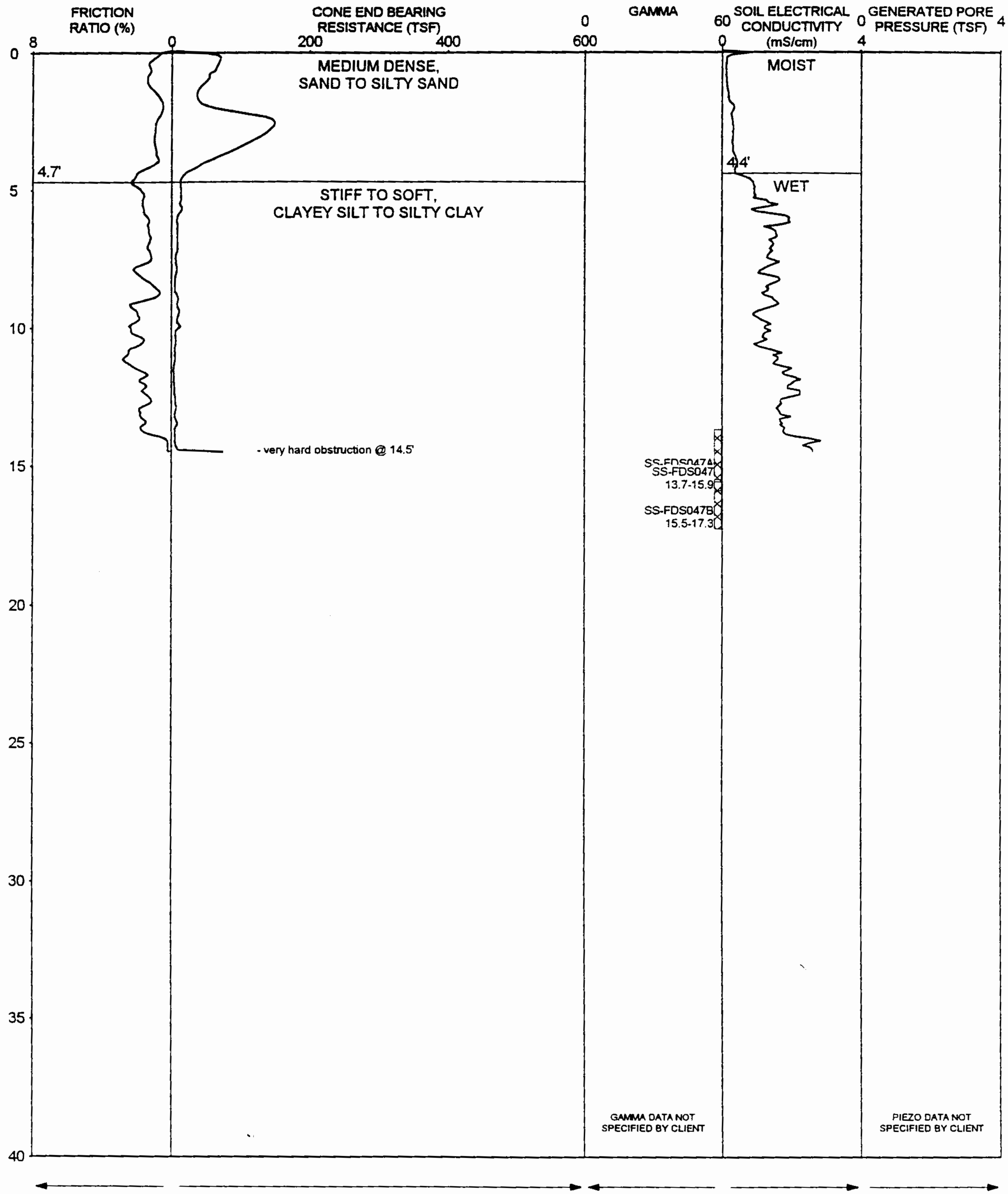


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP046

INTERPRETED CPT-EC LOG

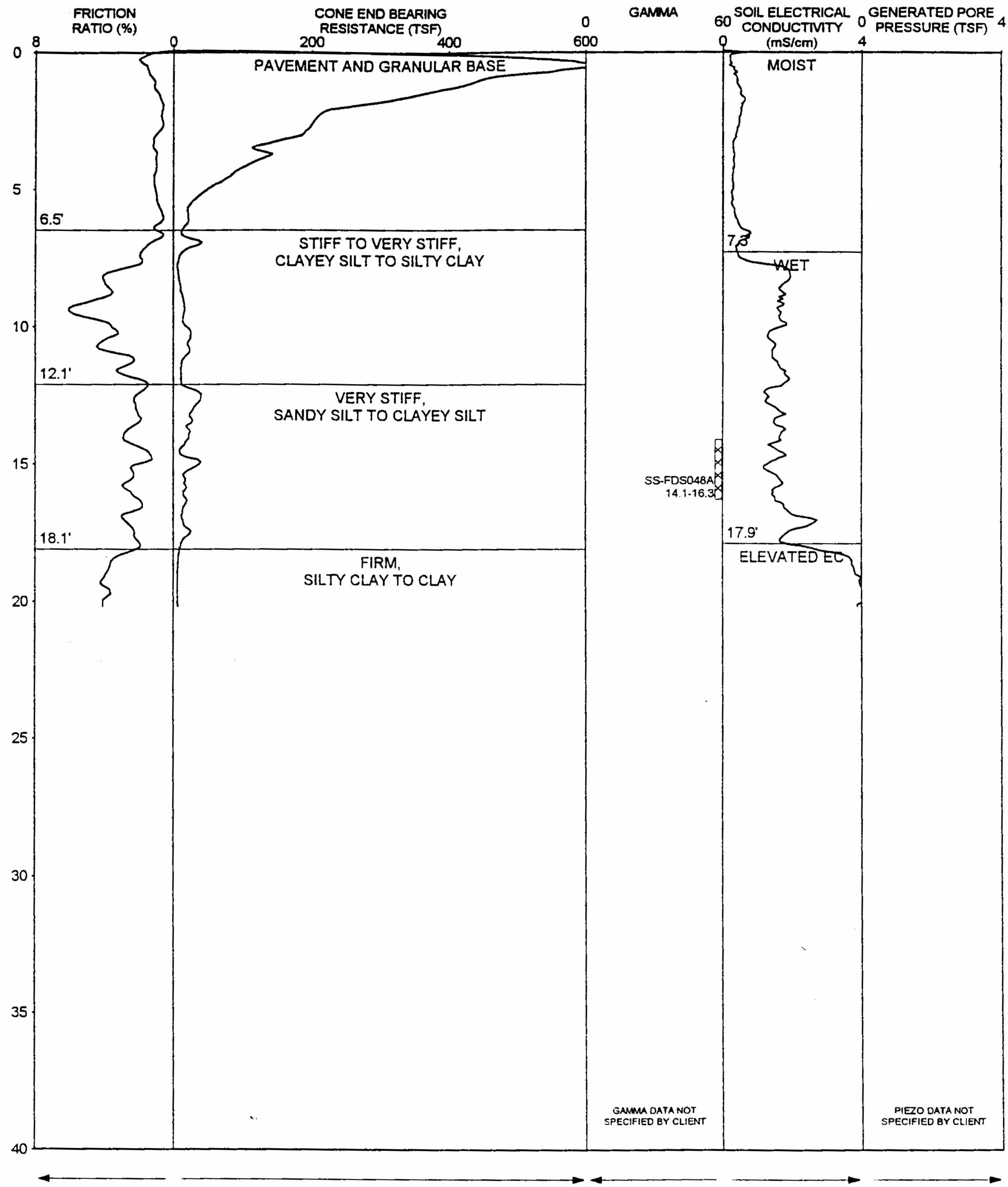


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP047

INTERPRETED CPT-EC LOG

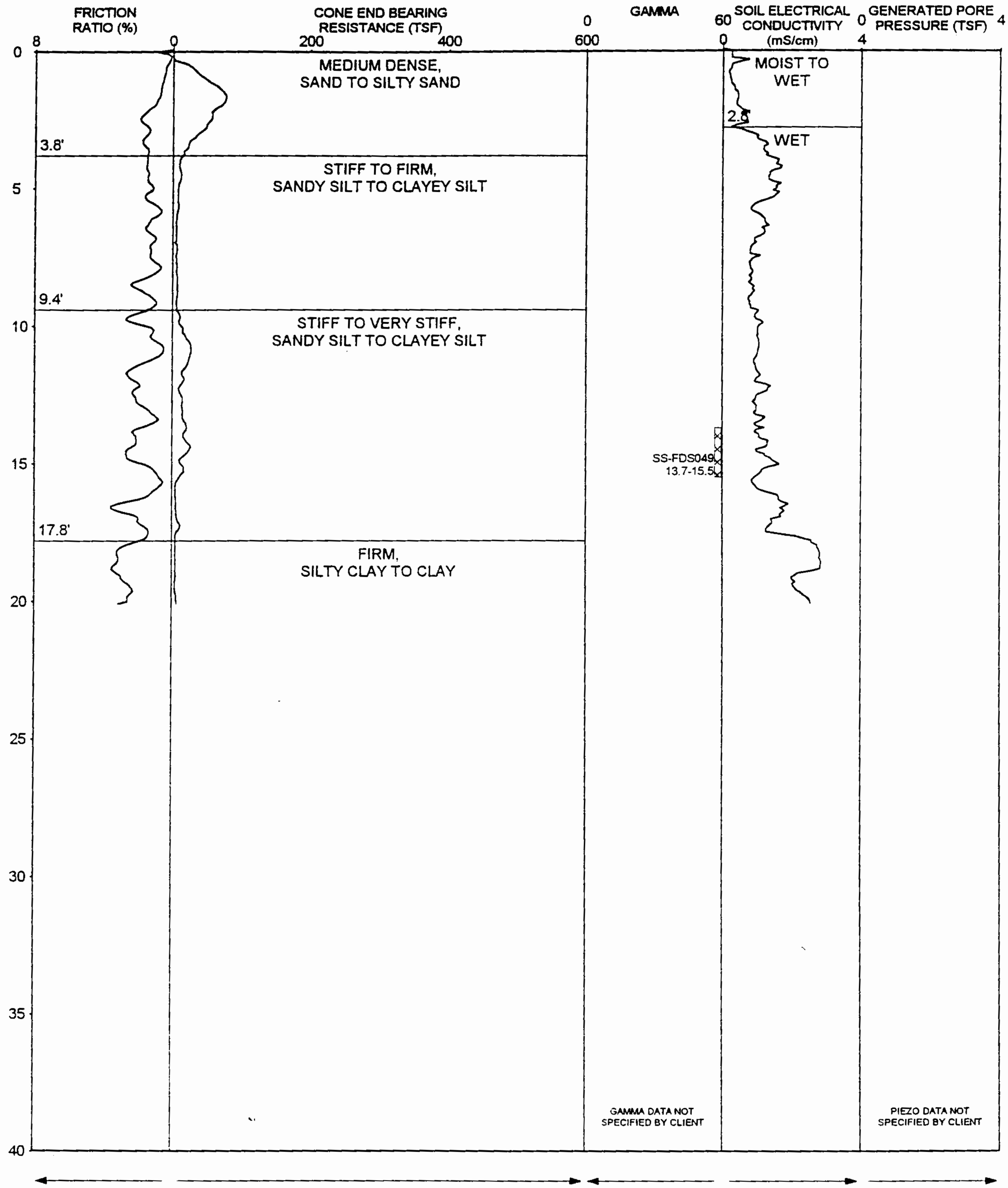


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP048

INTERPRETED CPT-EC LOG

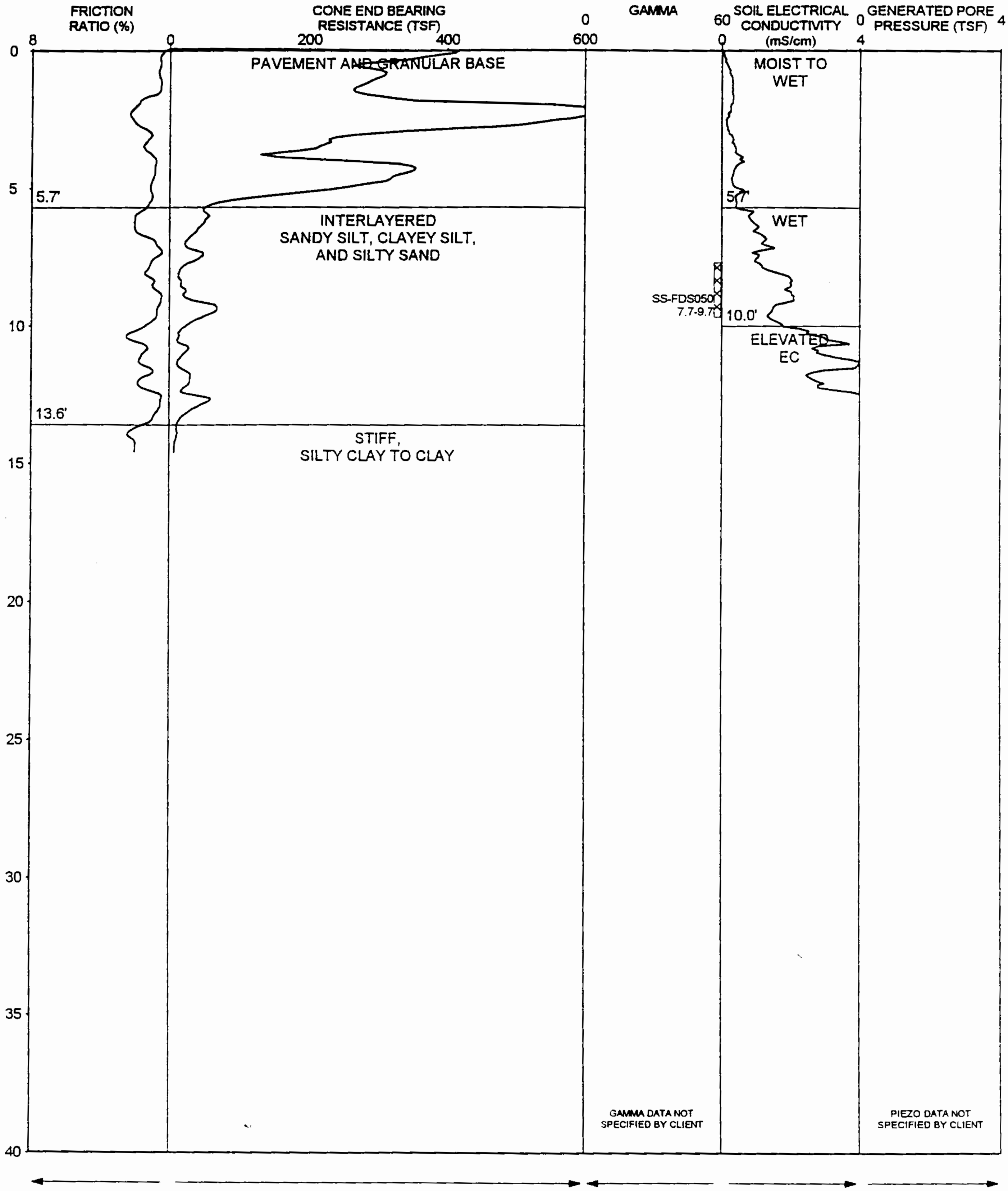


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP049

INTERPRETED CPT-EC LOG

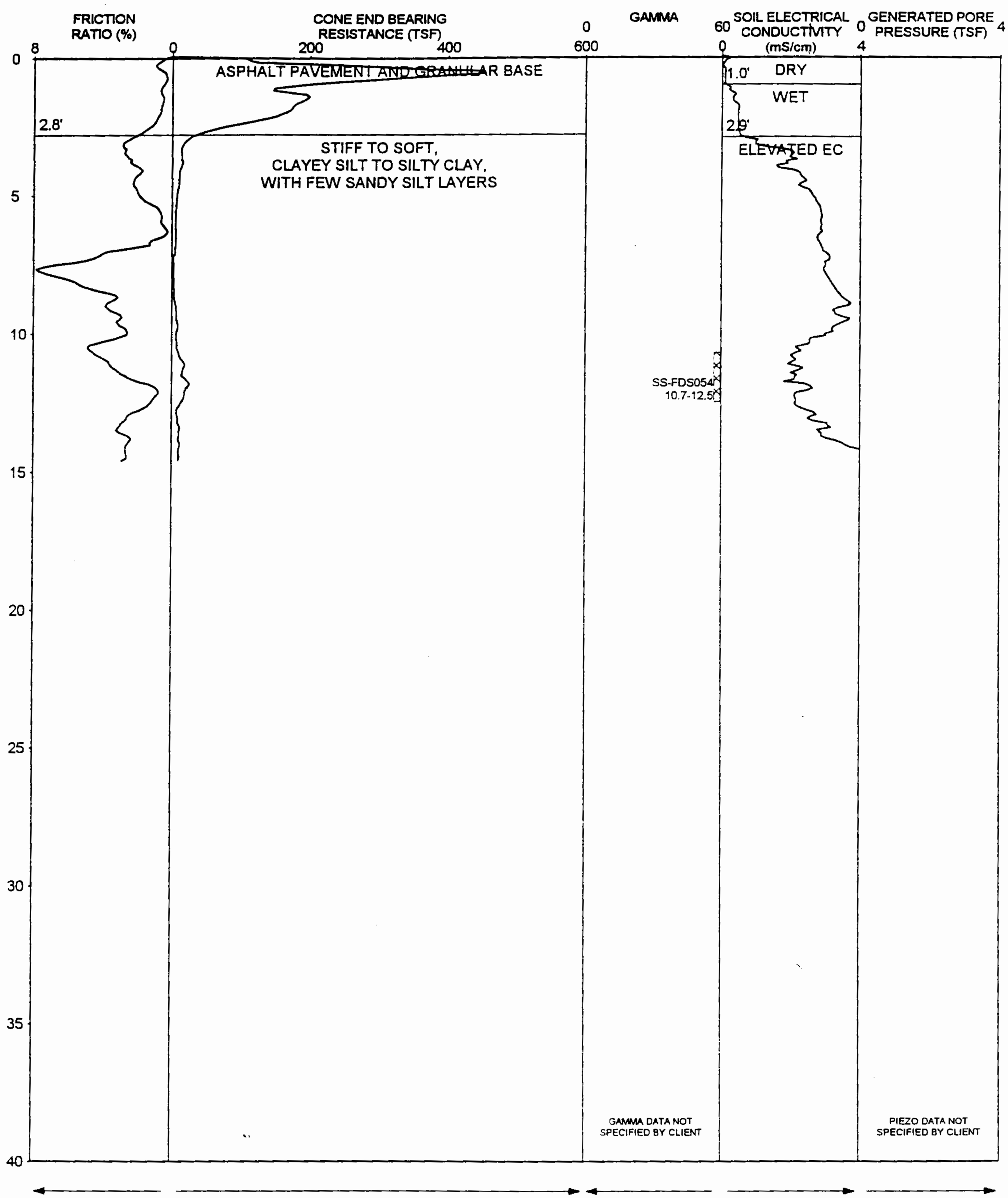


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/23/96
SOUNDING NUMBER: CP050

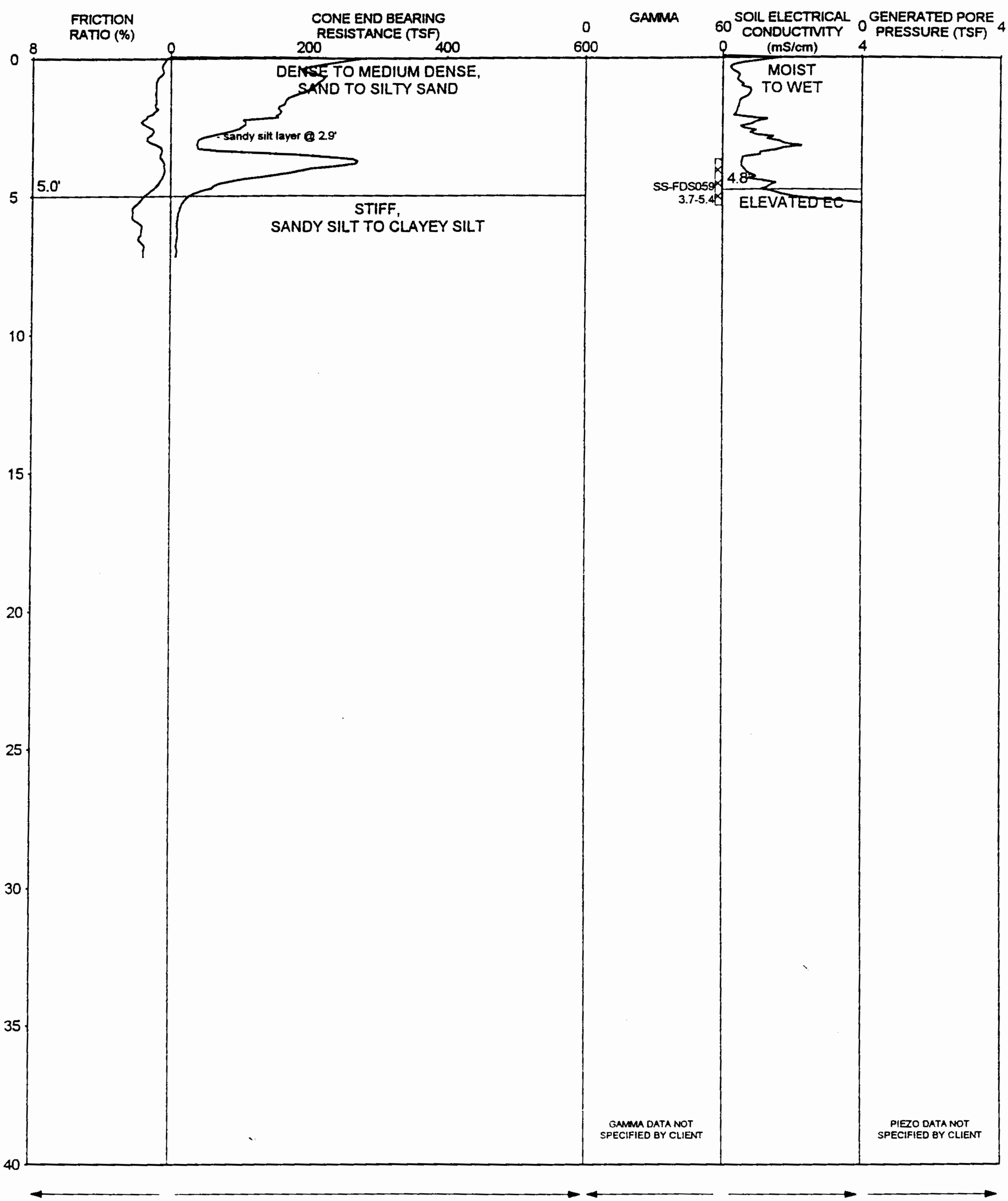
INTERPRETED CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 09/23/96
PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP054

INTERPRETED CPT-EC LOG

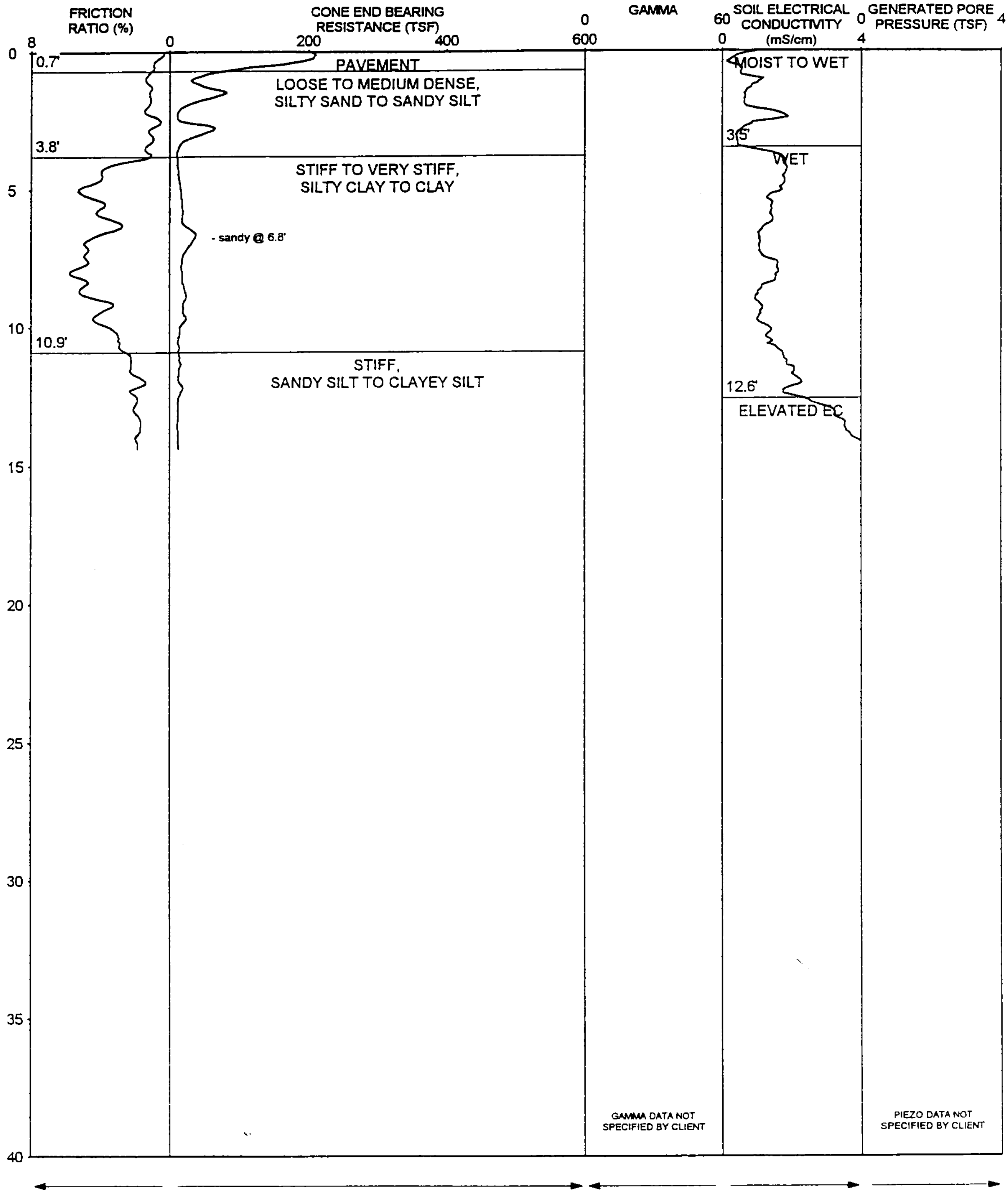


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/24/96
SOUNDING NUMBER: CP059

INTERPRETED CPT-EC LOG

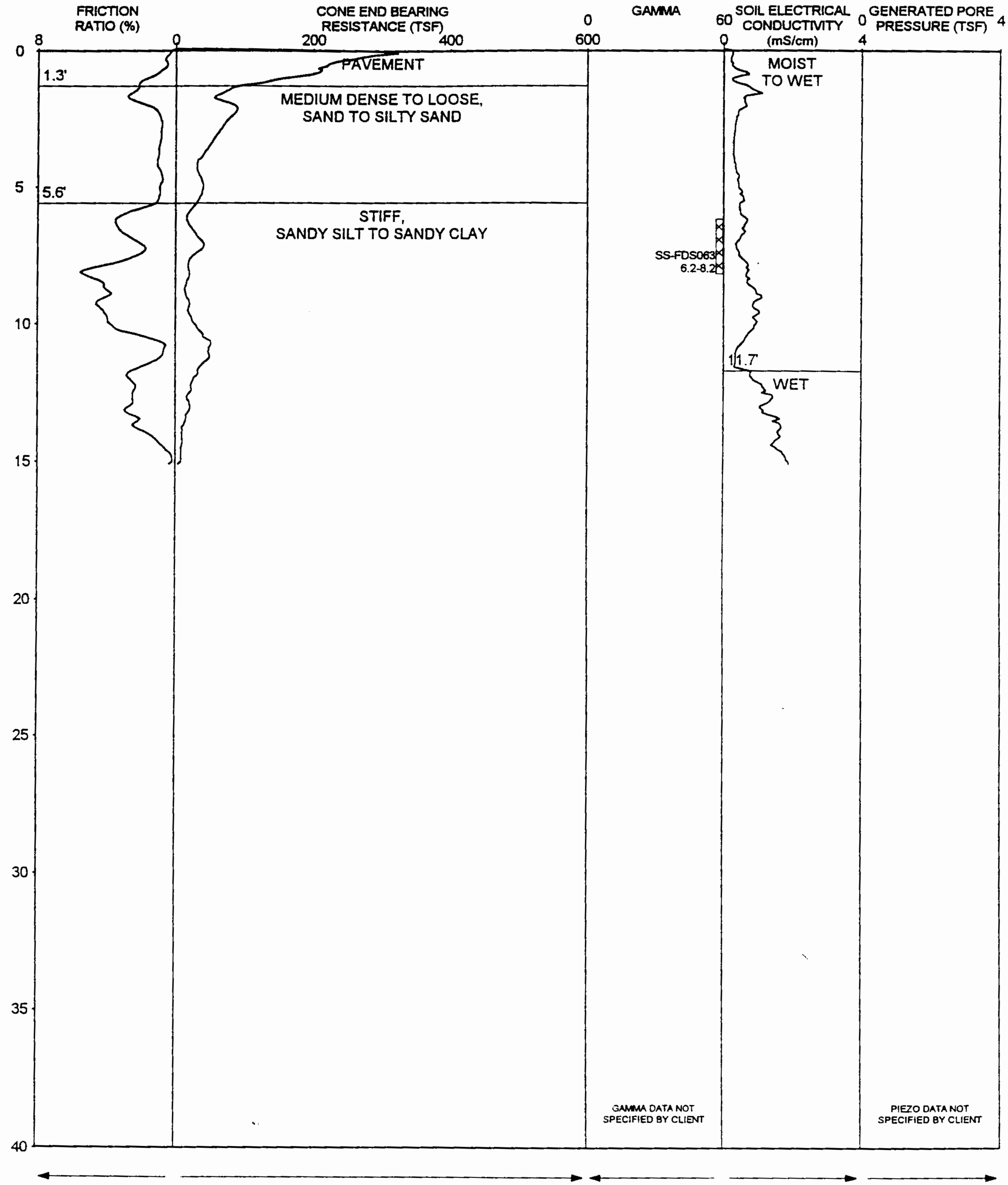


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/24/96
SOUNDING NUMBER: CP062

INTERPRETED CPT-EC LOG

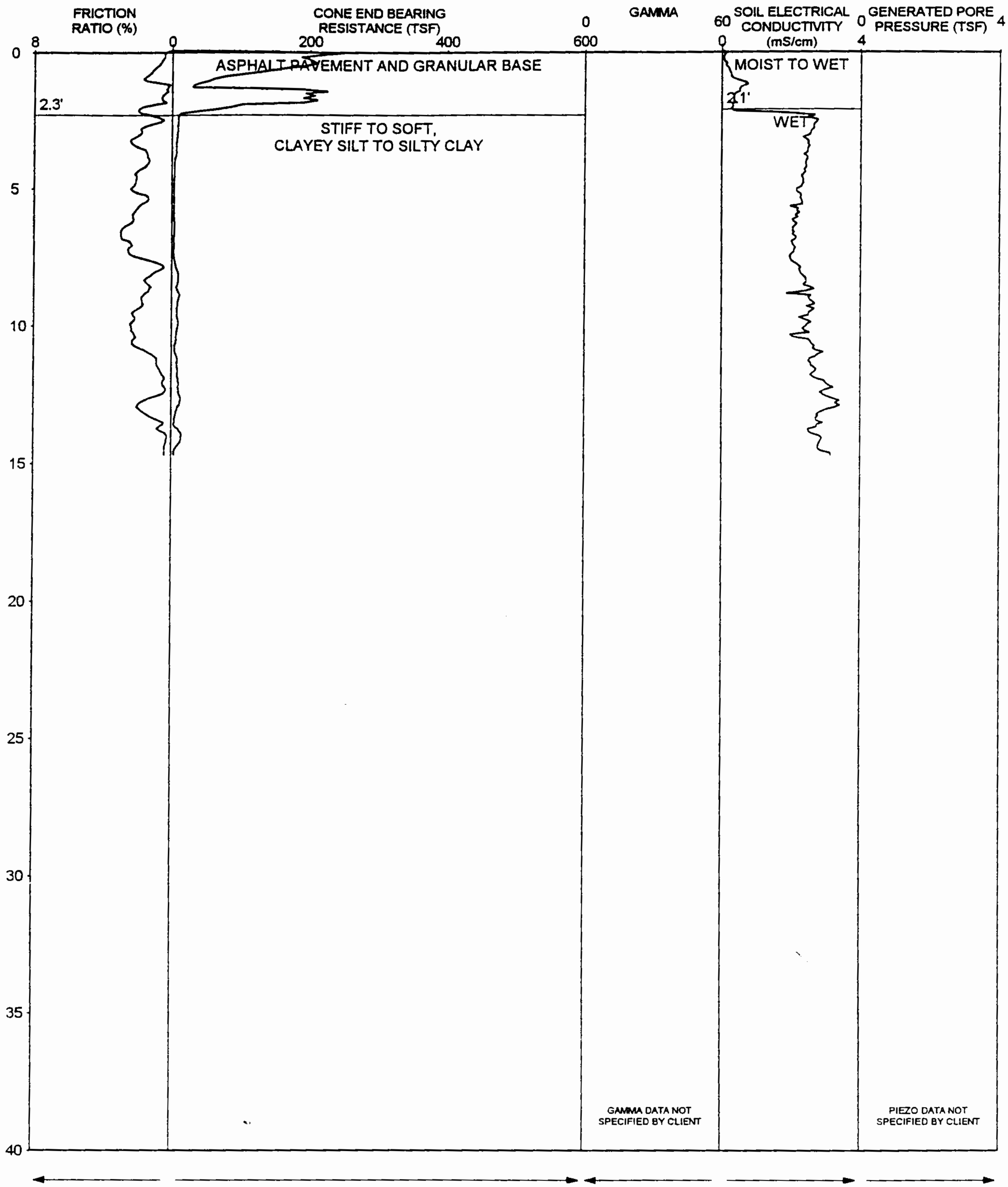


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/24/96
SOUNDING NUMBER: CP063

INTERPRETED CPT-EC LOG

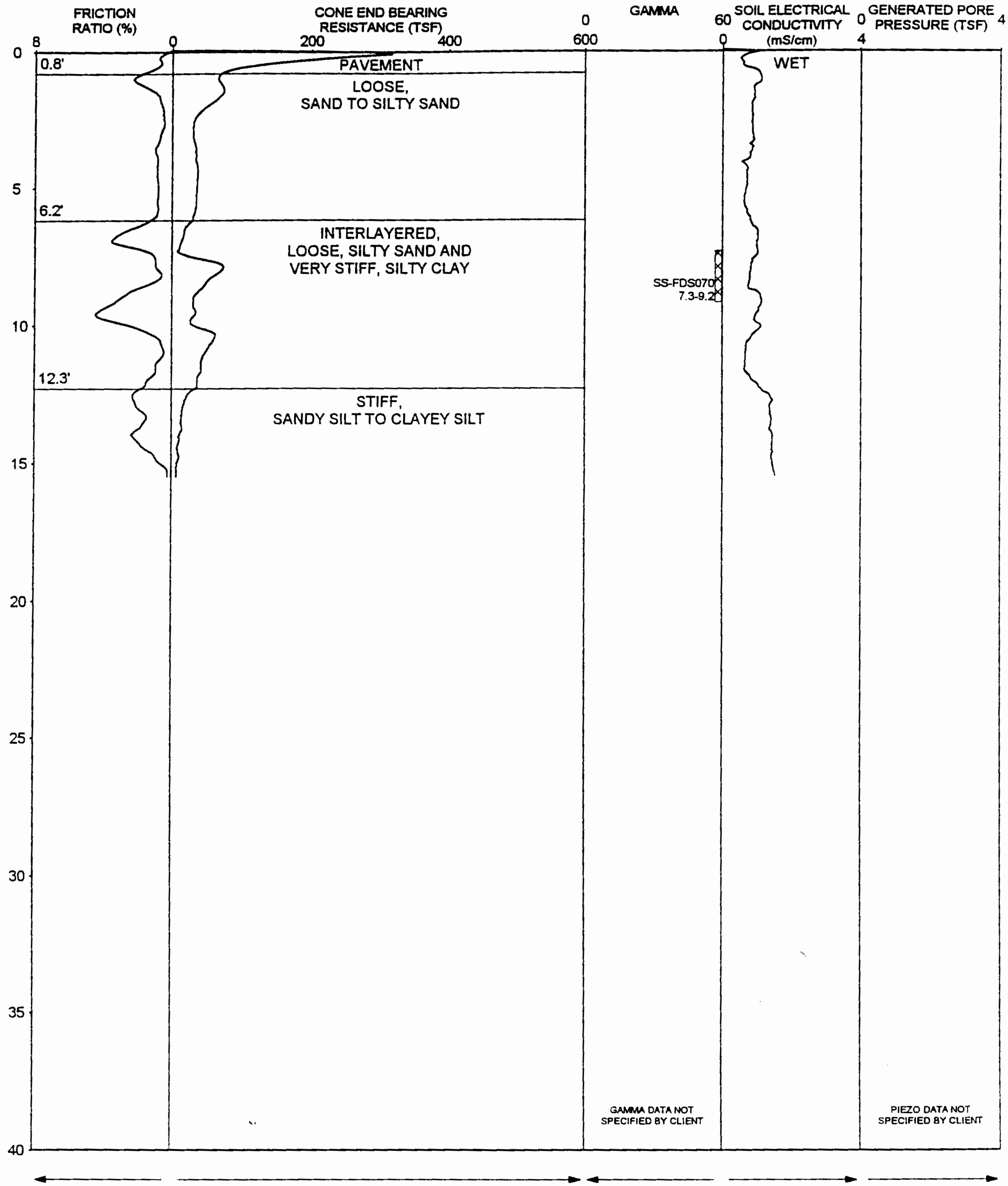


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/25/96
SOUNDING NUMBER: CP066

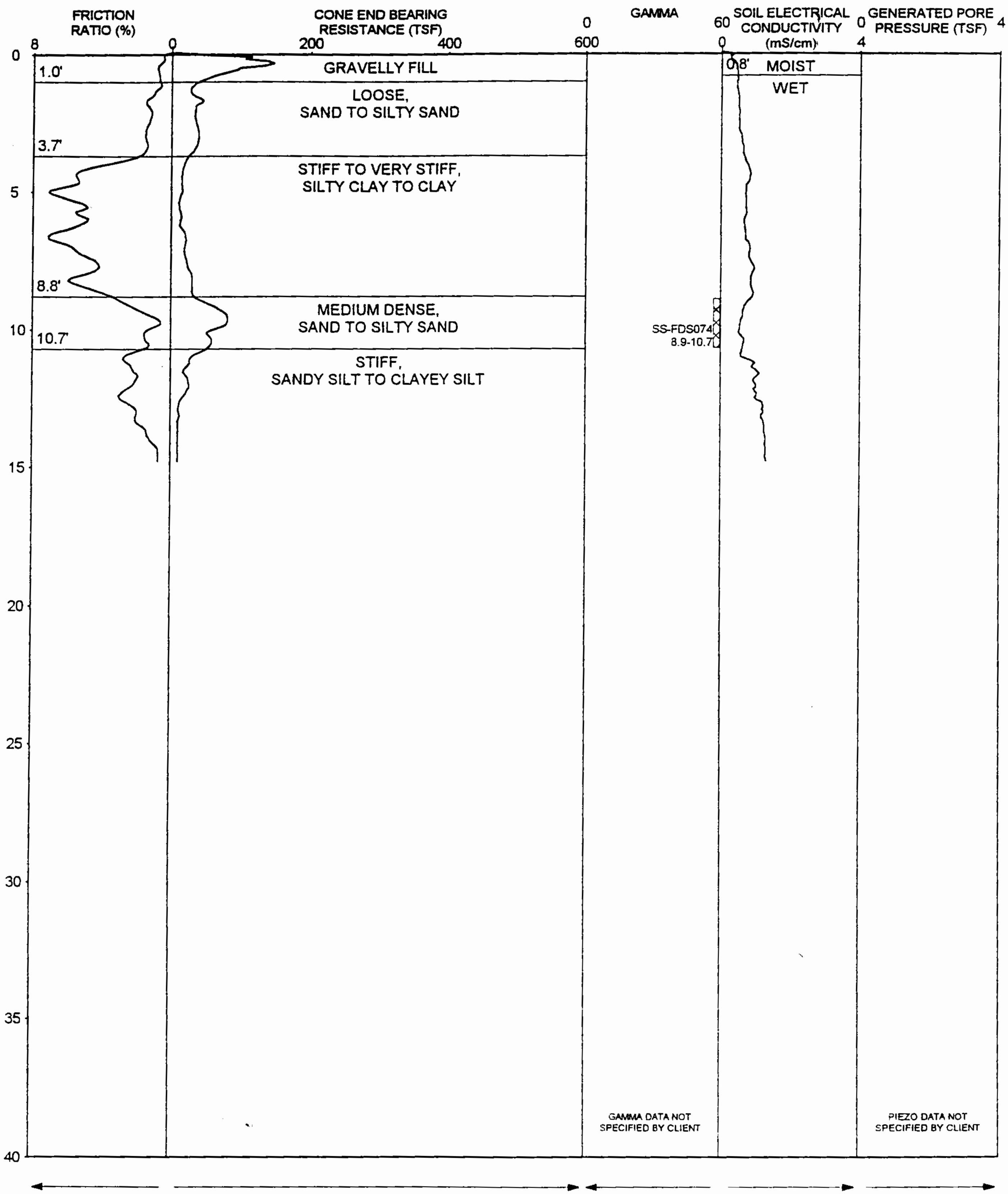
INTERPRETED CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 09/30/96
PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP070

INTERPRETED CPT-EC LOG

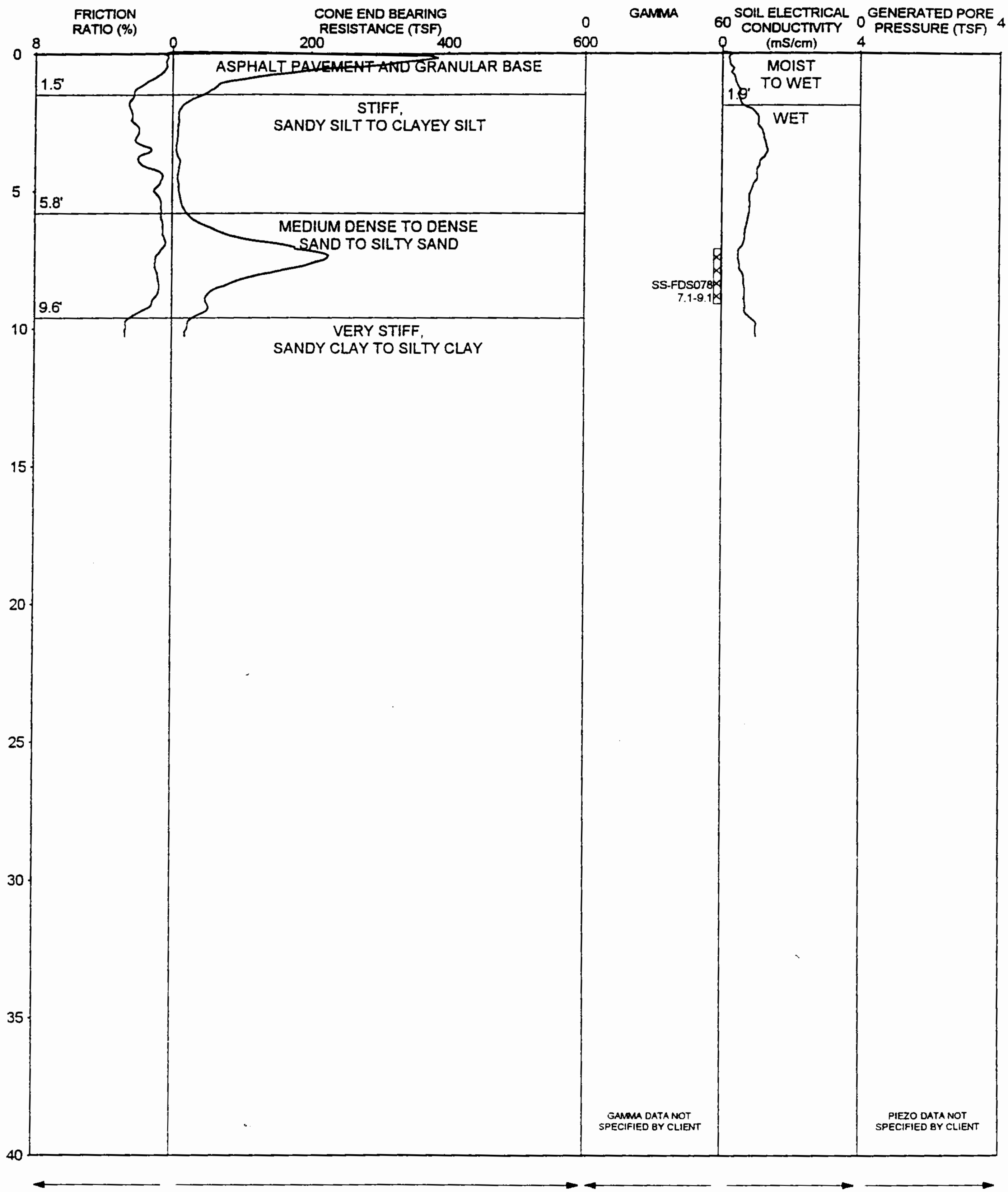


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base | DATE: 10/01/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CP074

INTERPRETED CPT-EC LOG

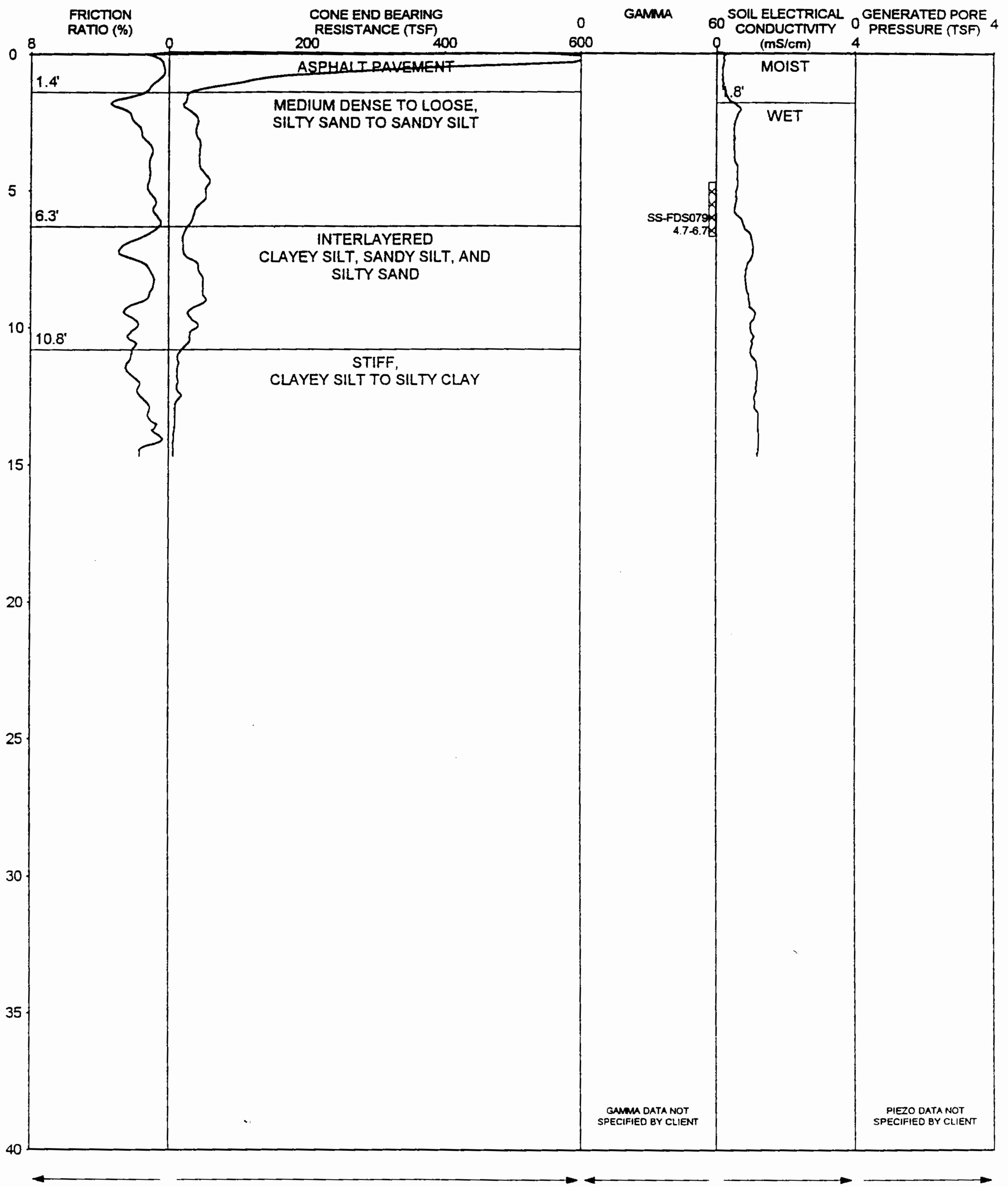


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/01/96
SOUNDING NUMBER: CP078

INTERPRETED CPT-EC LOG

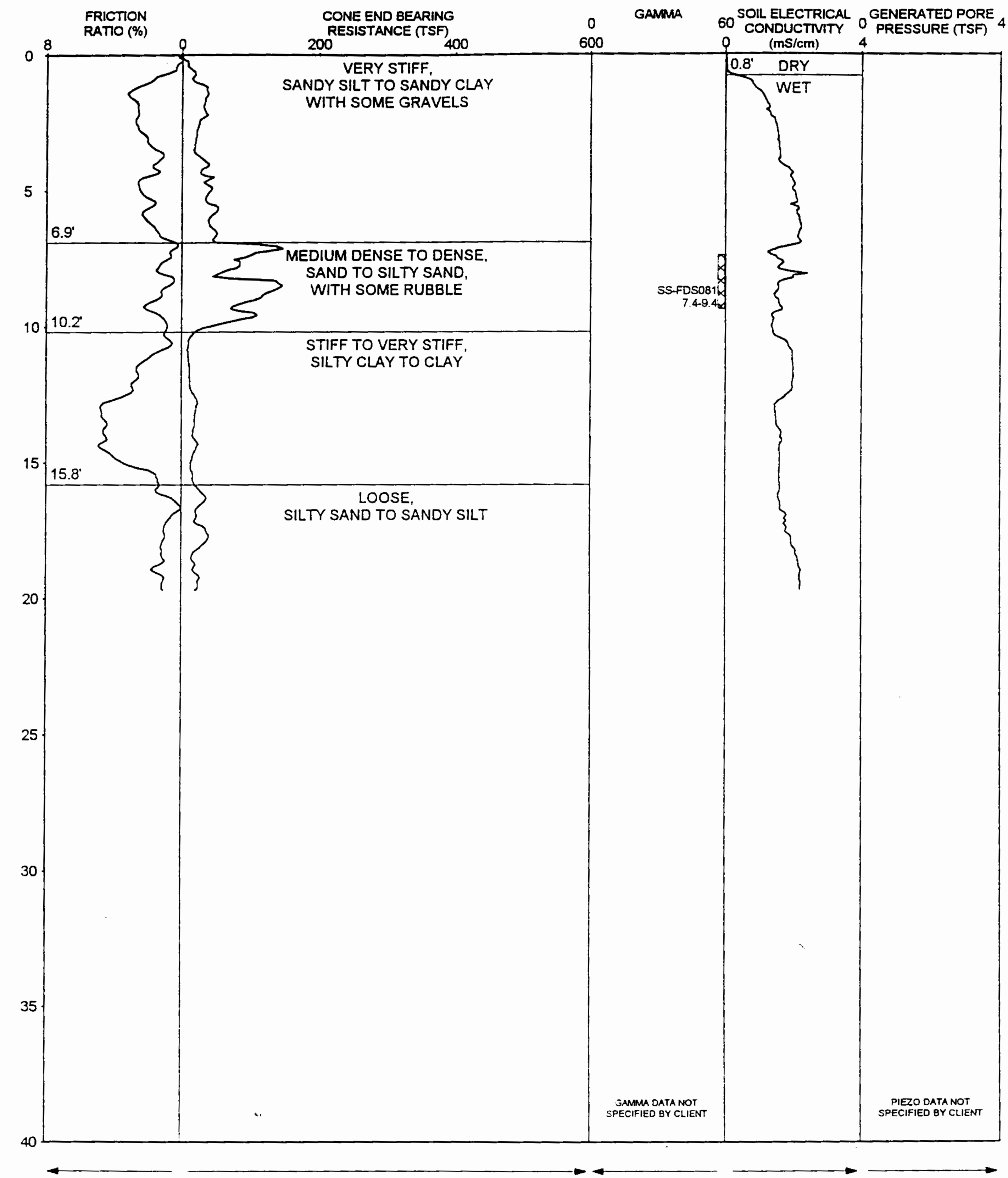


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/01/96
SOUNDING NUMBER: CP079

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

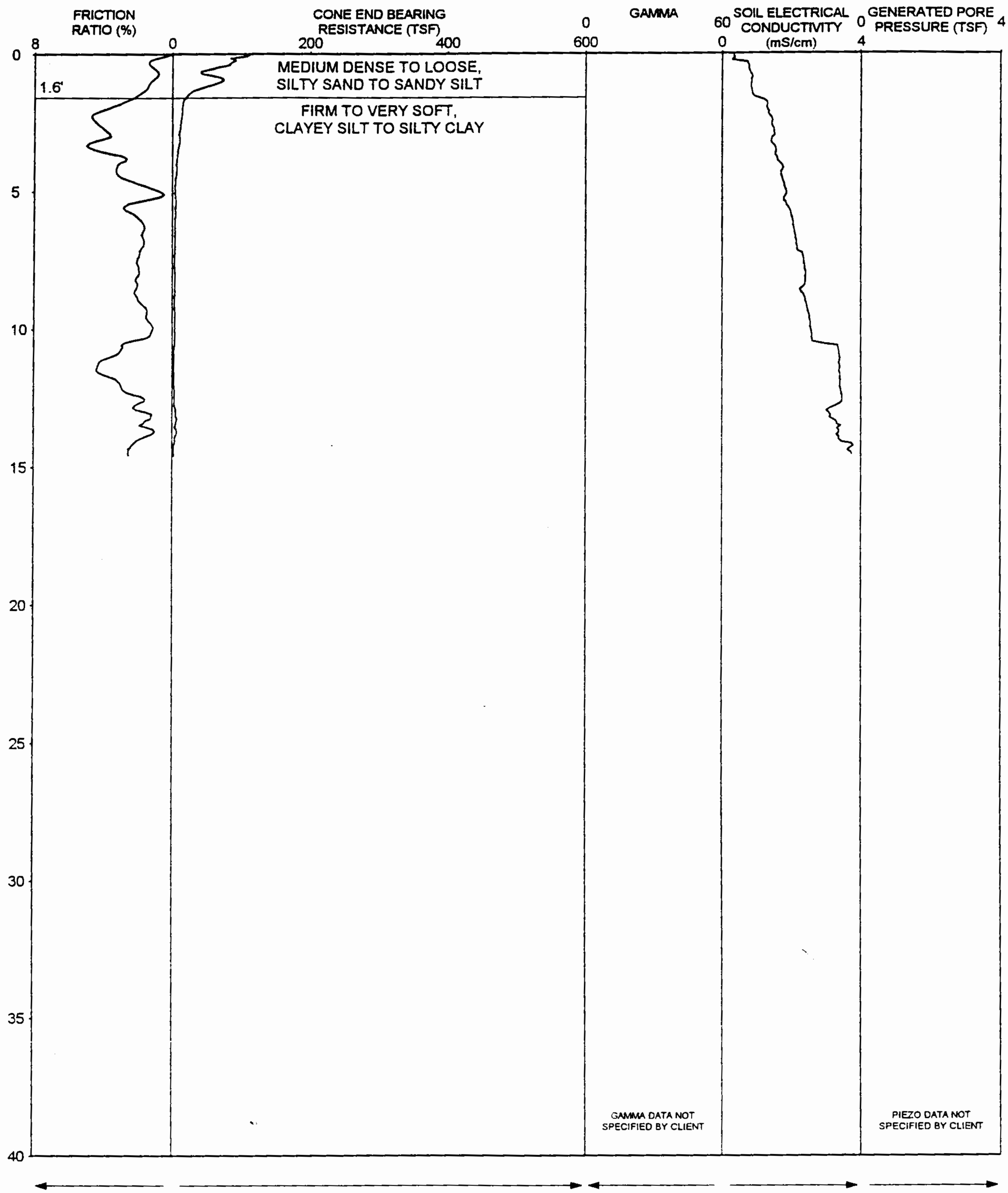
PROJECT NAME: Zone D, F, and G Charleston Naval Base

PROJECT NUMBER: 96-110-230

DATE: 10/02/96

SOUNDING NUMBER: CP081

INTERPRETED CPT-EC LOG

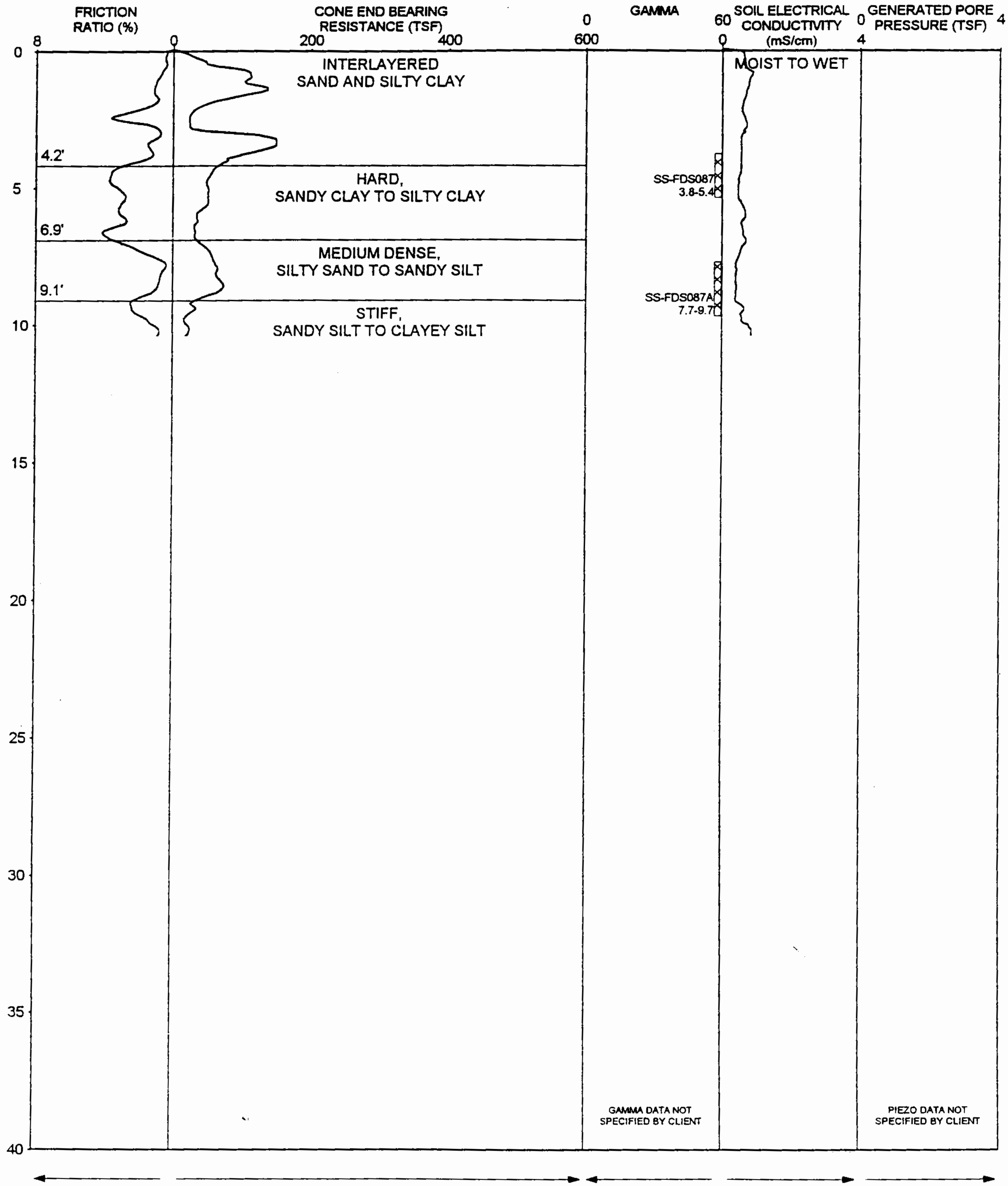


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP085

INTERPRETED CPT-EC LOG

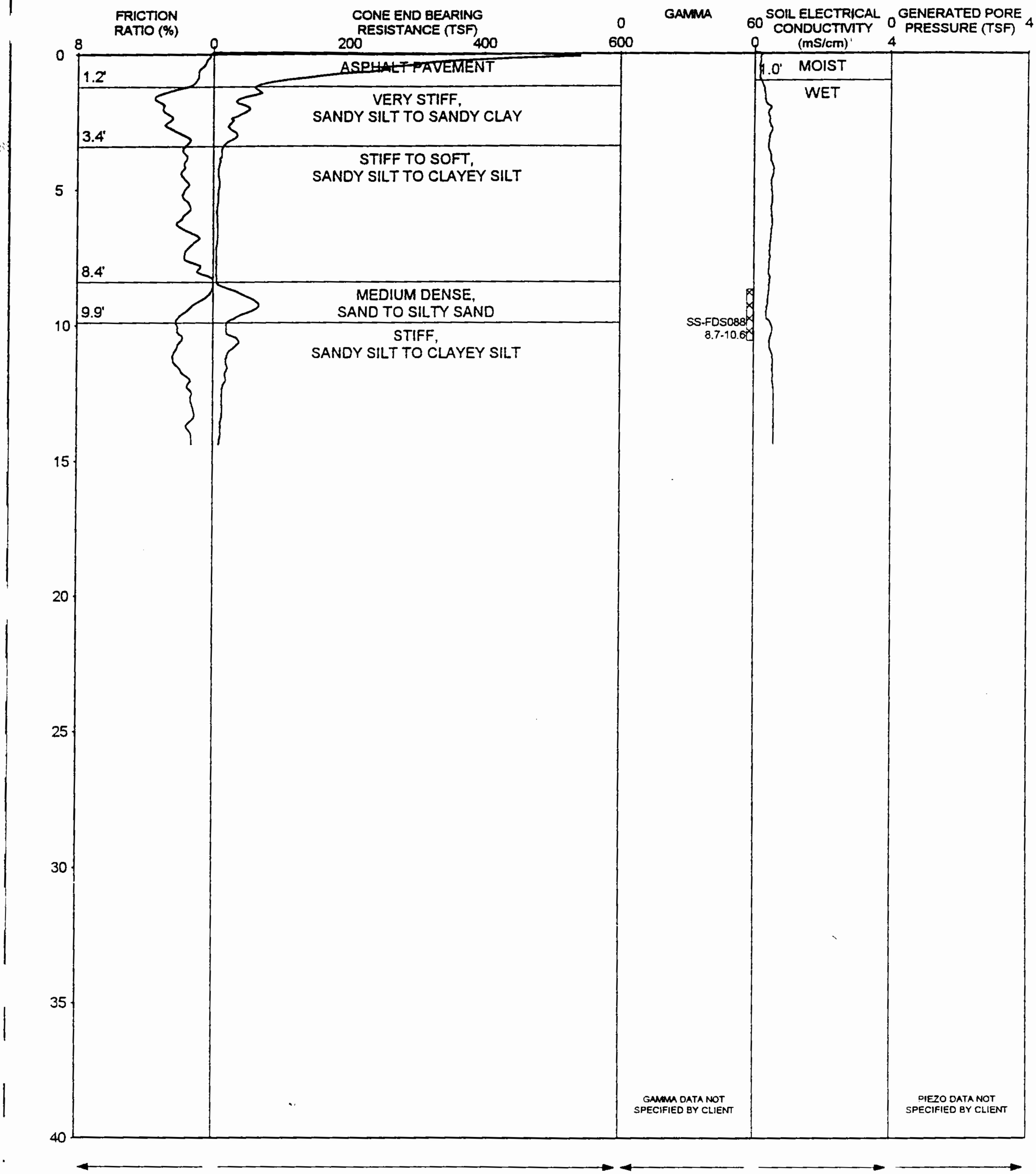


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP087

INTERPRETED CPT-EC LOG

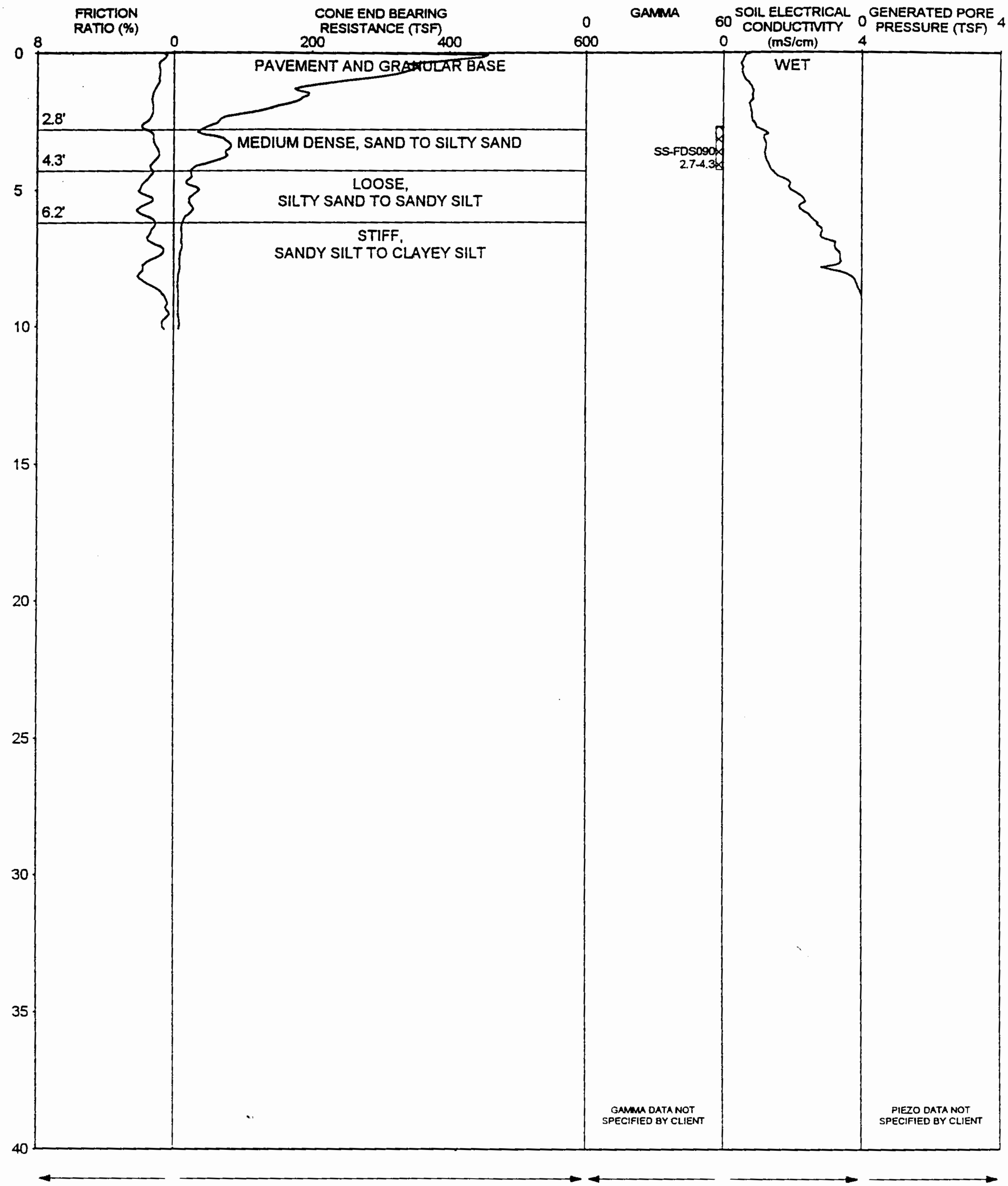


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP088

INTERPRETED CPT-EC LOG

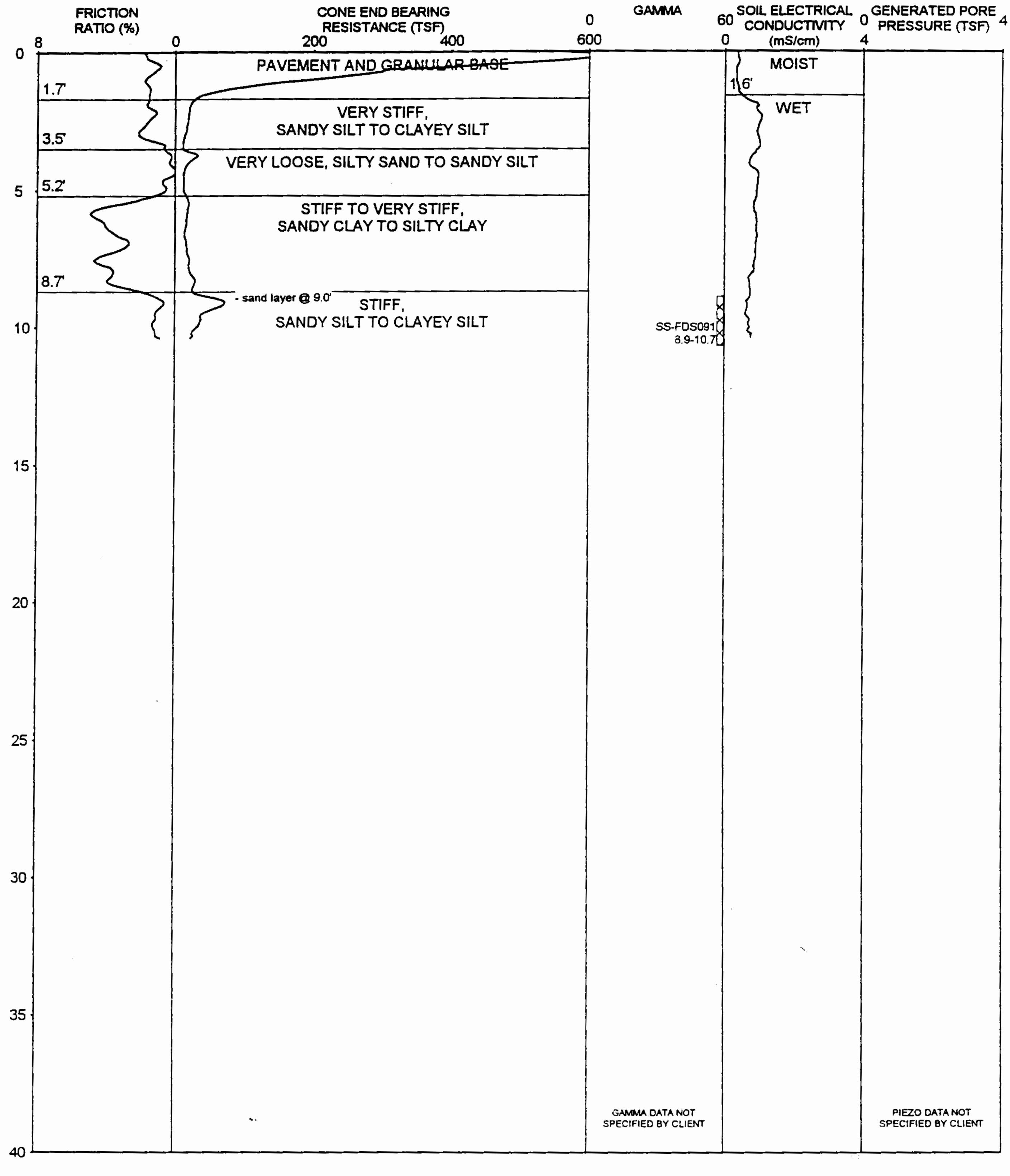


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP090

INTERPRETED CPT-EC LOG

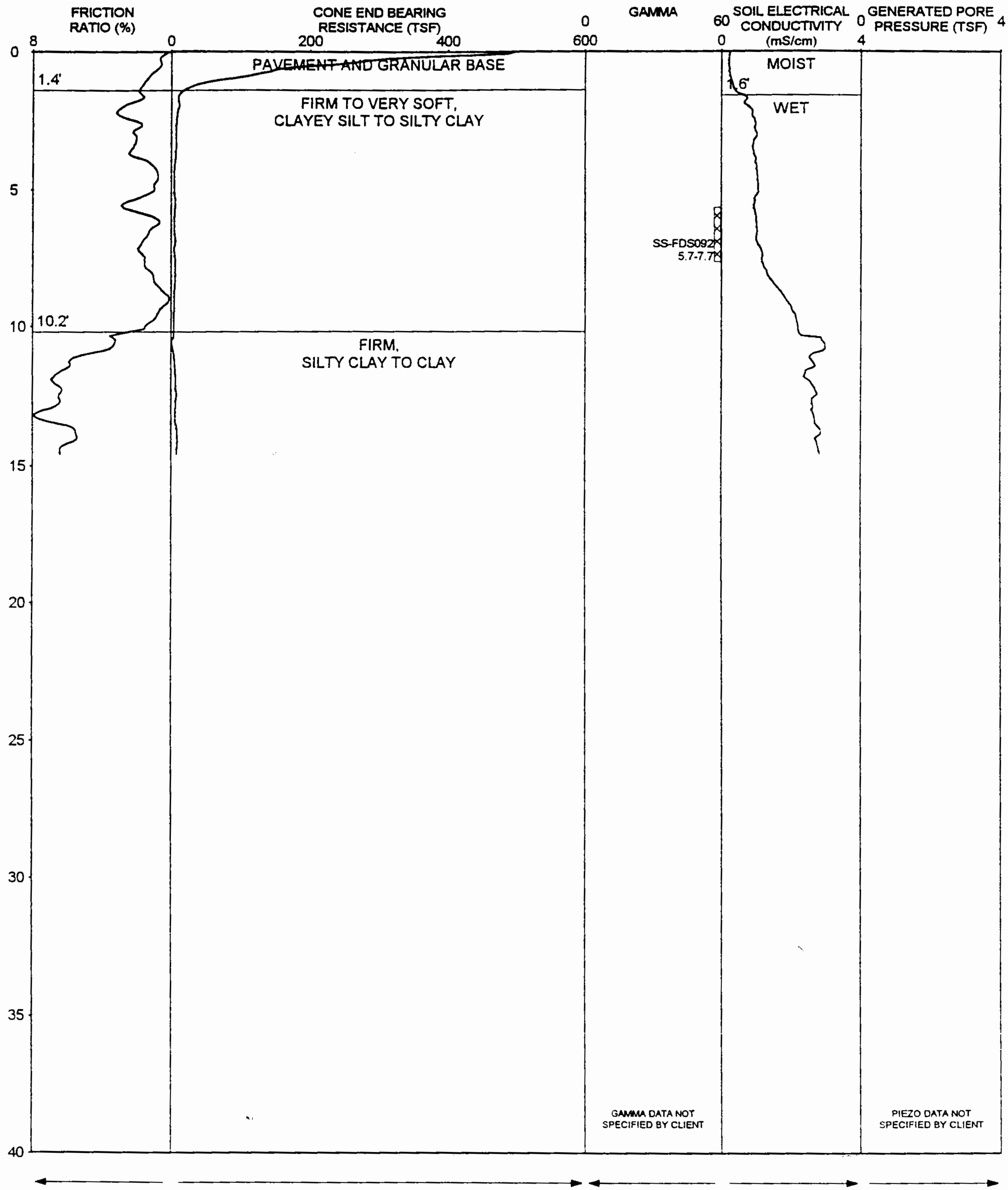


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base — DATE: 10/03/96

PROJECT NUMBER: 96-110-230 — SOUNDING NUMBER: CP091

INTERPRETED CPT-EC LOG

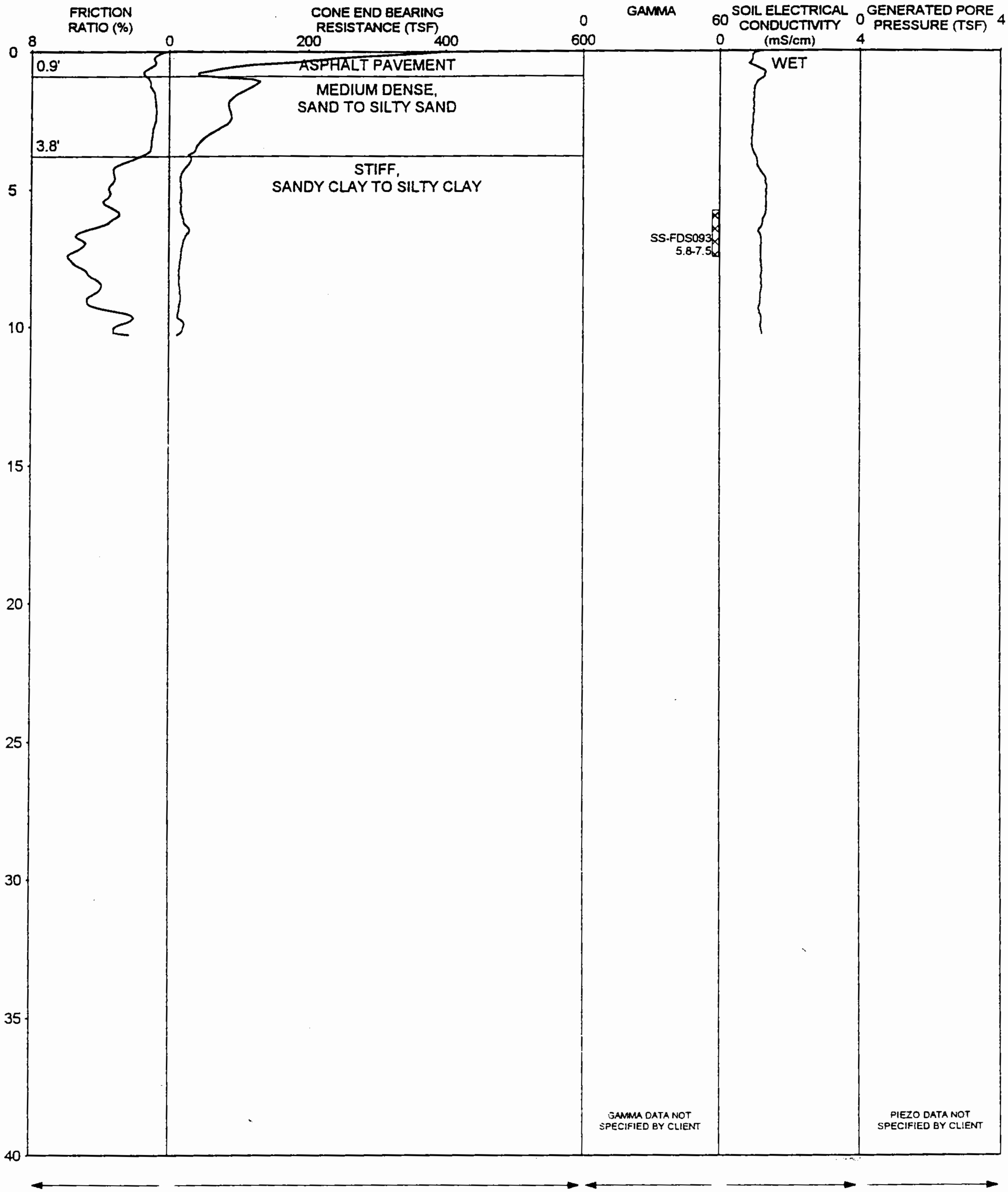


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP092

INTERPRETED CPT-EC LOG



STRATIGRAPHICS

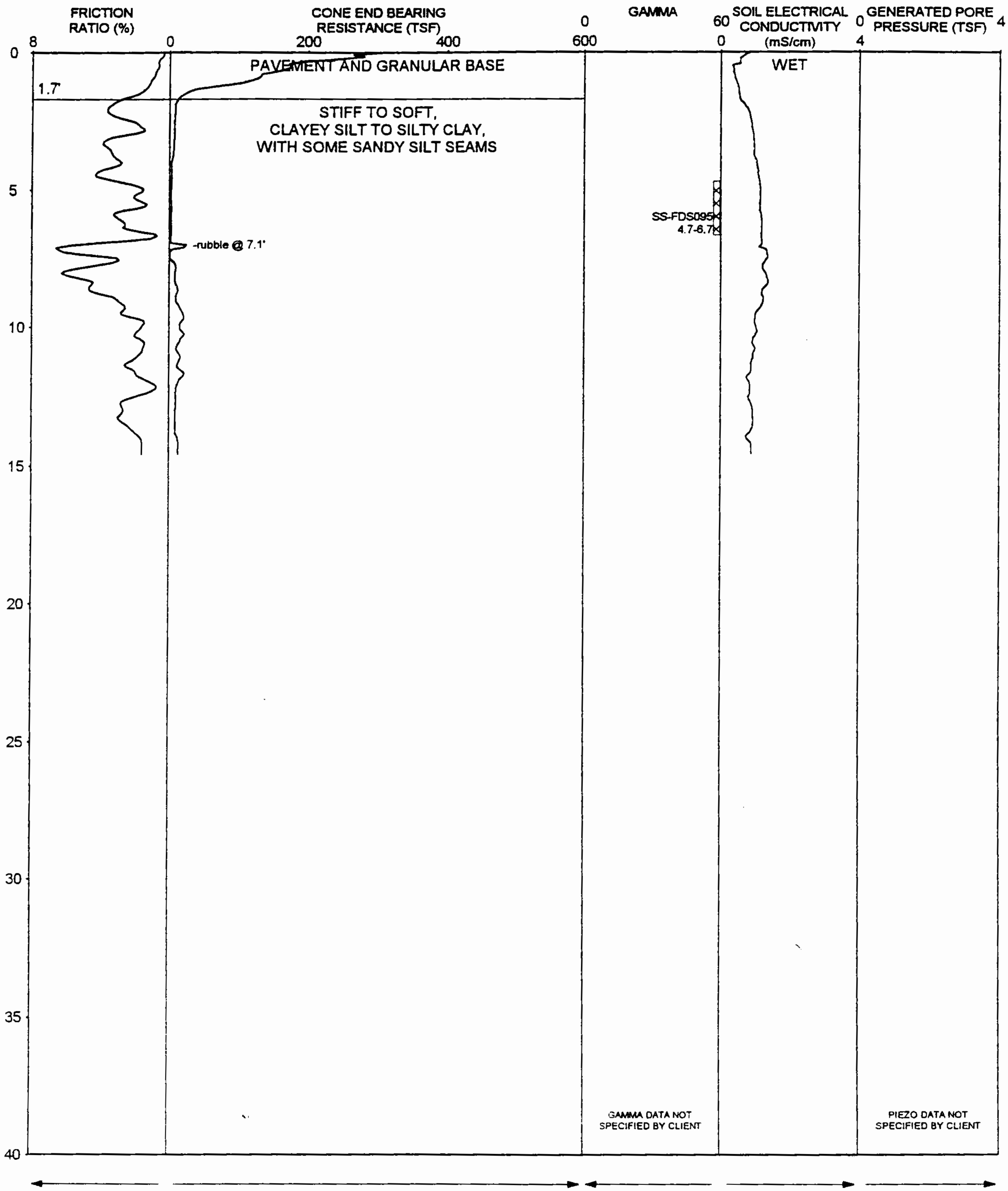
PROJECT NAME: Zone D, F, and G Charleston Naval Base

PROJECT NUMBER: 96-110-230

DATE: 10/03/96

SOUNDING NUMBER: CP093

INTERPRETED CPT-EC LOG

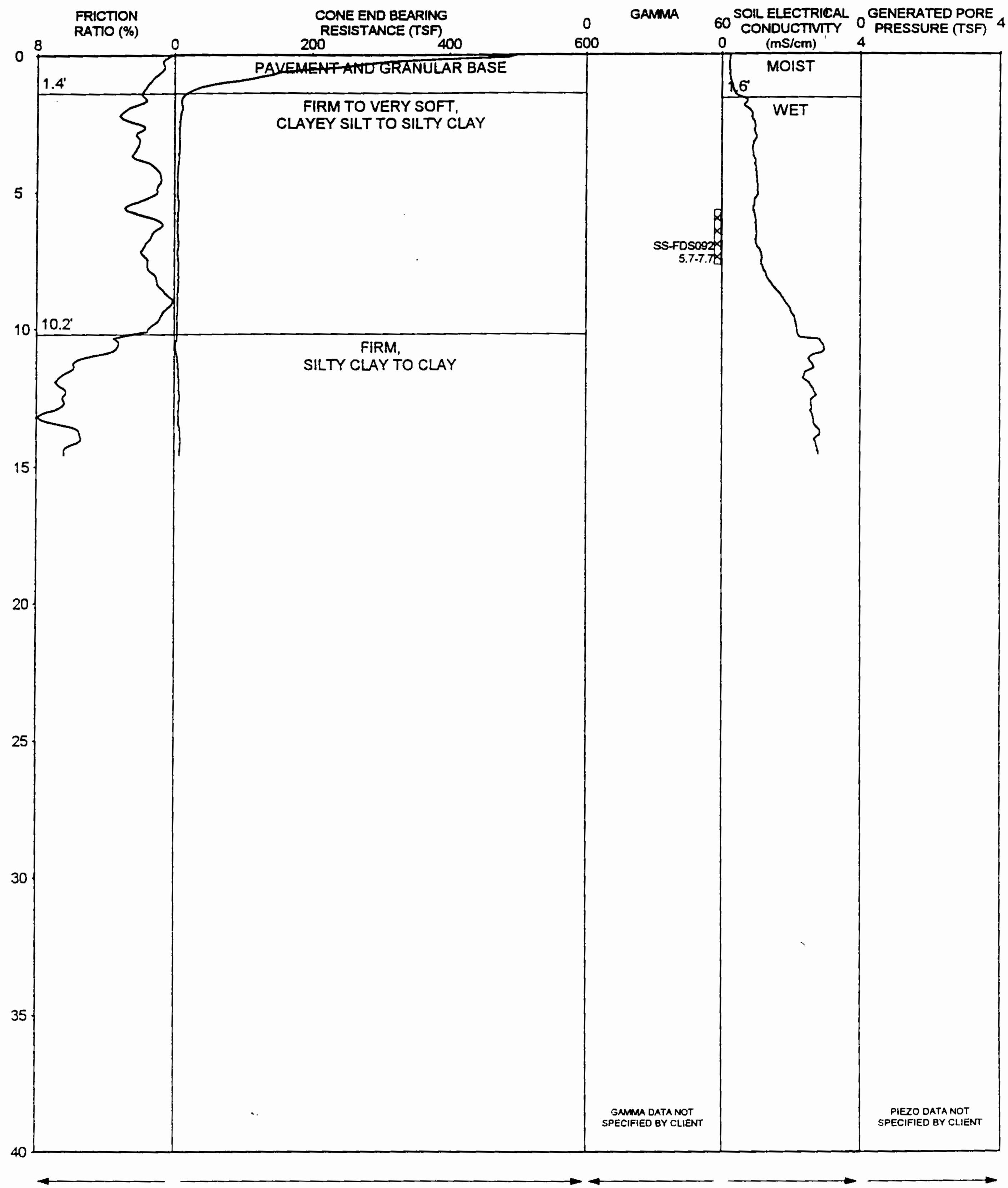


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP095

INTERPRETED CPT-EC LOG

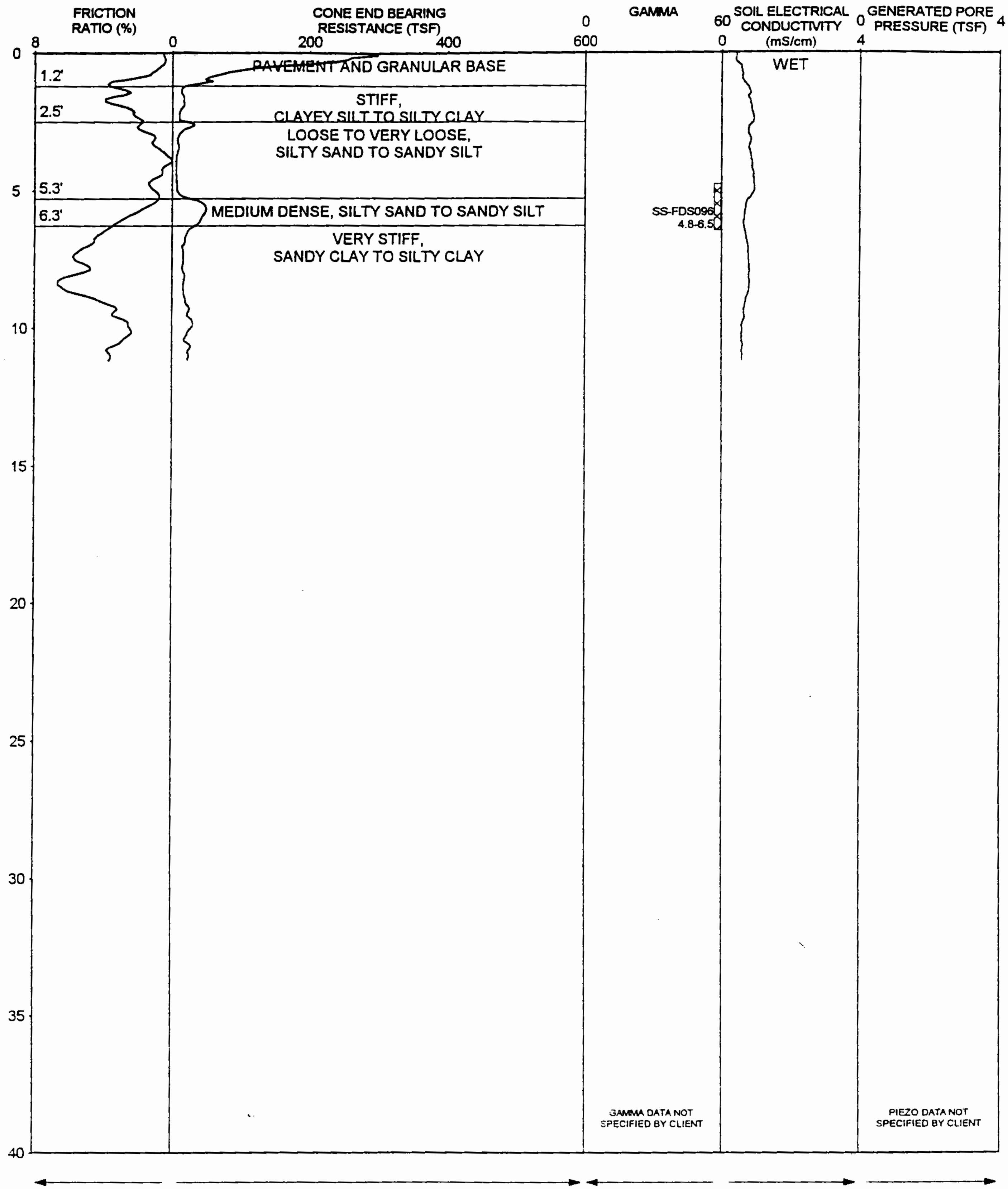


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP092

INTERPRETED CPT-EC LOG

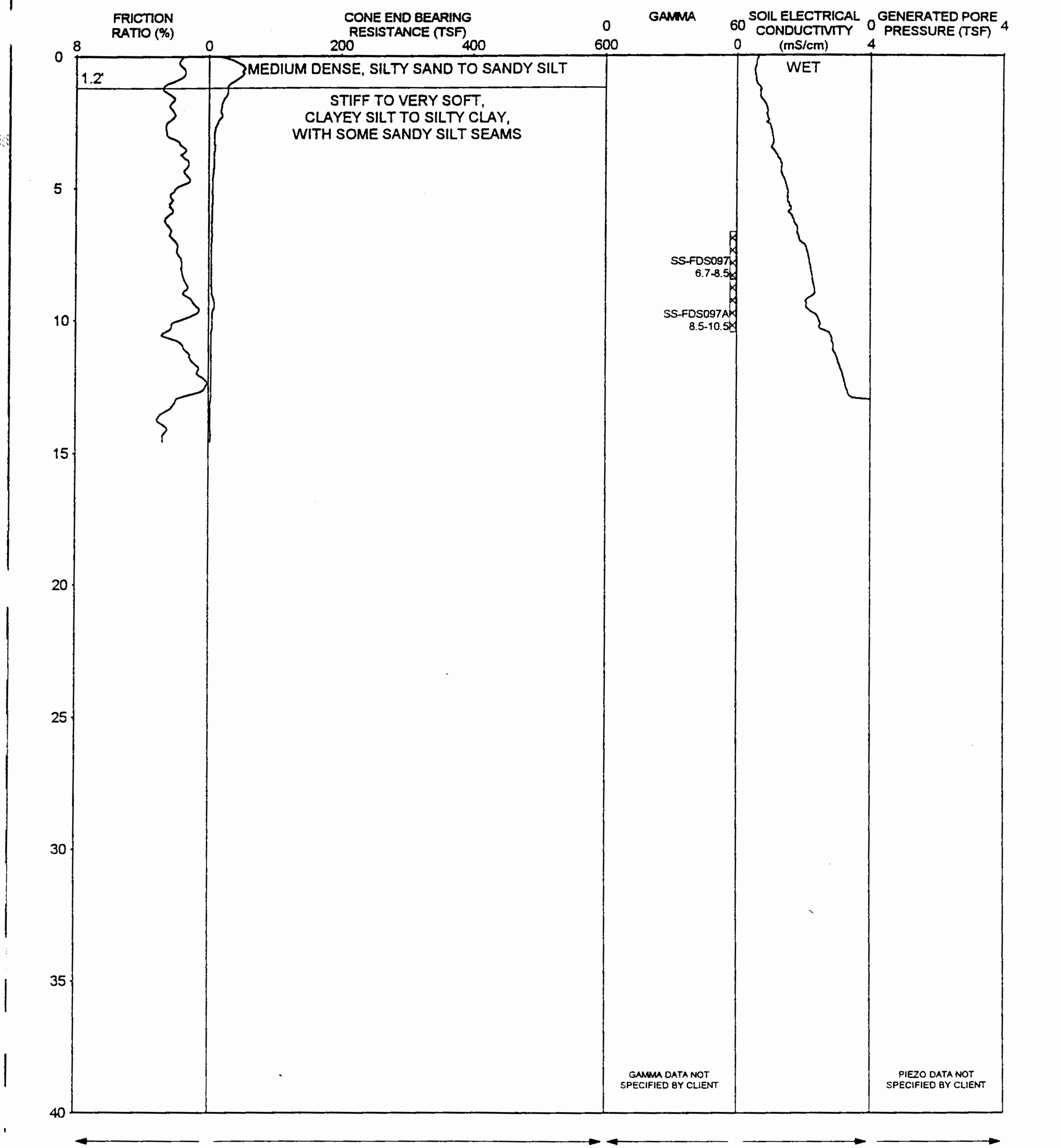


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP096

INTERPRETED CPT-EC LOG

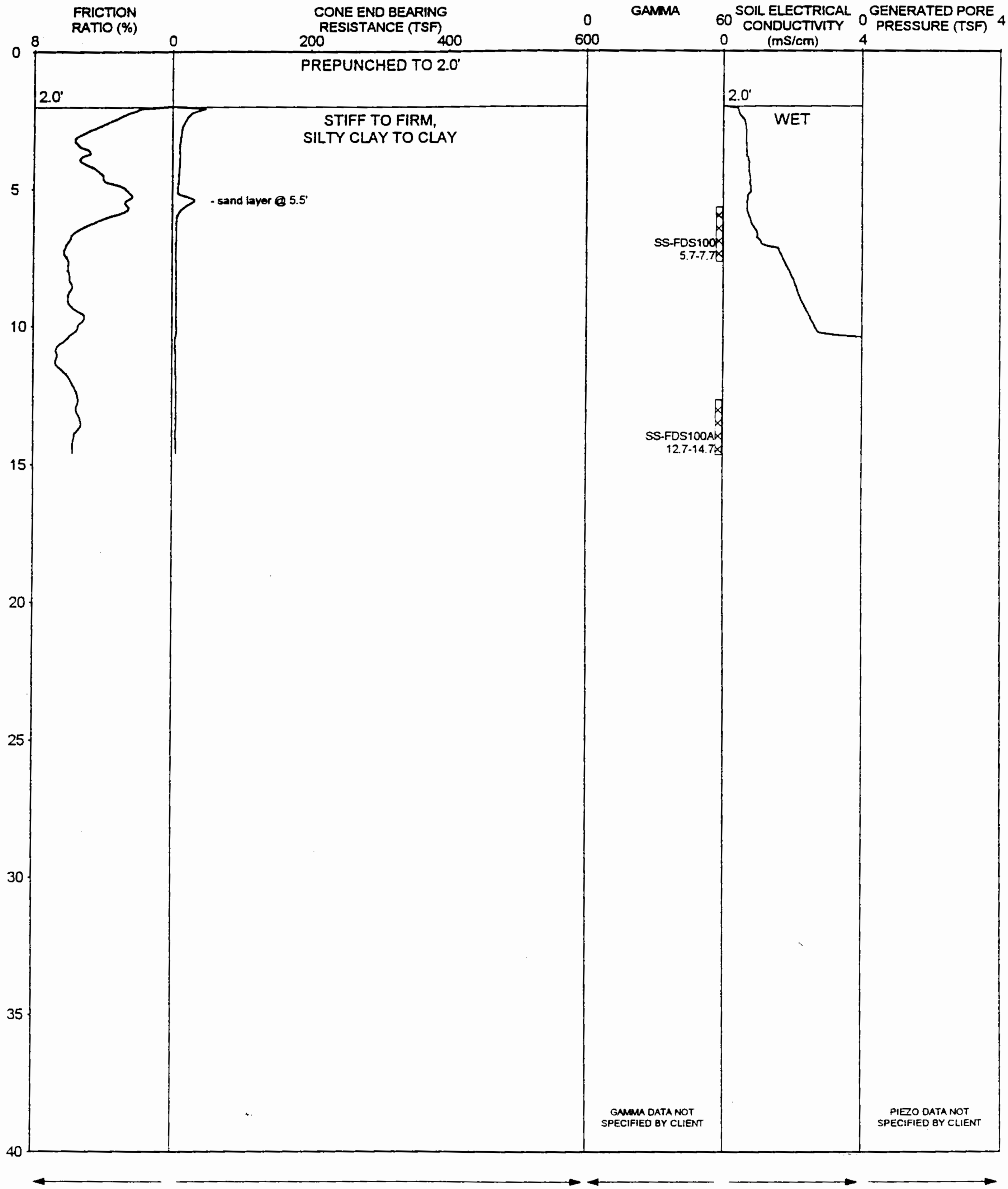


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP097

INTERPRETED CPT-EC LOG

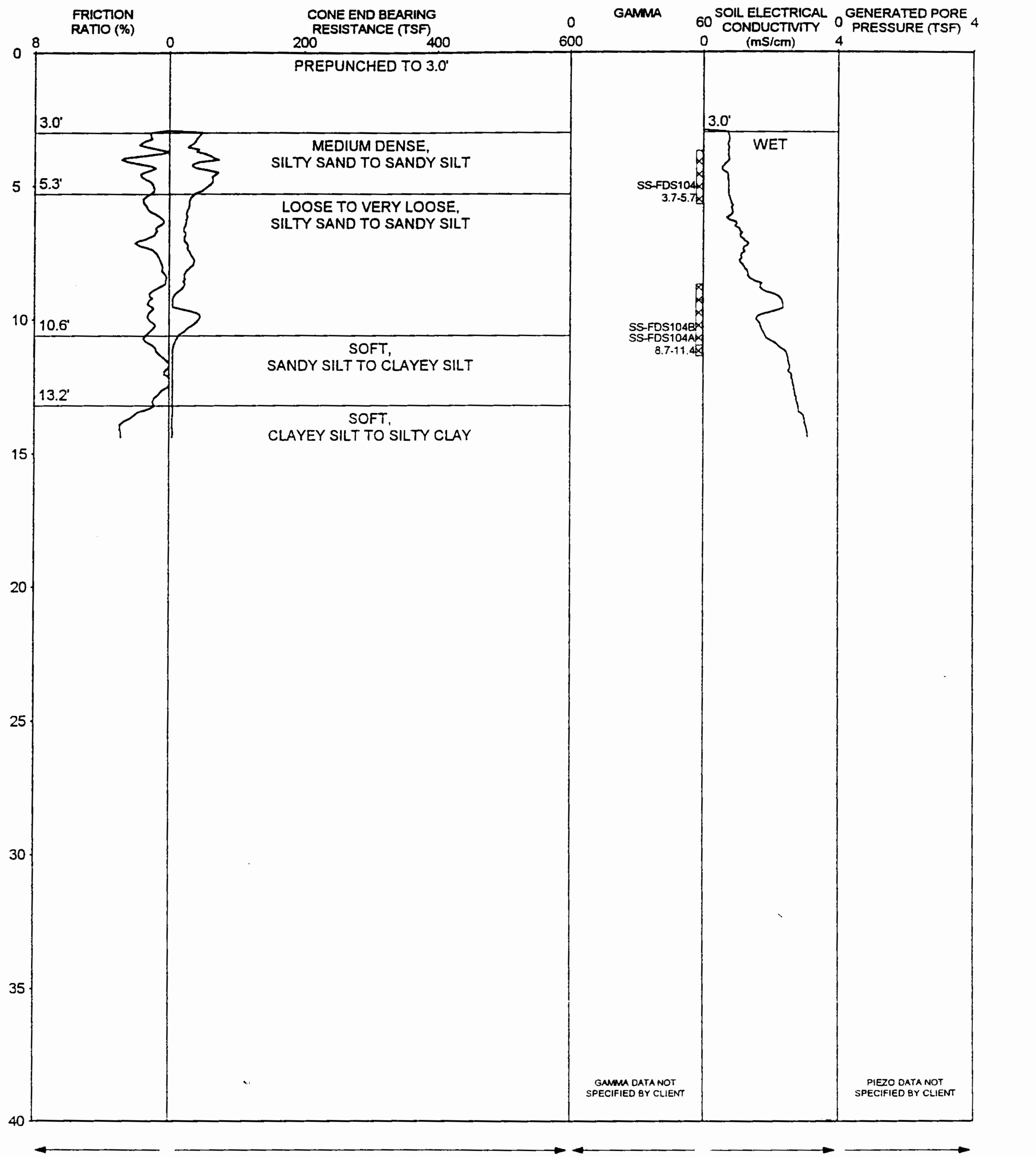


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base | DATE: 10/03/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CP100

INTERPRETED CPT-EC LOG

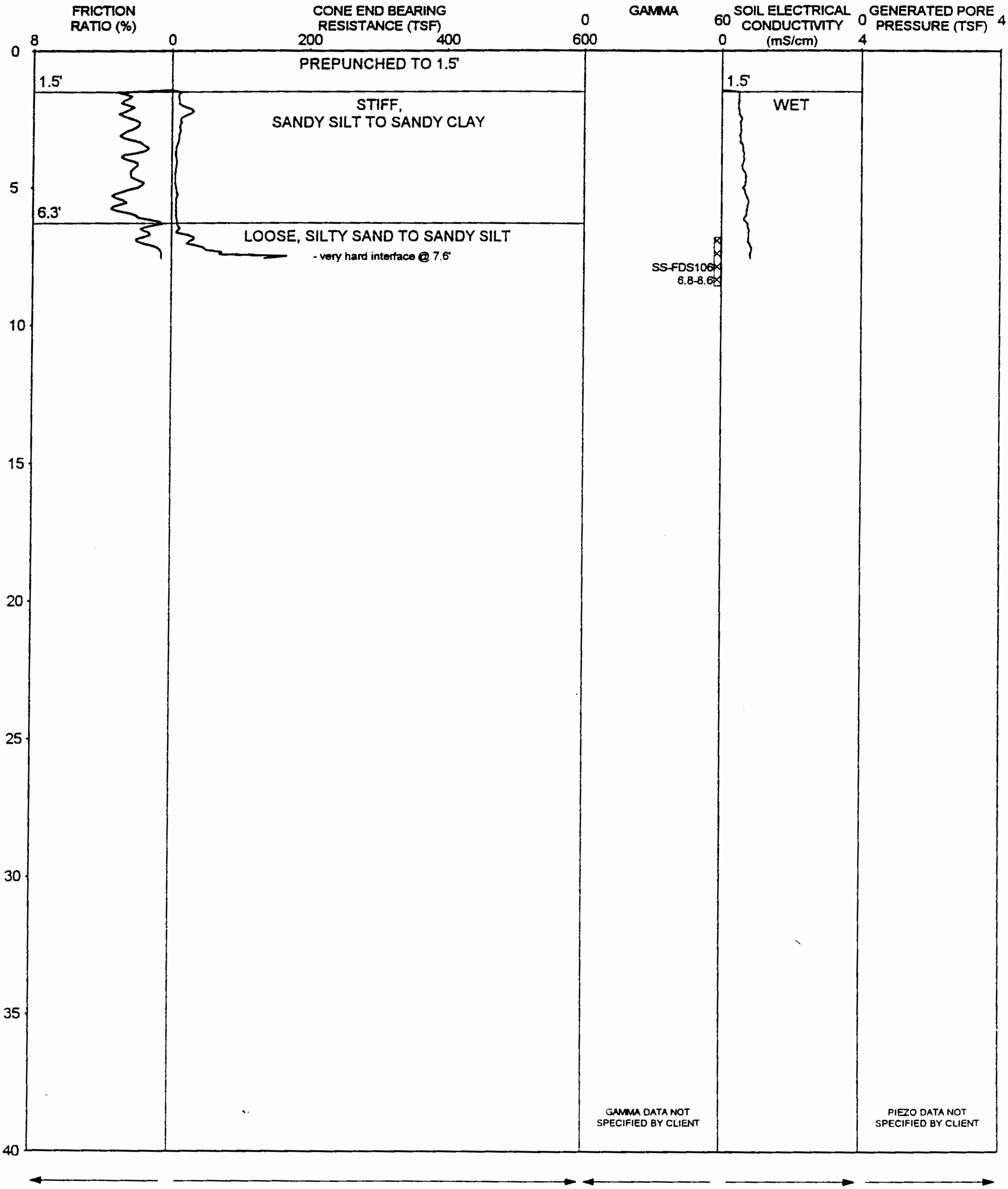


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/04/96
SOUNDING NUMBER: CP104

INTERPRETED CPT-EC LOG

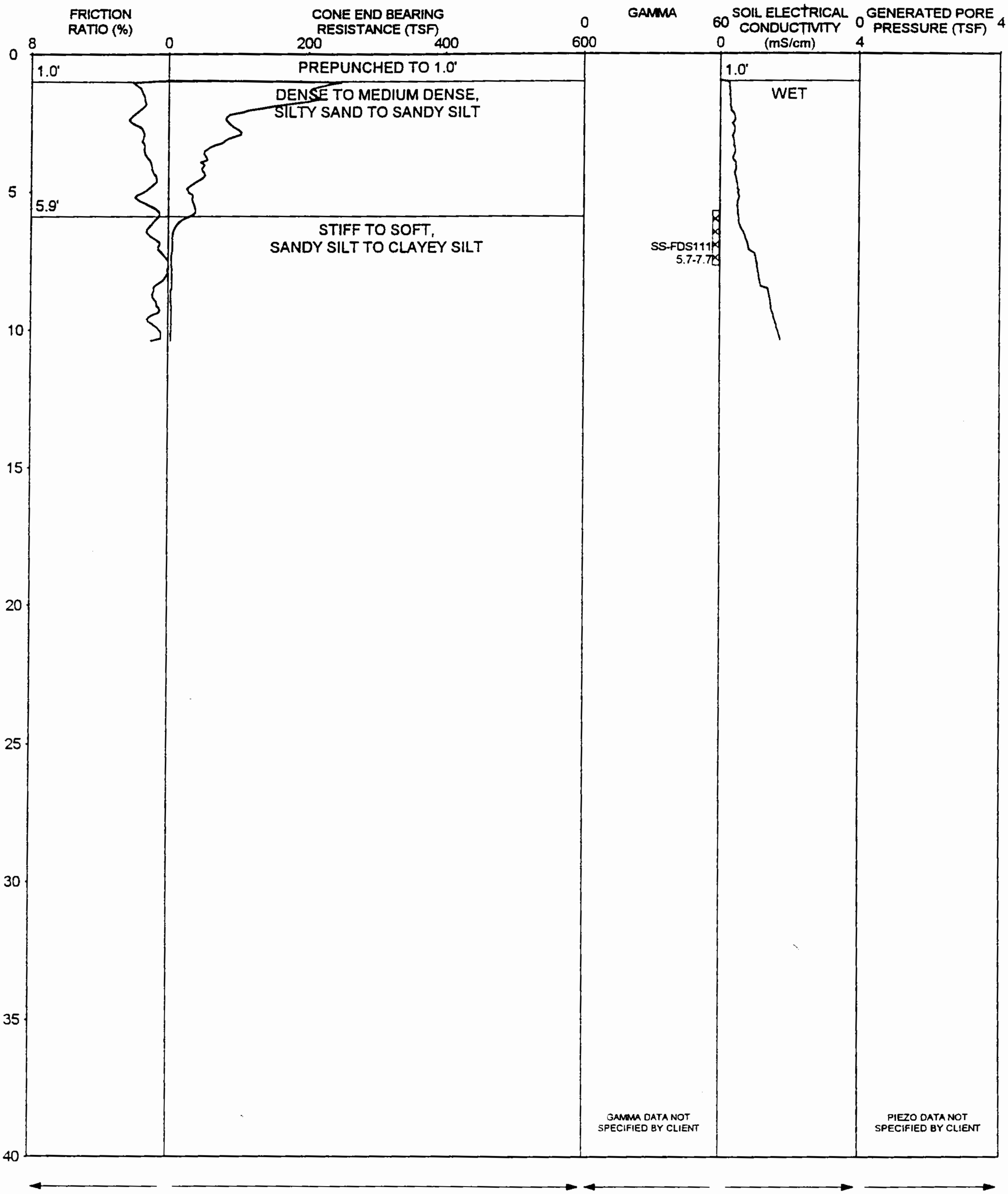


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/04/96
SOUNDING NUMBER: CP106

INTERPRETED CPT-EC LOG

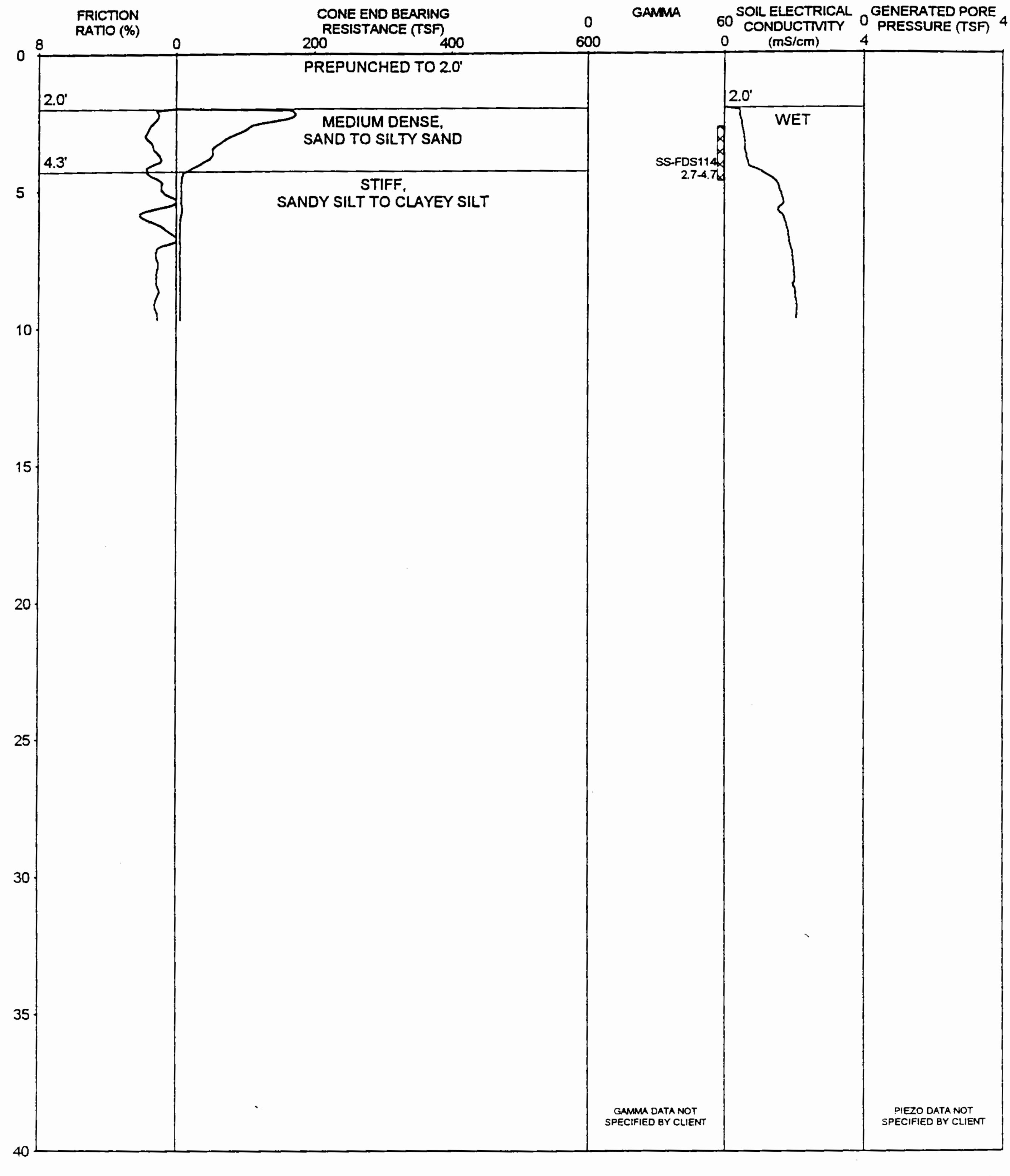


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/05/96
SOUNDING NUMBER: CP111

INTERPRETED CPT-EC LOG

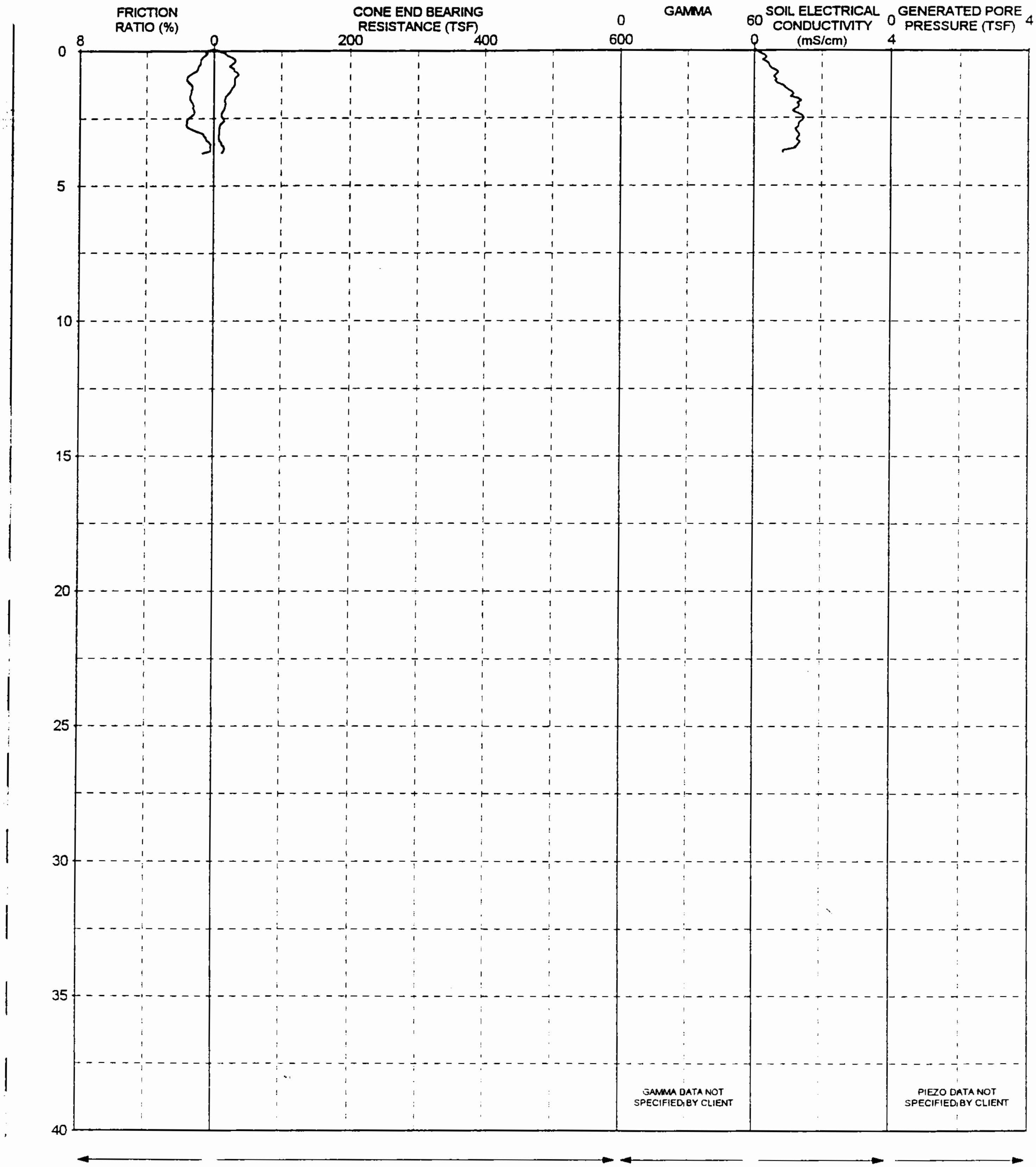


STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/05/96
SOUNDING NUMBER: CP114

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base, S.C.
PROJECT NUMBER: 96-110-230

DATE: 09/12/96
SOUNDING NUMBER: CPFDS001

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base, S.C.
SOUNDING NO: cpfds001

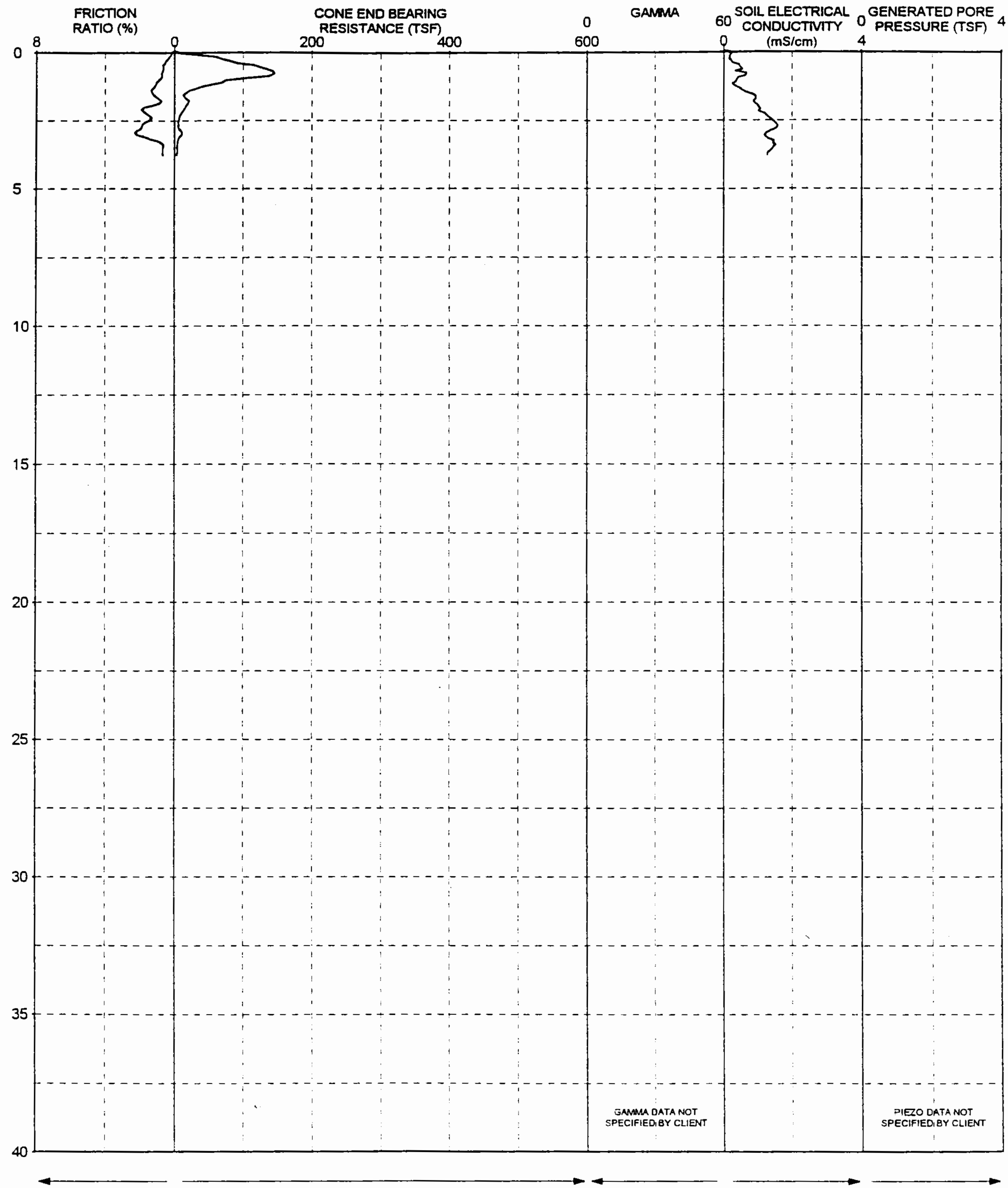
DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	30.5	49.1	0.5	1.7		694	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	15 - 17
1.5	24.5	37.4	0.4	1.4		1062	Loose, Silty sand to sandy silt	36-37	20-40				5 - 7	7 - 10
2.0	17.0	24.8	0.2	1.3		1312	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	4 - 6
2.5	13.7	19.3	0.2	1.5		1463	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	4 - 6
3.0	7.8	10.7	0.1	1.0		1265	Stiff, Sandy silt to clayey silt			15	1.01	0.18	1 - 2	1 - 3
3.5	12.3	16.5	0.1	0.2		1295	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3

NOTES:
* Indicates lightly overconsolidated soil
** Indicates heavily overconsolidated or cemented soil

Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base, S.C. DATE: 09/12/96
PROJECT NUMBER: 96-110-230 SOUNDING NUMBER: CPFDS002

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base, S.C.
SOUNDING NO: cpfds002

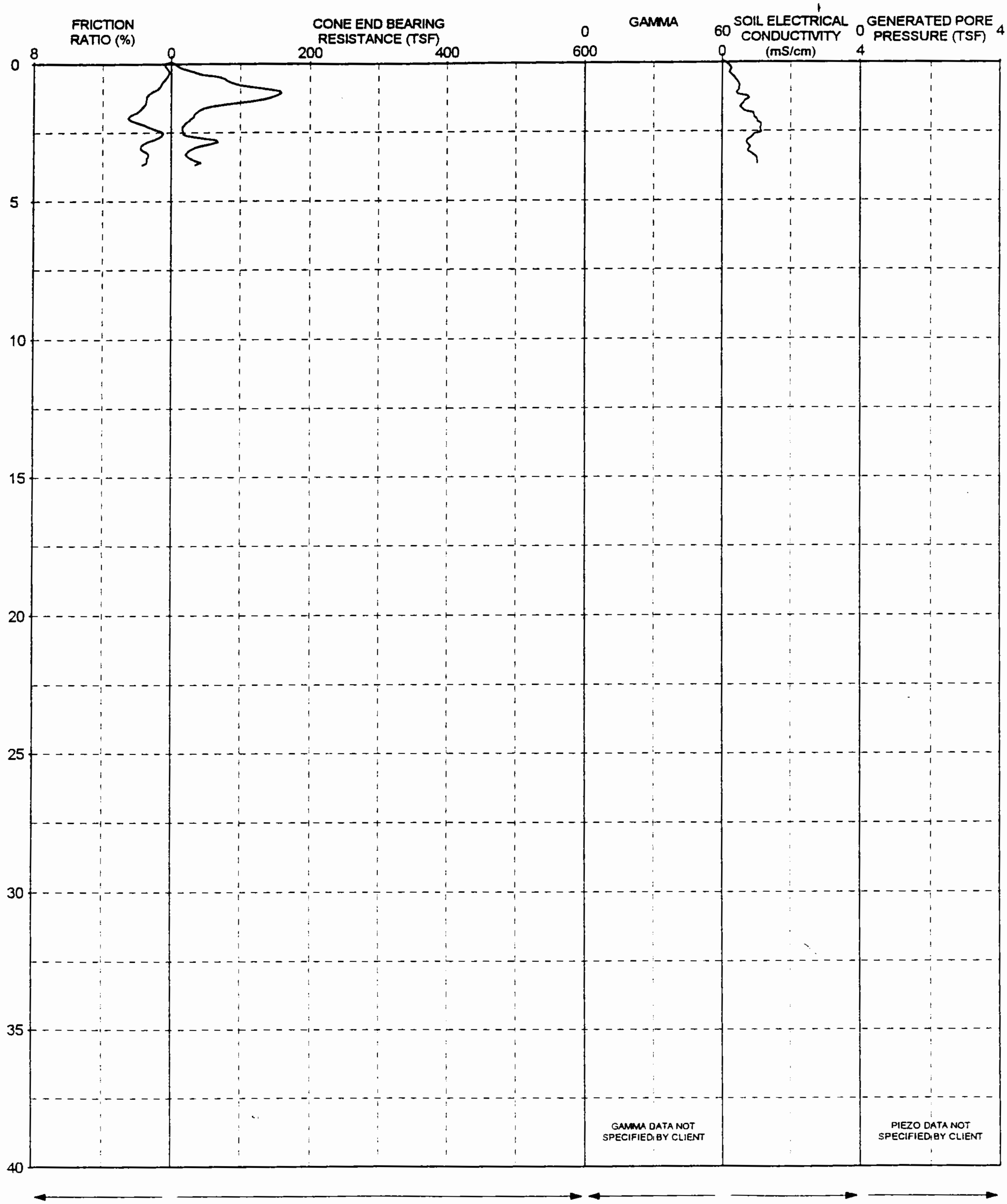
DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	76.3	122.9	1.3	0.9		395	Med dense, Sand to silty sand	40-42	40-60				20 - 25	33 - 40
1.5	16.2	24.7	0.5	1.3		727	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	4 - 6
2.0	16.1	23.5	0.3	1.6		1025	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
2.5	6.4	9.0	0.1	1.5		1437	Stiff, Sandy silt to clayey silt			10	1.25	0.28	1 - 2	1 - 3
3.0	10.7	14.7	0.2	2.2		1222	Stiff, Clayey silt to silty clay			15	1.41	0.36	2 - 3	3 - 4
3.5	4.3	5.8	0.0	0.7		1465	Soft, Sensitive fine grained soil			18	0.46	0.09	1 - 2	1 - 3

NOTES:
* Indicates lightly overconsolidated soil
** Indicates heavily overconsolidated or cemented soil

Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C
PROJECT NUMBER: 96-110-230
DATE: 09/12/96
SOUNDING NUMBER: CPFDS003

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charlston Navy Base, S.C

SOUNDING NO: cpfds003

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	156.8	252.5	1.4	1.0		503	Dense, Sand to silty sand	42-46	60-80				37 - 45	60 - 72
1.5	74.8	114.0	1.9	1.5		604	Dense, Silty sand to sandy silt	37-40	60-80				26 - 30	40 - 46
2.0	30.0	43.9	1.1	2.5		926	V stiff, Sandy silt to sandy clay			25	2.39	2.17	12 - 14	17 - 20
2.5	17.3	24.4	0.2	0.6		1122	Loose, Silty sand to sandy silt	31-36	20-40				2 - 3	3 - 4
3.0	43.8	60.1	0.8	1.8		767	Med dense, Silty sand to sandy silt	36-37	40-60				15 - 17	20 - 23
3.5	31.2	41.8	0.6	1.4		1004	Med dense, Silty sand to sandy silt	36-37	40-60				7 - 9	10 - 12

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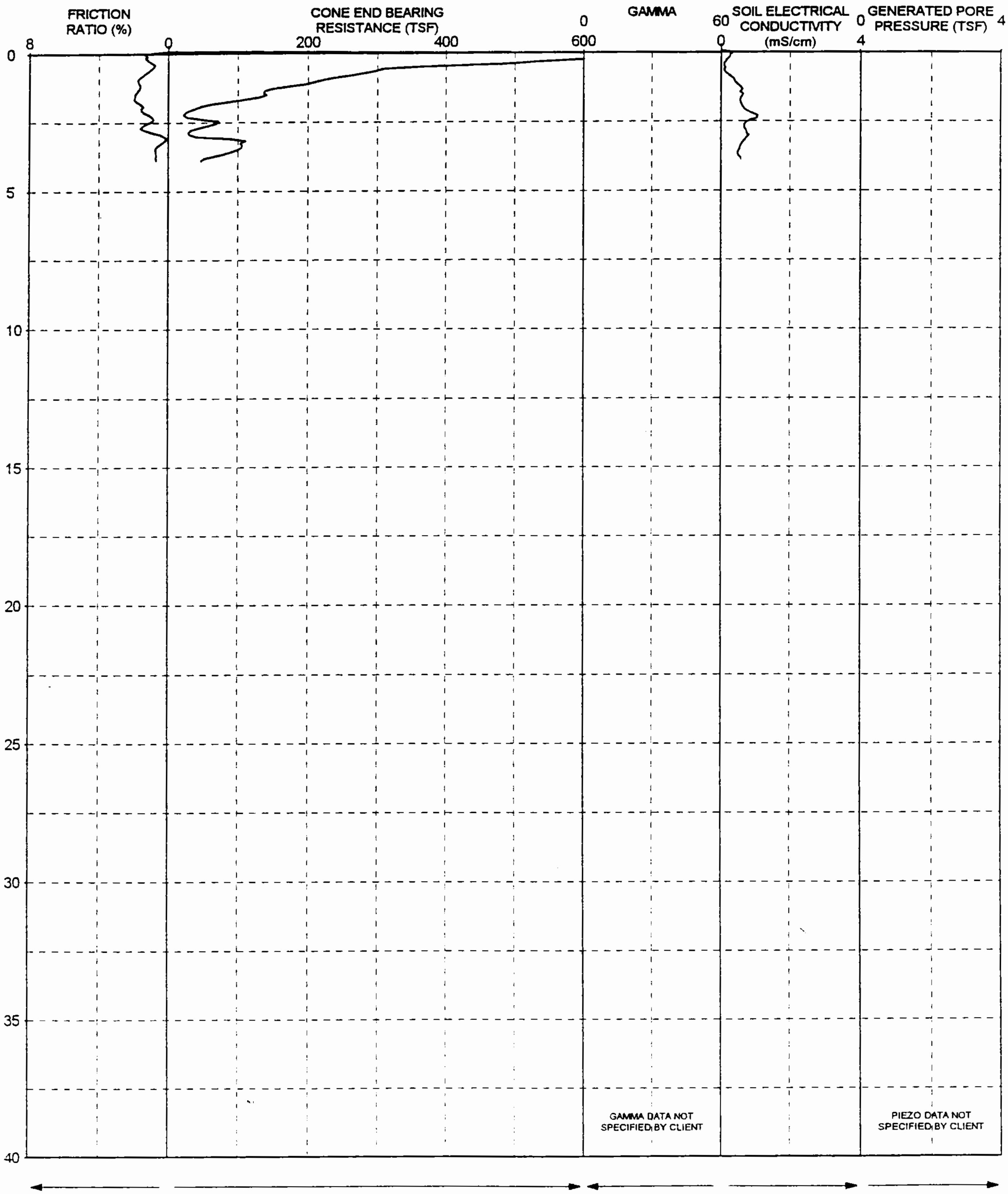
Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C DATE: 09/12/96
PROJECT NUMBER: 96-110-230 SOUNDING NUMBER: CPFDS004

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charlston Navy Base, S.C
SOUNDING NO: cpfds004

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	217.7	350.7	4.9	1.7		375	V dense, Sa gravel to si gr sand	42-46	80-100				+ 62	+ 100
1.5	139.4	212.3	3.2	1.9		611	V dense, Silty sand to sandy silt	40-42	80-100				47 - 65	72 - 99
2.0	38.9	56.8	1.3	1.5		641	Med dense, Silty sand to sandy silt	36-37	40-60				12 - 14	17 - 20
2.5	70.8	100.0	0.5	1.1		818	Med dense, Sand to silty sand	40-42	40-60				21 - 23	30 - 33
3.0	38.0	52.1	0.2	0.3		785	Loose, Sand to silty sand	37-40	20-40				5 - 7	7 - 10
3.5	99.5	133.2	0.7	0.7		553	Med dense, Sand to silty sand	40-42	40-60				25 - 30	33 - 40

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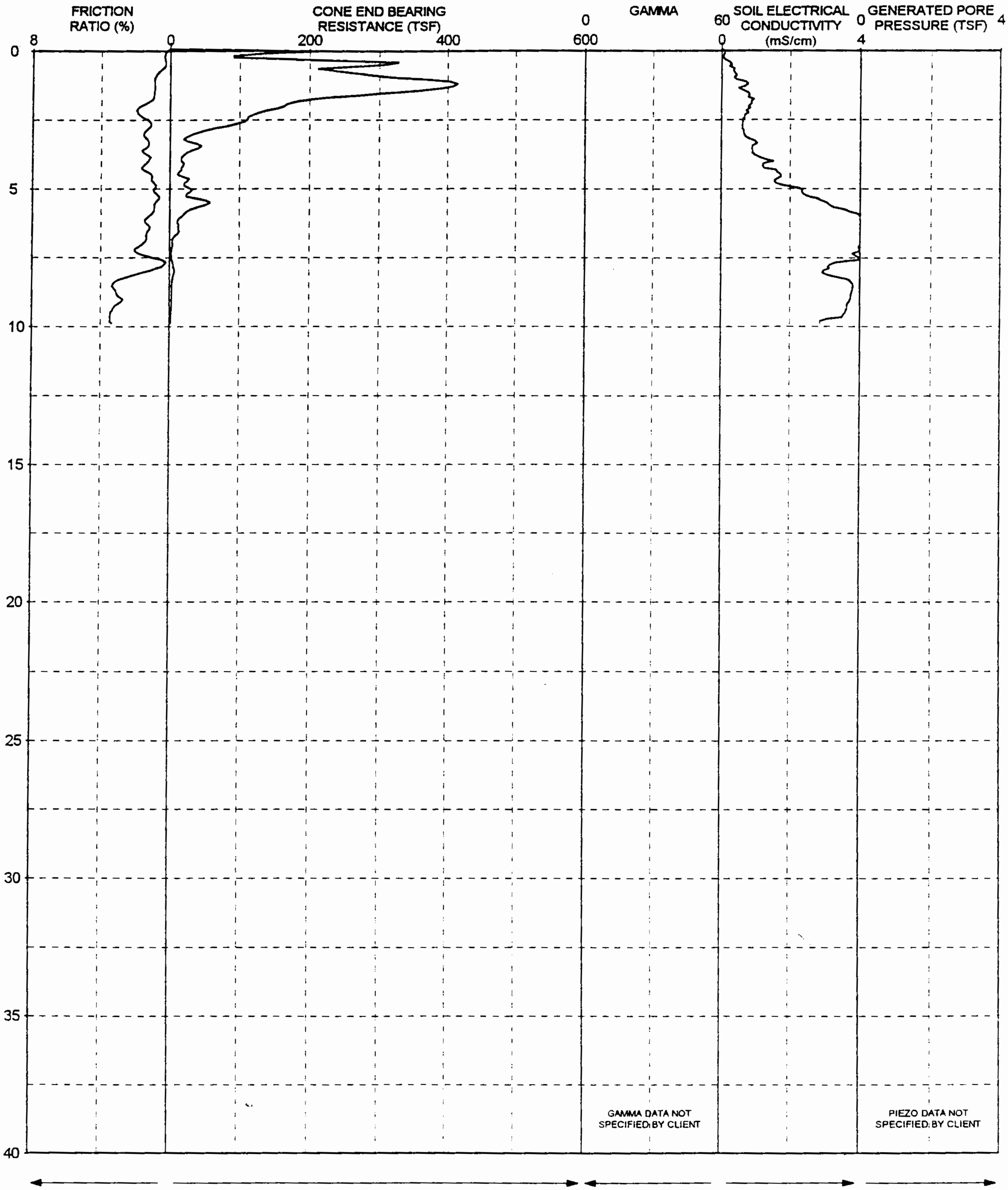
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C
PROJECT NUMBER: 96-110-230

DATE: 09/12/96
SOUNDING NUMBER: CPFDS005

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charlston Navy Base, S.C

SOUNDING NO: cpfds005

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	346.3	557.9	3.8	0.9		223	V dense, Sa gravel to gr sand	+46	80-100				+ 62	+ 100
1.5	329.0	501.0	3.5	0.9		722	V dense, Sand to silty sand	+46	80-100				+ 66	+ 100
2.0	163.2	238.4	3.8	1.7		794	V dense, Sand to silty sand	40-42	80-100				49 - 68	72 - 99
2.5	110.5	156.0	1.7	1.3		638	Dense, Sand to silty sand	40-42	60-80				33 - 42	46 - 60
3.0	36.3	49.8	1.1	1.5		667	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 12	15 - 17
3.5	42.4	56.8	0.4	1.4		890	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 13	15 - 17
4.0	17.4	22.7	0.3	1.3		1497	Loose, Silty sand to sandy silt	27-31	20-40				3 - 5	4 - 6
4.5	13.2	17.0	0.2	1.1		1736	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
5.0	30.1	37.9	0.3	0.9		2275	Loose, Silty sand to sandy silt	36-37	20-40				6 - 8	7 - 10
5.5	57.4	71.3	0.3	0.8		3028	Med dense, Sand to silty sand	37-40	40-60				14 - 16	17 - 20
6.0	18.6	22.8	0.4	1.2		4263	Loose, Silty sand to sandy silt	27-31	20-40				3 - 5	4 - 6
6.5	13.1	15.8	0.2	1.2		4289	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
7.0	4.3	5.1	0.1	1.6		4582	Soft, Clayey silt to silty clay			18	0.43	0.24	1 - 3	1 - 3
7.5	2.7	3.1	0.1	1.0		4132	V soft, Sensitive fine grained soil			18	0.25	0.11	0 - 1	0 - 1
8.0	7.3	8.5	0.1	1.2		2952	Stiff, Sandy silt to clayey silt			10	1.37	0.15	1 - 3	1 - 3
8.5	3.8	4.3	0.2	3.3		3804	Soft, Silty clay to clay			18	0.36	0.36	1 - 3	1 - 3
9.0	3.4	3.9	0.1	2.7		3739	Soft, Silty clay to clay			18	0.32	0.19	1 - 3	1 - 3
9.5	2.6	2.9	0.1	3.4		3587	V soft, Silty clay to clay			18	0.22	0.21	0 - 1	0 - 1

NOTES:

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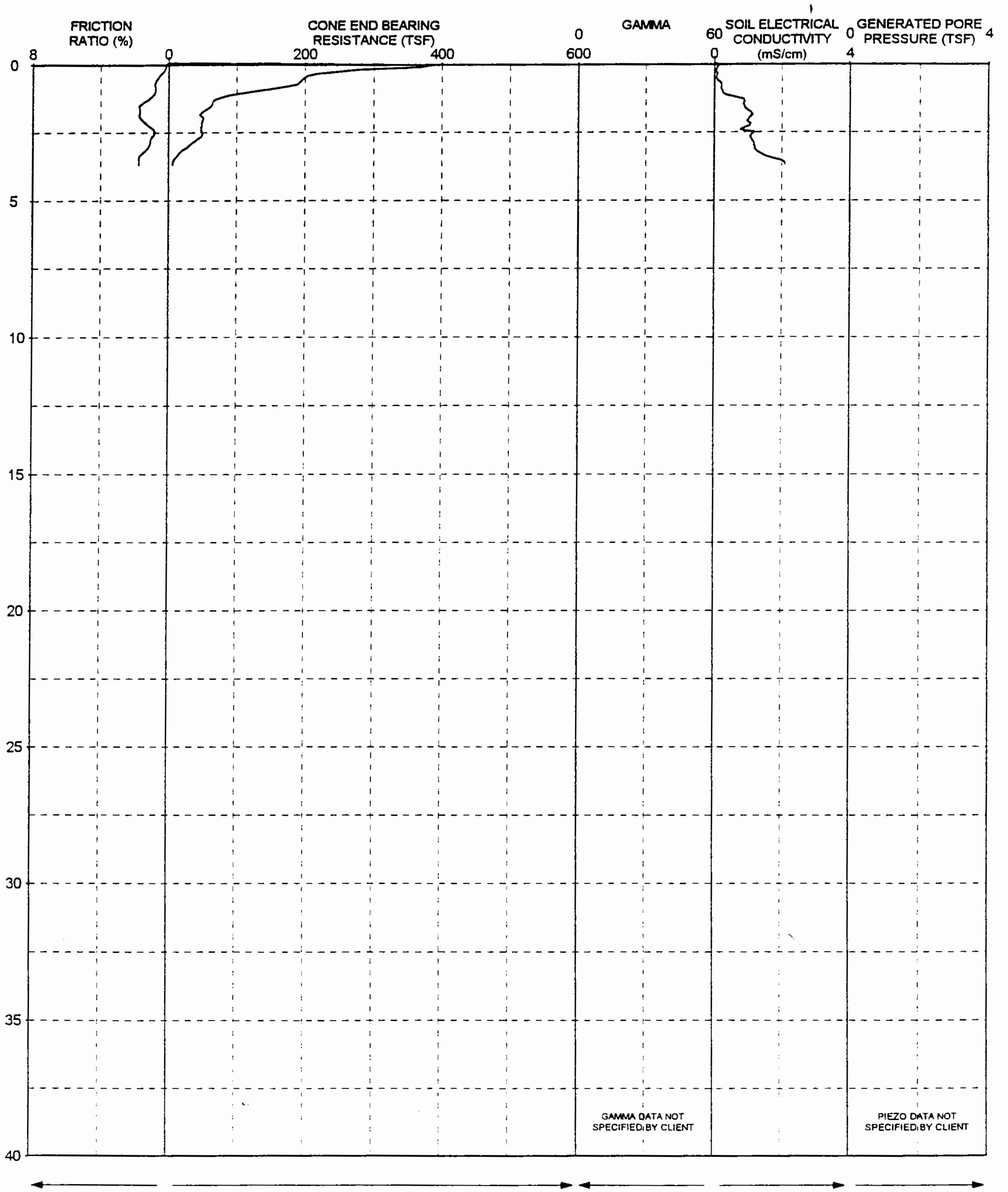
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C | DATE: 09/12/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CPFDS006

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charlston Navy Base, S.C
SOUNDING NO: cpfds006

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	119.9	193.1	1.3	0.8		206	Dense, Sand to silty sand	42-46	60-80				29 - 37	46 - 60
1.5	64.0	97.5	1.4	1.7		886	Dense, Silty sand to sandy silt	37-40	60-80				22 - 26	33 - 40
2.0	51.2	74.8	0.9	1.7		1045	Med dense, Silty sand to sandy silt	37-40	40-60				16 - 21	23 - 30
2.5	50.0	70.6	0.4	0.8		1177	Med dense, Sand to silty sand	37-40	40-60				11 - 12	15 - 17
3.0	29.5	40.4	0.5	1.2		1184	Loose, Silty sand to sandy silt	36-37	20-40				5 - 7	7 - 10
3.5	8.6	11.5	0.3	1.8		1847	Stiff, Sandy silt to clayey silt			15	1.12	0.59	1 - 2	1 - 3

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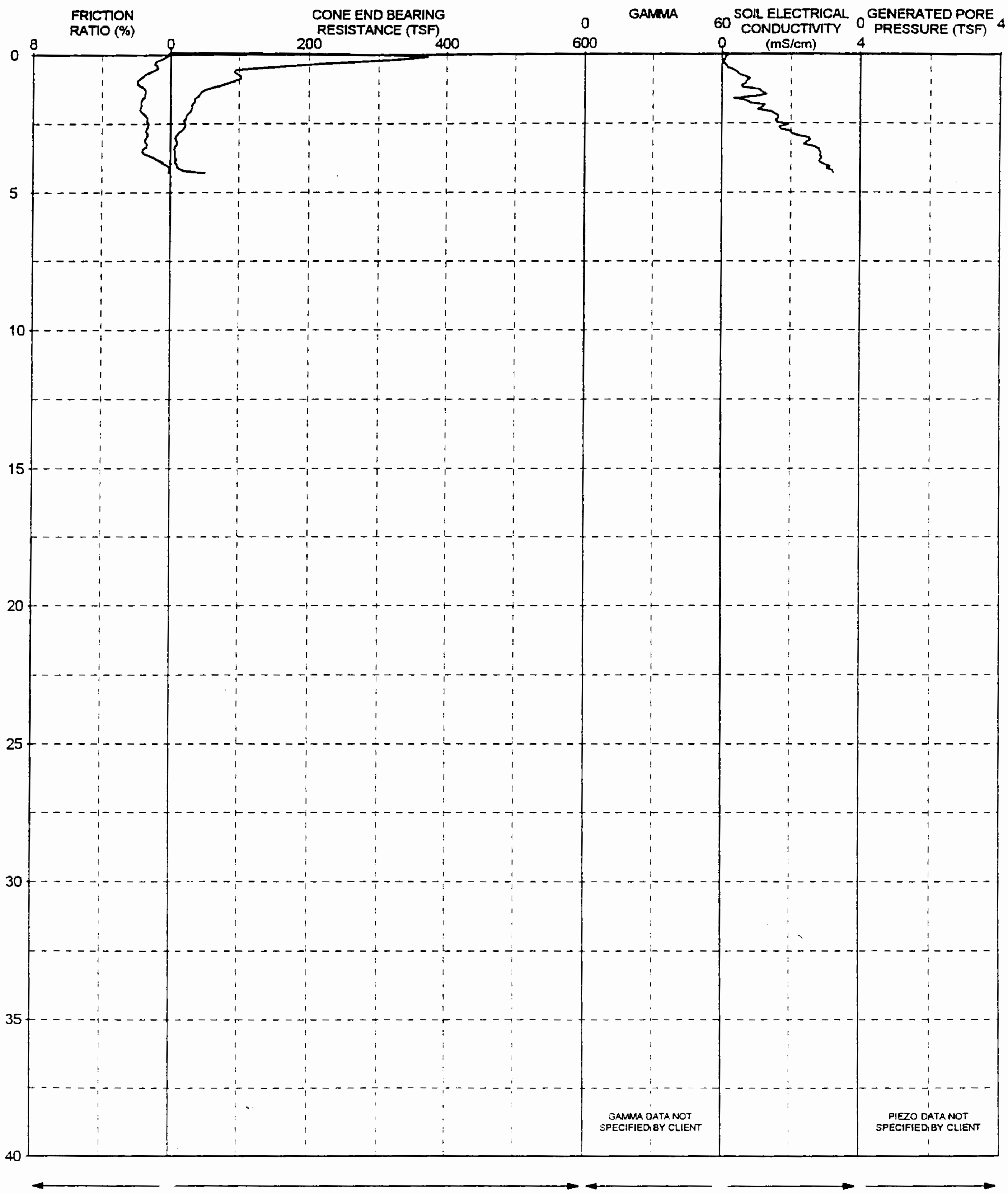
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charlston Navy Base, S.C | DATE: 09/12/96

PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CPFDS007

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charlston Navy Base, S.C

SOUNDING NO: cpfds007

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	89.4	144.0	2.0	2.1		779	Dense, Silty sand to sandy silt	37-40	60-80				37 - 45	60 - 72
1.5	41.7	63.6	0.9	1.5		1137	Med dense, Silty sand to sandy silt	36-37	40-60				13 - 15	20 - 23
2.0	31.6	46.1	0.6	1.8		1037	Med dense, Silty sand to sandy silt	36-37	40-60				10 - 12	15 - 17
2.5	21.4	30.2	0.3	1.3		1728	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
3.0	8.0	11.0	0.2	1.4		2403	Stiff, Sandy silt to clayey silt			15	1.04	0.42	1 - 2	1 - 3
3.5	6.4	8.6	0.2	1.7		2834	Stiff, Clayey silt to silty clay			10	1.25	0.30	1 - 2	1 - 3
4.0	9.3	12.2	0.0	0.3		3011	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3

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STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base, S
SOUNDING NO: cpfds008

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	92.4	148.8	1.7	1.1		164	Dense, Sand to silty sand	40-42	60-80				29 - 37	46 - 60
1.5	31.2	47.5	0.9	1.8		807	Med dense, Silty sand to sandy silt	36-37	40-60				10 - 11	15 - 17
2.0	40.9	59.8	0.6	1.1		1059	Med dense, Silty sand to sandy silt	37-40	40-60				10 - 12	15 - 17
2.5	51.9	73.3	0.6	1.0		447	Med dense, Sand to silty sand	37-40	40-60				12 - 14	17 - 20
3.0	24.2	33.2	0.5	1.2		650	Loose, Silty sand to sandy silt	36-37	20-40				4 - 5	6 - 7
3.5	7.9	10.5	0.2	1.9		1119	Stiff, Clayey silt to silty clay			15	1.02	0.48	1 - 2	1 - 3
4.0	4.8	6.3	0.1	1.7		1123	Firm, Clayey silt to silty clay			10	0.91	0.21	1 - 2	1 - 3
4.5	4.1	5.3	0.0	0.6		1283	Soft, Sensitive fine grained soil			18	0.43	0.08	1 - 2	1 - 3
5.0	6.4	8.0	0.3	4.6		944	Stiff, Silty clay to clay			10	1.22	0.60	2 - 3	3 - 4
5.5	3.8	4.7	0.1	1.9		2147	Soft, Clayey silt to silty clay			18	0.38	0.27	1 - 2	1 - 3
6.0	9.4	11.4	0.2	2.4		1411	Stiff, Clayey silt to silty clay			15	1.20	0.43	2 - 3	3 - 4
6.5	5.9	7.1	0.2	2.4		1640	Stiff, Clayey silt to silty clay			10	1.10	0.40	1 - 2	1 - 3

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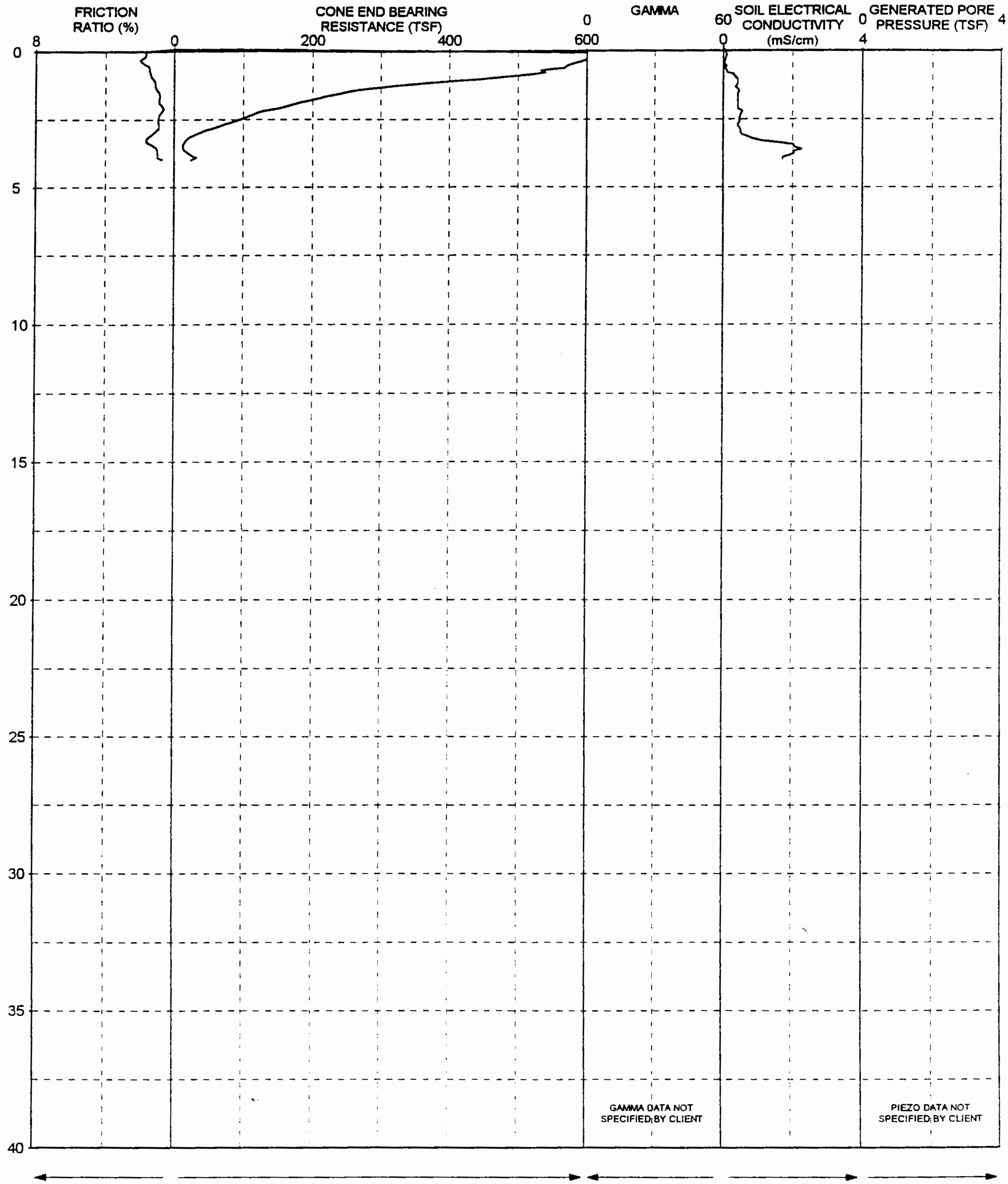
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base, S — DATE: 09/13/96

PROJECT NUMBER: 96-110-230 — SOUNDING NUMBER: CPFDS009

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base, S
SOUNDING NO: cpfds009

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	463.3	746.4	7.1	1.3		409	V dense, Sa gravel to si gr sand	42-46	+100				+ 62	+ 100
1.5	249.9	380.5	3.1	0.9		463	V dense, Sand to silty sand	42-46	80-100				+ 66	+ 100
2.0	165.0	240.9	1.5	0.7		426	Dense, Sand to silty sand	42-46	60-80				41 - 49	60 - 72
2.5	95.7	135.1	1.2	0.9		496	Med dense, Sand to silty sand	40-42	40-60				28 - 33	40 - 46
3.0	37.2	51.0	0.8	1.2		514	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	12 - 15
3.5	13.5	18.1	0.3	1.2		2044	Loose, Silty sand to sandy silt	27-31	20-40				2 - 3	3 - 4
4.0	24.7	32.4	0.3	0.7		1725	Loose, Silty sand to sandy silt	36-37	20-40				5 - 5	6 - 7

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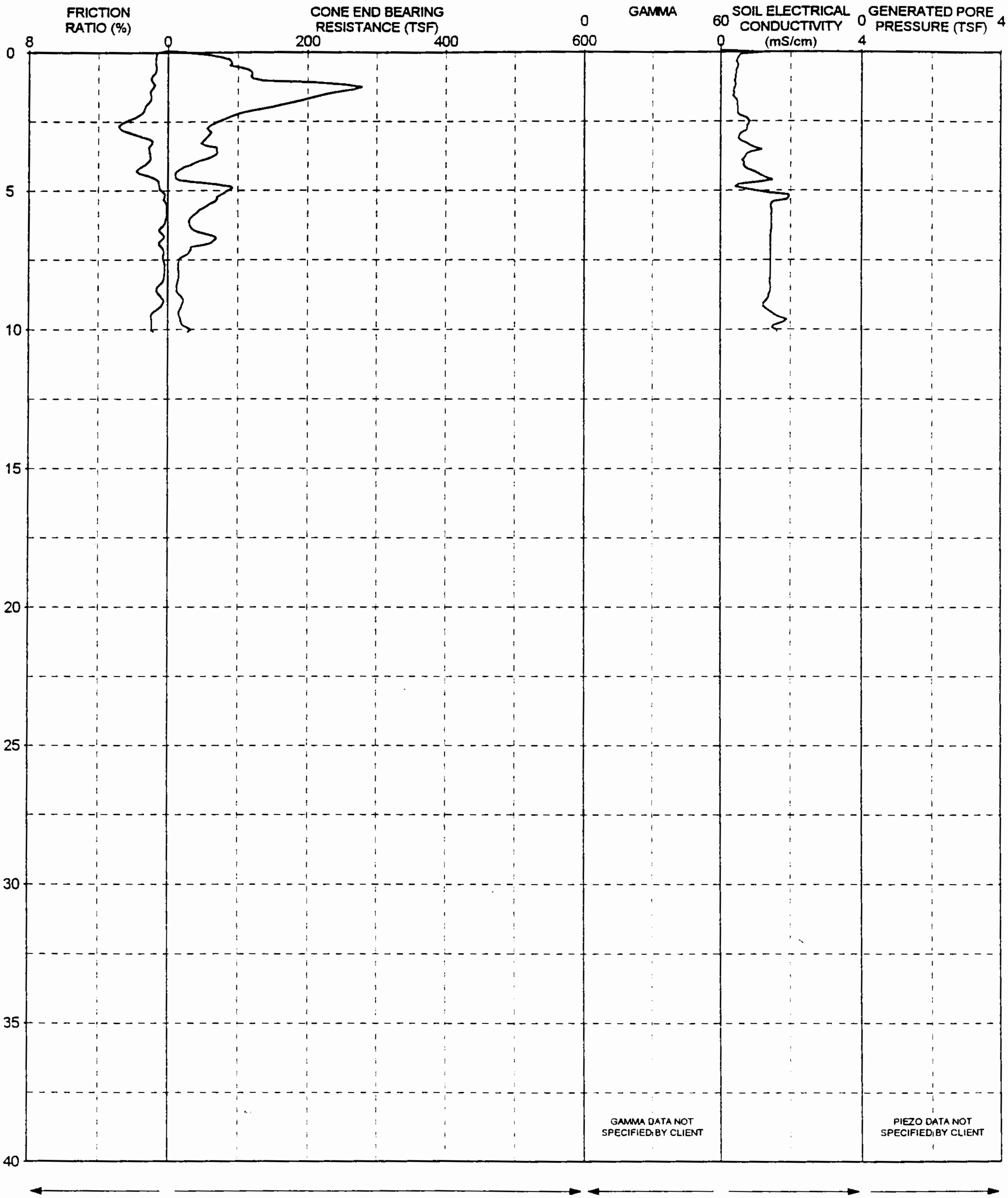
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230
DATE: 09/16/96
SOUNDING NUMBER: CPFDS010

STRATIGRAPHICS
JOB NO: 96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cpfds010

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	109.3	176.1	2.4	1.0		403	Dense, Sand to silty sand	42-46	60-80				29 - 37	46 - 60
1.5	229.6	349.7	2.3	1.0		386	V dense, Sand to silty sand	42-46	80-100				47 - 65	72 - 99
2.0	144.6	211.1	2.5	1.3		497	Dense, Sand to silty sand	42-46	60-80				41 - 49	60 - 72
2.5	72.4	102.3	2.4	2.4		814	Dense, Silty sand to sandy silt	37-40	60-80				33 - 42	46 - 60
3.0	58.4	80.1	1.1	1.8		541	Dense, Silty sand to sandy silt	37-40	60-80				22 - 24	30 - 33
3.5	70.0	93.7	0.7	1.1		1092	Med dense, Sand to silty sand	40-42	40-60				17 - 22	23 - 30
4.0	38.5	50.4	0.7	1.2		673	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	12 - 15
4.5	11.3	14.5	0.5	1.1		1217	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
5.0	86.2	108.8	0.3	0.4		938	Med dense, Sand to silty sand	40-42	40-60				18 - 24	23 - 30
5.5	59.4	73.7	0.1	0.1		1454	Loose, Sand to silty sand	40-42	20-40				10 - 12	12 - 15
6.0	32.9	40.2	0.0	0.1		1451	Loose, Sand to silty sand	37-40	20-40				5 - 6	6 - 7
6.5	42.6	51.4	0.3	0.5		1443	Loose, Sand to silty sand	37-40	20-40				6 - 8	7 - 10
7.0	45.7	54.3	0.3	0.5		1430	Loose, Sand to silty sand	37-40	20-40				6 - 8	7 - 10
7.5	16.7	19.6	0.1	0.2		1428	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
8.0	16.1	18.7	0.0	0.2		1433	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
8.5	13.2	15.1	0.1	0.6		1431	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
9.0	22.7	25.8	0.0	0.3		1284	V loose, Silty sand to sandy silt	36-37	0-20				3 - 4	3 - 4
9.5	16.2	18.2	0.2	0.9		1571	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
10.0	32.0	35.6	0.2	0.9		1577	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7

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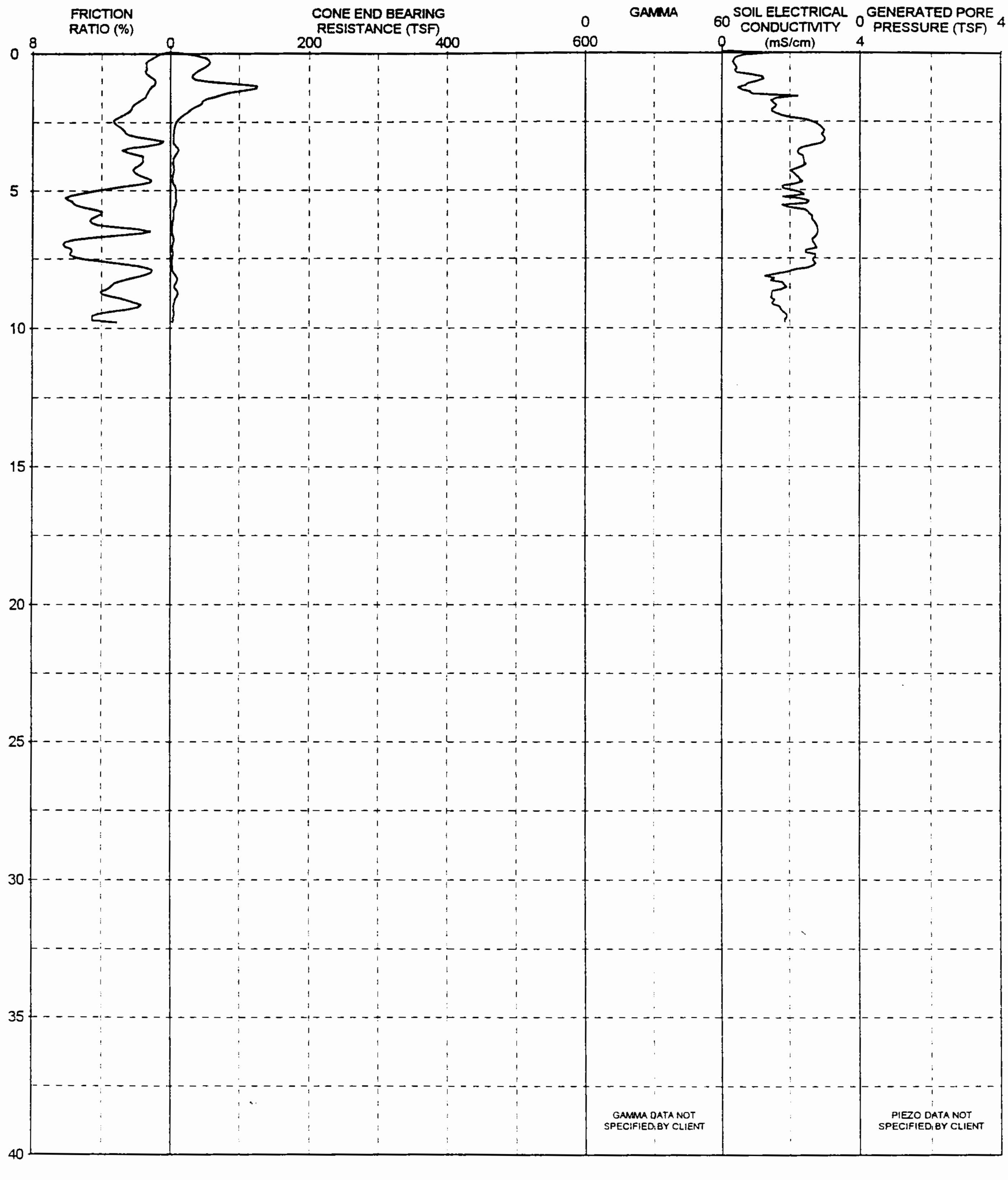
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP011

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp011

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	41.0	66.0	0.7	0.9		1179	Med dense, Sand to silty sand	37-40	40-60				9 - 11	15 - 17
1.5	75.3	114.7	1.3	1.4		892	Dense, Sand to silty sand	40-42	60-80				26 - 30	40 - 46
2.0	32.7	47.7	1.1	2.2		1547	Med dense, Silty sand to sandy silt	27-31	40-60				12 - 14	17 - 20
2.5	9.3	13.1	0.6	3.3		2614	Stiff, Silty clay to clay *			15	1.21	1.26	3 - 4	4 - 6
3.0	4.9	6.7	0.2	2.2		2931	Firm, Clayey silt to silty clay			10	0.94	0.32	1 - 2	1 - 3
3.5	11.5	15.4	0.2	2.6		2313	Stiff, Sandy clay to silty clay *			15	1.50	0.43	3 - 4	4 - 6
4.0	4.3	5.7	0.1	1.6		2407	Soft, Clayey silt to silty clay			18	0.45	0.24	1 - 2	1 - 3
4.5	3.4	4.3	0.1	1.6		2202	Soft, Clayey silt to silty clay			18	0.34	0.18	1 - 2	1 - 3
5.0	8.3	10.5	0.3	4.2		1966	Stiff, Silty clay to clay *			15	1.07	0.69	3 - 5	4 - 6
5.5	8.1	10.0	0.5	5.6		2424	Stiff, Silty clay to clay *			15	1.03	0.94	5 - 6	6 - 7
6.0	4.7	5.7	0.3	4.5		2645	Firm, Clay			10	0.87	0.51	1 - 2	1 - 3
6.5	2.6	3.1	0.0	1.3		2806	V soft, Sensitive fine grained soil			18	0.25	0.05	0 - 1	0 - 1
7.0	3.6	4.3	0.2	6.2		2715	Firm, Clay			10	0.64	0.50	1 - 3	1 - 3
7.5	3.2	3.7	0.2	5.2		2699	Firm, Clay			10	0.55	0.36	1 - 3	1 - 3
8.0	4.7	5.5	0.1	1.1		1928	Soft, Sandy silt to clayey silt			18	0.47	0.21	1 - 3	1 - 3
8.5	6.7	7.6	0.3	3.4		1854	Stiff, Silty clay to clay			10	1.23	0.60	1 - 3	1 - 3
9.0	7.2	8.2	0.2	2.6		1534	Stiff, Clayey silt to silty clay			10	1.34	0.45	1 - 3	1 - 3
9.5	5.4	6.0	0.2	4.2		1878	Firm, Silty clay to clay			10	0.96	0.49	1 - 3	1 - 3

NOTES:
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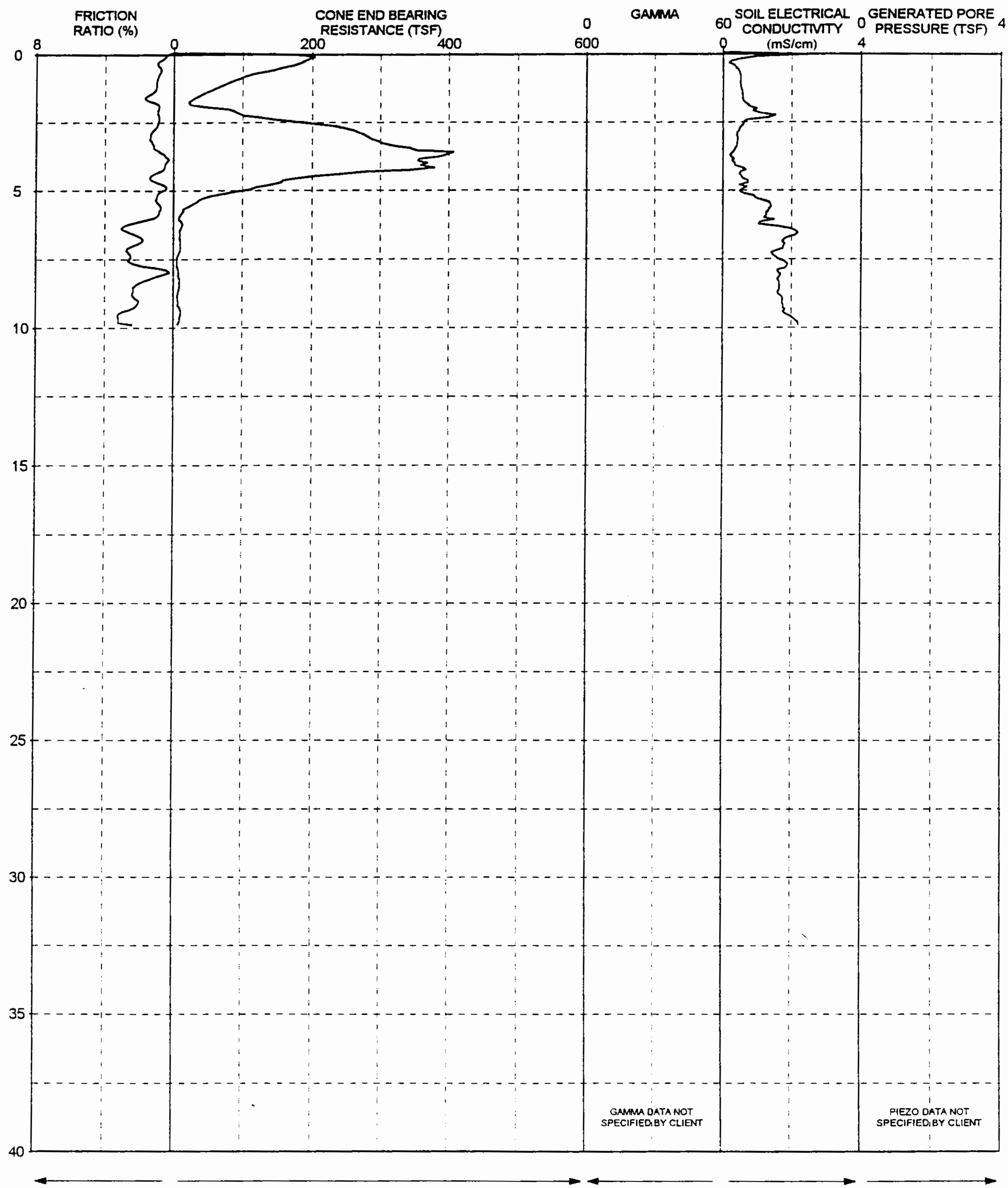
Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230
DATE: 09/16/96
SOUNDING NUMBER: CPFDS012

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cpfds012

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	84.4	136.0	1.1	1.0		494	Med dense, Sand to silty sand	40-42	40-60				25 - 29	40 - 46
1.5	38.7	59.0	0.9	1.5		565	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 13	17 - 20
2.0	75.0	109.6	1.0	0.9		965	Med dense, Sand to silty sand	40-42	40-60				21 - 23	30 - 33
2.5	182.0	257.0	2.1	0.9		610	Dense, Sand to silty sand	42-46	60-80				42 - 51	60 - 72
3.0	279.0	382.9	4.2	1.4		403	V dense, Sa gravel to si gr sand	42-46	80-100				+ 73	+ 100
3.5	349.3	467.6	4.2	1.0		332	V dense, Sand to silty sand	42-46	80-100				+ 75	+ 100
4.0	368.0	482.0	2.0	0.4		325	V dense, Sa gravel to gr sand	+46	80-100				55 - 76	72 - 99
4.5	194.7	250.0	4.4	1.4		544	Dense, Sand to silty sand	42-46	60-80				56 - 77	72 - 99
5.0	101.5	128.0	0.9	0.6		509	Med dense, Sand to silty sand	40-42	40-60				26 - 32	33 - 40
5.5	28.4	35.2	0.5	0.9		1375	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
6.0	8.2	10.0	0.2	1.1		1205	Stiff, Sandy silt to clayey silt			10	1.56	0.30	1 - 2	1 - 3
6.5	9.4	11.3	0.3	2.7		2130	Stiff, Clayey silt to silty clay			15	1.20	0.59	2 - 3	3 - 4
7.0	10.2	12.1	0.2	2.3		1772	Stiff, Clayey silt to silty clay			15	1.31	0.45	3 - 3	3 - 4
7.5	5.5	6.5	0.2	2.6		1633	Stiff, Clayey silt to silty clay			10	1.02	0.43	1 - 3	1 - 3
8.0	7.5	8.7	0.0	0.3		1622	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
8.5	8.5	9.8	0.2	2.3		1644	Stiff, Clayey silt to silty clay			15	1.07	0.40	1 - 3	1 - 3
9.0	6.8	7.7	0.2	2.1		1739	Stiff, Clayey silt to silty clay			10	1.25	0.34	1 - 3	1 - 3
9.5	10.5	11.8	0.3	3.2		1818	Stiff, Silty clay to clay			15	1.32	0.60	3 - 4	3 - 4

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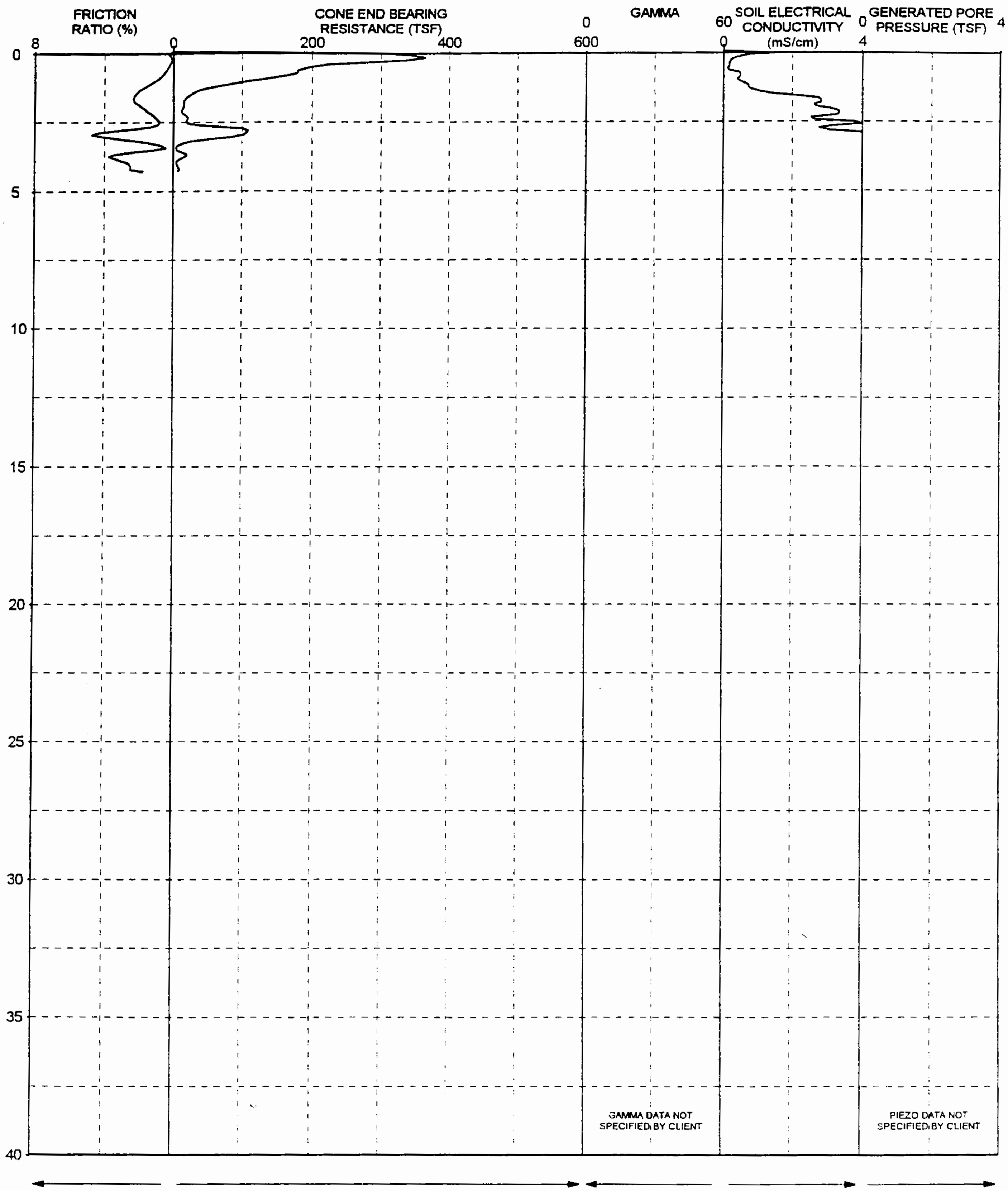
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP013

STRATIGRAPHICS

JOB NO: 96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp013

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	113.6	183.1	1.6	1.0		406	Dense, Sand to silty sand	42-46	60-80				29 - 37	46 - 60
1.5	25.7	39.1	1.2	2.2		1496	Med dense, Silty sand to sandy silt	27-31	40-60				8 - 10	12 - 15
2.0	14.0	20.5	0.3	1.8		2899	Stiff, Sandy silt to clayey silt			15	1.85	0.61	3 - 4	4 - 6
2.5	18.6	26.2	0.6	0.8		3636	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	4 - 6
3.0	96.1	131.9	3.6	4.5		7416	Hard, Gr sa clay to gr si clay **			33	5.82	7.11	+ 73	+ 100
3.5	4.8	6.5	0.1	0.9		6904	Firm, Sandy silt to clayey silt			10	0.93	0.27	1 - 2	1 - 3
4.0	4.8	6.3	0.2	2.7		6797	Firm, Silty clay to clay			10	0.92	0.48	1 - 2	1 - 3

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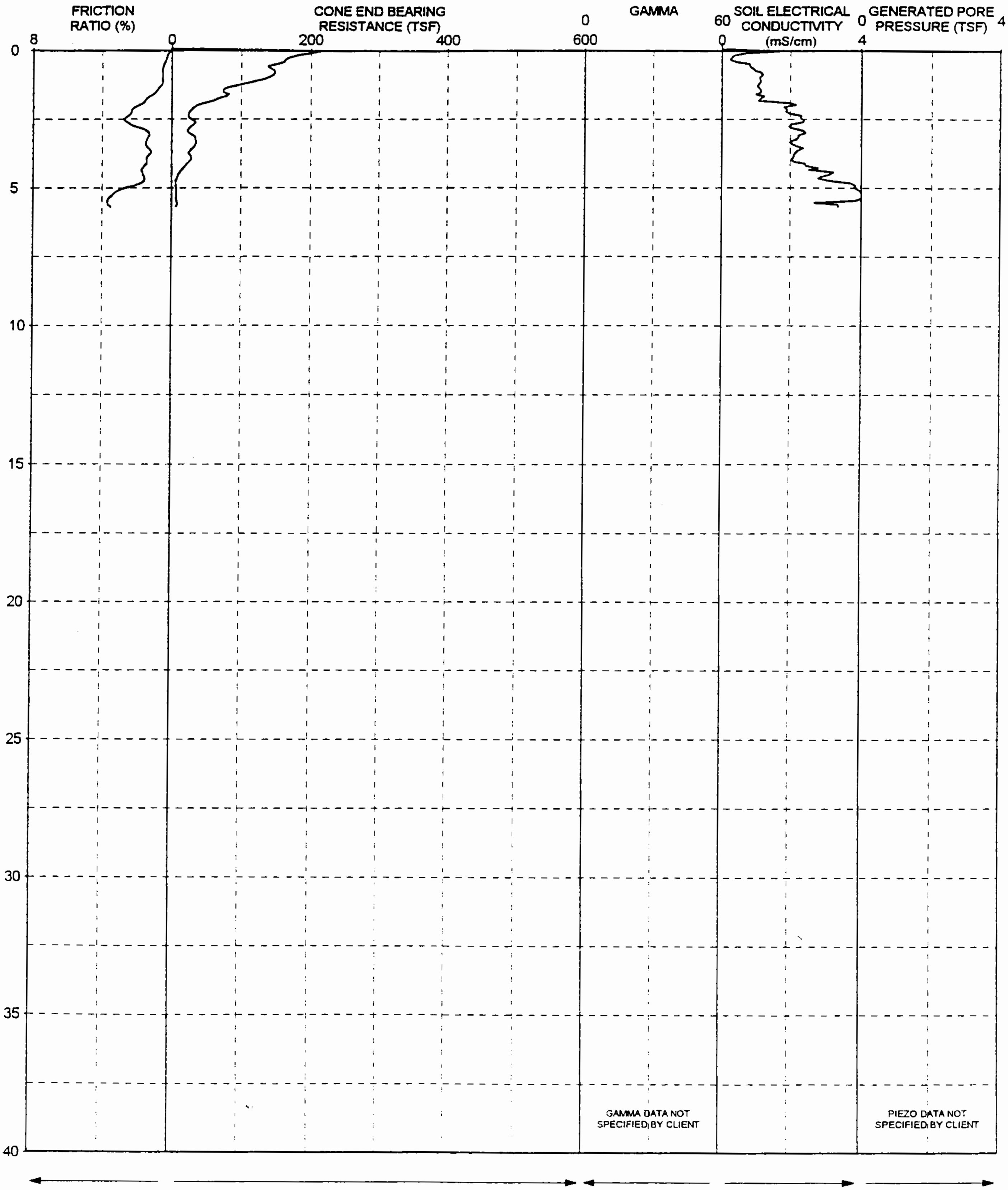
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP014

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp014

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	137.7	221.8	0.8	0.5		1116	Dense, Sand to silty sand	42-46	60-80				29 - 37	46 - 60
1.5	73.9	112.5	0.9	0.9		1141	Med dense, Sand to silty sand	40-42	40-60				20 - 22	30 - 33
2.0	38.0	55.5	1.1	1.8		2098	Med dense, Silty sand to sandy silt	36-37	40-60				14 - 16	20 - 23
2.5	27.8	39.2	0.8	2.7		2341	V stiff, Sandy silt to sandy clay			25	2.21	1.59	12 - 14	17 - 20
3.0	24.5	33.7	0.4	1.3		2417	Loose, Silty sand to sandy silt	27-31	20-40				5 - 7	7 - 10
3.5	33.0	44.1	0.5	1.4		2186	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	12 - 15
4.0	26.7	34.9	0.4	1.4		2070	Loose, Silty sand to sandy silt	27-31	20-40				5 - 8	7 - 10
4.5	10.1	12.9	0.3	1.7		3125	Stiff, Sandy silt to clayey silt			15	1.31	0.57	1 - 2	1 - 3
5.0	6.6	8.3	0.2	2.6		3833	Stiff, Clayey silt to silty clay			10	1.26	0.38	1 - 2	1 - 3
5.5	7.7	9.6	0.3	3.7		3300	Firm, Silty clay to clay			15	0.99	0.61	2 - 3	3 - 4

NOTES:
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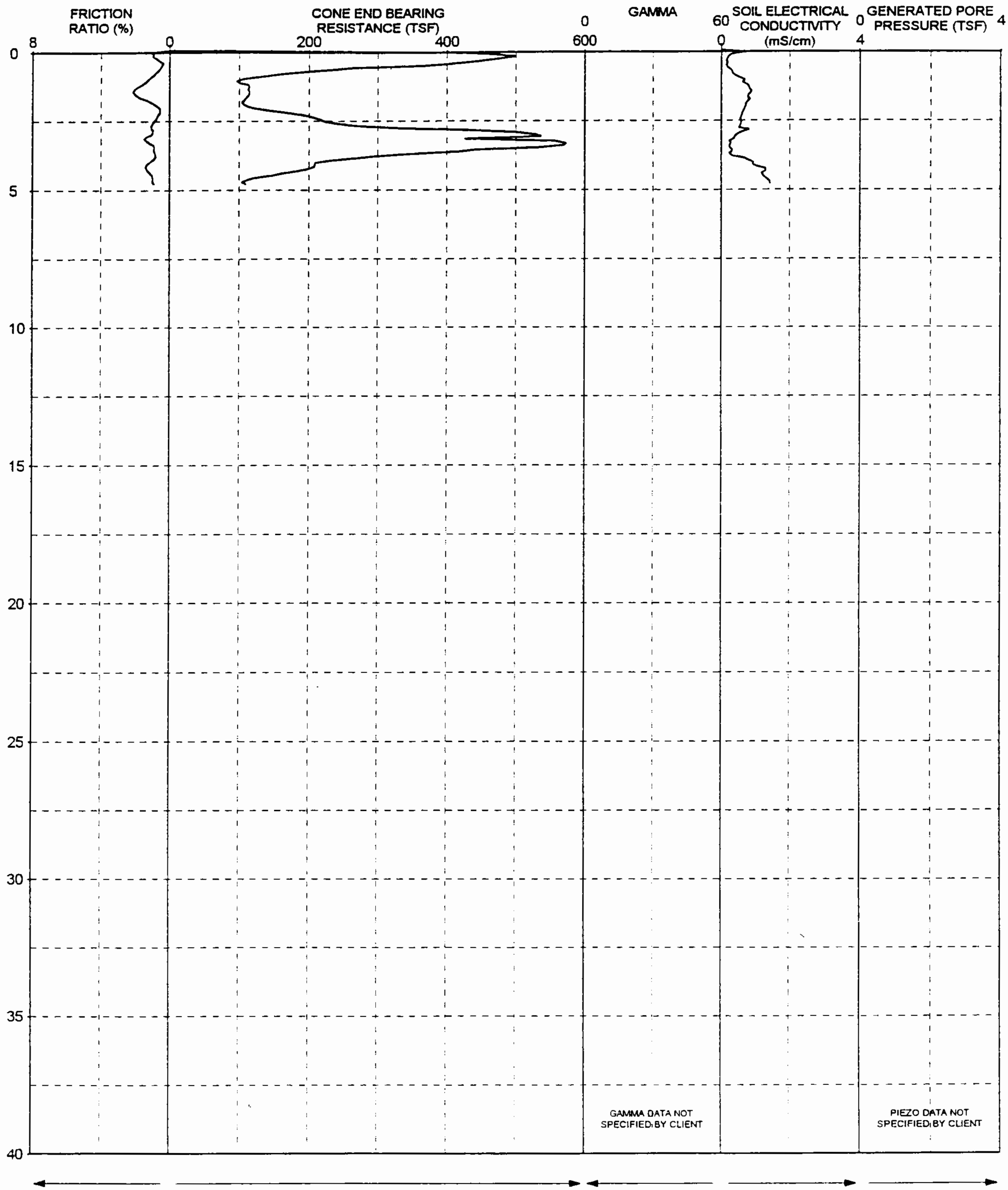
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP015

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp015

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	96.2	154.9	2.3	1.2		732	Dense, Sand to silty sand	40-42	60-80				29 - 37	46 - 60
1.5	114.7	174.7	2.3	2.1		874	V dense, Silty sand to sandy silt	40-42	80-100				47 - 65	72 - 99
2.0	116.3	169.9	1.0	0.6		710	Med dense, Sand to silty sand	42-46	40-60				27 - 31	40 - 46
2.5	221.3	312.4	3.0	0.9		582	Dense, Sand to silty sand	42-46	60-80				51 - 70	72 - 99
3.0	529.1	726.1	6.1	1.1		469	V dense, Sa gravel to si gr sand	+46	+100				+ 73	+ 100
3.5	494.3	661.8	4.8	0.9		290	V dense, Sa gravel to gr sand	+46	80-100				+ 75	+ 100
4.0	213.5	279.7	3.8	1.2		913	Dense, Sand to silty sand	42-46	60-80				55 - 76	72 - 99
4.5	141.9	182.2	1.6	1.0		1230	Dense, Sand to silty sand	42-46	60-80				36 - 47	46 - 60

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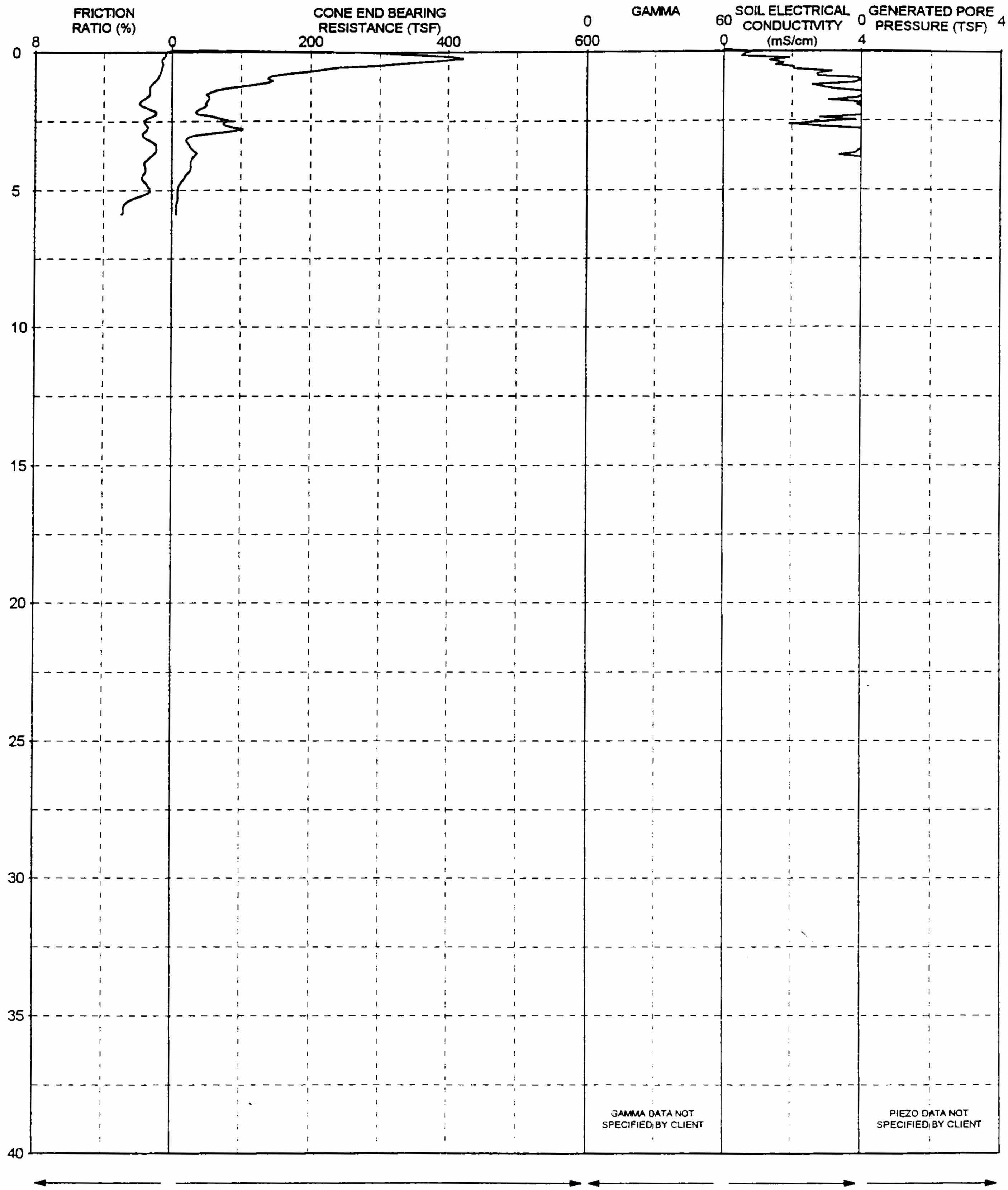
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/16/96
SOUNDING NUMBER: CP016

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp016

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	152.9	246.3	1.6	0.9		4084	Dense, Sand to silty sand	42-46	60-80				37 - 45	60 - 72
1.5	53.3	81.2	1.3	1.3		4409	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 20	23 - 30
2.0	47.6	69.5	0.8	1.6		4188	Med dense, Silty sand to sandy silt	37-40	40-60				14 - 16	20 - 23
2.5	80.5	113.6	1.2	1.6		3609	Dense, Silty sand to sandy silt	37-40	60-80				28 - 33	40 - 46
3.0	41.7	57.2	1.3	1.7		6461	Med dense, Silty sand to sandy silt	36-37	40-60				12 - 15	17 - 20
3.5	29.4	39.4	0.3	0.9		4914	Loose, Silty sand to sandy silt	36-37	20-40				5 - 7	7 - 10
4.0	28.2	36.9	0.5	1.6		5127	Med dense, Silty sand to sandy silt	27-31	40-60				8 - 9	10 - 12
4.5	19.9	25.6	0.5	1.7		4965	Loose, Silty sand to sandy silt	27-31	20-40				5 - 5	6 - 7
5.0	8.9	11.2	0.2	1.3		7367	Stiff, Sandy silt to clayey silt			15	1.15	0.33	1 - 2	1 - 3
5.5	7.4	9.1	0.2	2.7		11287	Stiff, Clayey silt to silty clay			10	1.41	0.46	1 - 2	1 - 3

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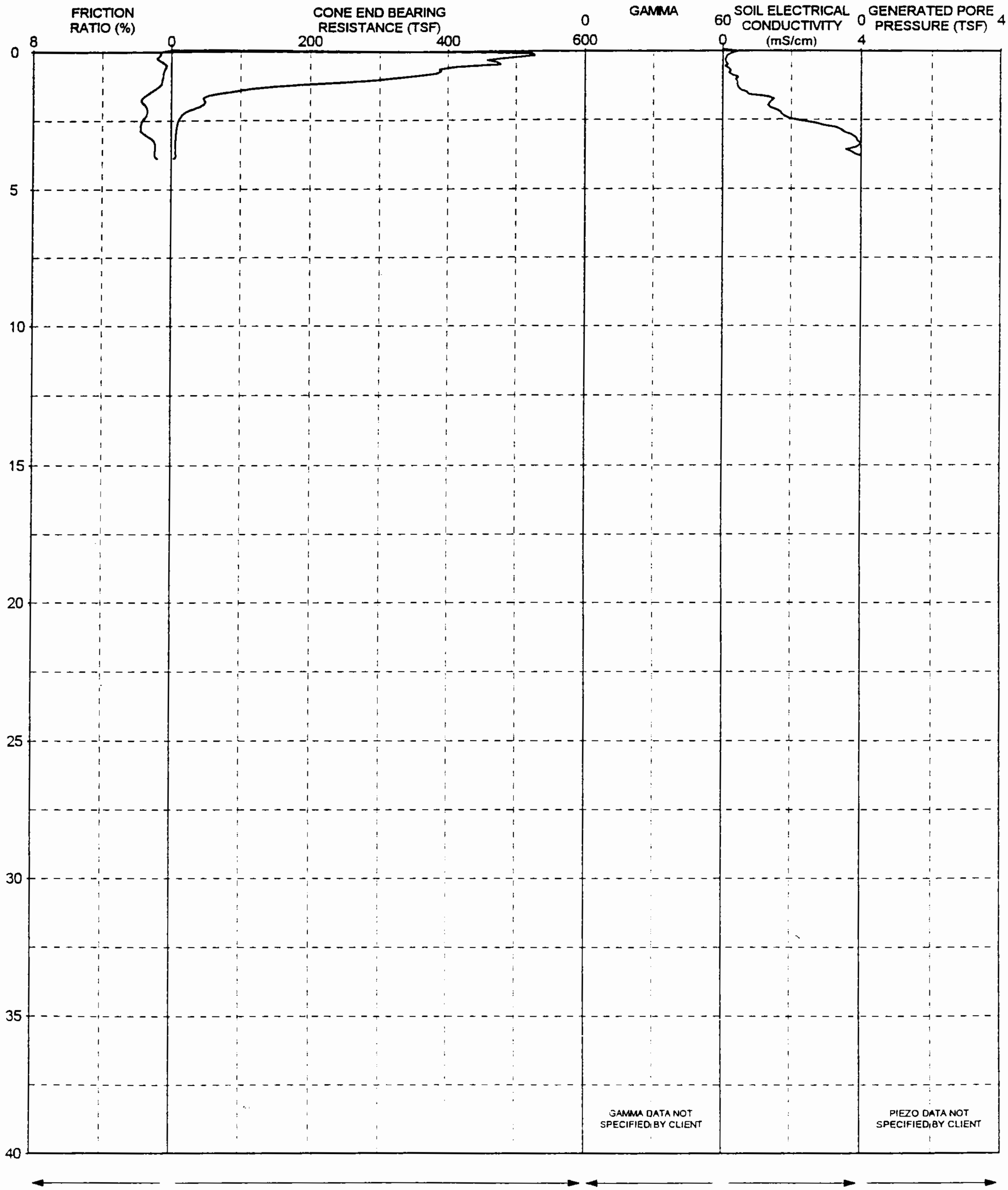
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 09/17/96

PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP017

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp017

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	322.6	519.7	2.2	0.5		374	V dense, Sa gravel to gr sand	+46	80-100				+ 62	+ 100
1.5	79.1	120.5	2.2	1.3		656	Dense, Sand to silty sand	40-42	60-80				26 - 30	40 - 46
2.0	40.9	59.7	0.7	1.5		1325	Med dense, Silty sand to sandy silt	36-37	40-60				12 - 14	17 - 20
2.5	11.0	15.6	0.4	1.7		2074	Stiff, Sandy silt to clayey silt			15	1.45	0.71	2 - 3	3 - 4
3.0	6.9	9.4	0.1	1.6		3637	Stiff, Sandy silt to clayey silt			10	1.34	0.26	1 - 2	1 - 3
3.5	6.1	8.1	0.1	0.9		3863	Stiff, Sandy silt to clayey silt			10	1.17	0.11	1 - 2	1 - 3

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STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp019

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	202.8	326.7	1.2	0.4		1271	Dense, Sa gravel to gr sand	+46	60-80				37 - 45	60 - 72
1.5	152.5	232.2	1.4	0.8		1448	Dense, Sand to silty sand	42-46	60-80				39 - 47	60 - 72
2.0	73.1	106.7	1.0	0.9		2242	Med dense, Sand to silty sand	40-42	40-60				21 - 23	30 - 33
2.5	19.0	26.8	0.7	1.5		2928	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
3.0	17.5	24.0	0.2	1.1		4277	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	4 - 6
3.5	11.1	14.9	0.2	1.1		4353	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
4.0	6.3	8.2	0.0	0.4		7957	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
4.5	5.6	7.2	0.0	0.4		8247	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3

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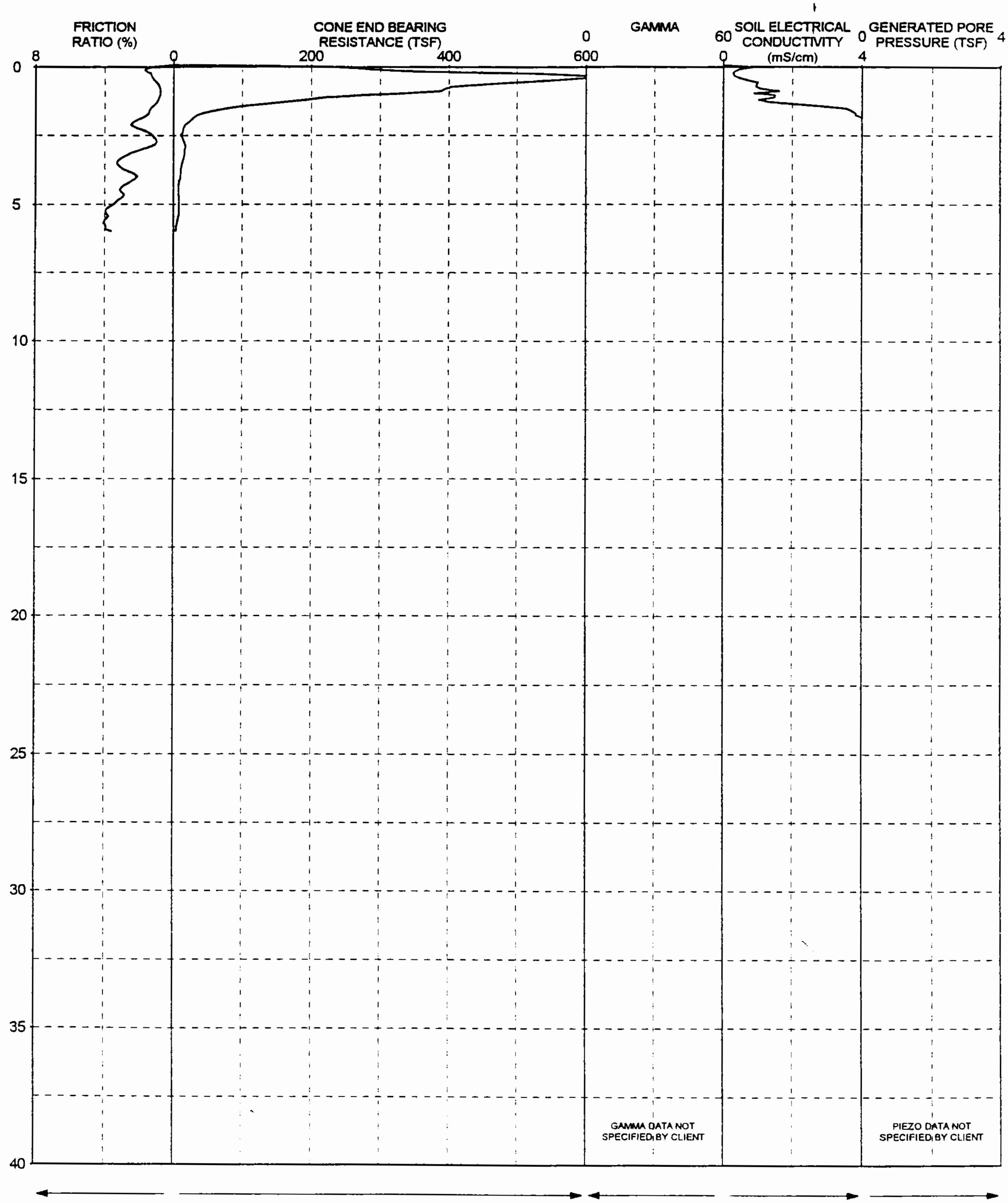
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP020

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp020

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	307.5	495.3	3.2	0.7		1508	V dense, Sa gravel to gr sand	+46	80-100				+ 62	+ 100
1.5	85.9	130.8	2.4	1.3		3261	Dense, Sand to silty sand	40-42	60-80				26 - 30	40 - 46
2.0	23.6	34.4	1.0	2.3		5404	V stiff, Sandy silt to sandy clay			20	2.34	2.03	8 - 10	12 - 15
2.5	10.8	15.3	0.2	1.2		8866	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
3.0	16.7	23.0	0.3	1.8		8399	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
3.5	12.9	17.2	0.5	3.3		9096	Stiff, Sandy clay to silty clay *			15	1.69	1.00	4 - 5	6 - 7
4.0	10.1	13.2	0.2	2.1		9844	Stiff, Clayey silt to silty clay			15	1.31	0.46	2 - 3	3 - 4
4.5	7.4	9.5	0.3	3.1		10811	Firm, Silty clay to clay			15	0.95	0.53	2 - 3	3 - 4
5.0	8.1	10.2	0.3	3.5		9915	Stiff, Silty clay to clay			15	1.04	0.54	2 - 3	3 - 4
5.5	6.7	8.3	0.3	3.9		11633	Stiff, Silty clay to clay			10	1.27	0.58	2 - 3	3 - 4
6.0	3.6	4.4	0.2	2.6		13243	Soft, Silty clay to clay			18	0.36	0.44	1 - 2	1 - 3

NOTES:

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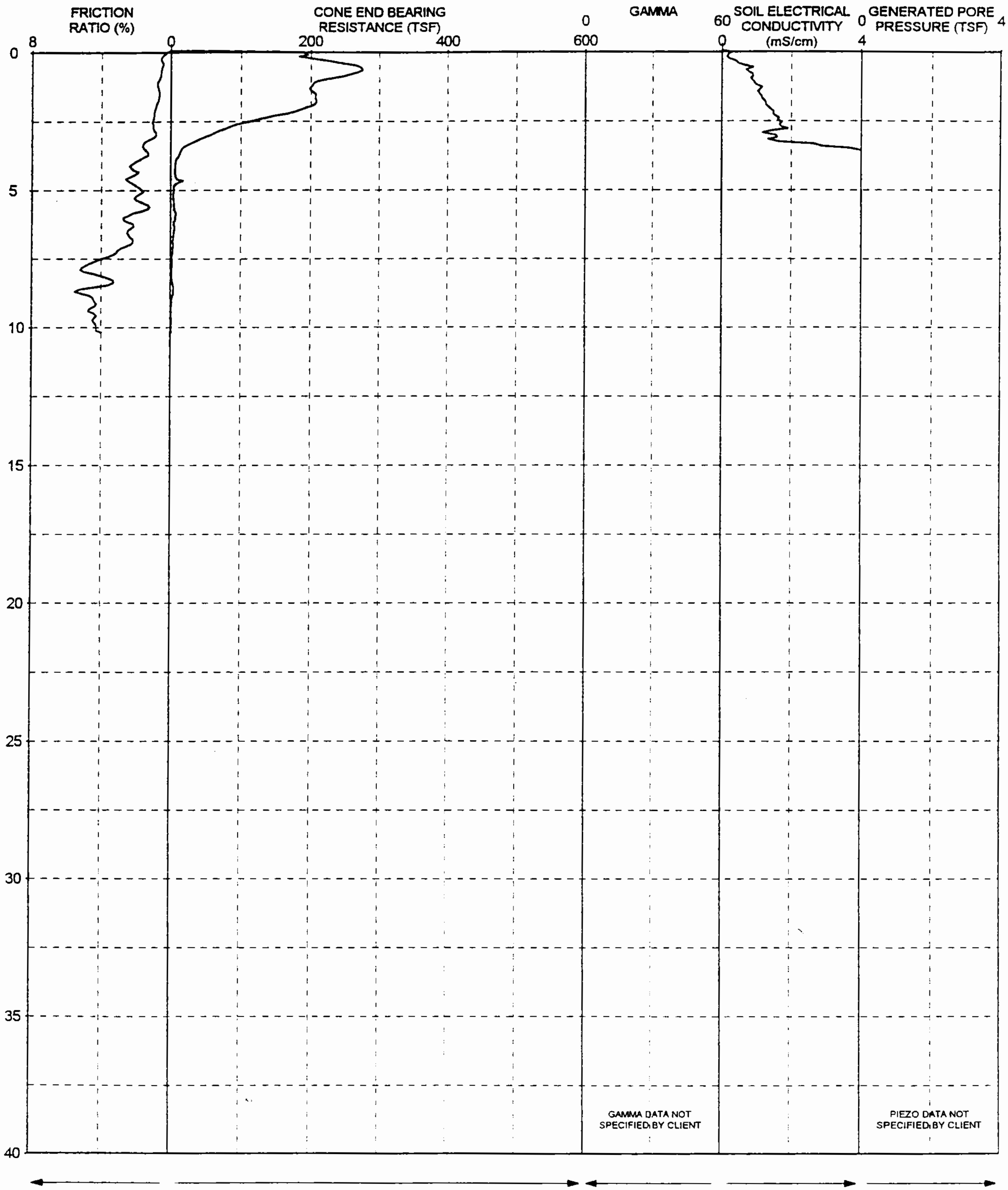
Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/17/96
SOUNDING NUMBER: CP021

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp021

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	212.8	342.9	1.8	0.7		886	Dense, Sand to silty sand	+46	60-80				45 - 61	72 - 99
1.5	206.2	314.0	1.4	0.7		1085	Dense, Sand to silty sand	42-46	60-80				47 - 65	72 - 99
2.0	195.5	285.5	1.8	0.9		1338	Dense, Sand to silty sand	42-46	60-80				49 - 68	72 - 99
2.5	113.2	159.8	1.6	1.0		1677	Dense, Sand to silty sand	40-42	60-80				33 - 42	46 - 60
3.0	55.9	76.8	0.6	0.8		1476	Med dense, Sand to silty sand	40-42	40-60				12 - 15	17 - 20
3.5	15.7	21.0	0.5	1.5		4048	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	4 - 6
4.0	7.2	9.4	0.2	2.1		5927	Stiff, Clayey silt to silty clay			10	1.39	0.47	1 - 2	1 - 3
4.5	7.0	9.0	0.2	2.2		6702	Stiff, Clayey silt to silty clay			10	1.35	0.38	1 - 2	1 - 3
5.0	4.4	5.5	0.1	1.7		8141	Soft, Clayey silt to silty clay			18	0.45	0.25	1 - 2	1 - 3
5.5	4.8	5.9	0.1	1.5		8261	Firm, Clayey silt to silty clay			10	0.88	0.19	1 - 2	1 - 3
6.0	6.9	8.5	0.2	2.7		7878	Stiff, Clayey silt to silty clay			10	1.31	0.33	1 - 2	1 - 3
6.5	5.2	6.3	0.1	2.5		7926	Firm, Clayey silt to silty clay			10	0.97	0.29	1 - 2	1 - 3
7.0	3.8	4.5	0.1	2.4		10421	Soft, Silty clay to clay			18	0.38	0.20	1 - 3	1 - 3
7.5	2.3	2.7	0.1	3.9		11891	V soft, Clay			18	0.20	0.24	0 - 1	0 - 1
8.0	2.2	2.5	0.1	4.9		11264	Soft, Clay			10	0.34	0.26	1 - 3	1 - 3
8.5	4.2	4.9	0.1	4.0		10238	Soft, Silty clay to clay			18	0.41	0.30	1 - 3	1 - 3
9.0	2.1	2.4	0.2	4.4		10346	V soft, Clay			18	0.18	0.34	0 - 1	0 - 1
9.5	1.5	1.7	0.1	4.4		14140	V soft, PROCESSING ERROR			10	0.19	0.15	0 - 1	0 - 1
10.0	1.5	1.7	0.1	4.3		14293	V soft, PROCESSING ERROR			10	0.18	0.13	0 - 1	0 - 1

NOTES:

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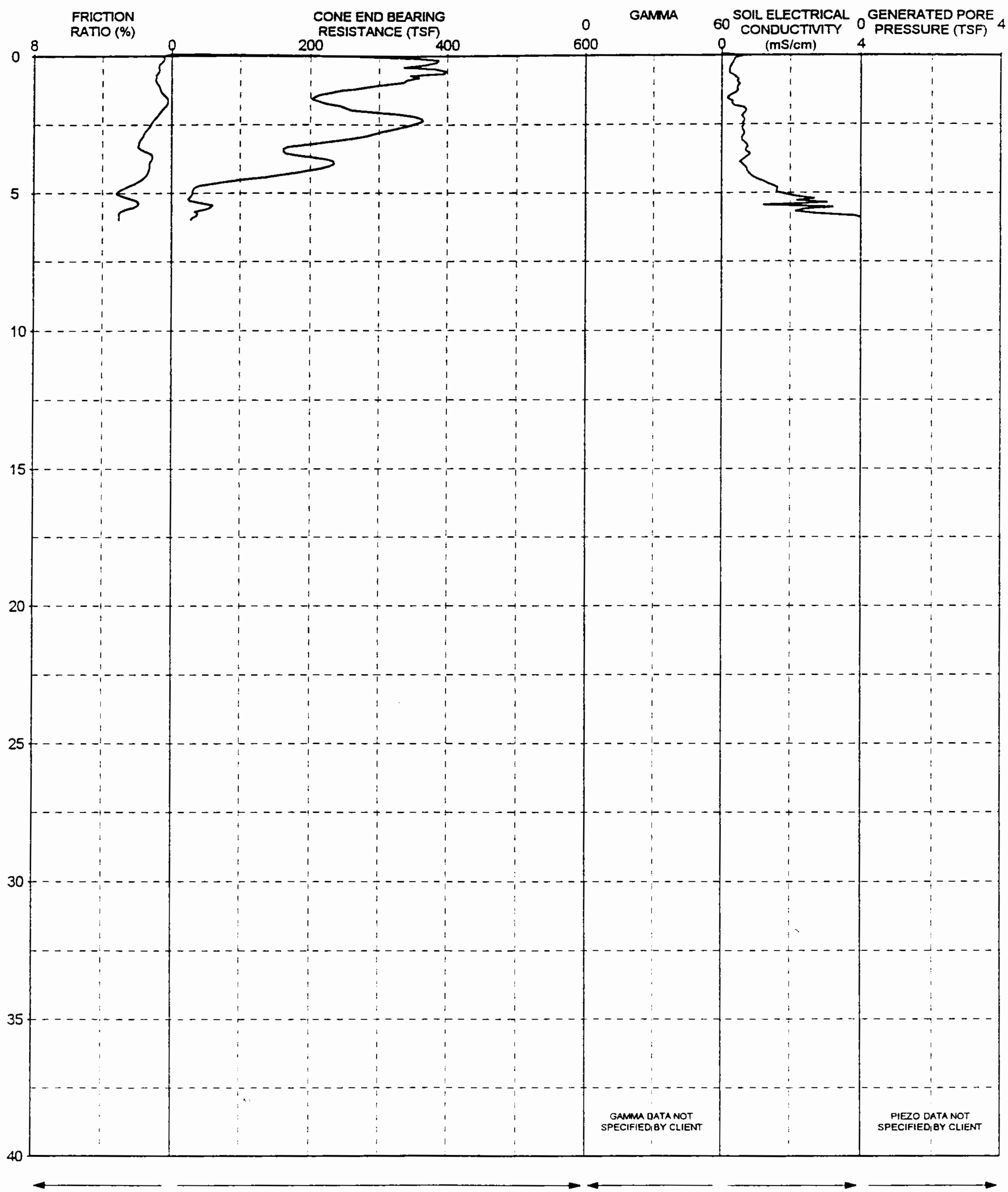
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 09/17/96
PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP024

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp024

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	325.8	524.8	3.1	0.8		557	V dense, Sa gravel to gr sand	+46	80-100				+ 62	+ 100
1.5	206.0	313.7	0.8	0.3		215	Dense, Sa gravel to gr sand	+46	60-80				39 - 47	60 - 72
2.0	266.9	389.7	2.0	0.6		724	Dense, Sa gravel to gr sand	+46	60-80				49 - 68	72 - 99
2.5	350.3	494.6	4.0	1.2		635	V dense, Sa gravel to si gr sand	42-46	80-100				+ 71	+ 100
3.0	266.4	365.6	5.1	1.7		590	V dense, Sa gravel to si gr sand	42-46	80-100				+ 73	+ 100
3.5	162.5	217.6	2.9	1.5		738	Dense, Sand to silty sand	42-46	60-80				54 - 74	72 - 99
4.0	229.9	301.1	2.7	1.3		652	V dense, Sand to silty sand	42-46	80-100				55 - 76	72 - 99
4.5	110.6	142.0	3.0	1.7		1037	Dense, Silty sand to sandy silt	40-42	60-80				47 - 56	60 - 72
5.0	30.8	38.9	1.7	3.1		1699	V stiff, Sandy clay to silty clay *			25	2.44	3.40	16 - 18	20 - 23
5.5	58.4	72.4	0.8	2.1		2511	Dense, Silty sand to sandy silt	36-37	60-80				24 - 27	30 - 33
6.0	18.4	22.5	1.2	2.1		5582	Stiff, Sandy silt to sandy clay			20	1.80	2.37	5 - 6	6 - 7

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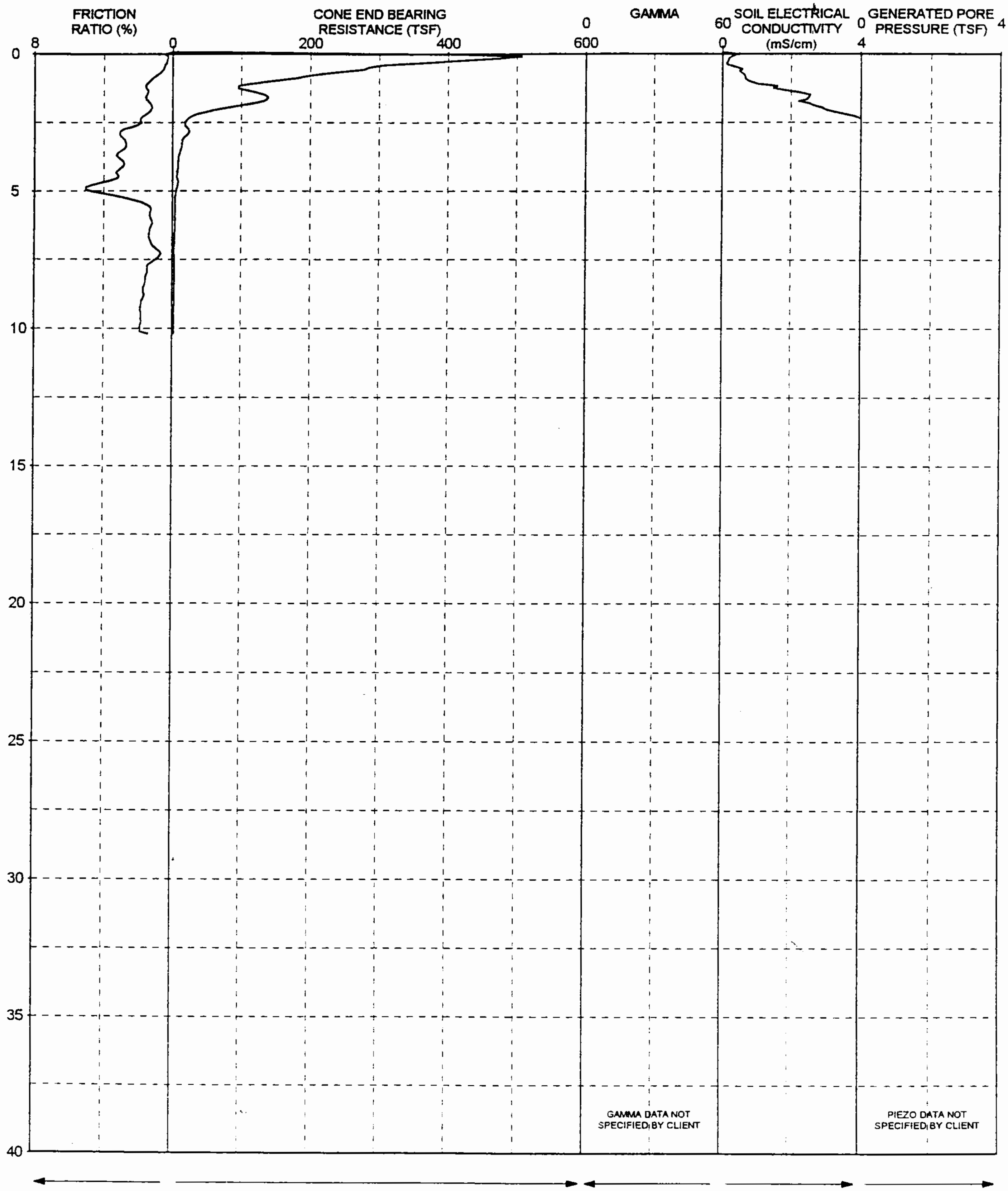
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/19/96
SOUNDING NUMBER: CP033

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp033

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	145.0	233.6	2.8	1.3		731	Dense, Sand to silty sand	42-46	60-80				45 - 61	72 - 99
1.5	132.8	202.3	1.8	1.5		2553	Dense, Sand to silty sand	40-42	60-80				39 - 47	60 - 72
2.0	74.1	108.2	1.4	1.2		2940	Med dense, Sand to silty sand	40-42	40-60				23 - 27	33 - 40
2.5	19.1	27.0	0.7	1.8		5032	Med dense, Silty sand to sandy silt	27-31	40-60				5 - 7	7 - 10
3.0	20.2	27.7	0.7	3.0		6686	V stiff, Sandy clay to silty clay *			20	2.00	1.32	9 - 11	12 - 15
3.5	12.7	17.0	0.4	2.9		10387	Stiff, Sandy clay to silty clay *			15	1.66	0.85	4 - 5	6 - 7
4.0	9.0	11.7	0.3	2.8		11297	Stiff, Clayey silt to silty clay			15	1.16	0.56	2 - 3	3 - 4
4.5	6.9	8.9	0.2	3.2		12208	Stiff, Silty clay to clay			10	1.33	0.47	1 - 2	1 - 3
5.0	5.8	7.3	0.4	4.8		11842	Stiff, Clay			10	1.09	0.73	2 - 3	3 - 4
5.5	3.8	4.7	0.1	1.5		13415	Soft, Clayey silt to silty clay			18	0.38	0.13	1 - 2	1 - 3
6.0	3.7	4.6	0.0	1.2		14242	Soft, Sensitive fine grained soil			18	0.37	0.09	1 - 2	1 - 3
6.5	3.8	4.6	0.1	1.3		13722	Soft, Clayey silt to silty clay			18	0.38	0.10	1 - 2	1 - 3
7.0	3.1	3.7	0.0	1.2		15303	Soft, Sensitive fine grained soil			18	0.30	0.08	0 - 1	0 - 1
7.5	3.3	3.9	0.0	0.9		15139	Soft, Sensitive fine grained soil			18	0.32	0.06	0 - 1	0 - 1
8.0	3.3	3.8	0.0	1.5		14478	Soft, Sensitive fine grained soil			18	0.31	0.09	0 - 1	0 - 1
8.5	3.1	3.5	0.1	1.7		14717	Soft, Sensitive fine grained soil			18	0.29	0.11	0 - 1	0 - 1
9.0	3.1	3.5	0.1	1.8		14725	Soft, Sensitive fine grained soil			18	0.28	0.11	0 - 1	0 - 1
9.5	2.8	3.2	0.1	1.8		15446	Soft, Sensitive fine grained soil			18	0.25	0.11	0 - 1	0 - 1
10.0	2.8	3.1	0.1	1.9		15651	V soft, Sensitive fine grained soil			18	0.24	0.10	0 - 1	0 - 1

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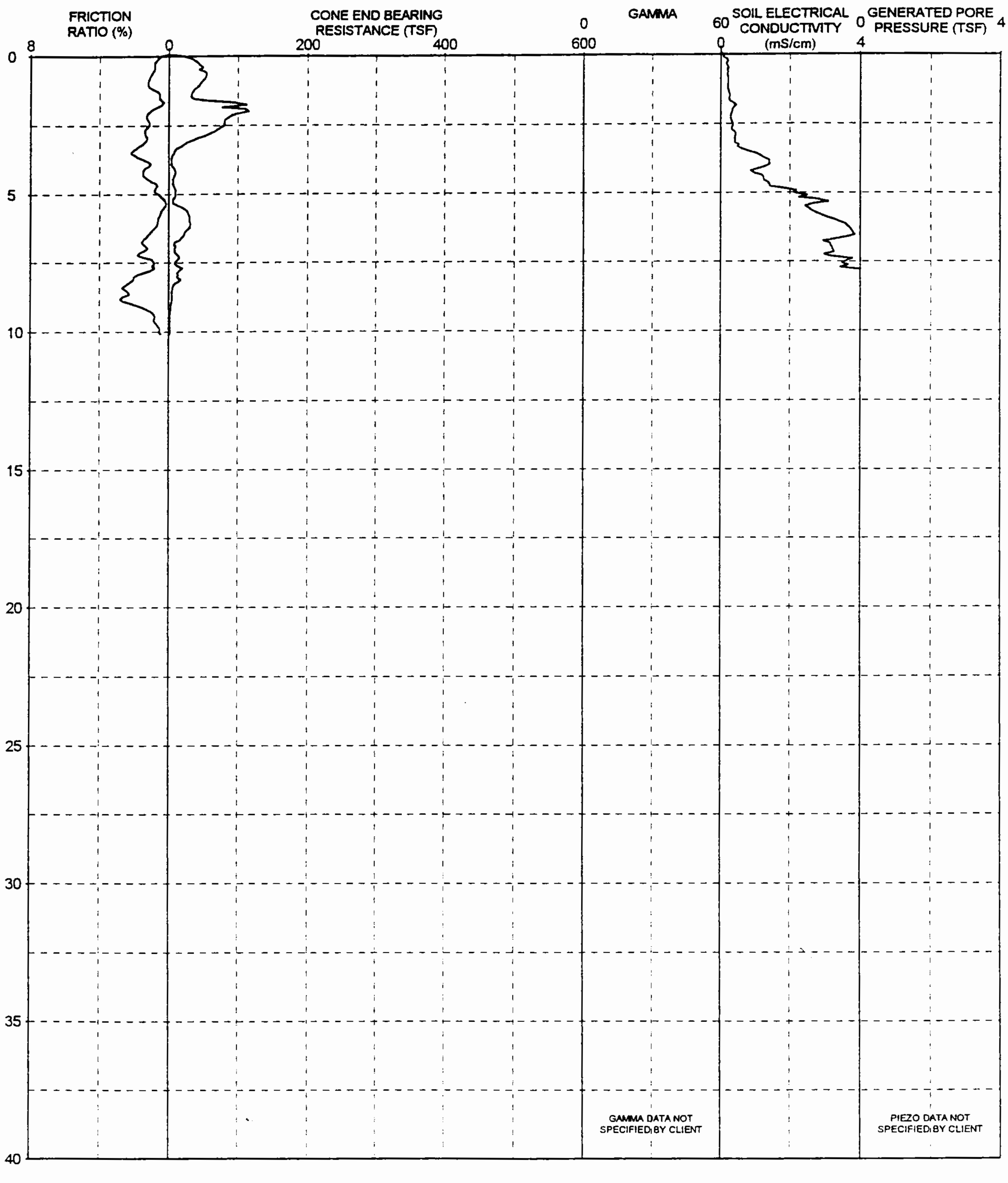
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230
DATE: 09/19/96
SOUNDING NUMBER: CP035

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp035

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	46.5	74.8	0.6	1.2		209	Med dense, Silty sand to sandy silt	37-40	40-60				12 - 14	20 - 23
1.5	34.3	52.2	0.5	0.5		270	Loose, Sand to silty sand	37-40	20-40				5 - 7	7 - 10
2.0	116.0	169.4	1.0	1.1		343	Dense, Sand to silty sand	42-46	60-80				31 - 41	46 - 60
2.5	80.0	113.0	1.0	1.1		353	Med dense, Sand to silty sand	40-42	40-60				23 - 28	33 - 40
3.0	38.7	53.1	0.8	1.3		419	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	12 - 15
3.5	7.5	10.0	0.4	2.1		804	Firm, Clayey silt to silty clay			15	0.97	0.84	1 - 2	1 - 3
4.0	5.9	7.7	0.1	1.2		1406	Stiff, Sandy silt to clayey silt			10	1.13	0.20	1 - 2	1 - 3
4.5	6.1	7.8	0.1	1.1		1240	Stiff, Sandy silt to clayey silt			10	1.16	0.17	1 - 2	1 - 3
5.0	9.5	11.9	0.1	0.6		2129	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
5.5	20.1	24.9	0.1	0.3		2436	V loose, Silty sand to sandy silt	36-37	0-20				2 - 3	3 - 4
6.0	30.6	37.4	0.2	0.6		3293	Loose, Sand to silty sand	36-37	20-40				5 - 6	6 - 7
6.5	21.9	26.4	0.3	1.2		3834	Loose, Silty sand to sandy silt	27-31	20-40				5 - 6	6 - 7
7.0	8.6	10.2	0.2	1.2		3201	Stiff, Sandy silt to clayey silt			10	1.63	0.34	1 - 3	1 - 3
7.5	9.7	11.4	0.1	0.9		3569	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
8.0	12.8	14.8	0.3	1.9		4606	Stiff, Sandy silt to clayey silt			15	1.64	0.54	3 - 3	3 - 4
8.5	5.7	6.5	0.3	2.5		6876	Stiff, Clayey silt to silty clay			10	1.04	0.57	1 - 3	1 - 3
9.0	4.0	4.5	0.1	2.2		9019	Soft, Clayey silt to silty clay			18	0.38	0.20	1 - 3	1 - 3
9.5	2.0	2.3	0.0	0.8		13921	V soft, Sensitive fine grained soil			25	0.12	0.04	0 - 1	0 - 1
10.0	1.8	2.0	0.0	0.5		15225	V soft, Sensitive fine grained soil			25	0.10	0.01	0 - 1	0 - 1

NOTES:

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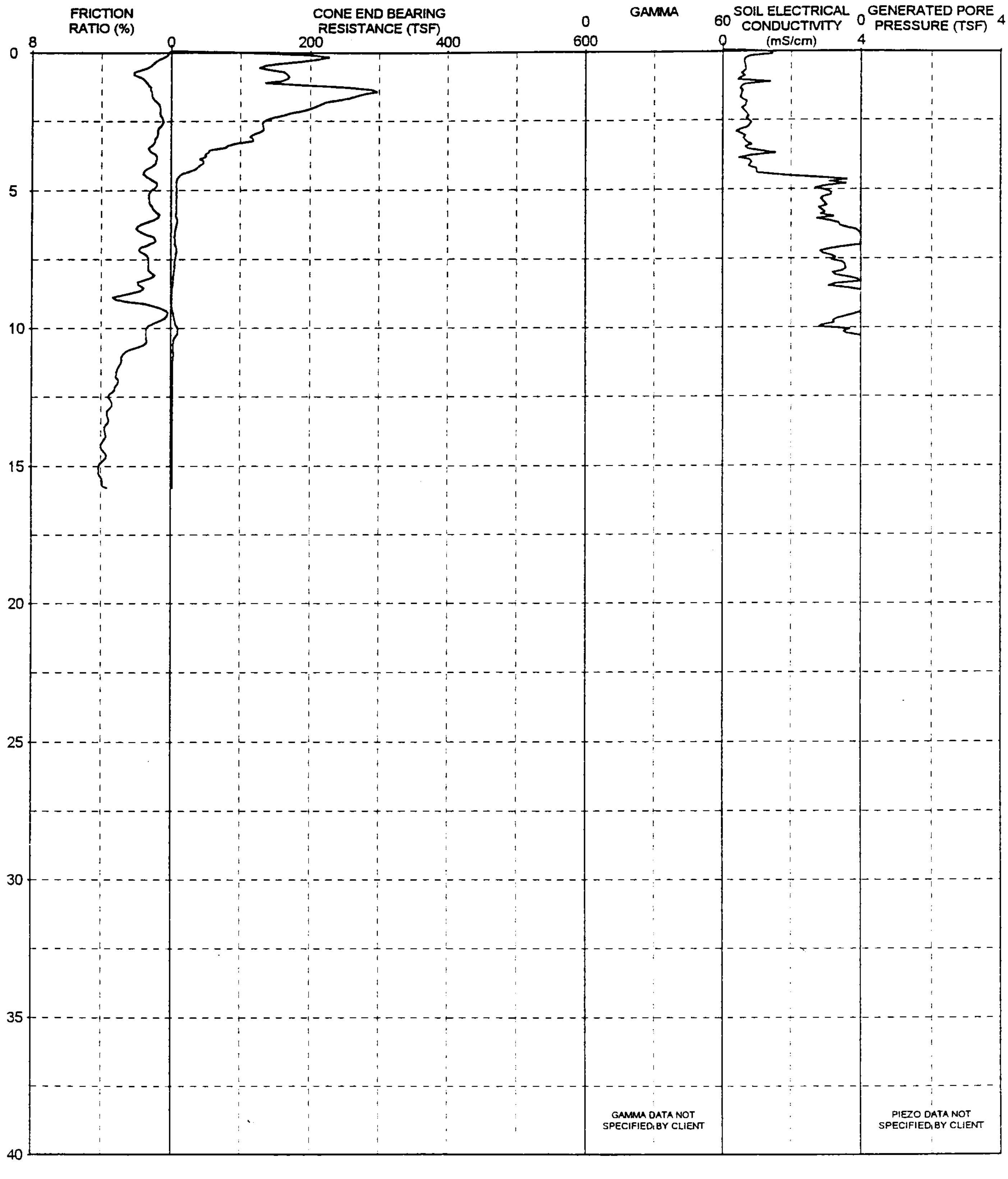
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base

PROJECT NUMBER: 96-110-230

DATE: 09/20/96

SOUNDING NUMBER: CP037

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp037

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	170.5	274.7	3.4	1.6		46	V dense, Sand to silty sand	42-46	80-100				+ 62	+ 100
1.5	281.5	428.6	2.5	1.1		559	V dense, Sand to silty sand	42-46	80-100				+ 66	+ 100
2.0	206.0	300.9	1.5	0.6		633	Dense, Sand to silty sand	42-46	60-80				41 - 49	60 - 72
2.5	135.3	191.0	0.7	0.4		752	Med dense, Sand to silty sand	42-46	40-60				33 - 42	46 - 60
3.0	119.6	164.1	0.8	0.7		555	Med dense, Sand to silty sand	42-46	40-60				29 - 34	40 - 46
3.5	70.1	93.8	1.3	1.3		685	Med dense, Sand to silty sand	37-40	40-60				22 - 25	30 - 33
4.0	47.1	61.7	0.4	0.9		834	Med dense, Sand to silty sand	37-40	40-60				9 - 11	12 - 15
4.5	12.5	16.1	0.5	1.4		1686	Loose, Silty sand to sandy silt	27-31	20-40				2 - 3	3 - 4
5.0	8.5	10.7	0.1	1.1		2840	Stiff, Sandy silt to clayey silt			15	1.09	0.20	1 - 2	1 - 3
5.5	8.0	9.9	0.1	1.2		2975	Stiff, Sandy silt to clayey silt			10	1.53	0.20	1 - 2	1 - 3
6.0	8.3	10.2	0.1	0.8		3116	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
6.5	6.1	7.4	0.1	1.8		3909	Stiff, Clayey silt to silty clay			10	1.15	0.29	1 - 2	1 - 3
7.0	6.6	7.9	0.1	1.4		4073	Stiff, Sandy silt to clayey silt			10	1.25	0.23	1 - 3	1 - 3
7.5	6.2	7.2	0.1	1.3		3237	Stiff, Sandy silt to clayey silt			10	1.14	0.19	1 - 3	1 - 3
8.0	4.6	5.3	0.1	1.1		3284	Soft, Sandy silt to clayey silt			18	0.45	0.11	1 - 3	1 - 3
8.5	2.3	2.7	0.1	1.7		3108	V soft, Sensitive fine grained soil			18	0.20	0.11	0 - 1	0 - 1
9.0	1.3	1.5	0.1	2.9		5493	V soft, Sensitive fine grained soil			25	0.06	0.12	0 - 1	0 - 1
9.5	4.1	4.6	0.0	0.2		3847	Soft, Sensitive fine grained soil			18	0.39	0.02	0 - 1	0 - 1
10.0	9.9	11.0	0.1	1.4		2942	Stiff, Sandy silt to clayey silt			15	1.24	0.23	1 - 3	1 - 3
10.5	4.0	4.4	0.1	1.4		6462	Soft, Clayey silt to silty clay			18	0.38	0.21	1 - 3	1 - 3
11.0	3.8	4.2	0.1	2.8		9485	Soft, Silty clay to clay			18	0.35	0.20	1 - 3	1 - 3
11.5	2.4	2.6	0.1	3.0		15626	V soft, Silty clay to clay			18	0.19	0.18	0 - 1	0 - 1
12.0	2.4	2.6	0.1	3.0		9757	V soft, Silty clay to clay			18	0.19	0.16	0 - 1	0 - 1
12.5	2.9	3.1	0.1	3.6		11009	V soft, Silty clay to clay			18	0.24	0.21	1 - 3	1 - 3
13.0	2.8	3.0	0.1	3.6		12897	V soft, Silty clay to clay			18	0.22	0.21	1 - 3	1 - 3
13.5	2.8	3.0	0.1	3.7		14517	V soft, Clay			18	0.22	0.21	1 - 3	1 - 3
14.0	2.5	2.6	0.1	3.8		17731	V soft, Clay			18	0.18	0.19	0 - 1	0 - 1
14.5	2.5	2.6	0.1	3.8		18263	V soft, Clay			18	0.18	0.19	0 - 1	0 - 1
15.0	2.6	2.7	0.1	4.1		18131	V soft, Clay			18	0.18	0.21	1 - 3	1 - 3
15.5	2.4	2.6	0.1	3.9		18360	V soft, Clay			18	0.17	0.19	0 - 1	0 - 1

NOTES:
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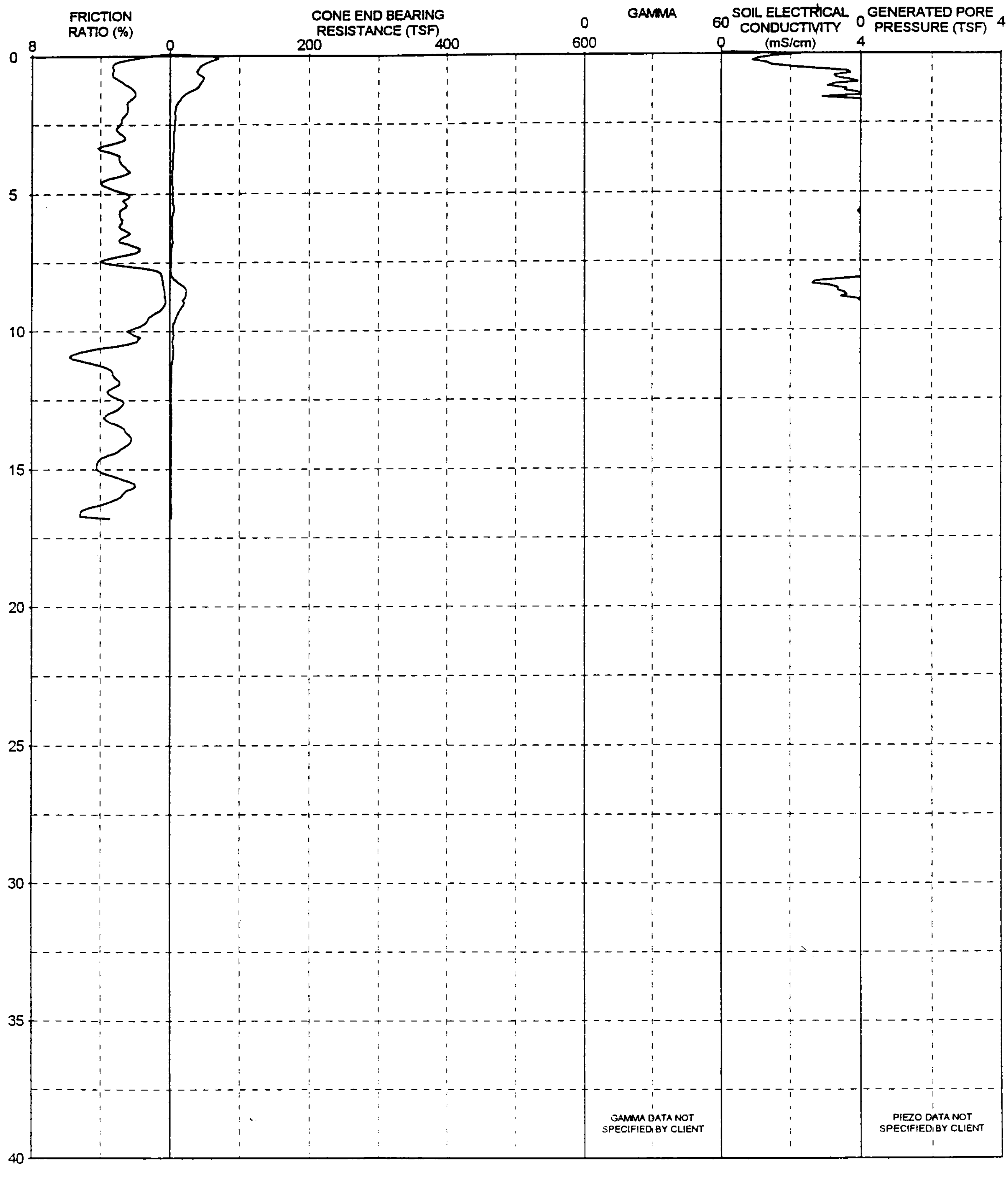
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 09/20/96
PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP039

STRATIGRAPHICS
JOB NO: 96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp039

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	44.6	71.8	1.2	2.7		4300	V stiff, Sandy silt to sandy clay			25	3.56	2.33	20 - 25	33 - 40
1.5	17.7	27.0	0.6	2.1		5178	Stiff, Sandy silt to sandy clay			20	1.76	1.24	5 - 7	7 - 10
2.0	8.0	11.6	0.3	2.4		6629	Stiff, Clayey silt to silty clay			15	1.04	0.54	2 - 3	3 - 4
2.5	7.0	9.8	0.2	2.9		7003	Firm, Clayey silt to silty clay			15	0.91	0.42	1 - 2	1 - 3
3.0	5.4	7.4	0.2	2.6		7872	Stiff, Clayey silt to silty clay			10	1.04	0.31	1 - 2	1 - 3
3.5	5.4	7.3	0.2	3.5		8122	Stiff, Silty clay to clay			10	1.04	0.40	1 - 2	1 - 3
4.0	4.4	5.7	0.1	2.7		8742	Firm, Silty clay to clay			10	0.82	0.25	1 - 2	1 - 3
4.5	3.6	4.6	0.1	3.7		8578	Soft, Silty clay to clay			18	0.37	0.28	1 - 2	1 - 3
5.0	3.7	4.6	0.1	2.5		8558	Soft, Silty clay to clay			18	0.38	0.22	1 - 2	1 - 3
5.5	6.2	7.7	0.1	2.6		7780	Stiff, Clayey silt to silty clay			10	1.18	0.25	1 - 2	1 - 3
6.0	3.1	3.8	0.1	2.7		6790	Soft, Silty clay to clay			18	0.31	0.24	1 - 2	1 - 3
6.5	3.3	4.0	0.1	2.4		6698	Soft, Silty clay to clay			18	0.32	0.16	1 - 2	1 - 3
7.0	2.5	3.0	0.1	1.7		5391	V soft, Sensitive fine grained soil			18	0.23	0.12	0 - 1	0 - 1
7.5	1.8	2.1	0.1	3.8		4714	V soft, PROCESSING ERROR			18	0.15	0.16	0 - 1	0 - 1
8.0	3.0	3.5	0.1	0.5		5025	Soft, Sensitive fine grained soil			18	0.28	0.12	0 - 1	0 - 1
8.5	23.1	26.5	0.1	0.3		3368	Loose, Silty sand to sandy silt	36-37	20-40				3 - 3	3 - 4
9.0	20.0	22.6	0.1	0.3		4148	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
9.5	9.9	11.1	0.2	1.2		4740	Stiff, Sandy silt to clayey silt			15	1.24	0.36	1 - 3	1 - 3
10.0	4.9	5.4	0.2	2.4		9225	Firm, Clayey silt to silty clay			10	0.86	0.33	1 - 3	1 - 3
10.5	4.7	5.1	0.1	2.6		13107	Soft, Silty clay to clay			18	0.45	0.26	1 - 3	1 - 3
11.0	4.5	4.9	0.3	5.6		14137	Firm, Clay			10	0.76	0.57	1 - 3	1 - 3
11.5	2.5	2.8	0.1	3.3		15942	V soft, Silty clay to clay			18	0.20	0.20	0 - 1	0 - 1
12.0	2.3	2.5	0.1	3.1		16365	V soft, Sensitive fine grained soil			18	0.18	0.15	0 - 1	0 - 1
12.5	2.2	2.3	0.1	2.8		16820	V soft, Sensitive fine grained soil			18	0.16	0.13	0 - 1	0 - 1
13.0	2.6	2.8	0.1	3.5		17021	V soft, Silty clay to clay			18	0.20	0.17	0 - 1	0 - 1
13.5	2.5	2.7	0.1	2.7		17238	V soft, Sensitive fine grained soil			18	0.19	0.12	0 - 1	0 - 1
14.0	2.1	2.3	0.1	2.2		17881	V soft, Sensitive fine grained soil			18	0.14	0.10	0 - 1	0 - 1
14.5	2.3	2.5	0.1	3.5		18647	V soft, Clay			18	0.16	0.16	0 - 1	0 - 1
15.0	2.2	2.4	0.1	4.2		18862	V soft, Clay			18	0.15	0.19	0 - 1	0 - 1
15.5	2.1	2.2	0.0	2.2		18055	V soft, Sensitive fine grained soil			25	0.10	0.09	0 - 1	0 - 1
16.0	2.3	2.4	0.1	2.8		18870	V soft, Sensitive fine grained soil			18	0.14	0.13	0 - 1	0 - 1
16.5	2.7	2.9	0.1	5.0		20725	Soft, Clay			10	0.35	0.26	1 - 3	1 - 3

NOTES:

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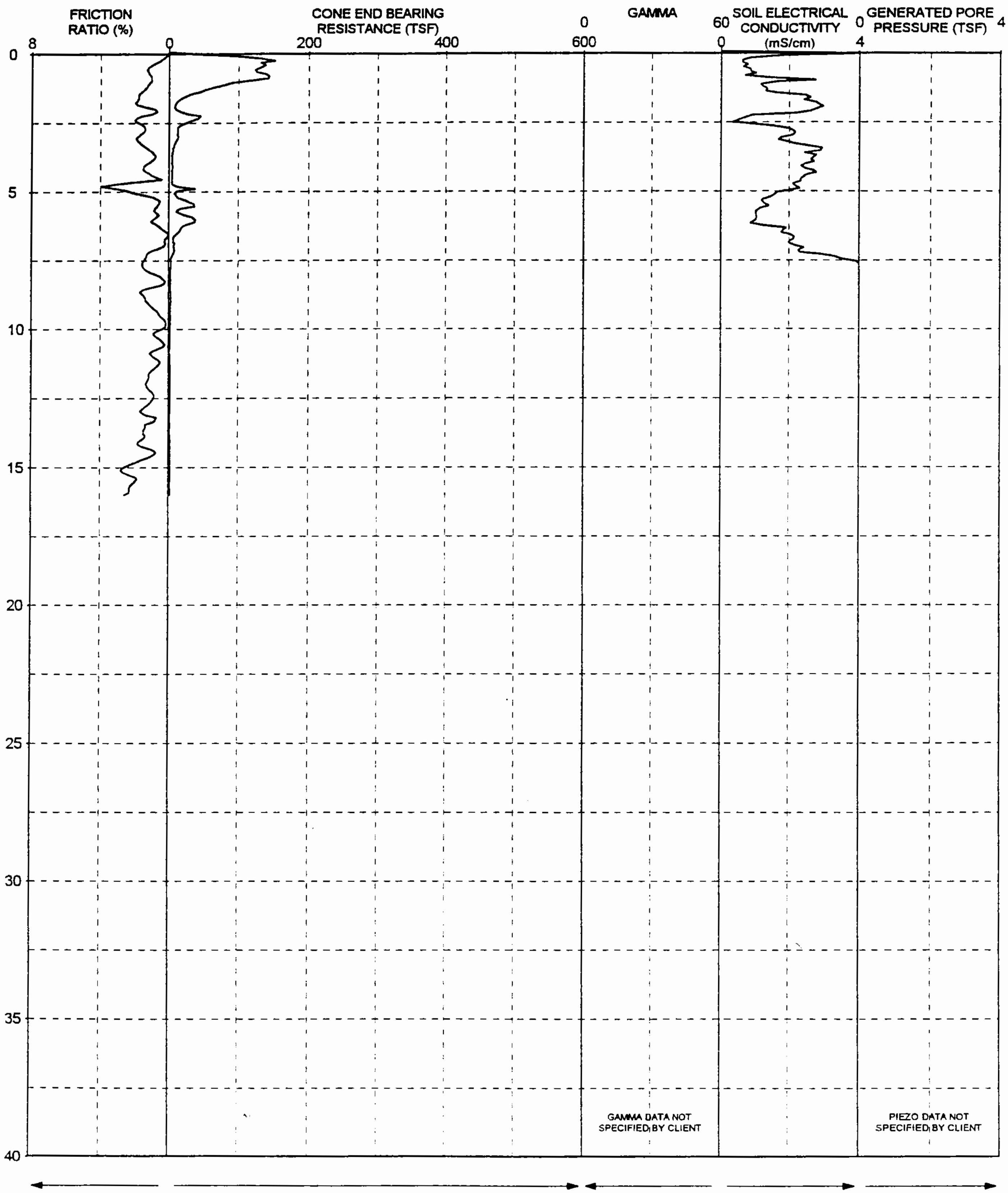
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/20/96
SOUNDING NUMBER: CP040

STRATIGRAPHICS
JOB NO: 96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp040

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	100.0	161.1	1.3	1.0		1963	Dense, Sand to silty sand	40-42	60-80				29 - 37	46 - 60
1.5	28.8	43.8	1.1	1.7		2069	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 10	12 - 15
2.0	10.3	15.1	0.2	0.9		2837	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
2.5	25.1	35.4	0.5	1.8		389	Med dense, Silty sand to sandy silt	27-31	40-60				7 - 8	10 - 12
3.0	13.4	18.4	0.3	1.8		1990	Stiff, Sandy silt to clayey silt			15	1.77	0.55	3 - 4	4 - 6
3.5	5.9	7.9	0.1	1.1		2922	Stiff, Sandy silt to clayey silt			10	1.14	0.21	1 - 2	1 - 3
4.0	5.3	6.9	0.1	1.3		2514	Stiff, Sandy silt to clayey silt			10	1.01	0.13	1 - 2	1 - 3
4.5	4.6	5.9	0.1	0.6		2409	Soft, Sensitive fine grained soil			18	0.48	0.17	1 - 2	1 - 3
5.0	11.1	14.0	0.5	2.3		1897	Stiff, Clayey silt to silty clay			15	1.44	0.94	2 - 3	3 - 4
5.5	37.1	46.1	0.1	0.6		1356	Loose, Sand to silty sand	37-40	20-40				6 - 8	7 - 10
6.0	38.2	46.7	0.3	0.9		1044	Loose, Silty sand to sandy silt	37-40	20-40				8 - 10	10 - 12
6.5	13.0	15.7	0.0	0.1		1810	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
7.0	7.6	9.0	0.0	0.3		2264	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
7.5	3.4	4.0	0.1	1.4		3766	Soft, Sensitive fine grained soil			18	0.33	0.18	1 - 3	1 - 3
8.0	2.6	3.0	0.0	0.8		4960	V soft, Sensitive fine grained soil			25	0.17	0.04	0 - 1	0 - 1
8.5	2.8	3.2	0.0	1.1		5636	V soft, Sensitive fine grained soil			18	0.25	0.07	0 - 1	0 - 1
9.0	3.2	3.7	0.0	1.3		6043	Soft, Sensitive fine grained soil			18	0.30	0.08	0 - 1	0 - 1
9.5	2.4	2.7	0.0	0.5		6783	V soft, Sensitive fine grained soil			25	0.15	0.03	0 - 1	0 - 1
10.0	2.5	2.8	0.0	0.4		7093	V soft, Sensitive fine grained soil			25	0.15	0.01	0 - 1	0 - 1
10.5	1.8	2.0	0.0	0.3		9034	V soft, Sensitive fine grained soil			25	0.09	0.01	0 - 1	0 - 1
11.0	1.9	2.1	0.0	0.9		9693	V soft, Sensitive fine grained soil			25	0.10	0.04	0 - 1	0 - 1
11.5	2.4	2.6	0.0	1.0		9896	V soft, Sensitive fine grained soil			25	0.14	0.04	0 - 1	0 - 1
12.0	2.4	2.7	0.0	1.3		10210	V soft, Sensitive fine grained soil			25	0.14	0.06	0 - 1	0 - 1
12.5	2.3	2.5	0.0	0.9		10764	V soft, Sensitive fine grained soil			25	0.13	0.04	0 - 1	0 - 1
13.0	2.3	2.5	0.0	1.6		11054	V soft, Sensitive fine grained soil			25	0.13	0.08	0 - 1	0 - 1
13.5	2.2	2.4	0.0	1.3		13299	V soft, Sensitive fine grained soil			25	0.11	0.06	0 - 1	0 - 1
14.0	2.4	2.5	0.0	1.6		14482	V soft, Sensitive fine grained soil			25	0.12	0.08	0 - 1	0 - 1
14.5	2.5	2.6	0.0	0.8		14711	V soft, Sensitive fine grained soil			25	0.13	0.03	0 - 1	0 - 1
15.0	2.5	2.6	0.1	2.6		14937	V soft, Sensitive fine grained soil			18	0.17	0.13	0 - 1	0 - 1
15.5	2.4	2.5	0.0	1.9		15280	V soft, Sensitive fine grained soil			18	0.16	0.09	0 - 1	0 - 1
16.0	2.6	2.7	0.1	1.6		15535	V soft, Sensitive fine grained soil			18	0.18	0.11	0 - 1	0 - 1

NOTES:

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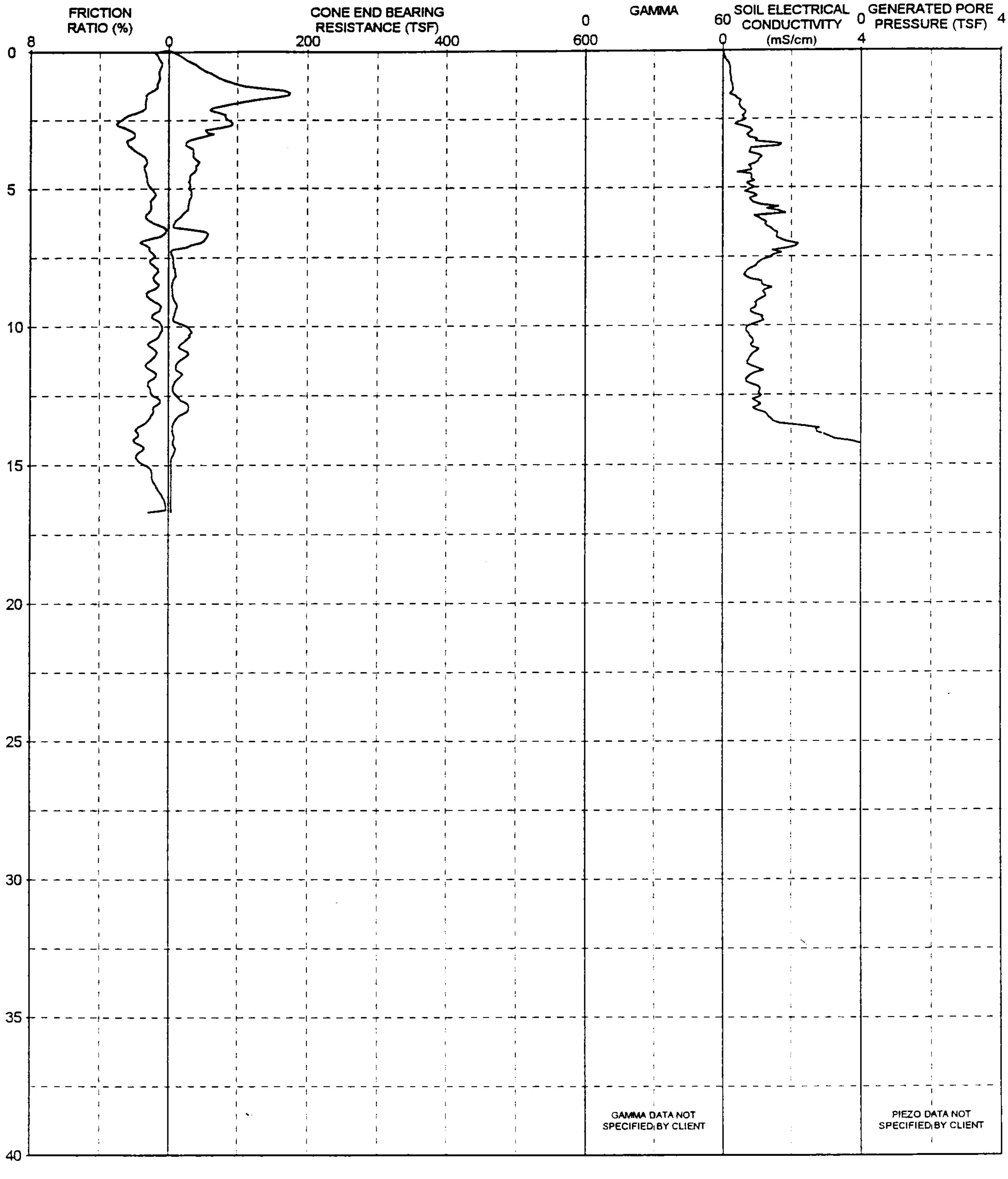
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP042

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp042

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	76.6	123.4	0.4	0.5		228	Med dense, Sand to silty sand	40-42	40-60				19 - 20	30 - 33
1.5	172.8	263.2	1.6	1.1		286	Dense, Sand to silty sand	42-46	60-80				47 - 65	72 - 99
2.0	74.5	108.8	1.7	1.3		476	Med dense, Sand to silty sand	40-42	40-60				23 - 27	33 - 40
2.5	87.2	123.1	2.1	2.8		624	V dense, Gr si sand to cl gr sand	36-37	80-100				42 - 51	60 - 72
3.0	63.5	87.2	1.5	2.0		796	Dense, Silty sand to sandy silt	37-40	60-80				24 - 29	33 - 40
3.5	32.0	42.8	0.9	2.2		1589	Med dense, Silty sand to sandy silt	27-31	40-60				11 - 13	15 - 17
4.0	43.3	56.7	0.5	1.3		1051	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 13	15 - 17
4.5	33.6	43.1	0.5	1.3		711	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 9	10 - 12
5.0	30.9	39.0	0.3	1.0		927	Loose, Silty sand to sandy silt	36-37	20-40				6 - 8	7 - 10
5.5	30.4	37.8	0.3	1.0		841	Loose, Silty sand to sandy silt	36-37	20-40				6 - 8	7 - 10
6.0	19.4	23.8	0.4	1.3		1222	Loose, Silty sand to sandy silt	27-31	20-40				3 - 5	4 - 6
6.5	33.9	40.8	0.0	0.1		1413	Loose, Sand to silty sand	37-40	20-40				5 - 6	6 - 7
7.0	43.4	51.6	0.8	1.6		1972	Med dense, Silty sand to sandy silt	36-37	40-60				13 - 14	15 - 17
7.5	6.9	8.2	0.1	0.9		1421	Stiff, Sandy silt to clayey silt			10	1.30	0.23	1 - 3	1 - 3
8.0	10.2	11.9	0.0	0.6		729	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
8.5	5.9	6.8	0.0	0.6		1140	Stiff, Sandy silt to clayey silt			10	1.08	0.08	1 - 3	1 - 3
9.0	7.9	9.0	0.1	1.0		1159	Stiff, Sandy silt to clayey silt			10	1.48	0.23	1 - 3	1 - 3
9.5	10.1	11.3	0.1	0.7		820	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
10.0	27.6	30.6	0.1	0.4		797	Loose, Sand to silty sand	36-37	20-40				4 - 5	4 - 6
10.5	26.0	28.7	0.3	0.9		882	Loose, Silty sand to sandy silt	36-37	20-40				4 - 5	4 - 6
11.0	30.0	33.0	0.2	0.7		901	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
11.5	11.3	12.3	0.2	1.2		920	Stiff, Sandy silt to clayey silt			15	1.41	0.45	1 - 3	1 - 3
12.0	10.3	11.2	0.2	1.2		680	Stiff, Sandy silt to clayey silt			15	1.28	0.36	1 - 3	1 - 3
12.5	12.8	13.9	0.2	0.9		1114	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
13.0	29.6	32.0	0.2	0.9		912	Loose, Silty sand to sandy silt	36-37	20-40				6 - 6	6 - 7
13.5	8.0	8.7	0.2	1.4		1553	Stiff, Sandy silt to clayey silt			10	1.44	0.45	1 - 3	1 - 3
14.0	8.6	9.2	0.2	1.9		3105	Stiff, Clayey silt to silty clay			10	1.55	0.32	1 - 3	1 - 3
14.5	10.0	10.7	0.1	1.6		4764	Stiff, Sandy silt to clayey silt			15	1.22	0.29	1 - 3	1 - 3
15.0	4.2	4.4	0.1	1.4		9626	Soft, Clayey silt to silty clay			18	0.36	0.17	1 - 3	1 - 3
15.5	4.1	4.3	0.0	0.9		14917	Soft, Sensitive fine grained soil			18	0.35	0.08	1 - 3	1 - 3
16.0	4.0	4.2	0.0	0.5		16905	Soft, Sensitive fine grained soil			18	0.34	0.04	0 - 1	0 - 1
16.5	4.1	4.3	0.0	0.2		18325	Soft, Sensitive fine grained soil			18	0.34	0.01	0 - 1	0 - 1

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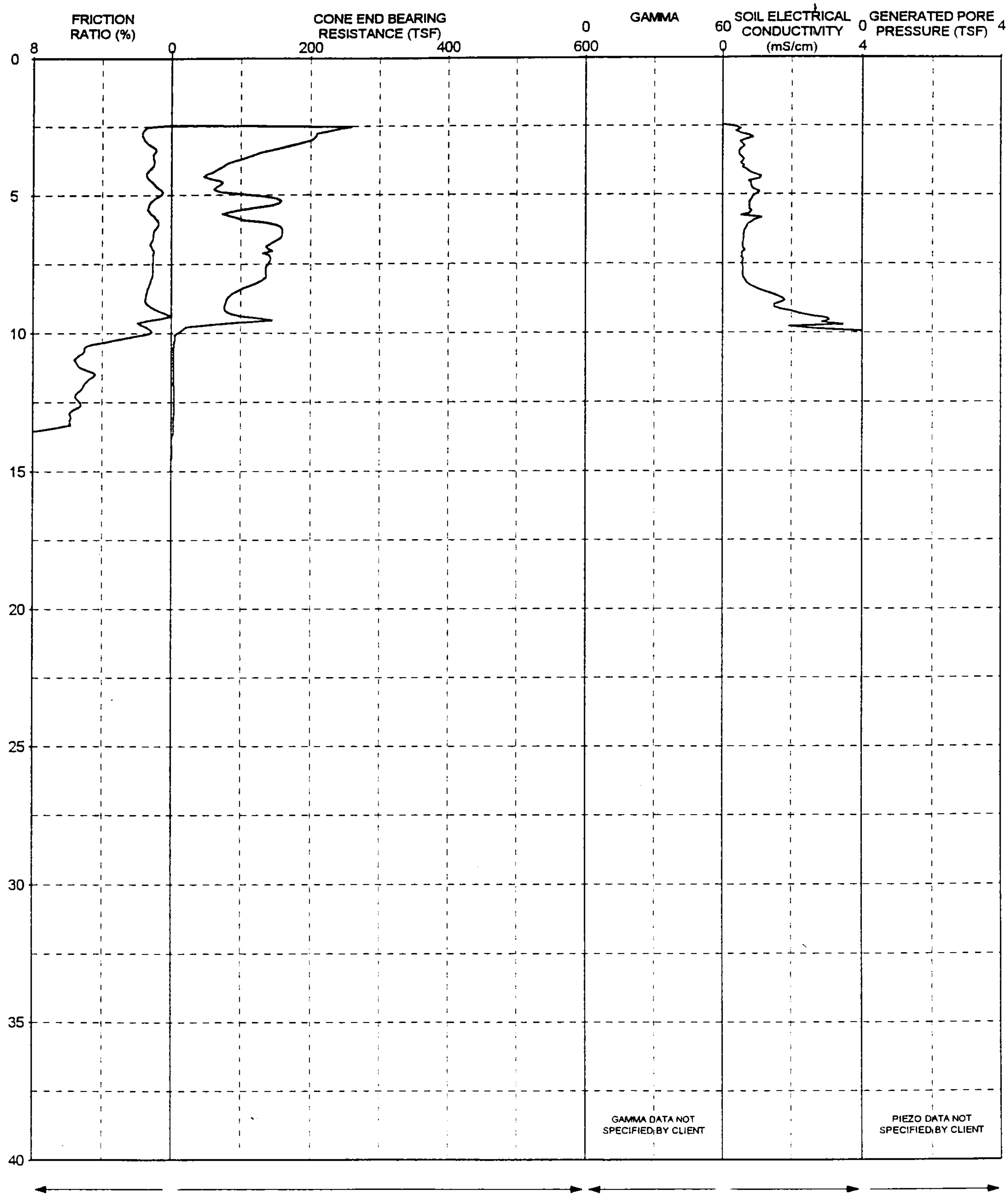
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base | DATE: 09/22/96
PROJECT NUMBER: 96-110-230 | SOUNDING NUMBER: CP043

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp043

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.00	PREPUNCH													
1.50	PREPUNCH													
2.00	PREPUNCH													
2.5	134.0	189.1	2.1	0.7		191	Dense, Sand to silty sand	42-46	60-80				33 - 42	46 - 60
3.0	201.9	277.1	3.5	1.6		679	V dense, Sand to silty sand	42-46	80-100				+ 73	+ 100
3.5	125.6	168.2	1.6	1.0		478	Dense, Sand to silty sand	42-46	60-80				34 - 45	46 - 60
4.0	73.4	96.2	1.0	1.1		599	Med dense, Sand to silty sand	40-42	40-60				23 - 25	30 - 33
4.5	70.4	90.4	0.8	1.2		797	Med dense, Sand to silty sand	37-40	40-60				18 - 23	23 - 30
5.0	109.1	137.6	0.8	0.6		976	Med dense, Sand to silty sand	40-42	40-60				26 - 32	33 - 40
5.5	115.2	143.0	1.9	1.4		773	Dense, Sand to silty sand	40-42	60-80				37 - 48	46 - 60
6.0	130.8	159.9	1.1	0.7		847	Med dense, Sand to silty sand	42-46	40-60				33 - 38	40 - 46
6.5	159.1	191.6	1.6	1.1		610	Dense, Sand to silty sand	42-46	60-80				50 - 60	60 - 72
7.0	142.8	169.7	1.5	1.1		636	Dense, Sand to silty sand	42-46	60-80				39 - 50	46 - 60
7.5	139.9	164.1	1.5	1.1		575	Dense, Sand to silty sand	40-42	60-80				39 - 51	46 - 60
8.0	135.7	157.3	1.5	1.1		605	Dense, Sand to silty sand	40-42	60-80				40 - 52	46 - 60
8.5	94.6	108.4	1.7	1.4		1153	Dense, Sand to silty sand	40-42	60-80				29 - 35	33 - 40
9.0	77.6	87.9	1.3	1.4		1495	Med dense, Silty sand to sandy silt	37-40	40-60				26 - 29	30 - 33
9.5	134.5	151.0	0.5	0.8		3039	Med dense, Sand to silty sand	40-42	40-60				36 - 41	40 - 46
10.0	9.6	10.7	0.6	1.3		5719	Stiff, Sandy silt to clayey silt			15	1.20	1.17	1 - 3	1 - 3
10.5	3.8	4.2	0.3	5.0		12492	Soft, Clay			18	0.35	0.53	1 - 3	1 - 3
11.0	3.4	3.8	0.2	5.6		13228	Firm, Clay			10	0.56	0.39	1 - 3	1 - 3
11.5	3.3	3.6	0.1	4.4		13757	Soft, Clay			18	0.29	0.30	1 - 3	1 - 3
12.0	3.7	4.0	0.2	5.2		13891	Firm, Clay			10	0.59	0.38	1 - 3	1 - 3
12.5	3.7	4.0	0.2	5.3		13997	Firm, Clay			10	0.59	0.40	1 - 3	1 - 3
13.0	3.7	4.1	0.2	5.8		14170	Firm, Clay			10	0.59	0.44	1 - 3	1 - 3
13.5	3.4	3.7	0.3	7.3		14206	Firm, Clay to organic soil			10	0.52	0.56	1 - 3	1 - 3
14.0	0.9	1.0	0.3	15.0		15673	V soft, Organics to peat			10	0.02	0.53	0 - 1	0 - 1
14.5	1.3	1.4	0.3	26.6		16676	V soft, Silty clay to clay **			10	0.08	0.56	+ 94	+ 100

NOTES:
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Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP045

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp045

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	38.4	61.9	0.6	1.5		90	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 12	17 - 20
1.5	37.9	57.8	0.3	0.4		201	Loose, Sand to silty sand	37-40	20-40				7 - 8	10 - 12
2.0	105.4	153.9	0.3	0.3		222	Med dense, Sand to silty sand	42-46	40-60				23 - 27	33 - 40
2.5	87.2	123.1	0.8	0.8		346	Med dense, Sand to silty sand	40-42	40-60				23 - 28	33 - 40
3.0	67.4	92.4	0.6	0.8		338	Med dense, Sand to silty sand	40-42	40-60				17 - 22	23 - 30
3.5	46.3	62.0	0.4	0.7		351	Loose, Sand to silty sand	37-40	20-40				9 - 11	12 - 15
4.0	36.0	47.2	0.2	0.4		428	Loose, Sand to silty sand	37-40	20-40				5 - 8	7 - 10
4.5	72.7	93.4	0.4	0.5		378	Med dense, Sand to silty sand	40-42	40-60				16 - 18	20 - 23
5.0	96.7	122.0	0.3	0.3		523	Med dense, Sand to silty sand	40-42	40-60				18 - 24	23 - 30
5.5	56.5	70.0	0.5	0.6		659	Loose, Sand to silty sand	40-42	20-40				12 - 14	15 - 17
6.0	49.3	60.2	0.3	0.5		959	Loose, Sand to silty sand	37-40	20-40				8 - 10	10 - 12
6.5	26.9	32.4	0.1	0.4		1128	Loose, Sand to silty sand	36-37	20-40				3 - 5	4 - 6
7.0	17.7	21.0	0.1	0.4		1430	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
7.5	12.7	14.9	0.0	0.2		1869	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
8.0	27.5	31.8	0.1	0.4		776	Loose, Sand to silty sand	36-37	20-40				3 - 5	4 - 6
8.5	23.2	26.6	0.2	0.7		688	Loose, Silty sand to sandy silt	31-36	20-40				3 - 5	4 - 6
9.0	21.4	24.2	0.2	0.7		724	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
9.5	30.3	34.0	0.2	0.7		620	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
10.0	22.3	24.8	0.2	0.6		715	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
10.5	21.4	23.7	0.1	0.4		766	V loose, Silty sand to sandy silt	31-36	0-20				3 - 4	3 - 4
11.0	33.5	36.8	0.4	1.2		703	Loose, Silty sand to sandy silt	36-37	20-40				6 - 9	7 - 10
11.5	20.1	22.0	0.2	0.8		554	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
12.0	14.3	15.6	0.2	0.9		708	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
12.5	12.0	13.1	0.1	0.6		905	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
13.0	18.5	20.0	0.1	0.5		1153	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
13.5	28.0	30.2	0.2	0.6		1480	Loose, Silty sand to sandy silt	36-37	20-40				4 - 6	4 - 6
14.0	30.8	33.0	0.2	0.7		2268	Loose, Silty sand to sandy silt	36-37	20-40				6 - 7	6 - 7
14.5	10.8	11.5	0.3	1.6		2781	Stiff, Sandy silt to clayey silt			15	1.32	0.69	1 - 3	1 - 3
15.0	5.7	6.0	0.2	2.3		4830	Firm, Clayey silt to silty clay			10	0.96	0.31	1 - 3	1 - 3
15.5	4.3	4.6	0.1	2.9		11984	Soft, Silty clay to clay			18	0.38	0.29	1 - 3	1 - 3
16.0	4.7	4.9	0.2	3.5		12873	Soft, Silty clay to clay			18	0.41	0.34	1 - 3	1 - 3
16.5	4.9	5.1	0.2	3.1		12835	Soft, Silty clay to clay			18	0.43	0.32	1 - 3	1 - 3
17.0	5.3	5.6	0.3	4.7		12839	Firm, Clay			10	0.86	0.50	1 - 3	1 - 3
17.5	3.6	3.8	0.2	4.4		14736	Soft, Clay			18	0.28	0.36	1 - 3	1 - 3
18.0	4.0	4.1	0.2	4.6		14755	Soft, Clay			18	0.32	0.35	1 - 3	1 - 3
18.5	3.8	3.9	0.2	4.6		14293	Soft, Clay			18	0.29	0.37	1 - 3	1 - 3
19.0	4.0	4.1	0.2	3.5		14452	Soft, Silty clay to clay			18	0.32	0.36	1 - 3	1 - 3
19.5	11.0	11.4	0.2	1.4		10247	Stiff, Sandy silt to clayey silt			15	1.32	0.41	1 - 3	1 - 3
20.0	11.8	12.1	0.3	2.4		10020	Stiff, Clayey silt to silty clay			15	1.41	0.66	3 - 4	3 - 4
20.5	3.5	3.5	0.1	1.9		12720	V soft, Sensitive fine grained soil			18	0.25	0.24	0 - 1	0 - 1

STRATIGRAPHICS
JOB NO: 96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp045

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
21.0	7.5	7.6	0.1	1.7		10384	Stiff, Clayey silt to silty clay			10	1.25	0.26	1 - 3	1 - 3
21.5	5.9	6.0	0.1	1.3		10197	Firm, Clayey silt to silty clay			10	0.92	0.20	1 - 3	1 - 3
22.0	4.5	4.6	0.1	2.0		10718	Soft, Clayey silt to silty clay			18	0.35	0.21	1 - 3	1 - 3
22.5	6.2	6.3	0.1	2.2		10798	Firm, Clayey silt to silty clay			10	0.98	0.24	1 - 3	1 - 3
23.0	3.8	3.8	0.1	1.9		10744	Soft, Clayey silt to silty clay			18	0.27	0.22	1 - 3	1 - 3
23.5	11.4	11.4	0.2	2.0		8855	Stiff, Clayey silt to silty clay			15	1.33	0.39	1 - 3	1 - 3
24.0	8.1	8.1	0.2	2.1		9412	Stiff, Clayey silt to silty clay			10	1.34	0.40	1 - 3	1 - 3
24.5	10.4	10.4	0.2	1.6		8975	Stiff, Sandy silt to clayey silt			15	1.19	0.40	1 - 3	1 - 3

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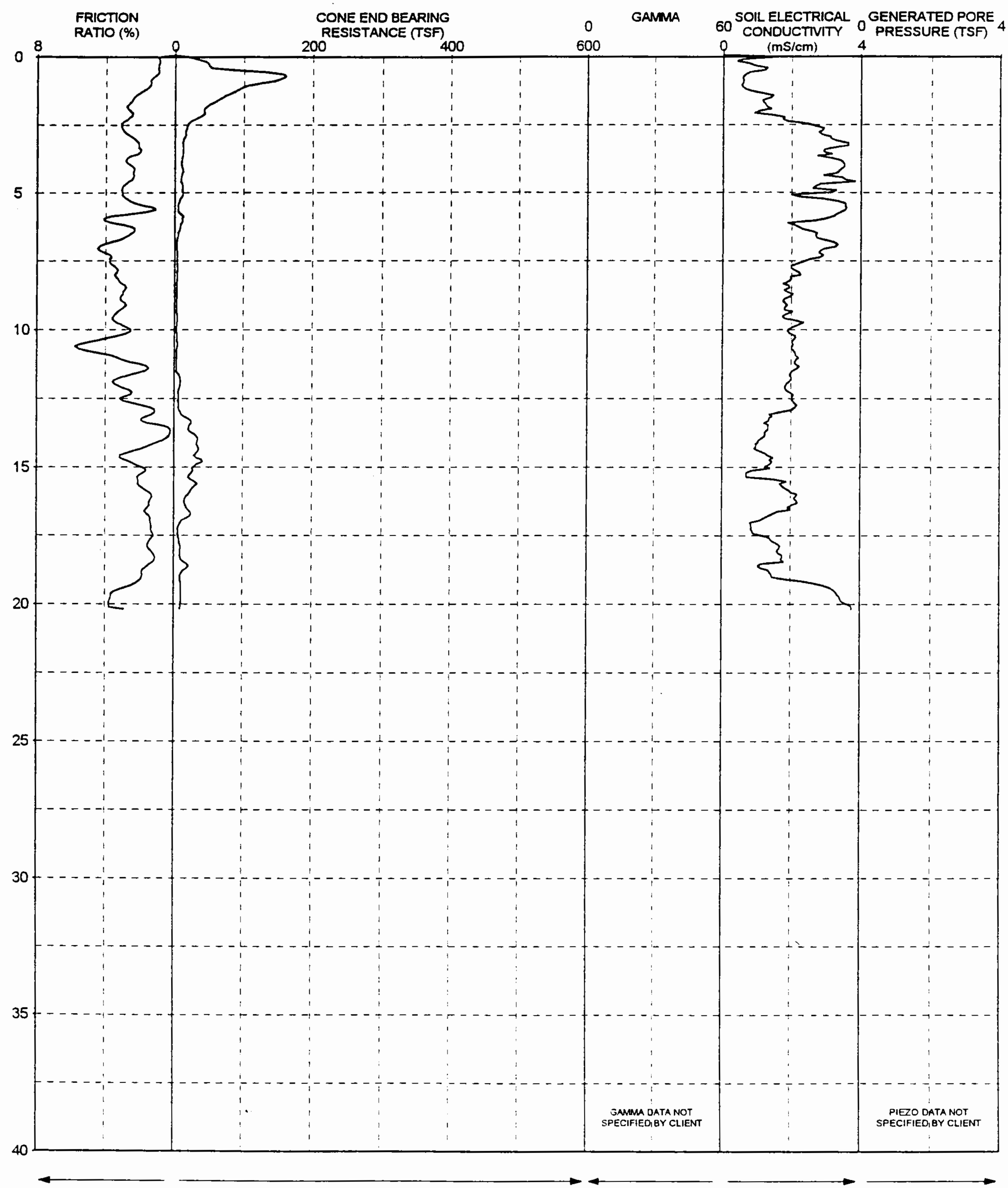
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP046

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp046

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	112.3	181.0	1.8	1.3		527	Dense, Sand to silty sand	40-42	60-80				37 - 45	60 - 72
1.5	69.4	105.8	2.1	2.4		1410	Dense, Silty sand to sandy silt	37-40	60-80				30 - 39	46 - 60
2.0	42.6	62.3	1.3	2.6		1055	V stiff, Sandy silt to sandy clay			25	3.40	2.63	21 - 23	30 - 33
2.5	19.6	27.7	1.0	3.1		2538	Stiff, Sandy clay to silty clay *			20	1.95	2.05	8 - 11	12 - 15
3.0	13.9	19.1	0.4	2.4		3144	Stiff, Sandy silt to sandy clay			15	1.83	0.81	4 - 5	6 - 7
3.5	12.1	16.2	0.2	2.0		2939	Stiff, Sandy silt to clayey silt			15	1.58	0.41	2 - 3	3 - 4
4.0	10.2	13.3	0.3	2.5		3529	Stiff, Clayey silt to silty clay			15	1.33	0.58	2 - 3	3 - 4
4.5	9.7	12.4	0.3	2.5		3533	Stiff, Clayey silt to silty clay			15	1.25	0.58	2 - 3	3 - 4
5.0	11.8	14.8	0.3	3.0		3147	Stiff, Sandy clay to silty clay *			15	1.53	0.69	3 - 5	4 - 6
5.5	5.4	6.7	0.2	1.7		3572	Stiff, Clayey silt to silty clay			10	1.02	0.31	1 - 2	1 - 3
6.0	11.6	14.2	0.4	4.1		2814	Stiff, Silty clay to clay *			15	1.50	0.79	5 - 6	6 - 7
6.5	5.7	6.9	0.2	2.5		2735	Stiff, Clayey silt to silty clay			10	1.07	0.44	1 - 2	1 - 3
7.0	3.6	4.3	0.2	4.4		3217	Soft, Clay			18	0.35	0.41	1 - 3	1 - 3
7.5	4.1	4.8	0.2	3.8		2422	Soft, Silty clay to clay			18	0.41	0.37	1 - 3	1 - 3
8.0	4.2	4.8	0.2	3.5		2260	Soft, Silty clay to clay			18	0.41	0.34	1 - 3	1 - 3
8.5	3.1	3.6	0.1	2.8		1917	Soft, Silty clay to clay			18	0.29	0.22	1 - 3	1 - 3
9.0	3.5	4.0	0.1	3.0		1787	Soft, Silty clay to clay			18	0.33	0.23	1 - 3	1 - 3
9.5	3.8	4.3	0.1	3.5		1770	Soft, Silty clay to clay			18	0.36	0.29	1 - 3	1 - 3
10.0	3.6	4.0	0.1	2.5		1928	Soft, Silty clay to clay			18	0.34	0.22	1 - 3	1 - 3
10.5	4.9	5.4	0.2	5.3		2040	Firm, Clay			12	0.70	0.48	1 - 3	1 - 3
11.0	3.2	3.6	0.1	3.4		2189	Soft, Silty clay to clay			18	0.29	0.28	1 - 3	1 - 3
11.5	3.3	3.6	0.1	1.7		2049	Soft, Sensitive fine grained soil			18	0.29	0.27	0 - 1	0 - 1
12.0	8.9	9.7	0.3	3.4		1853	Stiff, Silty clay to clay			15	1.08	0.56	3 - 4	3 - 4
12.5	6.5	7.1	0.3	3.1		2028	Stiff, Silty clay to clay			10	1.16	0.50	1 - 3	1 - 3
13.0	9.3	10.1	0.2	1.1		1695	Stiff, Sandy silt to clayey silt			10	1.71	0.37	1 - 3	1 - 3
13.5	22.6	24.4	0.1	0.7		1339	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
14.0	34.7	37.3	0.2	0.6		1100	Loose, Sand to silty sand	36-37	20-40				6 - 7	6 - 7
14.5	32.8	35.0	1.0	2.8		1235	V stiff, Sandy silt to sandy clay			20	3.19	1.98	14 - 16	15 - 17
15.0	28.8	30.6	0.7	1.9		1297	Med dense, Silty sand to sandy silt	27-31	40-60				7 - 9	7 - 10
15.5	28.5	30.2	0.6	2.1		1733	V stiff, Sandy silt to sandy clay			20	2.75	1.16	7 - 9	7 - 10
16.0	21.2	22.4	0.4	1.3		2180	Loose, Silty sand to sandy silt	27-31	20-40				4 - 6	4 - 6
16.5	19.2	20.2	0.3	1.6		1924	Loose, Silty sand to sandy silt	27-31	20-40				4 - 6	4 - 6
17.0	10.6	11.1	0.3	1.4		966	Stiff, Sandy silt to clayey silt			15	1.28	0.55	1 - 3	1 - 3
17.5	6.7	7.0	0.1	1.2		1176	Stiff, Sandy silt to clayey silt			10	1.13	0.20	1 - 3	1 - 3
18.0	9.8	10.2	0.2	1.4		1651	Stiff, Sandy silt to clayey silt			15	1.16	0.32	1 - 3	1 - 3
18.5	17.2	17.8	0.2	1.3		1479	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	3 - 4
19.0	9.2	9.5	0.3	1.9		1459	Stiff, Clayey silt to silty clay			10	1.61	0.58	1 - 3	1 - 3
19.5	10.5	10.8	0.4	3.3		3249	Stiff, Silty clay to clay			15	1.24	0.71	3 - 4	3 - 4
20.0	10.4	10.7	0.4	3.8		3640	Stiff, Silty clay to clay *			15	1.22	0.83	4 - 6	4 - 6

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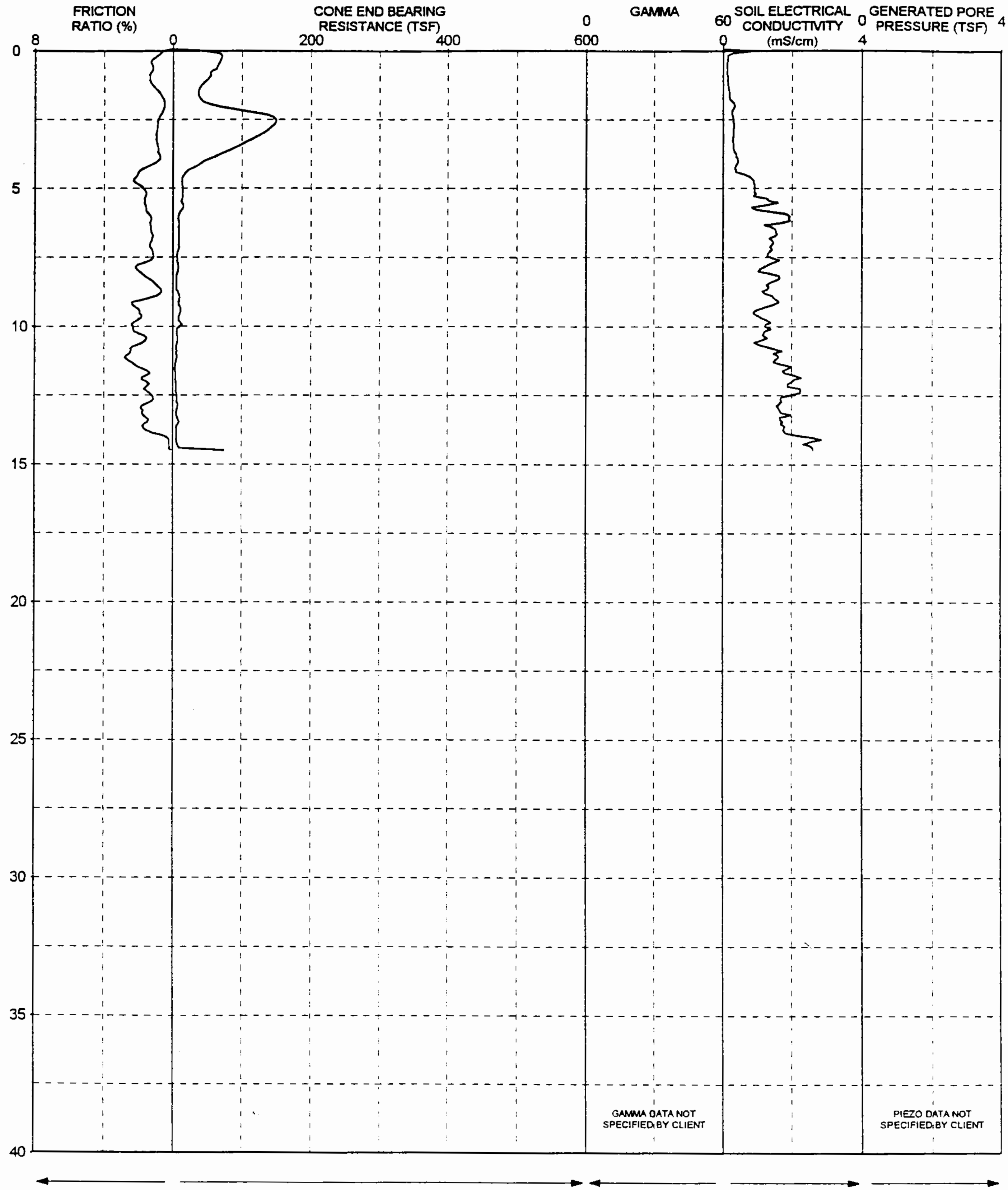
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP047

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp047

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	52.8	85.0	0.8	1.4		134	Med dense, Silty sand to sandy silt	37-40	40-60				14 - 19	23 - 30
1.5	37.8	57.5	0.4	0.8		190	Loose, Sand to silty sand	37-40	20-40				8 - 10	12 - 15
2.0	61.6	89.9	0.6	0.5		341	Med dense, Sand to silty sand	40-42	40-60				14 - 16	20 - 23
2.5	149.0	210.4	1.2	0.9		300	Dense, Sand to silty sand	42-46	60-80				42 - 51	60 - 72
3.0	131.0	179.7	1.4	1.0		303	Dense, Sand to silty sand	42-46	60-80				34 - 44	46 - 60
3.5	93.3	124.9	1.0	0.9		311	Med dense, Sand to silty sand	40-42	40-60				25 - 30	33 - 40
4.0	48.1	63.0	0.6	0.9		439	Med dense, Sand to silty sand	37-40	40-60				11 - 13	15 - 17
4.5	16.4	21.0	0.6	2.0		604	V stiff, Sandy silt to sandy clay			15	2.15	1.24	5 - 5	6 - 7
5.0	14.0	17.6	0.2	1.8		921	Stiff, Sandy silt to clayey silt			15	1.82	0.50	3 - 5	4 - 6
5.5	12.9	16.1	0.2	1.7		1461	Stiff, Sandy silt to clayey silt			15	1.68	0.47	2 - 3	3 - 4
6.0	8.7	10.6	0.2	1.4		1898	Stiff, Sandy silt to clayey silt			15	1.11	0.33	1 - 2	1 - 3
6.5	8.7	10.4	0.1	1.3		1529	Stiff, Sandy silt to clayey silt			15	1.10	0.23	1 - 2	1 - 3
7.0	8.6	10.3	0.1	1.4		1456	Stiff, Sandy silt to clayey silt			15	1.09	0.23	1 - 3	1 - 3
7.5	6.4	7.5	0.1	1.2		1360	Stiff, Sandy silt to clayey silt			10	1.19	0.17	1 - 3	1 - 3
8.0	7.6	8.8	0.1	2.0		1053	Stiff, Clayey silt to silty clay			10	1.42	0.29	1 - 3	1 - 3
8.5	5.1	5.8	0.1	1.0		1271	Firm, Sandy silt to clayey silt			18	0.51	0.14	1 - 3	1 - 3
9.0	9.9	11.2	0.1	1.5		1505	Stiff, Sandy silt to clayey silt			15	1.25	0.28	1 - 3	1 - 3
9.5	10.9	12.3	0.2	1.9		899	Stiff, Sandy silt to clayey silt			15	1.38	0.40	1 - 3	1 - 3
10.0	10.8	12.0	0.2	2.3		1235	Stiff, Clayey silt to silty clay			15	1.36	0.48	3 - 4	3 - 4
10.5	6.4	7.1	0.1	1.6		1139	Stiff, Clayey silt to silty clay			10	1.15	0.22	1 - 3	1 - 3
11.0	5.5	6.1	0.2	2.6		1500	Firm, Silty clay to clay			10	0.97	0.31	1 - 3	1 - 3
11.5	3.7	4.1	0.1	1.9		1936	Soft, Clayey silt to silty clay			18	0.34	0.19	1 - 3	1 - 3
12.0	4.4	4.8	0.1	1.6		2016	Soft, Clayey silt to silty clay			18	0.41	0.15	1 - 3	1 - 3
12.5	6.0	6.5	0.1	1.3		1941	Stiff, Sandy silt to clayey silt			10	1.05	0.15	1 - 3	1 - 3
13.0	6.3	6.8	0.1	1.8		1636	Stiff, Clayey silt to silty clay			10	1.11	0.25	1 - 3	1 - 3
13.5	8.5	9.1	0.1	1.6		1708	Stiff, Sandy silt to clayey silt			10	1.53	0.22	1 - 3	1 - 3
14.0	5.2	5.6	0.0	0.5		2432	Soft, Sensitive fine grained soil			18	0.49	0.08	1 - 3	1 - 3
14.5	74.4	79.4	0.3	0.1		2615	Loose, Sand to silty sand	40-42	20-40				11 - 14	12 - 15

NOTES:

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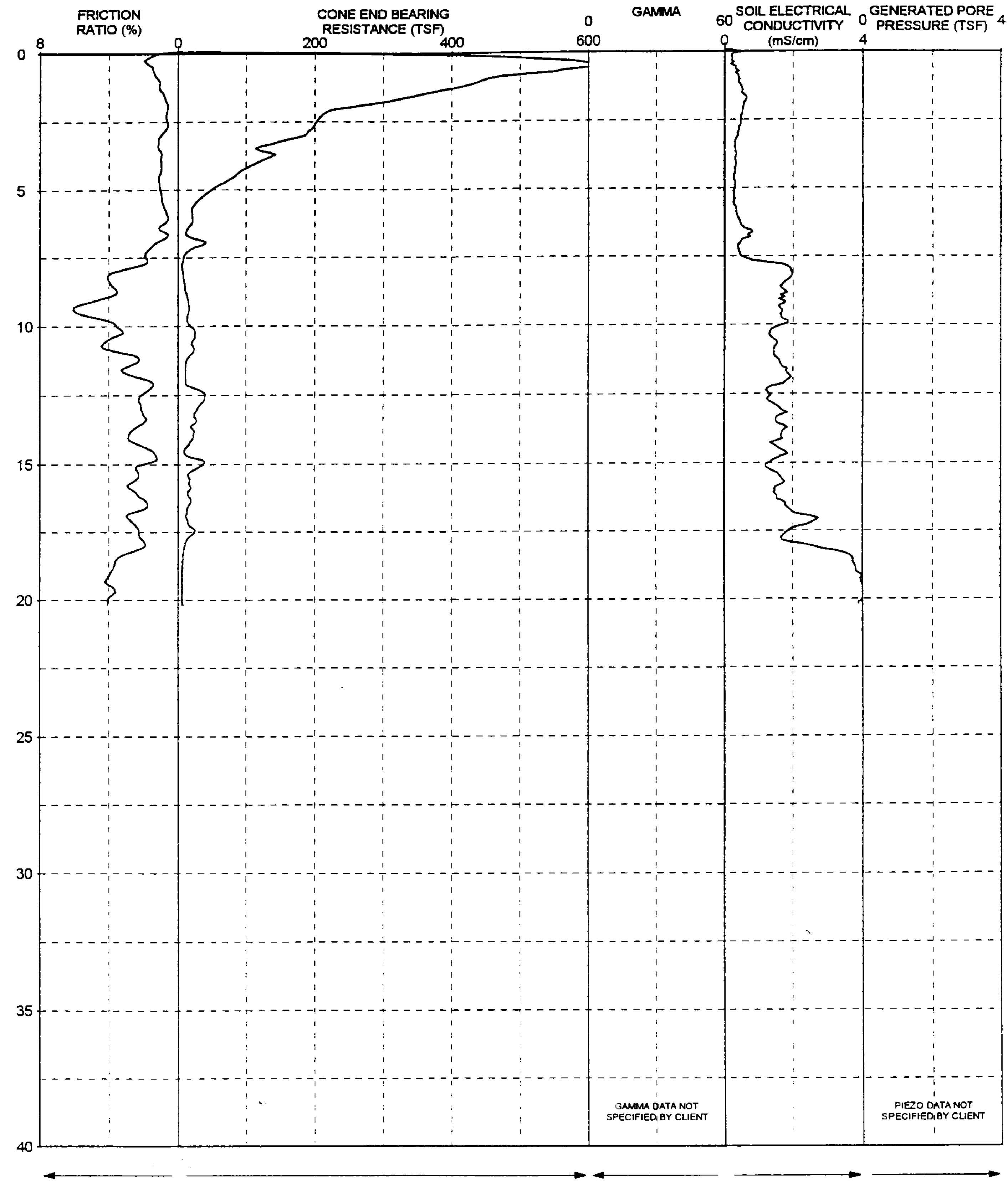
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/22/96
SOUNDING NUMBER: CP048

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp048

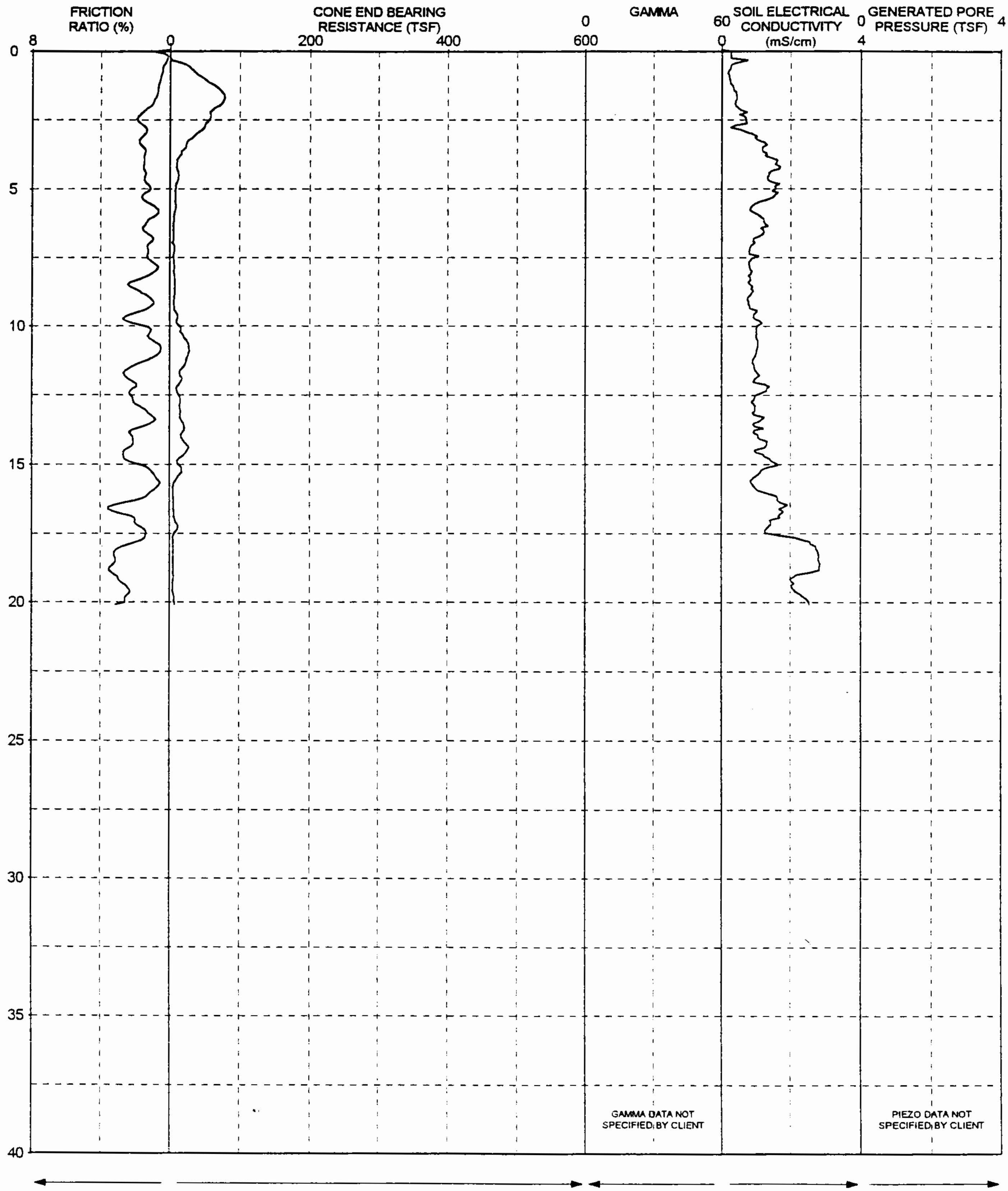
DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	448.7	722.8	5.5	1.1		448	V dense, Sa gravel to si gr sand	+46	+100				+ 62	+ 100
1.5	359.6	547.7	3.3	0.8		517	V dense, Sa gravel to gr sand	+46	80-100				+ 66	+ 100
2.0	246.6	360.2	1.8	0.6		551	Dense, Sa gravel to gr sand	+46	60-80				49 - 68	72 - 99
2.5	202.8	286.3	1.4	0.6		488	Dense, Sand to silty sand	42-46	60-80				42 - 51	60 - 72
3.0	185.1	254.0	2.0	1.0		392	Dense, Sand to silty sand	42-46	60-80				44 - 52	60 - 72
3.5	115.1	154.1	1.8	1.1		304	Dense, Sand to silty sand	40-42	60-80				34 - 45	46 - 60
4.0	117.8	154.3	1.3	1.0		324	Dense, Sand to silty sand	40-42	60-80				35 - 46	46 - 60
4.5	83.7	107.5	1.1	1.1		299	Med dense, Sand to silty sand	40-42	40-60				23 - 26	30 - 33
5.0	50.0	63.1	0.7	1.0		309	Med dense, Sand to silty sand	37-40	40-60				12 - 13	15 - 17
5.5	26.2	32.5	0.3	0.9		273	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
6.0	21.4	26.1	0.1	0.6		371	Loose, Silty sand to sandy silt	36-37	20-40				3 - 5	4 - 6
6.5	13.0	15.7	0.2	1.0		629	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
7.0	39.0	46.3	0.3	1.4		463	Med dense, Silty sand to sandy silt	36-37	40-60				10 - 13	12 - 15
7.5	8.5	10.0	0.3	1.9		483	Stiff, Clayey silt to silty clay			15	1.07	0.69	1 - 3	1 - 3
8.0	7.3	8.5	0.3	3.5		1939	Stiff, Silty clay to clay			10	1.37	0.60	3 - 3	3 - 4
8.5	10.4	11.9	0.5	3.9		1728	Stiff, Silty clay to clay *			15	1.32	0.93	3 - 5	4 - 6
9.0	14.6	16.6	0.7	4.4		1753	Stiff, Silty clay to clay *			15	1.88	1.41	6 - 9	7 - 10
9.5	15.6	17.5	0.9	5.9		1687	V stiff, Silty clay to clay *			15	2.01	1.89	13 - 15	15 - 17
10.0	18.8	20.9	0.8	3.6		1727	Stiff, Sandy clay to silty clay *			20	1.82	1.69	9 - 11	10 - 12
10.5	23.6	26.1	1.0	4.0		1393	V stiff, Silty clay to clay *			20	2.30	1.92	14 - 15	15 - 17
11.0	20.9	23.0	0.6	3.0		1437	V stiff, Sandy clay to silty clay *			20	2.03	1.29	6 - 9	7 - 10
11.5	11.6	12.7	0.4	3.1		1677	Stiff, Sandy clay to silty clay *			15	1.46	0.89	4 - 5	4 - 6
12.0	11.7	12.8	0.4	1.6		1848	Stiff, Sandy silt to clayey silt			15	1.47	0.76	1 - 3	1 - 3
12.5	40.6	44.0	0.8	2.1		1312	Med dense, Silty sand to sandy silt	27-31	40-60				14 - 16	15 - 17
13.0	29.1	31.5	0.8	2.1		1593	V stiff, Sandy silt to sandy clay			20	2.84	1.54	9 - 11	10 - 12
13.5	26.3	28.3	0.6	2.0		1502	V stiff, Sandy silt to sandy clay			20	2.55	1.14	6 - 9	7 - 10
14.0	22.8	24.5	0.6	2.9		1660	V stiff, Sandy clay to silty clay *			20	2.20	1.30	9 - 11	10 - 12
14.5	9.8	10.5	0.3	1.6		1618	Stiff, Sandy silt to clayey silt			15	1.19	0.70	1 - 3	1 - 3
15.0	37.6	40.0	0.5	2.1		1297	Med dense, Silty sand to sandy silt	27-31	40-60				11 - 14	12 - 15
15.5	16.6	17.6	0.5	2.3		1630	V stiff, Sandy silt to sandy clay			15	2.09	1.04	4 - 6	4 - 6
16.0	15.6	16.5	0.4	2.5		1470	Stiff, Sandy clay to silty clay *			15	1.96	0.83	4 - 6	4 - 6
16.5	16.3	17.2	0.3	1.8		1787	V stiff, Sandy silt to clayey silt			15	2.04	0.62	3 - 4	3 - 4
17.0	13.3	13.9	0.5	2.9		2613	Stiff, Sandy clay to silty clay *			15	1.64	1.03	4 - 6	4 - 6
17.5	25.2	26.3	0.4	2.2		1888	V stiff, Sandy silt to sandy clay			20	2.42	0.85	7 - 10	7 - 10
18.0	10.3	10.7	0.3	1.9		2373	Stiff, Clayey silt to silty clay			15	1.22	0.56	1 - 3	1 - 3
18.5	7.3	7.5	0.3	3.5		3705	Stiff, Silty clay to clay			10	1.23	0.60	1 - 3	1 - 3
19.0	6.2	6.4	0.3	3.9		3819	Stiff, Silty clay to clay			10	1.01	0.52	1 - 3	1 - 3
19.5	6.0	6.1	0.2	3.9		4028	Firm, Silty clay to clay			10	0.96	0.45	1 - 3	1 - 3
20.0	6.1	6.3	0.2	4.1		4088	Firm, Silty clay to clay			10	0.98	0.46	1 - 3	1 - 3

NOTES: * Indicates lightly overconsolidated soil
** Indicates heavily overconsolidated or cemented soil

Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base

PROJECT NUMBER: 96-110-230

DATE: 09/22/96

SOUNDING NUMBER: CP049

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp049

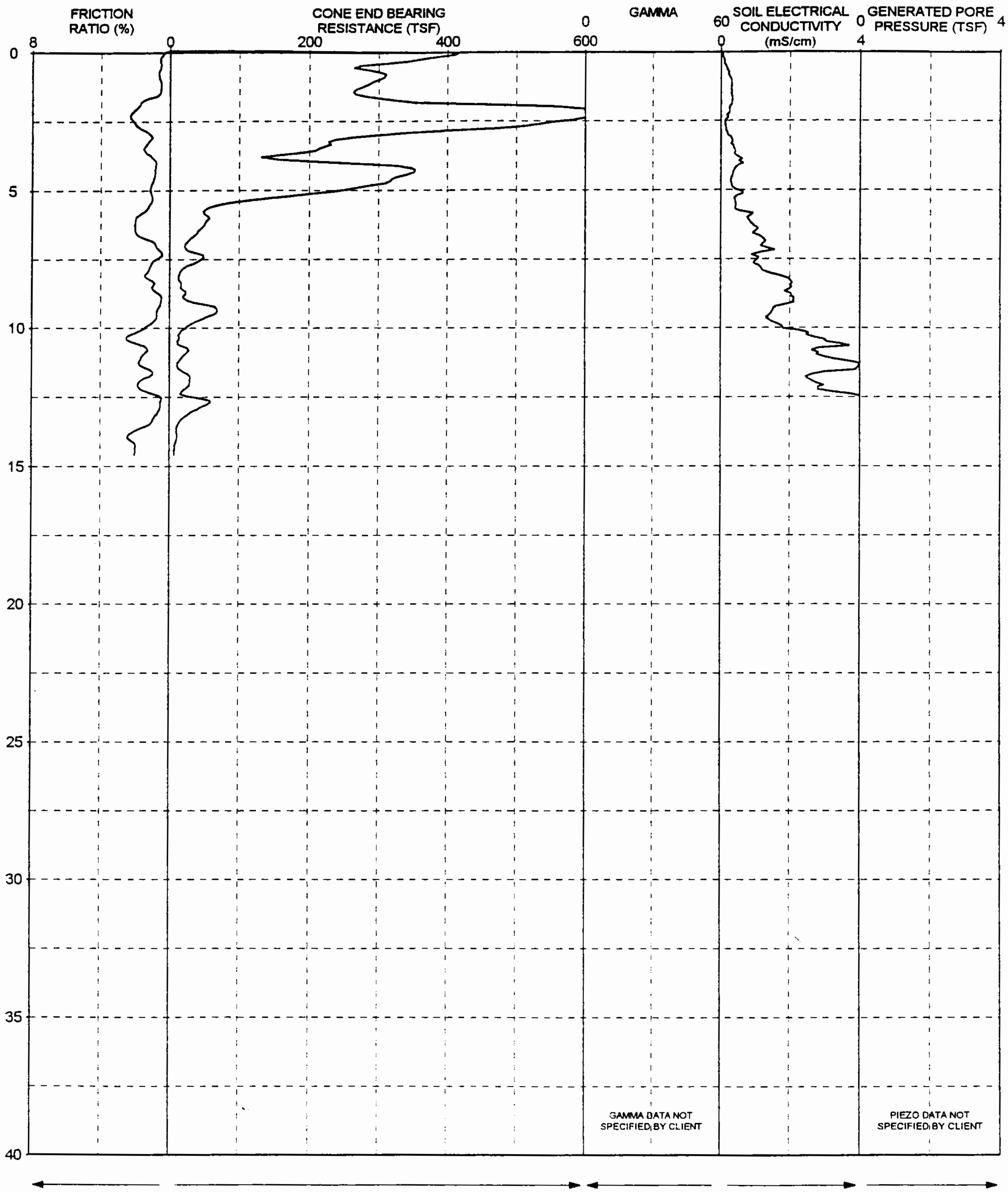
DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	49.3	79.4	0.3	0.5		234	Med dense, Sand to silty sand	40-42	40-60				11 - 12	17 - 20
1.5	74.8	113.9	0.5	0.7		409	Med dense, Sand to silty sand	40-42	40-60				20 - 22	30 - 33
2.0	69.9	102.1	0.8	1.1		416	Med dense, Sand to silty sand	40-42	40-60				21 - 23	30 - 33
2.5	57.0	80.4	1.2	1.9		708	Dense, Silty sand to sandy silt	37-40	60-80				21 - 23	30 - 33
3.0	39.3	53.9	0.7	1.4		831	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 12	15 - 17
3.5	22.9	30.7	0.4	1.5		1193	Loose, Silty sand to sandy silt	27-31	20-40				5 - 7	7 - 10
4.0	10.7	14.0	0.2	1.5		1619	Stiff, Sandy silt to clayey silt			15	1.40	0.47	1 - 2	1 - 3
4.5	12.9	16.5	0.2	1.4		1371	Loose, Silty sand to sandy silt	27-31	20-40				2 - 3	3 - 4
5.0	8.5	10.7	0.1	1.1		1571	Stiff, Sandy silt to clayey silt			15	1.09	0.21	1 - 2	1 - 3
5.5	8.4	10.4	0.1	1.3		1063	Stiff, Sandy silt to clayey silt			15	1.07	0.22	1 - 2	1 - 3
6.0	6.2	7.5	0.1	0.9		1122	Stiff, Sandy silt to clayey silt			10	1.16	0.13	1 - 2	1 - 3
6.5	5.5	6.6	0.1	1.5		1218	Stiff, Clayey silt to silty clay			10	1.02	0.17	1 - 2	1 - 3
7.0	4.9	5.8	0.1	1.2		936	Soft, Sandy silt to clayey silt			18	0.50	0.15	1 - 3	1 - 3
7.5	5.7	6.7	0.1	1.3		945	Stiff, Sandy silt to clayey silt			10	1.05	0.16	1 - 3	1 - 3
8.0	6.2	7.2	0.1	0.8		876	Stiff, Sandy silt to clayey silt			10	1.15	0.12	1 - 3	1 - 3
8.5	7.3	8.4	0.2	2.4		849	Stiff, Clayey silt to silty clay			10	1.36	0.38	1 - 3	1 - 3
9.0	6.5	7.3	0.1	1.1		754	Stiff, Sandy silt to clayey silt			10	1.18	0.16	1 - 3	1 - 3
9.5	9.1	10.2	0.2	1.9		1014	Stiff, Clayey silt to silty clay			15	1.14	0.40	1 - 3	1 - 3
10.0	13.9	15.5	0.3	1.5		1044	Stiff, Sandy silt to clayey silt			15	1.78	0.52	3 - 4	3 - 4
10.5	23.2	25.7	0.3	1.1		1044	Loose, Silty sand to sandy silt	31-36	20-40				4 - 5	4 - 6
11.0	27.6	30.4	0.2	0.6		1011	Loose, Silty sand to sandy silt	36-37	20-40				4 - 5	4 - 6
11.5	19.9	21.8	0.5	2.2		966	Stiff, Sandy silt to sandy clay			20	1.92	1.09	5 - 6	6 - 7
12.0	16.8	18.3	0.4	2.2		941	V stiff, Sandy silt to sandy clay			15	2.14	0.75	4 - 6	4 - 6
12.5	13.8	15.0	0.3	2.2		1006	Stiff, Clayey silt to silty clay			15	1.74	0.68	3 - 4	3 - 4
13.0	15.4	16.7	0.2	1.5		969	Stiff, Sandy silt to clayey silt			15	1.96	0.47	3 - 4	3 - 4
13.5	19.5	20.9	0.2	1.0		1001	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	3 - 4
14.0	16.9	18.1	0.5	2.1		1066	V stiff, Sandy silt to clayey silt			15	2.14	0.95	4 - 6	4 - 6
14.5	25.7	27.5	0.6	2.6		982	V stiff, Sandy silt to sandy clay			20	2.49	1.22	9 - 11	10 - 12
15.0	13.0	13.8	0.3	1.8		1614	Stiff, Sandy silt to clayey silt			15	1.61	0.60	3 - 4	3 - 4
15.5	10.8	11.4	0.1	0.8		924	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
16.0	5.2	5.5	0.1	1.1		1197	Soft, Sandy silt to clayey silt			18	0.47	0.14	1 - 3	1 - 3
16.5	6.1	6.4	0.2	3.3		1865	Stiff, Silty clay to clay			10	1.01	0.46	1 - 3	1 - 3
17.0	8.0	8.4	0.2	2.0		1470	Stiff, Clayey silt to silty clay			10	1.39	0.39	1 - 3	1 - 3
17.5	7.4	7.8	0.1	1.4		1314	Stiff, Sandy silt to clayey silt			10	1.28	0.28	1 - 3	1 - 3
18.0	5.1	5.3	0.2	2.8		2745	Firm, Silty clay to clay			10	0.81	0.31	1 - 3	1 - 3
18.5	5.3	5.5	0.2	3.1		2836	Firm, Silty clay to clay			10	0.84	0.34	1 - 3	1 - 3
19.0	5.7	5.9	0.2	3.1		2182	Firm, Silty clay to clay			10	0.91	0.34	1 - 3	1 - 3
19.5	4.9	5.0	0.1	2.4		2071	Soft, Silty clay to clay			18	0.41	0.29	1 - 3	1 - 3
20.0	7.4	7.6	0.2	2.6		2535	Stiff, Clayey silt to silty clay			10	1.24	0.36	1 - 3	1 - 3

NOTES:
* Indicates lightly overconsolidated soil
** Indicates heavily overconsolidated or cemented soil

Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/23/96
SOUNDING NUMBER: CP050

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp050

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	299.4	482.3	1.6	0.5		310	V dense, Sa gravel to gr sand	+46	80-100				+ 62	+ 100
1.5	265.2	403.9	2.0	0.6		313	Dense, Sa gravel to gr sand	+46	60-80				47 - 65	72 - 99
2.0	562.7	821.7	11.3	1.9		267	V dense, Sa gravel to si gr sand	42-46	+100				+ 68	+ 100
2.5	568.6	802.9	12.7	2.1		147	V dense, Sa gravel to si gr sand	42-46	+100				+ 71	+ 100
3.0	301.0	413.0	4.7	1.1		205	V dense, Sand to silty sand	42-46	80-100				+ 73	+ 100
3.5	213.5	285.8	3.7	1.5		390	V dense, Sand to silty sand	42-46	80-100				+ 75	+ 100
4.0	237.0	310.4	2.6	0.8		591	Dense, Sand to silty sand	42-46	60-80				55 - 76	72 - 99
4.5	329.7	423.5	2.8	0.9		330	V dense, Sand to silty sand	42-46	80-100				+ 78	+ 100
5.0	245.7	310.0	3.3	1.1		480	V dense, Sand to silty sand	42-46	80-100				57 - 78	72 - 99
5.5	78.9	97.9	1.7	1.1		434	Med dense, Sand to silty sand	40-42	40-60				24 - 27	30 - 33
6.0	57.8	70.6	1.2	2.0		784	Dense, Silty sand to sandy silt	36-37	60-80				19 - 25	23 - 30
6.5	41.2	49.6	1.0	2.0		994	Med dense, Silty sand to sandy silt	27-31	40-60				14 - 17	17 - 20
7.0	23.1	27.4	0.3	0.8		1189	Loose, Silty sand to sandy silt	36-37	20-40				3 - 5	4 - 6
7.5	46.6	54.7	0.3	0.7		1082	Loose, Sand to silty sand	37-40	20-40				9 - 10	10 - 12
8.0	15.0	17.4	0.4	1.3		1400	Loose, Silty sand to sandy silt	27-31	20-40				3 - 3	3 - 4
8.5	17.0	19.5	0.2	1.0		2039	Loose, Silty sand to sandy silt	31-36	20-40				3 - 3	3 - 4
9.0	25.5	28.9	0.3	0.5		2101	Loose, Silty sand to sandy silt	36-37	20-40				4 - 5	4 - 6
9.5	65.2	73.2	0.4	0.7		1441	Med dense, Sand to silty sand	40-42	40-60				15 - 18	17 - 20
10.0	24.0	26.7	0.6	1.4		1805	Loose, Silty sand to sandy silt	27-31	20-40				5 - 6	6 - 7
10.5	12.2	13.5	0.5	2.3		3062	Stiff, Clayey silt to silty clay			15	1.55	0.97	3 - 4	3 - 4
11.0	21.5	23.7	0.3	1.6		2847	Loose, Silty sand to sandy silt	27-31	20-40				5 - 6	6 - 7
11.5	14.9	16.3	0.3	1.2		3884	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	3 - 4
12.0	30.0	32.8	0.5	1.8		2772	Med dense, Silty sand to sandy silt	27-31	40-60				6 - 9	7 - 10
12.5	31.5	34.3	0.2	0.5		4288	Loose, Sand to silty sand	36-37	20-40				6 - 6	6 - 7
13.0	36.1	39.0	0.3	0.6		6645	Loose, Sand to silty sand	36-37	20-40				6 - 6	6 - 7
13.5	12.6	13.5	0.3	1.2		6472	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
14.0	11.2	12.0	0.3	2.4		8675	Stiff, Clayey silt to silty clay			15	1.38	0.56	3 - 4	3 - 4
14.5	7.4	7.9	0.1	2.0		9108	Stiff, Clayey silt to silty clay			10	1.30	0.27	1 - 3	1 - 3

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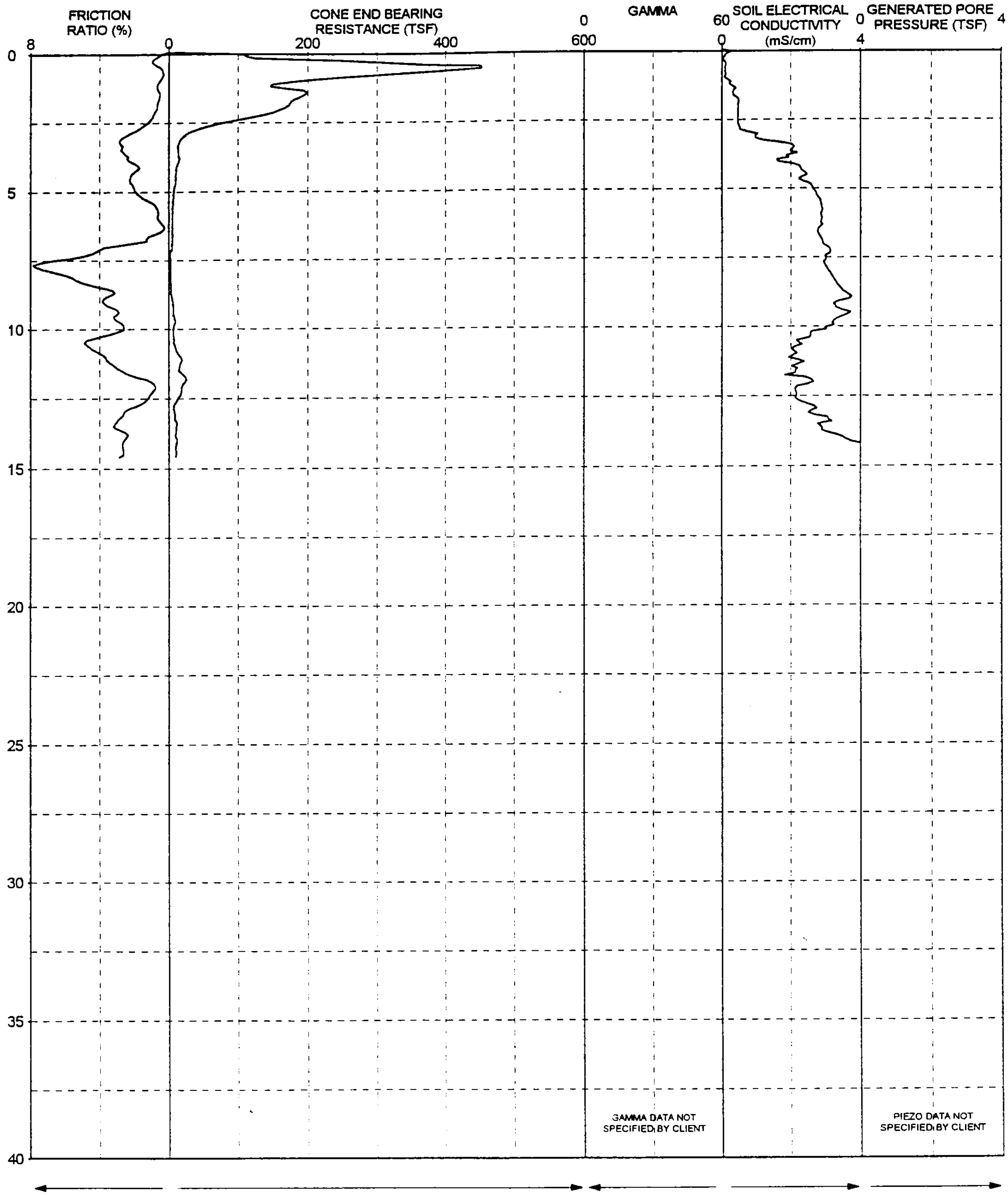
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/23/96
SOUNDING NUMBER: CP054

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp054

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	190.7	307.2	1.7	0.5		98	Dense, Sa gravel to gr sand	+46	60-80				37 - 45	60 - 72
1.5	195.5	297.8	0.9	0.5		336	Dense, Sa gravel to gr sand	+46	60-80				39 - 47	60 - 72
2.0	165.4	241.5	1.2	0.7		480	Dense, Sand to silty sand	42-46	60-80				41 - 49	60 - 72
2.5	79.9	112.8	1.5	1.2		482	Med dense, Sand to silty sand	40-42	40-60				23 - 28	33 - 40
3.0	21.6	29.6	1.1	2.6		1012	V stiff, Sandy silt to sandy clay			20	2.14	2.21	7 - 9	10 - 12
3.5	13.9	18.6	0.5	2.7		2093	Stiff, Sandy clay to silty clay *			15	1.83	0.90	4 - 5	6 - 7
4.0	13.4	17.5	0.3	1.9		1640	Stiff, Sandy silt to clayey silt			15	1.75	0.54	3 - 5	4 - 6
4.5	10.4	13.4	0.2	2.2		2459	Stiff, Clayey silt to silty clay			15	1.35	0.49	2 - 3	3 - 4
5.0	7.4	9.3	0.2	1.9		2650	Stiff, Clayey silt to silty clay			10	1.41	0.34	1 - 2	1 - 3
5.5	5.9	7.3	0.0	0.8		2874	Stiff, Sandy silt to clayey silt			10	1.11	0.10	1 - 2	1 - 3
6.0	5.5	6.7	0.0	0.6		2890	Stiff, Sandy silt to clayey silt			10	1.03	0.07	1 - 2	1 - 3
6.5	5.7	6.8	0.0	0.6		2784	Stiff, Sandy silt to clayey silt			10	1.05	0.07	1 - 2	1 - 3
7.0	5.0	5.9	0.2	3.3		2947	Firm, Silty clay to clay			10	0.92	0.39	1 - 3	1 - 3
7.5	2.6	3.0	0.2	6.6		3021	Soft, Clay to organic soil			10	0.42	0.39	1 - 3	1 - 3
8.0	2.7	3.1	0.2	6.2		3106	Soft, Clay			10	0.44	0.36	1 - 3	1 - 3
8.5	3.1	3.6	0.2	3.9		3371	Soft, Clay			18	0.29	0.32	1 - 3	1 - 3
9.0	5.8	6.5	0.3	3.8		3681	Stiff, Silty clay to clay			10	1.04	0.50	1 - 3	1 - 3
9.5	7.3	8.2	0.3	3.0		3697	Stiff, Silty clay to clay			10	1.34	0.52	1 - 3	1 - 3
10.0	6.9	7.7	0.2	2.6		3084	Stiff, Clayey silt to silty clay			10	1.27	0.42	1 - 3	1 - 3
10.5	7.4	8.2	0.5	4.9		2178	Stiff, Silty clay to clay *			10	1.36	1.07	4 - 5	4 - 6
11.0	16.4	18.0	0.6	3.7		2148	V stiff, Silty clay to clay *			15	2.09	1.25	6 - 9	7 - 10
11.5	15.1	16.6	0.6	2.8		2146	Stiff, Sandy clay to silty clay *			15	1.93	1.20	5 - 6	6 - 7
12.0	20.8	22.7	0.2	0.9		2662	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
12.5	14.1	15.3	0.2	1.2		2160	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
13.0	8.6	9.3	0.3	2.6		2662	Stiff, Clayey silt to silty clay			10	1.57	0.52	1 - 3	1 - 3
13.5	11.6	12.5	0.4	3.2		2808	Stiff, Sandy clay to silty clay *			15	1.43	0.72	4 - 6	4 - 6
14.0	11.9	12.8	0.3	2.6		3533	Stiff, Clayey silt to silty clay			15	1.48	0.57	3 - 4	3 - 4
14.5	10.9	11.6	0.3	2.6		4165	Stiff, Clayey silt to silty clay			15	1.33	0.51	3 - 4	3 - 4

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STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp059

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	209.3	337.2	1.9	0.9		382	Dense, Sand to silty sand	42-46	60-80				45 - 61	72 - 99
1.5	168.9	257.2	1.6	0.9		576	Dense, Sand to silty sand	42-46	60-80				39 - 47	60 - 72
2.0	158.8	232.0	2.4	1.0		399	Dense, Sand to silty sand	42-46	60-80				41 - 49	60 - 72
2.5	103.0	145.5	1.5	1.2		523	Dense, Sand to silty sand	40-42	60-80				33 - 42	46 - 60
3.0	40.4	55.4	1.1	1.3		1413	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 12	15 - 17
3.5	166.2	222.6	1.4	0.6		1080	Dense, Sand to silty sand	42-46	60-80				45 - 54	60 - 72
4.0	208.0	272.5	0.9	0.4		591	Dense, Sa gravel to gr sand	+46	60-80				46 - 55	60 - 72
4.5	83.6	107.4	0.9	0.7		1211	Med dense, Sand to silty sand	40-42	40-60				18 - 23	23 - 30
5.0	27.2	34.3	0.8	1.5		1847	Med dense, Silty sand to sandy silt	27-31	40-60				6 - 8	7 - 10
5.5	13.3	16.6	0.4	2.2		7537	Stiff, Sandy silt to clayey silt			15	1.74	0.84	3 - 5	4 - 6
6.0	9.5	11.6	0.2	1.8		9114	Stiff, Sandy silt to clayey silt			15	1.22	0.41	1 - 2	1 - 3
6.5	9.6	11.5	0.2	1.8		8660	Stiff, Sandy silt to clayey silt			15	1.22	0.36	1 - 2	1 - 3
7.0	9.2	11.0	0.2	1.6		8244	Stiff, Sandy silt to clayey silt			15	1.18	0.32	1 - 3	1 - 3

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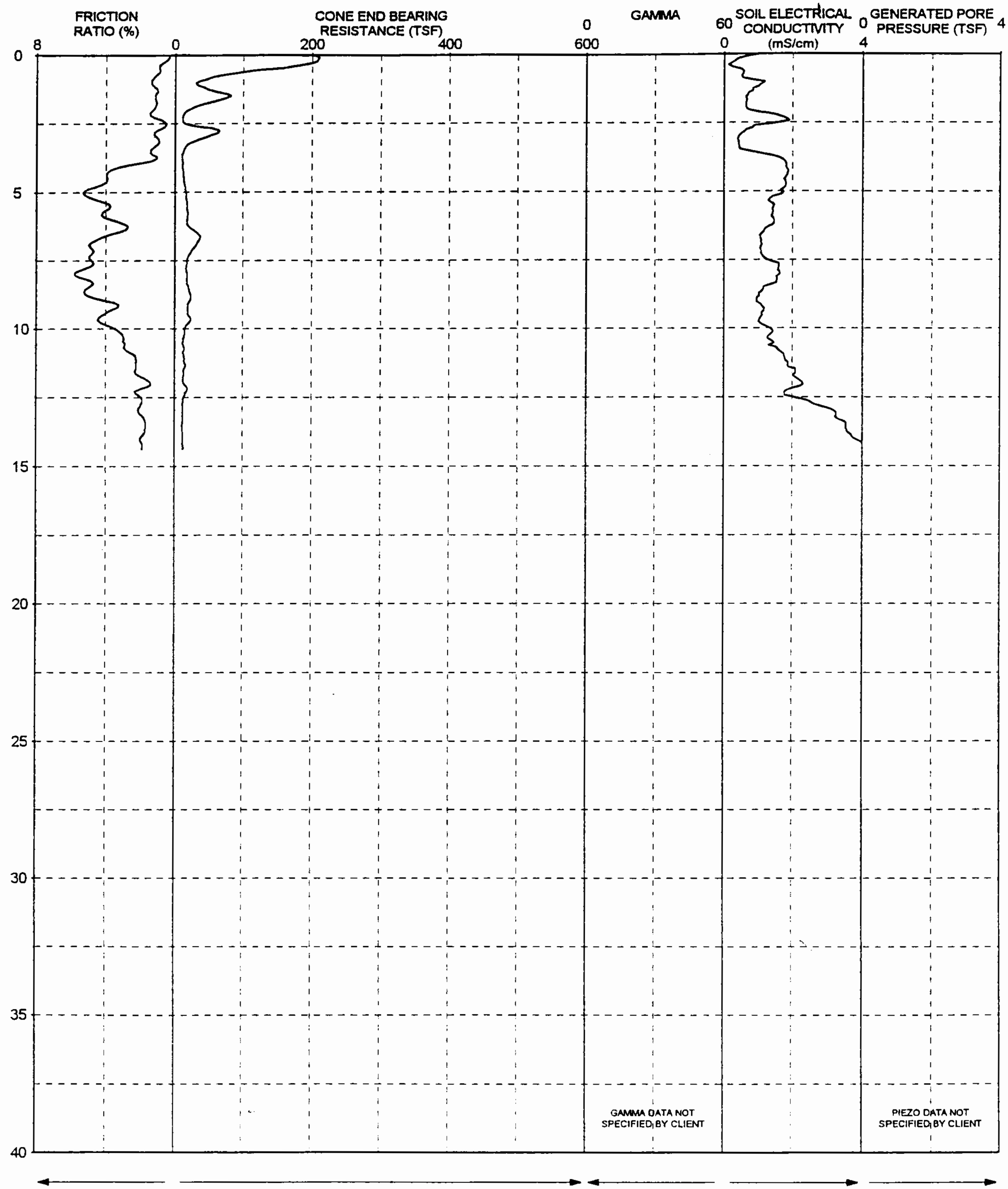
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base

PROJECT NUMBER: 96-110-230

DATE: 09/24/96

SOUNDING NUMBER: CP062

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp062

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	29.2	47.0	1.1	1.4		1240	Med dense, Silty sand to sandy silt	36-37	40-60				7 - 9	12 - 15
1.5	81.3	123.7	0.7	1.2		697	Med dense, Sand to silty sand	40-42	40-60				26 - 30	40 - 46
2.0	20.6	30.1	0.6	1.3		665	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
2.5	14.9	21.0	0.2	0.6		1638	Loose, Silty sand to sandy silt	31-36	20-40				2 - 3	3 - 4
3.0	45.9	63.0	0.5	1.1		445	Med dense, Sand to silty sand	37-40	40-60				11 - 12	15 - 17
3.5	13.1	17.6	0.3	1.4		590	Loose, Silty sand to sandy silt	27-31	20-40				2 - 3	3 - 4
4.0	11.4	15.0	0.3	2.6		1821	Stiff, Clayey silt to silty clay			15	1.49	0.64	3 - 5	4 - 6
4.5	13.1	16.9	0.6	3.9		1796	Stiff, Silty clay to clay *			15	1.72	1.14	5 - 8	7 - 10
5.0	16.1	20.3	0.9	5.3		1691	Stiff, Silty clay to clay *			20	1.58	1.83	12 - 13	15 - 17
5.5	18.2	22.6	0.7	3.8		1454	Stiff, Silty clay to clay *			20	1.79	1.37	8 - 10	10 - 12
6.0	18.5	22.5	0.9	3.8		1449	Stiff, Silty clay to clay *			20	1.81	1.71	8 - 10	10 - 12
6.5	33.7	40.6	1.2	3.5		1134	V stiff, Sandy clay to silty clay *			25	2.67	2.38	17 - 19	20 - 23
7.0	29.8	35.4	1.7	4.9		1083	V stiff, Silty clay to clay *			25	2.35	3.45	25 - 28	30 - 33
7.5	18.4	21.6	1.1	4.8		1259	Stiff, Silty clay to clay *			20	1.80	2.21	13 - 14	15 - 17
8.0	18.0	20.9	1.1	5.8		1636	Stiff, Silty clay to clay *			20	1.76	2.16	15 - 17	17 - 20
8.5	20.6	23.7	1.1	5.0		1174	V stiff, Silty clay to clay *			20	2.01	2.28	15 - 17	17 - 20
9.0	22.2	25.1	0.9	3.9		965	V stiff, Silty clay to clay *			20	2.16	1.72	11 - 13	12 - 15
9.5	20.4	22.9	0.9	4.2		1116	Stiff, Silty clay to clay *			20	1.99	1.70	11 - 13	12 - 15
10.0	14.8	16.5	0.7	3.5		1337	Stiff, Silty clay to clay *			15	1.90	1.37	5 - 6	6 - 7
10.5	12.2	13.5	0.4	2.9		1423	Stiff, Sandy clay to silty clay *			15	1.55	0.80	4 - 5	4 - 6
11.0	13.8	15.2	0.3	2.3		1757	Stiff, Clayey silt to silty clay			15	1.75	0.67	4 - 5	4 - 6
11.5	13.9	15.2	0.3	2.3		2088	Stiff, Clayey silt to silty clay			15	1.76	0.65	4 - 5	4 - 6
12.0	14.3	15.6	0.2	1.4		2309	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	3 - 4
12.5	13.5	14.7	0.3	1.9		2021	Stiff, Sandy silt to clayey silt			15	1.70	0.62	3 - 4	3 - 4
13.0	12.0	13.0	0.3	2.1		3193	Stiff, Clayey silt to silty clay			15	1.50	0.53	3 - 4	3 - 4
13.5	11.5	12.4	0.2	1.7		3539	Stiff, Sandy silt to clayey silt			15	1.43	0.41	1 - 3	1 - 3
14.0	12.2	13.1	0.3	2.0		3738	Stiff, Sandy silt to clayey silt			15	1.51	0.50	3 - 4	3 - 4

NOTES:
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STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp066

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	AVERAGED FRICTION (TSF)	FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	61.8	99.5	2.3	2.0		389	Dense, Silty sand to sandy silt	37-40	60-80				25 - 29	40 - 46
1.5	203.1	309.2	2.3	0.4		430	Dense, Sa gravel to gr sand	+46	60-80				39 - 47	60 - 72
2.0	87.2	127.4	3.2	1.7		315	Dense, Silty sand to sandy silt	40-42	60-80				31 - 41	46 - 60
2.5	9.5	13.5	0.2	0.5		2762	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
3.0	8.2	11.3	0.2	1.9		2548	Stiff, Sandy silt to clayey silt			15	1.07	0.33	1 - 2	1 - 3
3.5	6.6	8.8	0.1	1.9		2502	Stiff, Clayey silt to silty clay			10	1.27	0.30	1 - 2	1 - 3
4.0	4.5	5.9	0.1	1.3		2437	Soft, Clayey silt to silty clay			18	0.47	0.17	1 - 2	1 - 3
4.5	3.8	4.9	0.1	2.1		2335	Soft, Clayey silt to silty clay			18	0.40	0.20	1 - 2	1 - 3
5.0	3.3	4.2	0.1	2.4		2183	Soft, Silty clay to clay			18	0.33	0.20	1 - 2	1 - 3
5.5	3.1	3.8	0.1	1.5		2326	Soft, Sensitive fine grained soil			18	0.30	0.12	0 - 1	0 - 1
6.0	3.5	4.3	0.1	2.3		2143	Soft, Silty clay to clay			18	0.35	0.20	1 - 2	1 - 3
6.5	4.1	4.9	0.1	2.9		2044	Soft, Silty clay to clay			18	0.41	0.25	1 - 2	1 - 3
7.0	3.4	4.0	0.1	2.4		2028	Soft, Silty clay to clay			18	0.33	0.16	1 - 3	1 - 3
7.5	3.5	4.1	0.1	2.0		1970	Soft, Clayey silt to silty clay			18	0.33	0.25	1 - 3	1 - 3
8.0	8.6	10.0	0.1	0.8		2259	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
8.5	8.6	9.8	0.1	1.4		2373	Stiff, Sandy silt to clayey silt			10	1.61	0.25	1 - 3	1 - 3
9.0	10.5	11.9	0.2	1.8		2517	Stiff, Sandy silt to clayey silt			15	1.32	0.36	1 - 3	1 - 3
9.5	8.2	9.2	0.2	2.3		2547	Stiff, Clayey silt to silty clay			10	1.52	0.45	1 - 3	1 - 3
10.0	9.6	10.6	0.2	2.4		2451	Stiff, Clayey silt to silty clay			15	1.19	0.46	1 - 3	1 - 3
10.5	7.3	8.1	0.2	2.3		2493	Stiff, Clayey silt to silty clay			10	1.33	0.36	1 - 3	1 - 3
11.0	5.9	6.5	0.1	1.3		2879	Stiff, Sandy silt to clayey silt			10	1.05	0.22	1 - 3	1 - 3
11.5	8.2	9.0	0.1	0.8		2656	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
12.0	10.2	11.2	0.1	0.5		2968	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
12.5	11.8	12.8	0.1	0.6		2943	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
13.0	8.9	9.7	0.3	2.0		3136	Stiff, Clayey silt to silty clay			10	1.63	0.51	1 - 3	1 - 3
13.5	4.4	4.8	0.0	0.5		2901	Soft, Sensitive fine grained soil			18	0.40	0.08	1 - 3	1 - 3
14.0	15.0	16.1	0.0	0.3		2824	V loose, Silty sand to sandy silt	31-36	0-20				1 - 3	1 - 3
14.5	5.7	6.0	0.1	0.4		2838	Firm, Sensitive fine grained soil			18	0.53	0.11	1 - 3	1 - 3

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CPT-EC LOG

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 09/30/96
SOUNDING NUMBER: CP070

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp070

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	66.3	106.7	2.0	2.4		1129	Dense, Silty sand to sandy silt	37-40	60-80				29 - 37	46 - 60
1.5	74.2	113.0	0.7	1.0		923	Med dense, Sand to silty sand	40-42	40-60				20 - 22	30 - 33
2.0	51.7	75.5	0.4	0.6		854	Med dense, Sand to silty sand	40-42	40-60				10 - 12	15 - 17
2.5	33.1	46.8	0.2	0.5		869	Loose, Sand to silty sand	37-40	20-40				5 - 7	7 - 10
3.0	30.5	41.9	0.2	0.6		879	Loose, Sand to silty sand	37-40	20-40				5 - 7	7 - 10
3.5	34.8	46.7	0.3	0.9		890	Loose, Silty sand to sandy silt	37-40	20-40				7 - 9	10 - 12
4.0	34.9	45.7	0.3	0.8		702	Loose, Sand to silty sand	37-40	20-40				5 - 8	7 - 10
4.5	37.4	48.1	0.3	0.8		715	Loose, Sand to silty sand	37-40	20-40				8 - 9	10 - 12
5.0	36.3	45.8	0.3	0.8		695	Loose, Sand to silty sand	37-40	20-40				6 - 8	7 - 10
5.5	35.4	43.9	0.3	0.8		630	Loose, Silty sand to sandy silt	36-37	20-40				6 - 8	7 - 10
6.0	32.4	39.6	0.3	0.9		732	Loose, Silty sand to sandy silt	36-37	20-40				6 - 8	7 - 10
6.5	19.4	23.3	0.6	2.3		968	Stiff, Sandy silt to sandy clay			20	1.90	1.29	6 - 8	7 - 10
7.0	14.0	16.7	0.7	3.4		988	Stiff, Silty clay to clay *			15	1.82	1.33	5 - 6	6 - 7
7.5	26.3	30.9	0.6	1.0		967	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
8.0	71.7	83.2	0.5	0.8		816	Med dense, Sand to silty sand	40-42	40-60				17 - 20	20 - 23
8.5	48.6	55.7	0.7	1.3		767	Med dense, Silty sand to sandy silt	36-37	40-60				13 - 15	15 - 17
9.0	31.7	35.9	1.2	3.0		1104	V stiff, Sandy silt to sandy clay			25	2.49	2.48	15 - 18	17 - 20
9.5	35.5	39.9	1.4	4.3		1036	V stiff, Silty clay to clay *			25	2.80	2.89	20 - 27	23 - 30
10.0	31.4	34.9	1.3	2.5		1094	V stiff, Sandy silt to sandy clay			20	3.08	2.67	11 - 14	12 - 15
10.5	60.8	67.3	0.4	0.7		797	Med dense, Sand to silty sand	37-40	40-60				14 - 15	15 - 17
11.0	48.5	53.4	0.2	0.5		676	Loose, Sand to silty sand	37-40	20-40				6 - 9	7 - 10
11.5	42.4	46.5	0.4	0.9		649	Loose, Silty sand to sandy silt	36-37	20-40				9 - 11	10 - 12
12.0	37.3	40.7	0.6	1.4		849	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	10 - 12
12.5	23.8	25.9	0.8	2.2		1349	V stiff, Sandy silt to sandy clay			20	2.31	1.58	6 - 9	7 - 10
13.0	16.5	17.8	0.4	2.0		1370	V stiff, Sandy silt to clayey silt			15	2.09	0.87	4 - 6	4 - 6
13.5	14.2	15.3	0.3	1.6		1421	Stiff, Sandy silt to clayey silt			15	1.79	0.53	3 - 4	3 - 4
14.0	11.4	12.2	0.3	2.3		1464	Stiff, Clayey silt to silty clay			15	1.40	0.70	3 - 4	3 - 4
14.5	9.0	9.6	0.2	1.5		1446	Stiff, Sandy silt to clayey silt			10	1.63	0.37	1 - 3	1 - 3
15.0	8.3	8.9	0.1	0.7		1455	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
15.5	6.5	6.9	0.1	0.2		1530	, Sensitive fine grained soil	27-31	6				1 - 3	1 - 3

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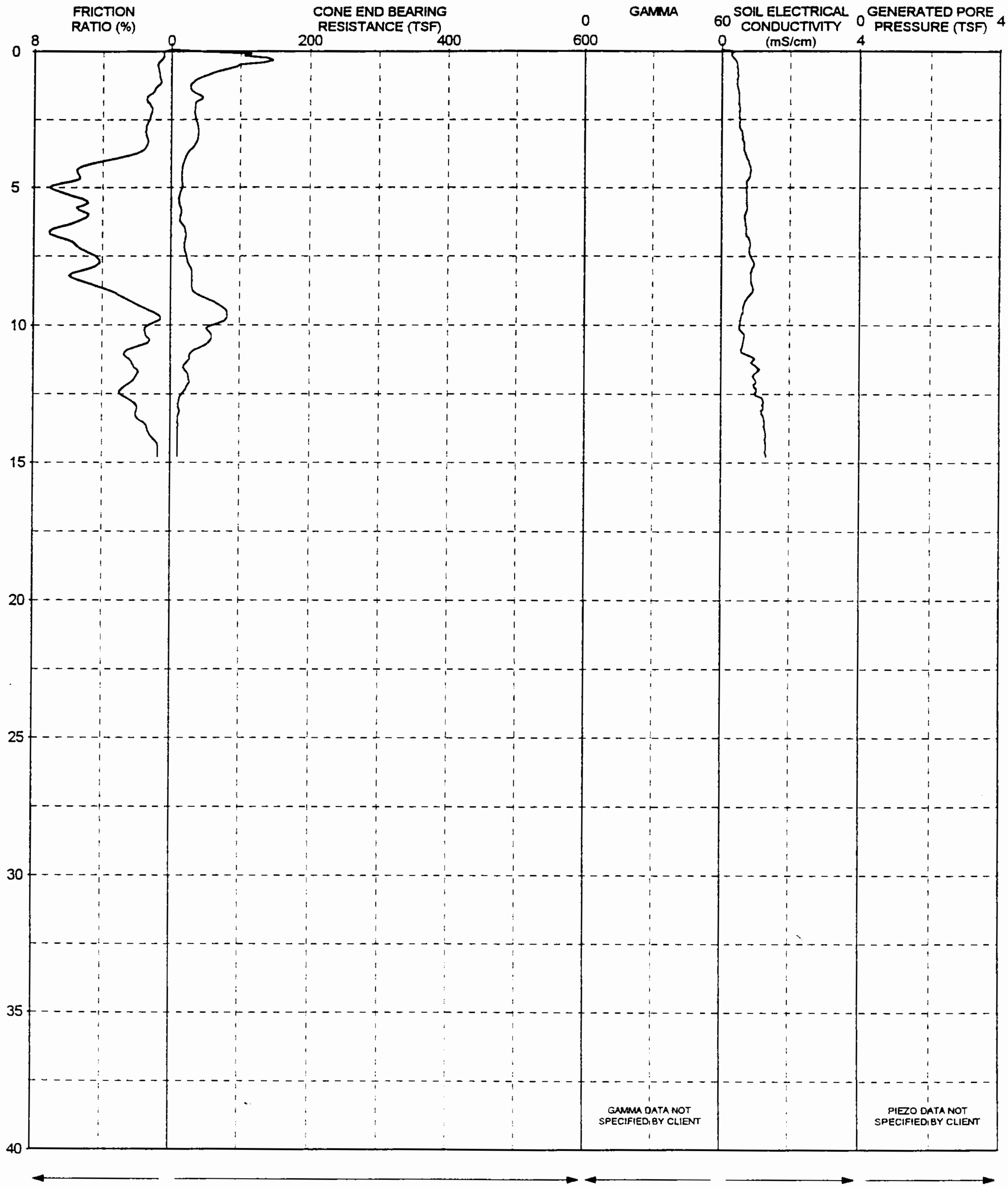
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/01/96
SOUNDING NUMBER: CP074

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp074

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	39.0	62.9	0.4	0.6		458	Loose, Sand to silty sand	37-40	20-40				7 - 9	12 - 15
1.5	33.1	50.4	0.4	1.1		497	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 10	12 - 15
2.0	35.2	51.5	0.5	1.2		523	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 10	12 - 15
2.5	36.1	51.0	0.5	1.3		530	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 11	12 - 15
3.0	39.6	54.3	0.6	1.5		602	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 12	15 - 17
3.5	32.9	44.0	0.6	1.5		656	Med dense, Silty sand to sandy silt	36-37	40-60				9 - 11	12 - 15
4.0	19.5	25.6	0.9	3.8		774	Stiff, Sandy clay to silty clay *			20	1.93	1.84	9 - 11	12 - 15
4.5	15.7	20.1	0.9	5.4		842	Stiff, Silty clay to clay *			20	1.54	1.81	12 - 13	15 - 17
5.0	16.0	20.2	1.1	7.1		732	Stiff, Silty clay to clay *			18	1.74	2.24	16 - 18	20 - 23
5.5	11.7	14.6	0.6	4.9		735	Stiff, Silty clay to clay *			15	1.52	1.28	6 - 8	7 - 10
6.0	14.3	17.5	0.7	4.8		688	Stiff, Silty clay to clay *			15	1.86	1.44	8 - 10	10 - 12
6.5	20.1	24.2	1.4	6.8		722	V stiff, Silty clay to clay *			18	2.19	2.83	19 - 25	23 - 30
7.0	19.9	23.6	1.2	5.8		832	Stiff, Silty clay to clay *			20	1.95	2.35	17 - 19	20 - 23
7.5	22.7	26.7	1.1	4.4		859	V stiff, Silty clay to clay *			20	2.23	2.23	14 - 17	17 - 20
8.0	30.3	35.1	1.5	5.0		904	V stiff, Silty clay to clay *			25	2.38	3.03	26 - 28	30 - 33
8.5	30.7	35.2	1.7	4.8		889	V stiff, Silty clay to clay *			25	2.41	3.34	20 - 26	23 - 30
9.0	49.0	55.6	1.9	2.8		768	V stiff, Sandy silt to sandy clay			25	3.88	3.71	20 - 26	23 - 30
9.5	81.5	91.5	0.9	1.1		642	Med dense, Sand to silty sand	40-42	40-60				20 - 27	23 - 30
10.0	61.9	68.7	1.0	1.3		549	Med dense, Silty sand to sandy silt	37-40	40-60				18 - 21	20 - 23
10.5	59.5	65.8	0.8	1.3		674	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 18	17 - 20
11.0	30.2	33.2	1.3	2.7		610	V stiff, Sandy silt to sandy clay			20	2.95	2.51	11 - 14	12 - 15
11.5	19.1	20.9	0.5	2.1		1047	V stiff, Sandy silt to sandy clay			15	2.46	1.08	5 - 6	6 - 7
12.0	27.0	29.4	0.5	2.1		1016	V stiff, Sandy silt to sandy clay			20	2.63	0.96	6 - 9	7 - 10
12.5	16.6	18.0	0.7	2.9		988	V stiff, Sandy clay to silty clay *			15	2.11	1.38	6 - 6	6 - 7
13.0	12.0	13.0	0.2	1.9		1244	Stiff, Sandy silt to clayey silt			15	1.50	0.48	3 - 4	3 - 4
13.5	10.9	11.7	0.2	1.7		1269	Stiff, Sandy silt to clayey silt			15	1.35	0.39	1 - 3	1 - 3
14.0	10.7	11.5	0.1	1.2		1302	Stiff, Sandy silt to clayey silt			15	1.31	0.24	1 - 3	1 - 3
14.5	10.7	11.5	0.1	0.7		1308	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3

NOTES:

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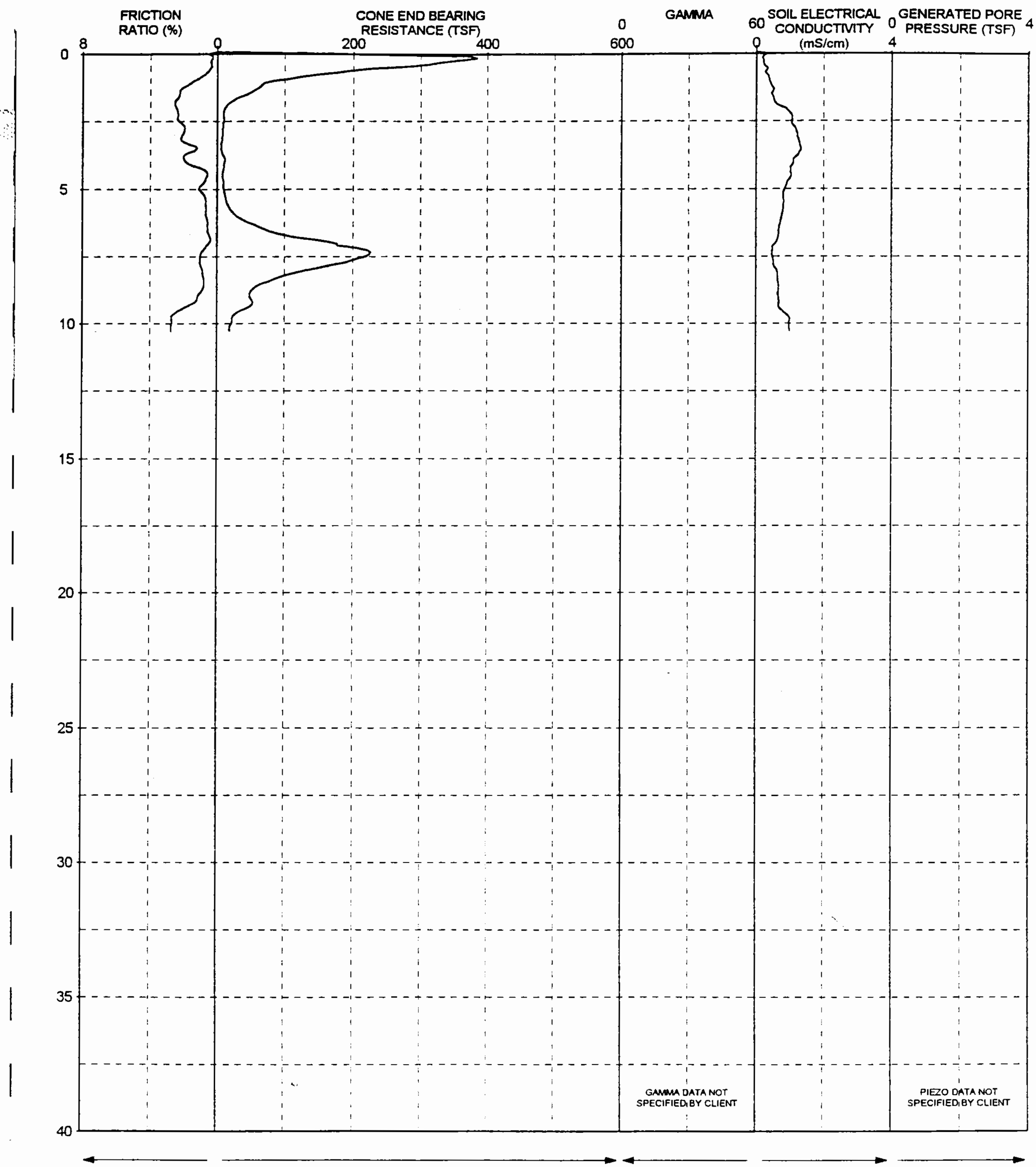
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 10/01/96
PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP078

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp078

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	88.1	141.9	2.2	1.3		391	Dense, Sand to silty sand	40-42	60-80				29 - 37	46 - 60
1.5	45.6	69.5	1.4	2.2		466	Dense, Silty sand to sandy silt	36-37	60-80				20 - 22	30 - 33
2.0	12.3	18.0	0.6	2.4		794	Stiff, Sandy clay to silty clay *			15	1.63	1.26	4 - 5	6 - 7
2.5	9.7	13.7	0.3	2.3		1082	Stiff, Clayey silt to silty clay			15	1.27	0.54	2 - 3	3 - 4
3.0	8.0	11.0	0.2	2.0		1224	Stiff, Clayey silt to silty clay			15	1.05	0.40	1 - 2	1 - 3
3.5	6.1	8.2	0.1	1.2		1324	Stiff, Sandy silt to clayey silt			10	1.18	0.21	1 - 2	1 - 3
4.0	11.3	14.8	0.2	1.9		1105	Stiff, Sandy silt to clayey silt			15	1.47	0.42	2 - 3	3 - 4
4.5	7.8	10.0	0.1	0.6		1036	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
5.0	10.1	12.7	0.2	1.1		857	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
5.5	14.6	18.2	0.1	0.7		812	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
6.0	29.6	36.1	0.3	0.6		766	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
6.5	71.7	86.4	0.6	0.6		674	Med dense, Sand to silty sand	40-42	40-60				14 - 17	17 - 20
7.0	171.7	204.1	1.0	0.5		584	Med dense, Sand to silty sand	42-46	40-60				39 - 50	46 - 60
7.5	217.7	255.5	2.0	1.0		491	Dense, Sand to silty sand	42-46	60-80				51 - 61	60 - 72
8.0	134.6	156.0	1.6	0.9		618	Med dense, Sand to silty sand	42-46	40-60				35 - 40	40 - 46
8.5	68.3	78.2	0.7	0.8		664	Med dense, Sand to silty sand	40-42	40-60				15 - 17	17 - 20
9.0	49.0	55.5	0.7	1.2		666	Med dense, Silty sand to sandy silt	37-40	40-60				13 - 15	15 - 17
9.5	37.9	42.6	1.1	2.2		742	Med dense, Silty sand to sandy silt	27-31	40-60				13 - 15	15 - 17
10.0	21.5	23.8	0.8	2.7		984	V stiff, Sandy clay to silty clay *			20	2.09	1.51	6 - 9	7 - 10

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CPT-EC LOG

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/01/96
SOUNDING NUMBER: CP079

STRATIGRAPHICS
JOB NO: 96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp079

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	116.4	187.6	1.7	0.8		191	Dense, Sand to silty sand	42-46	60-80				29 - 37	46 - 60
1.5	27.9	42.5	1.1	1.9		303	Med dense, Silty sand to sandy silt	27-31	40-60				8 - 10	12 - 15
2.0	26.6	38.9	1.0	2.7		701	V stiff, Sandy silt to sandy clay			25	2.12	2.00	12 - 14	17 - 20
2.5	42.9	60.6	0.8	2.0		553	Med dense, Silty sand to sandy silt	36-37	40-60				14 - 16	20 - 23
3.0	41.4	56.8	0.7	1.5		526	Med dense, Silty sand to sandy silt	36-37	40-60				12 - 15	17 - 20
3.5	45.5	60.9	0.4	0.9		525	Med dense, Sand to silty sand	37-40	40-60				11 - 13	15 - 17
4.0	45.0	59.0	0.6	1.1		578	Med dense, Silty sand to sandy silt	37-40	40-60				11 - 13	15 - 17
4.5	57.6	74.0	0.6	1.1		612	Med dense, Sand to silty sand	37-40	40-60				16 - 18	20 - 23
5.0	53.9	68.0	0.7	1.2		597	Med dense, Silty sand to sandy silt	37-40	40-60				13 - 16	17 - 20
5.5	45.1	56.0	0.4	0.8		565	Loose, Sand to silty sand	37-40	20-40				10 - 12	12 - 15
6.0	35.7	43.6	0.2	0.6		699	Loose, Sand to silty sand	37-40	20-40				6 - 8	7 - 10
6.5	23.8	28.7	0.3	1.0		927	Loose, Silty sand to sandy silt	31-36	20-40				5 - 6	6 - 7
7.0	21.1	25.0	0.7	2.7		1073	V stiff, Sandy silt to sandy clay			20	2.06	1.31	6 - 8	7 - 10
7.5	33.5	39.3	0.8	2.0		1015	Med dense, Silty sand to sandy silt	27-31	40-60				10 - 13	12 - 15
8.0	45.9	53.2	0.5	1.0		863	Med dense, Silty sand to sandy silt	37-40	40-60				10 - 13	12 - 15
8.5	50.2	57.5	0.5	0.9		876	Med dense, Sand to silty sand	37-40	40-60				10 - 13	12 - 15
9.0	55.2	62.6	0.7	1.4		961	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 18	17 - 20
9.5	28.3	31.7	1.0	2.5		1146	V stiff, Sandy silt to sandy clay			20	2.77	2.05	11 - 13	12 - 15
10.0	41.0	45.5	0.7	1.9		998	Med dense, Silty sand to sandy silt	27-31	40-60				14 - 15	15 - 17
10.5	30.7	34.0	0.7	2.0		1037	Med dense, Silty sand to sandy silt	27-31	40-60				9 - 11	10 - 12
11.0	13.9	15.3	0.5	2.2		1017	Stiff, Clayey silt to silty clay			15	1.76	0.95	3 - 4	3 - 4
11.5	13.0	14.2	0.3	2.5		1190	Stiff, Clayey silt to silty clay			15	1.64	0.69	3 - 4	3 - 4
12.0	13.9	15.2	0.2	1.7		1179	Stiff, Sandy silt to clayey silt			15	1.76	0.47	3 - 4	3 - 4
12.5	18.9	20.5	0.2	1.7		1130	Loose, Silty sand to sandy silt	27-31	20-40				4 - 6	4 - 6
13.0	9.6	10.4	0.1	1.1		1161	Stiff, Sandy silt to clayey silt			10	1.76	0.27	1 - 3	1 - 3
13.5	9.2	9.9	0.1	0.8		1228	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
14.0	7.4	7.9	0.0	0.4		1240	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
14.5	7.0	7.5	0.1	1.7		1227	Stiff, Clayey silt to silty clay			10	1.23	0.29	1 - 3	1 - 3

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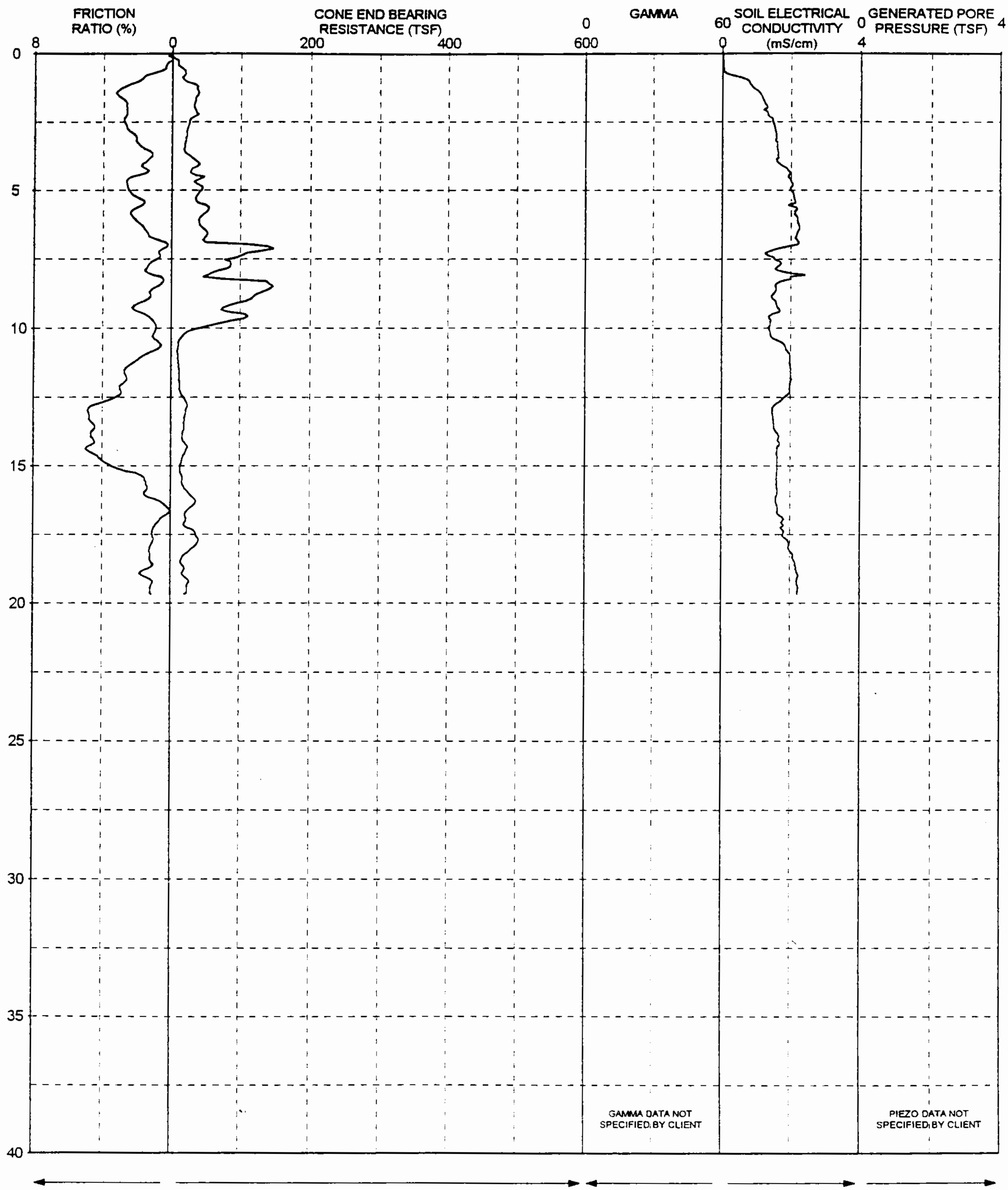
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP081

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp081

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	18.2	29.3	0.6	1.9		767	Med dense, Silty sand to sandy silt	27-31	40-60				4 - 6	7 - 10
1.5	38.3	58.3	1.2	3.2		1117	V stiff, Sandy silt to sandy clay			25	3.06	2.32	20 - 22	30 - 33
2.0	33.2	48.5	0.9	2.6		1292	V stiff, Sandy silt to sandy clay			25	2.65	1.88	14 - 16	20 - 23
2.5	25.9	36.5	0.9	2.8		1466	V stiff, Sandy silt to sandy clay			25	2.06	1.79	11 - 12	15 - 17
3.0	21.7	29.8	0.5	2.1		1563	V stiff, Sandy silt to sandy clay			20	2.15	0.98	5 - 7	7 - 10
3.5	18.2	24.4	0.4	1.5		1603	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
4.0	38.9	51.0	0.5	1.6		1615	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 13	15 - 17
4.5	43.7	56.2	0.9	2.2		1927	Dense, Silty sand to sandy silt	27-31	60-80				16 - 18	20 - 23
5.0	43.9	55.3	1.0	2.5		1974	V stiff, Sandy silt to sandy clay			25	3.48	2.04	18 - 24	23 - 30
5.5	42.8	53.1	0.8	1.6		2050	Med dense, Silty sand to sandy silt	36-37	40-60				14 - 16	17 - 20
6.0	42.2	51.5	1.1	2.2		2179	Dense, Silty sand to sandy silt	27-31	60-80				16 - 19	20 - 23
6.5	51.2	61.6	0.8	1.5		2201	Med dense, Silty sand to sandy silt	36-37	40-60				14 - 17	17 - 20
7.0	118.6	140.9	0.2	0.2		2094	Med dense, Sand to silty sand	42-46	40-60				25 - 28	30 - 33
7.5	83.5	98.0	1.0	0.8		1525	Med dense, Sand to silty sand	40-42	40-60				20 - 26	23 - 30
8.0	60.0	69.6	1.6	1.4		1887	Med dense, Silty sand to sandy silt	37-40	40-60				17 - 20	20 - 23
8.5	146.0	167.4	1.0	0.8		1553	Dense, Sand to silty sand	42-46	60-80				40 - 52	46 - 60
9.0	110.5	125.3	1.9	1.5		1526	Dense, Sand to silty sand	40-42	60-80				35 - 41	40 - 46
9.5	106.3	119.3	1.4	1.6		1473	Dense, Silty sand to sandy silt	40-42	60-80				36 - 41	40 - 46
10.0	41.9	46.5	0.7	0.9		1367	Loose, Silty sand to sandy silt	37-40	20-40				6 - 9	7 - 10
10.5	11.4	12.6	0.1	0.7		1706	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
11.0	10.0	11.0	0.2	1.7		1971	Stiff, Sandy silt to clayey silt			15	1.24	0.36	1 - 3	1 - 3
11.5	11.9	13.0	0.3	2.7		2004	Stiff, Clayey silt to silty clay			15	1.49	0.65	3 - 4	3 - 4
12.0	12.4	13.5	0.4	2.8		1988	Stiff, Clayey silt to silty clay			15	1.56	0.77	4 - 6	4 - 6
12.5	18.4	19.9	0.7	3.2		1833	V stiff, Sandy clay to silty clay *			15	2.35	1.43	6 - 9	7 - 10
13.0	22.0	23.8	1.1	4.8		1480	V stiff, Silty clay to clay *			20	2.12	2.17	16 - 18	17 - 20
13.5	19.5	21.0	0.9	4.5		1506	Stiff, Silty clay to clay *			20	1.87	1.83	11 - 14	12 - 15
14.0	17.0	18.2	1.0	4.6		1655	V stiff, Silty clay to clay *			15	2.15	2.01	9 - 11	10 - 12
14.5	21.9	23.4	1.0	4.7		1607	V stiff, Silty clay to clay *			20	2.10	2.03	14 - 16	15 - 17
15.0	14.4	15.3	0.6	3.5		1614	Stiff, Silty clay to clay *			15	1.80	1.23	6 - 7	6 - 7
15.5	17.1	18.2	0.3	1.5		1605	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	3 - 4
16.0	27.2	28.8	0.5	1.5		1625	Loose, Silty sand to sandy silt	27-31	20-40				6 - 7	6 - 7
16.5	30.9	32.5	0.1	0.2		1626	Loose, Sand to silty sand	36-37	20-40				4 - 6	4 - 6
17.0	22.6	23.6	0.2	0.6		1788	Loose, Silty sand to sandy silt	31-36	20-40				3 - 4	3 - 4
17.5	37.5	39.2	0.4	1.1		1800	Loose, Silty sand to sandy silt	36-37	20-40				7 - 10	7 - 10
18.0	32.6	33.9	0.4	1.2		1970	Loose, Silty sand to sandy silt	36-37	20-40				7 - 10	7 - 10
18.5	15.5	16.0	0.2	1.1		2137	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
19.0	18.6	19.2	0.4	1.7		2239	V stiff, Sandy silt to clayey silt			15	2.33	0.85	4 - 6	4 - 6
19.5	24.5	25.2	0.3	1.2		2234	Loose, Silty sand to sandy silt	27-31	20-40				4 - 6	4 - 6

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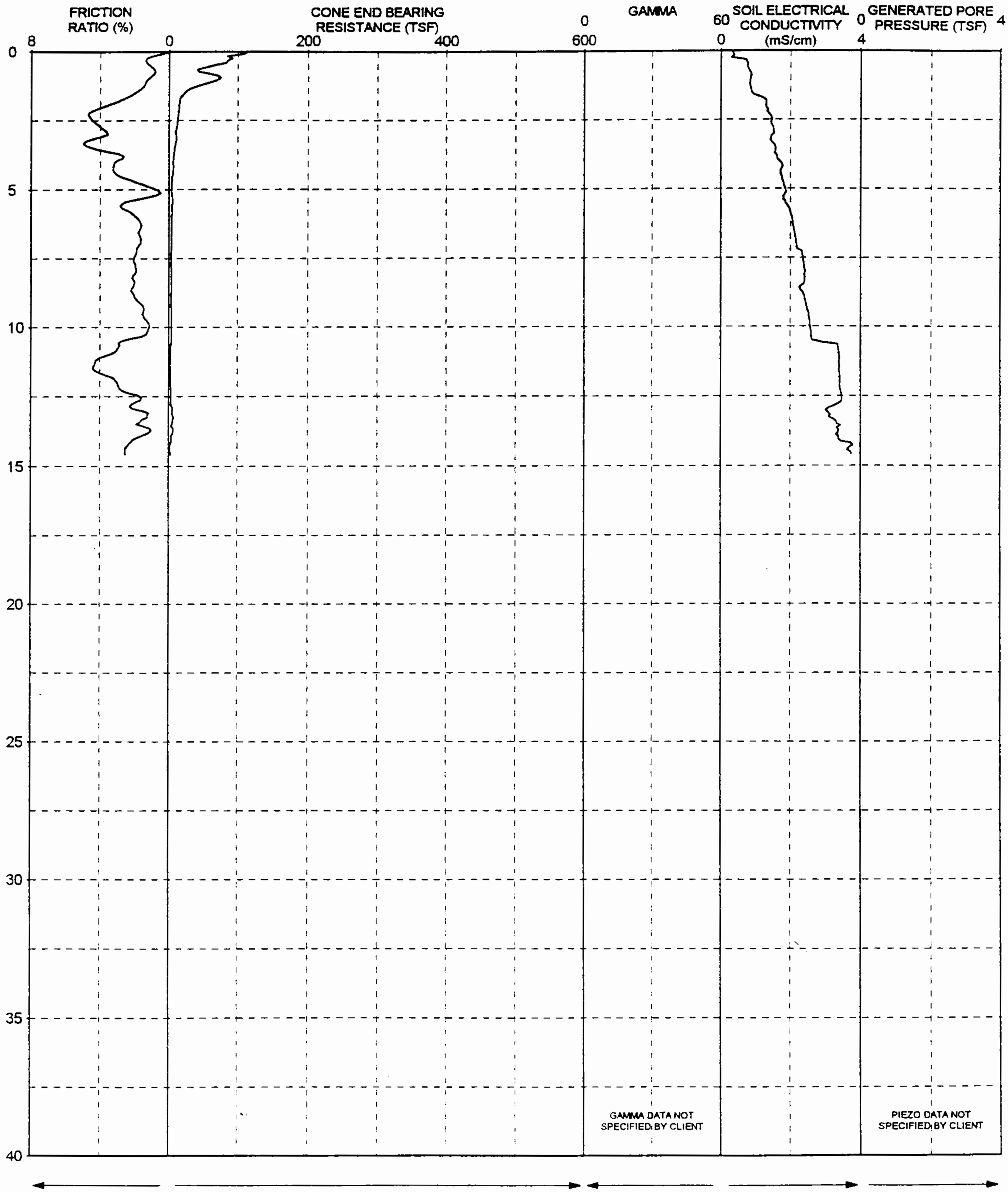
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP085

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp085

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	76.0	122.4	0.7	1.2		852	Dense, Sand to silty sand	40-42	60-80				25 - 29	40 - 46
1.5	23.5	35.7	0.9	2.0		890	Med dense, Silty sand to sandy silt	27-31	40-60				7 - 8	10 - 12
2.0	14.8	21.6	0.6	3.7		1308	Stiff, Silty clay to clay *			20	1.47	1.29	7 - 8	10 - 12
2.5	12.6	17.9	0.6	4.4		1471	Stiff, Silty clay to clay *			15	1.67	1.24	7 - 8	10 - 12
3.0	10.3	14.1	0.4	3.6		1548	Stiff, Silty clay to clay *			15	1.35	0.77	4 - 5	6 - 7
3.5	8.6	11.5	0.5	4.5		1575	Stiff, Silty clay to clay *			15	1.11	0.91	4 - 5	6 - 7
4.0	6.3	8.2	0.2	3.1		1682	Stiff, Silty clay to clay			10	1.21	0.46	1 - 2	1 - 3
4.5	5.5	7.0	0.2	2.9		1741	Stiff, Silty clay to clay			10	1.04	0.37	1 - 2	1 - 3
5.0	4.2	5.3	0.0	0.8		1851	Soft, Sensitive fine grained soil			18	0.43	0.07	1 - 2	1 - 3
5.5	5.3	6.5	0.1	2.6		1863	Firm, Silty clay to clay			10	0.99	0.26	1 - 2	1 - 3
6.0	4.3	5.3	0.1	1.9		2033	Soft, Clayey silt to silty clay			18	0.44	0.18	1 - 2	1 - 3
6.5	4.0	4.9	0.1	1.7		2107	Soft, Clayey silt to silty clay			18	0.41	0.15	1 - 2	1 - 3
7.0	3.9	4.7	0.1	1.7		2177	Soft, Clayey silt to silty clay			18	0.39	0.13	1 - 3	1 - 3
7.5	3.6	4.2	0.1	2.0		2368	Soft, Clayey silt to silty clay			18	0.35	0.16	1 - 3	1 - 3
8.0	3.8	4.4	0.1	1.9		2422	Soft, Clayey silt to silty clay			18	0.37	0.15	1 - 3	1 - 3
8.5	4.0	4.6	0.1	2.1		2352	Soft, Clayey silt to silty clay			18	0.39	0.16	1 - 3	1 - 3
9.0	3.7	4.1	0.1	1.9		2418	Soft, Clayey silt to silty clay			18	0.35	0.15	1 - 3	1 - 3
9.5	3.7	4.1	0.1	1.5		2519	Soft, Sensitive fine grained soil			18	0.35	0.11	1 - 3	1 - 3
10.0	3.8	4.2	0.0	1.1		2574	Soft, Sensitive fine grained soil			18	0.36	0.09	1 - 3	1 - 3
10.5	4.0	4.4	0.1	2.7		2622	Soft, Silty clay to clay			18	0.37	0.24	1 - 3	1 - 3
11.0	2.5	2.7	0.1	3.5		3397	V soft, Silty clay to clay			18	0.20	0.20	0 - 1	0 - 1
11.5	2.9	3.2	0.1	4.4		3403	Soft, Clay			18	0.25	0.26	1 - 3	1 - 3
12.0	3.0	3.2	0.1	3.0		3408	V soft, Silty clay to clay			18	0.25	0.19	1 - 3	1 - 3
12.5	3.3	3.6	0.1	1.7		3462	Soft, Sensitive fine grained soil			18	0.28	0.13	0 - 1	0 - 1
13.0	5.7	6.2	0.1	1.7		3043	Firm, Clayey silt to silty clay			10	0.98	0.22	1 - 3	1 - 3
13.5	5.5	5.9	0.1	1.9		3324	Firm, Clayey silt to silty clay			10	0.93	0.26	1 - 3	1 - 3
14.0	4.2	4.5	0.1	1.9		3384	Soft, Clayey silt to silty clay			18	0.37	0.21	1 - 3	1 - 3
14.5	2.3	2.5	0.1	2.5		3709	V soft, Sensitive fine grained soil			18	0.16	0.20	0 - 1	0 - 1

NOTES:
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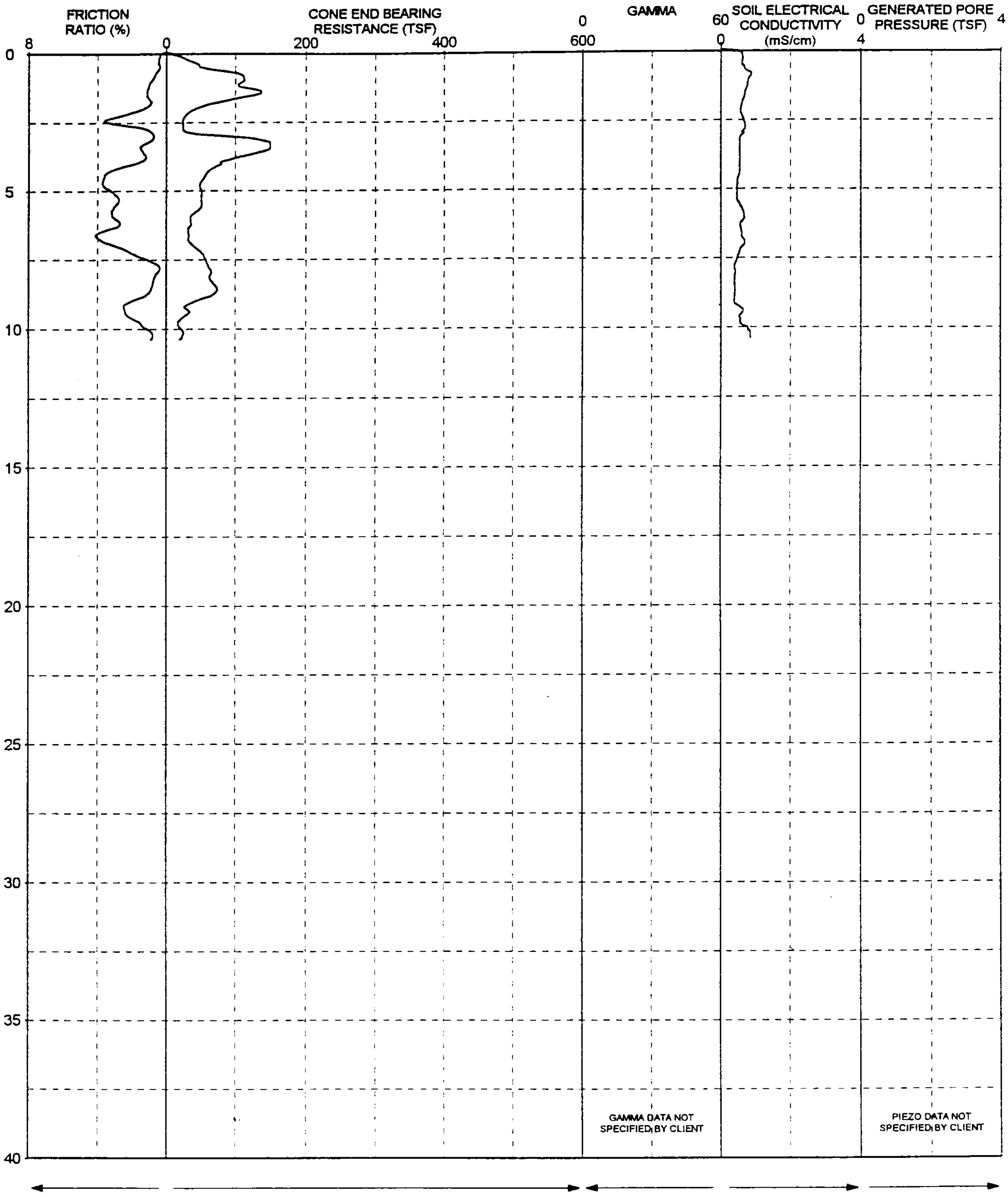
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP087

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp087

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	111.7	180.0	1.1	0.9		805	Dense, Sand to silty sand	42-46	60-80				29 - 37	46 - 60
1.5	126.8	193.1	1.4	1.1		701	Dense, Sand to silty sand	42-46	60-80				39 - 47	60 - 72
2.0	42.8	62.6	1.0	1.4		593	Med dense, Silty sand to sandy silt	37-40	40-60				12 - 14	17 - 20
2.5	24.3	34.3	1.2	3.4		662	Stiff, Sandy clay to silty clay *			25	1.93	2.46	12 - 14	17 - 20
3.0	79.4	109.0	0.9	0.7		660	Med dense, Sand to silty sand	40-42	40-60				22 - 24	30 - 33
3.5	146.4	196.1	2.0	1.4		547	Dense, Sand to silty sand	40-42	60-80				45 - 54	60 - 72
4.0	79.8	104.5	1.9	1.8		546	Dense, Silty sand to sandy silt	37-40	60-80				31 - 35	40 - 46
4.5	55.9	71.8	2.3	3.6		530	V stiff, Sandy clay to silty clay *			30	3.71	4.67	36 - 47	46 - 60
5.0	51.4	64.8	1.7	3.3		469	Hard, Sandy silt to sandy clay			25	4.09	3.34	26 - 32	33 - 40
5.5	51.9	64.4	1.5	2.9		521	Hard, Sandy silt to sandy clay			25	4.13	3.00	27 - 32	33 - 40
6.0	35.5	43.4	1.3	3.0		669	V stiff, Sandy silt to sandy clay			25	2.81	2.64	16 - 19	20 - 23
6.5	32.0	38.6	1.3	3.8		590	V stiff, Sandy clay to silty clay *			25	2.53	2.65	19 - 25	23 - 30
7.0	39.4	46.8	1.5	3.0		678	V stiff, Sandy silt to sandy clay			25	3.12	2.95	19 - 25	23 - 30
7.5	57.6	67.6	0.7	1.2		488	Med dense, Silty sand to sandy silt	37-40	40-60				14 - 17	17 - 20
8.0	65.3	75.7	0.4	0.5		423	Med dense, Sand to silty sand	40-42	40-60				13 - 15	15 - 17
8.5	73.7	84.5	0.6	0.8		406	Med dense, Sand to silty sand	40-42	40-60				17 - 20	20 - 23
9.0	42.8	48.6	1.3	2.0		396	Med dense, Silty sand to sandy silt	27-31	40-60				15 - 18	17 - 20
9.5	29.4	33.0	0.8	2.3		610	V stiff, Sandy silt to sandy clay			20	2.89	1.52	9 - 11	10 - 12
10.0	21.8	24.2	0.3	1.1		760	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	4 - 6

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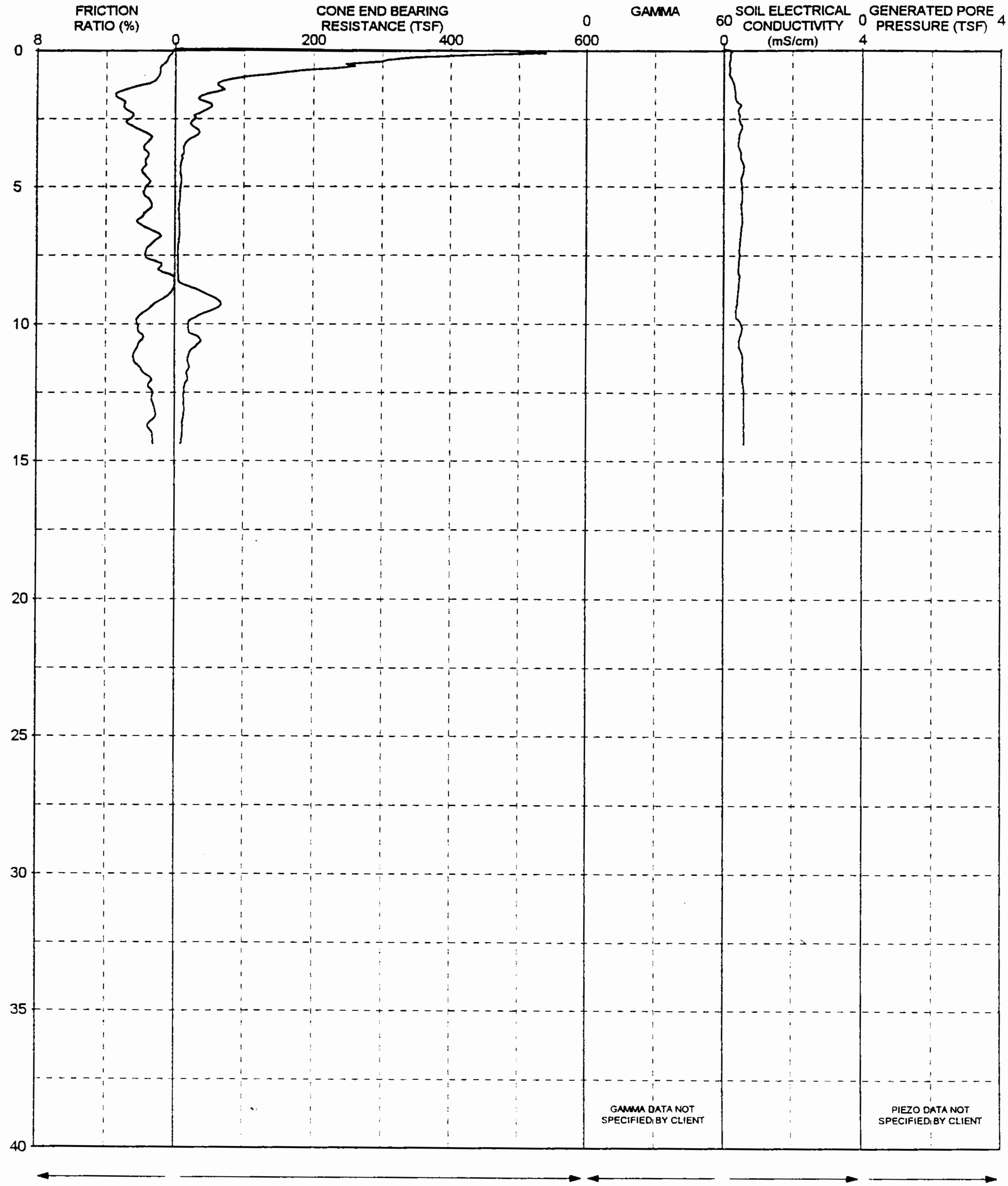
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/02/96
SOUNDING NUMBER: CP088

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp088

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	93.6	150.7	1.8	1.0		211	Dense, Sand to silty sand	40-42	60-80				29 - 37	46 - 60
1.5	64.3	98.0	2.2	3.2		333	Hard, Gr cl sand to gr sa silt			30	4.28	4.46	39 - 47	60 - 72
2.0	54.2	79.2	1.3	3.0		506	V stiff, Sandy silt to sandy clay			30	3.61	2.67	27 - 31	40 - 46
2.5	28.5	40.2	1.0	2.6		461	V stiff, Sandy silt to sandy clay			25	2.27	2.09	12 - 14	17 - 20
3.0	35.9	49.2	0.5	1.8		480	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 12	15 - 17
3.5	13.5	18.1	0.4	1.8		432	Stiff, Sandy silt to clayey silt			15	1.77	0.82	3 - 4	4 - 6
4.0	10.5	13.8	0.2	1.7		514	Stiff, Sandy silt to clayey silt			15	1.37	0.42	1 - 2	1 - 3
4.5	8.3	10.6	0.2	1.9		560	Stiff, Clayey silt to silty clay			15	1.06	0.32	1 - 2	1 - 3
5.0	8.4	10.7	0.2	1.7		523	Stiff, Sandy silt to clayey silt			15	1.09	0.31	1 - 2	1 - 3
5.5	7.2	8.9	0.1	1.5		532	Stiff, Sandy silt to clayey silt			10	1.36	0.22	1 - 2	1 - 3
6.0	5.9	7.3	0.1	1.8		523	Stiff, Clayey silt to silty clay			10	1.11	0.23	1 - 2	1 - 3
6.5	6.8	8.2	0.1	1.7		517	Stiff, Clayey silt to silty clay			10	1.29	0.23	1 - 2	1 - 3
7.0	5.9	7.0	0.1	1.2		476	Stiff, Sandy silt to clayey silt			10	1.10	0.16	1 - 3	1 - 3
7.5	4.6	5.4	0.1	1.7		474	Soft, Clayey silt to silty clay			18	0.46	0.17	1 - 3	1 - 3
8.0	4.8	5.6	0.1	0.9		436	Soft, Sandy silt to clayey silt			18	0.48	0.12	1 - 3	1 - 3
8.5	7.5	8.6	0.0	0.0		447	V loose, Sensitive fine grained soil	27-31	0-20				1 - 3	1 - 3
9.0	55.1	62.5	0.3	0.5		413	Loose, Sand to silty sand	40-42	20-40				11 - 13	12 - 15
9.5	54.1	60.7	1.0	1.6		368	Med dense, Silty sand to sandy silt	36-37	40-60				18 - 20	20 - 23
10.0	19.9	22.1	0.7	2.2		506	Stiff, Sandy silt to sandy clay			20	1.93	1.41	5 - 6	6 - 7
10.5	35.9	39.7	0.6	1.8		474	Med dense, Silty sand to sandy silt	27-31	40-60				11 - 14	12 - 15
11.0	23.4	25.7	0.7	2.3		513	V stiff, Sandy silt to sandy clay			20	2.27	1.49	6 - 9	7 - 10
11.5	21.0	23.0	0.4	2.2		550	V stiff, Sandy silt to sandy clay			20	2.03	0.90	5 - 6	6 - 7
12.0	19.5	21.2	0.3	1.4		547	Loose, Silty sand to sandy silt	27-31	20-40				4 - 6	4 - 6
12.5	13.7	14.9	0.2	1.3		589	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
13.0	13.8	14.9	0.2	1.2		590	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
13.5	12.5	13.5	0.2	1.3		591	Stiff, Sandy silt to clayey silt			15	1.56	0.35	1 - 3	1 - 3
14.0	11.4	12.2	0.2	1.3		590	Stiff, Sandy silt to clayey silt			15	1.41	0.31	1 - 3	1 - 3

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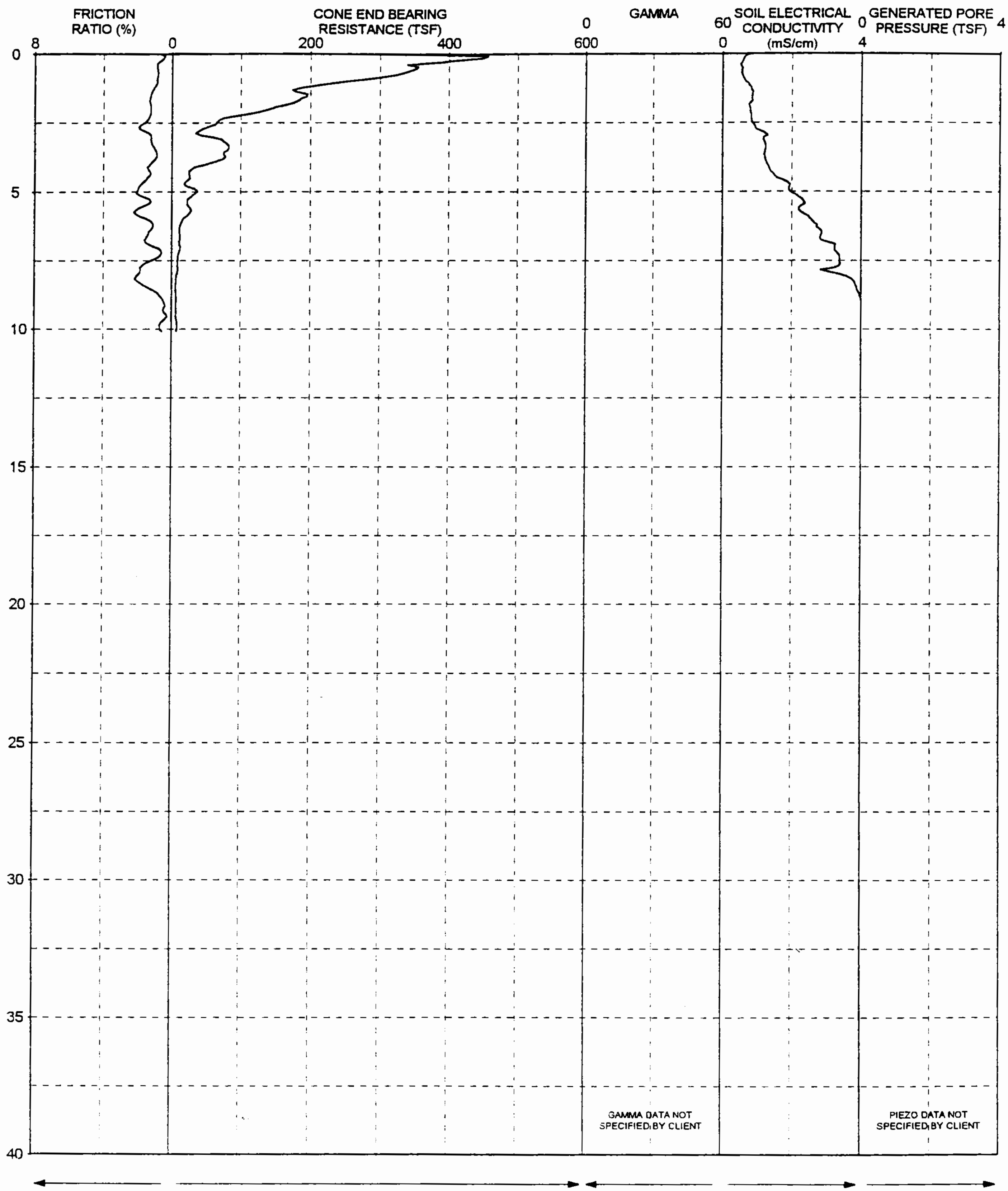
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP090

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp090

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	256.3	412.8	2.6	0.9		634	V dense, Sand to silty sand	42-46	80-100				+ 62	+ 100
1.5	195.2	297.2	2.5	1.2		863	V dense, Sand to silty sand	42-46	80-100				47 - 65	72 - 99
2.0	143.5	209.6	2.2	1.2		793	Dense, Sand to silty sand	42-46	60-80				41 - 49	60 - 72
2.5	65.8	92.9	1.5	1.6		859	Dense, Silty sand to sandy silt	37-40	60-80				23 - 28	33 - 40
3.0	51.8	71.0	0.9	1.2		1239	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 17	20 - 23
3.5	81.7	109.3	0.7	1.0		1226	Med dense, Sand to silty sand	40-42	40-60				22 - 25	30 - 33
4.0	52.2	68.4	0.9	1.2		1278	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 18	20 - 23
4.5	26.9	34.5	0.4	1.4		1574	Loose, Silty sand to sandy silt	27-31	20-40				5 - 8	7 - 10
5.0	36.7	46.3	0.6	2.0		1953	Med dense, Silty sand to sandy silt	27-31	40-60				12 - 13	15 - 17
5.5	23.6	29.2	0.4	1.5		2312	Loose, Silty sand to sandy silt	27-31	20-40				5 - 6	6 - 7
6.0	16.5	20.1	0.4	1.5		2533	Loose, Silty sand to sandy silt	27-31	20-40				3 - 5	4 - 6
6.5	11.6	14.0	0.2	1.4		2862	Stiff, Sandy silt to clayey silt			15	1.49	0.36	1 - 2	1 - 3
7.0	12.8	15.3	0.1	1.1		3239	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
7.5	8.9	10.5	0.1	1.2		3386	Stiff, Sandy silt to clayey silt			15	1.13	0.26	1 - 3	1 - 3
8.0	8.1	9.3	0.2	1.9		3367	Stiff, Clayey silt to silty clay			10	1.52	0.33	1 - 3	1 - 3
8.5	6.2	7.1	0.1	1.4		3871	Stiff, Sandy silt to clayey silt			10	1.13	0.19	1 - 3	1 - 3
9.0	6.6	7.5	0.0	0.5		4029	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
9.5	6.6	7.4	0.0	0.3		4131	V loose, Sensitive fine grained soil	27-31	0-20				1 - 3	1 - 3
10.0	8.2	9.1	0.1	0.7		4166	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3

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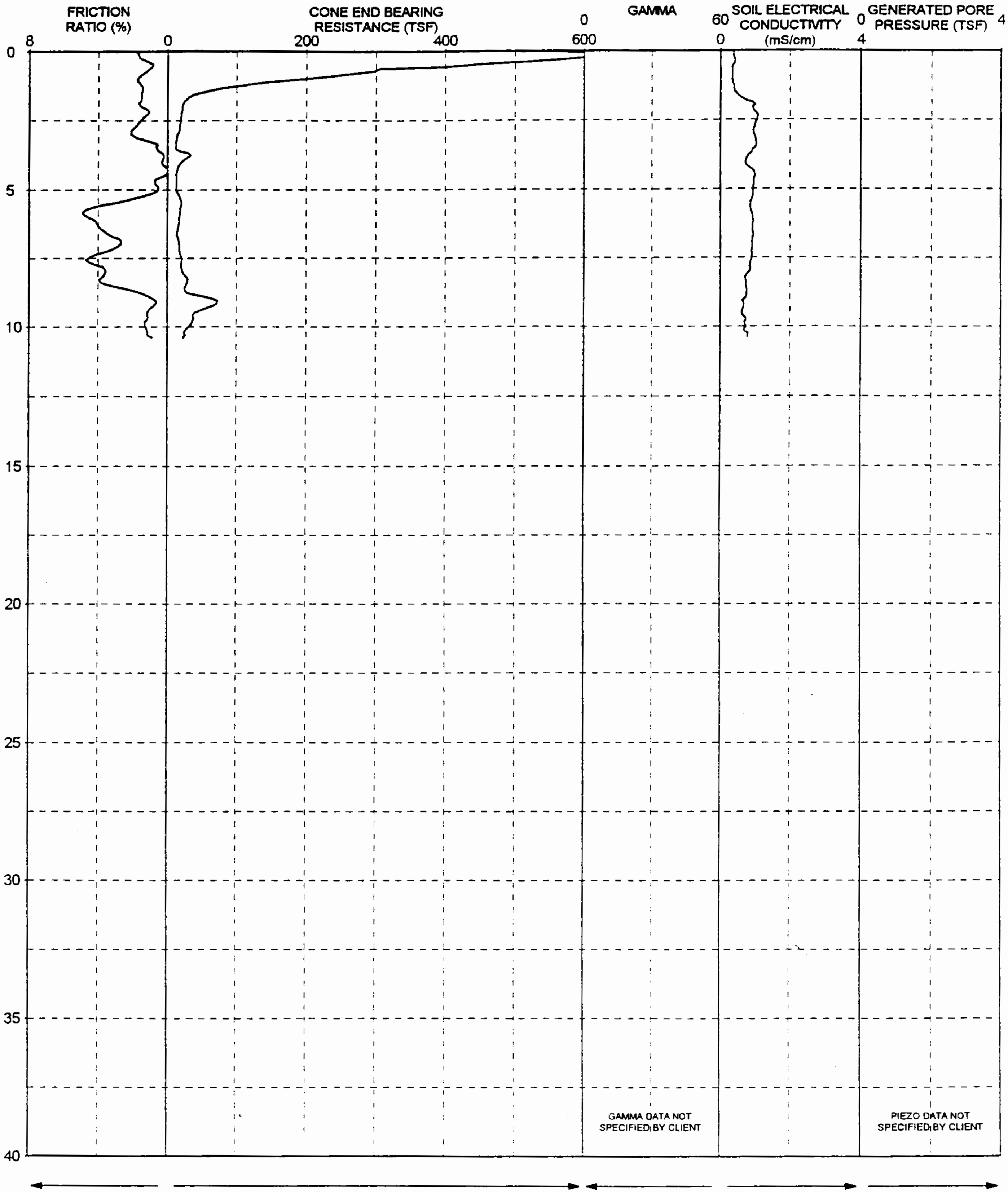
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
DATE: 10/03/96

PROJECT NUMBER: 96-110-230
SOUNDING NUMBER: CP091

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp091

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	197.2	317.7	5.2	1.8		336	V dense, Sa gravel to si gr sand	42-46	80-100				+ 62	+ 100
1.5	48.7	74.2	1.6	1.5		433	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 20	23 - 30
2.0	21.9	32.0	0.5	1.5		973	Loose, Silty sand to sandy silt	27-31	20-40				5 - 7	7 - 10
2.5	19.1	26.9	0.3	1.6		1055	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	6 - 7
3.0	14.7	20.2	0.4	2.1		961	Stiff, Sandy silt to sandy clay			15	1.94	0.73	4 - 5	6 - 7
3.5	12.6	16.8	0.2	0.6		1004	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
4.0	19.9	26.1	0.1	0.3		730	V loose, Silty sand to sandy silt	36-37	0-20				2 - 3	3 - 4
4.5	12.7	16.4	0.0	0.2		985	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
5.0	12.8	16.1	0.1	0.5		941	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
5.5	20.5	25.4	0.6	3.1		869	V stiff, Sandy clay to silty clay *			20	2.01	1.15	8 - 10	10 - 12
6.0	17.5	21.4	0.9	4.6		921	Stiff, Silty clay to clay *			20	1.72	1.73	10 - 12	12 - 15
6.5	14.7	17.7	0.6	3.7		926	Stiff, Silty clay to clay *			15	1.91	1.17	6 - 8	7 - 10
7.0	17.2	20.4	0.5	2.7		907	V stiff, Sandy clay to silty clay *			15	2.23	0.99	5 - 6	6 - 7
7.5	20.9	24.6	1.0	4.6		889	V stiff, Silty clay to clay *			20	2.05	1.92	13 - 14	15 - 17
8.0	22.4	26.0	1.0	3.6		839	V stiff, Sandy clay to silty clay *			20	2.20	1.93	10 - 13	12 - 15
8.5	27.1	31.0	1.2	3.3		737	V stiff, Sandy clay to silty clay *			20	2.66	2.41	13 - 15	15 - 17
9.0	68.0	77.1	0.4	0.8		687	Med dense, Sand to silty sand	40-42	40-60				15 - 18	17 - 20
9.5	40.2	45.1	0.7	1.1		618	Loose, Silty sand to sandy silt	36-37	20-40				9 - 11	10 - 12
10.0	31.7	35.2	0.5	1.3		727	Loose, Silty sand to sandy silt	36-37	20-40				6 - 9	7 - 10

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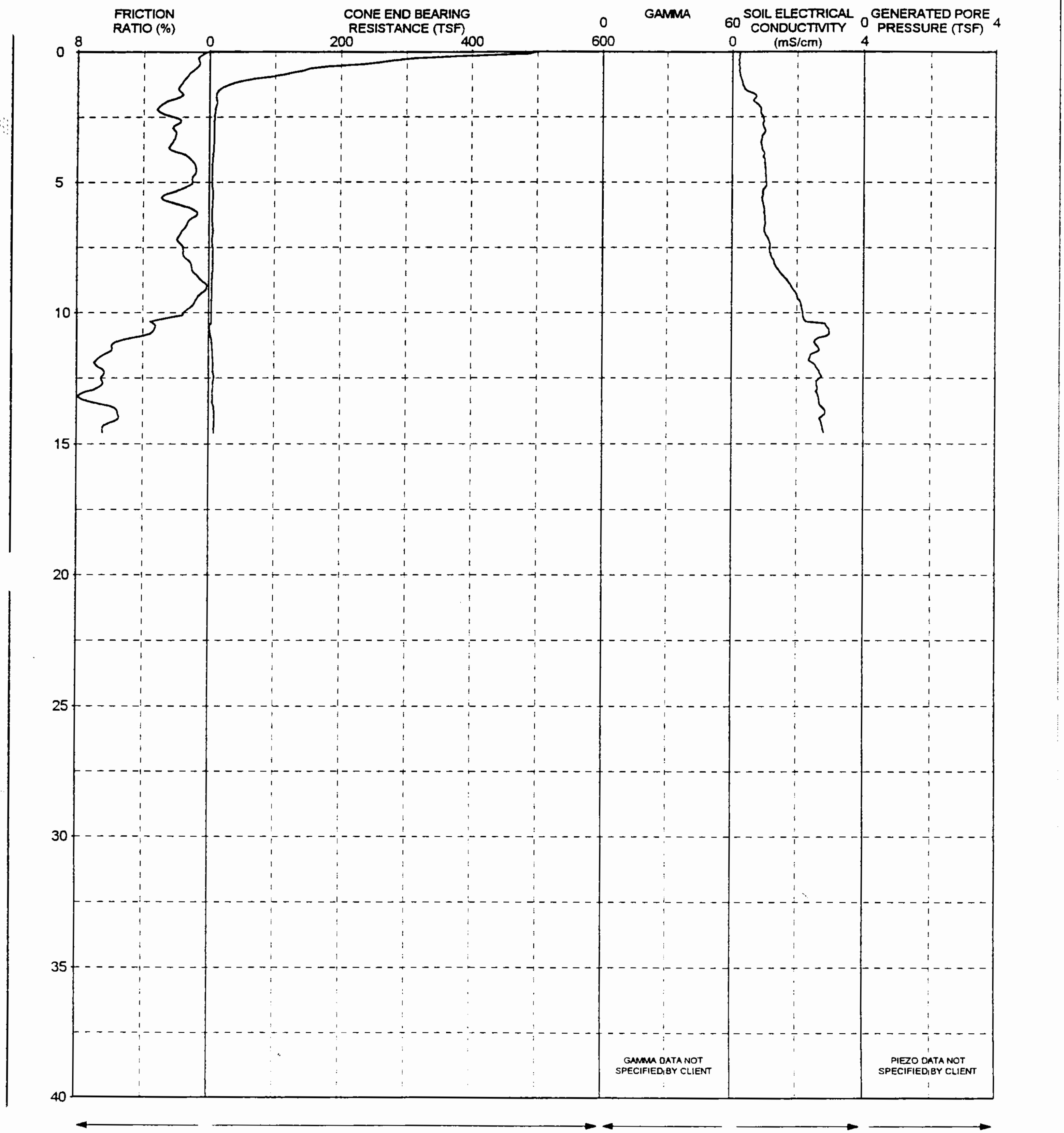

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP092

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp092

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	79.3	127.7	2.0	1.4		274	Dense, Sand to silty sand	40-42	60-80				25 - 29	40 - 46
1.5	13.9	21.1	0.7	1.8		444	Stiff, Sandy silt to clayey silt			15	1.84	1.37	3 - 4	4 - 6
2.0	11.8	17.3	0.3	2.8		770	Stiff, Sandy clay to silty clay *			15	1.56	0.64	4 - 5	6 - 7
2.5	7.8	11.1	0.2	2.2		956	Stiff, Clayey silt to silty clay			15	1.03	0.42	1 - 2	1 - 3
3.0	7.5	10.2	0.2	2.1		1004	Firm, Clayey silt to silty clay			15	0.97	0.32	1 - 2	1 - 3
3.5	7.1	9.5	0.2	2.2		896	Stiff, Clayey silt to silty clay			10	1.38	0.34	1 - 2	1 - 3
4.0	6.0	7.9	0.1	1.4		975	Stiff, Sandy silt to clayey silt			10	1.16	0.18	1 - 2	1 - 3
4.5	4.5	5.8	0.0	0.8		1023	Soft, Sandy silt to clayey silt			18	0.47	0.08	1 - 2	1 - 3
5.0	4.4	5.6	0.1	1.0		1046	Soft, Sandy silt to clayey silt			18	0.46	0.10	1 - 2	1 - 3
5.5	6.0	7.4	0.2	2.7		954	Stiff, Clayey silt to silty clay			10	1.13	0.30	1 - 2	1 - 3
6.0	5.0	6.1	0.1	1.2		979	Firm, Sandy silt to clayey silt			10	0.93	0.12	1 - 2	1 - 3
6.5	5.0	6.1	0.1	1.3		1008	Firm, Sandy silt to clayey silt			10	0.93	0.15	1 - 2	1 - 3
7.0	5.9	7.0	0.1	1.8		1032	Stiff, Clayey silt to silty clay			10	1.09	0.21	1 - 3	1 - 3
7.5	6.0	7.0	0.1	1.6		1167	Stiff, Clayey silt to silty clay			10	1.10	0.19	1 - 3	1 - 3
8.0	6.2	7.2	0.1	1.2		1279	Stiff, Sandy silt to clayey silt			10	1.15	0.15	1 - 3	1 - 3
8.5	5.6	6.4	0.1	0.8		1518	Stiff, Sandy silt to clayey silt			10	1.01	0.10	1 - 3	1 - 3
9.0	4.7	5.3	0.0	0.1		1828	Soft, Sensitive fine grained soil			18	0.46	0.01	1 - 3	1 - 3
9.5	4.3	4.9	0.0	0.7		2056	Soft, Sensitive fine grained soil			18	0.42	0.06	1 - 3	1 - 3
10.0	4.1	4.5	0.1	1.5		2177	Soft, Clayey silt to silty clay			18	0.38	0.13	1 - 3	1 - 3
10.5	1.3	1.5	0.1	3.2		2883	V soft, PROCESSING ERROR			25	0.06	0.23	0 - 1	0 - 1
11.0	4.0	4.4	0.2	4.8		2626	Soft, Clay			18	0.37	0.49	1 - 3	1 - 3
11.5	5.7	6.3	0.4	6.0		2624	Firm, Clay			12	0.84	0.74	3 - 4	3 - 4
12.0	6.8	7.4	0.5	6.8		2556	Stiff, Silty clay to clay *			12	1.01	1.01	6 - 6	6 - 7
12.5	7.8	8.5	0.5	6.5		2721	Stiff, Silty clay to clay *			12	1.18	0.95	6 - 6	6 - 7
13.0	6.3	6.8	0.5	7.3		2597	Firm, Clay			12	0.92	0.99	6 - 6	6 - 7
13.5	6.7	7.2	0.5	6.5		2694	Firm, Silty clay to clay *			12	0.98	1.07	4 - 6	4 - 6
14.0	9.0	9.6	0.5	5.5		2735	Stiff, Silty clay to clay *			15	1.09	0.94	6 - 7	6 - 7
14.5	8.2	8.8	0.5	6.4		2806	Stiff, Silty clay to clay *			12	1.22	0.98	6 - 7	6 - 7

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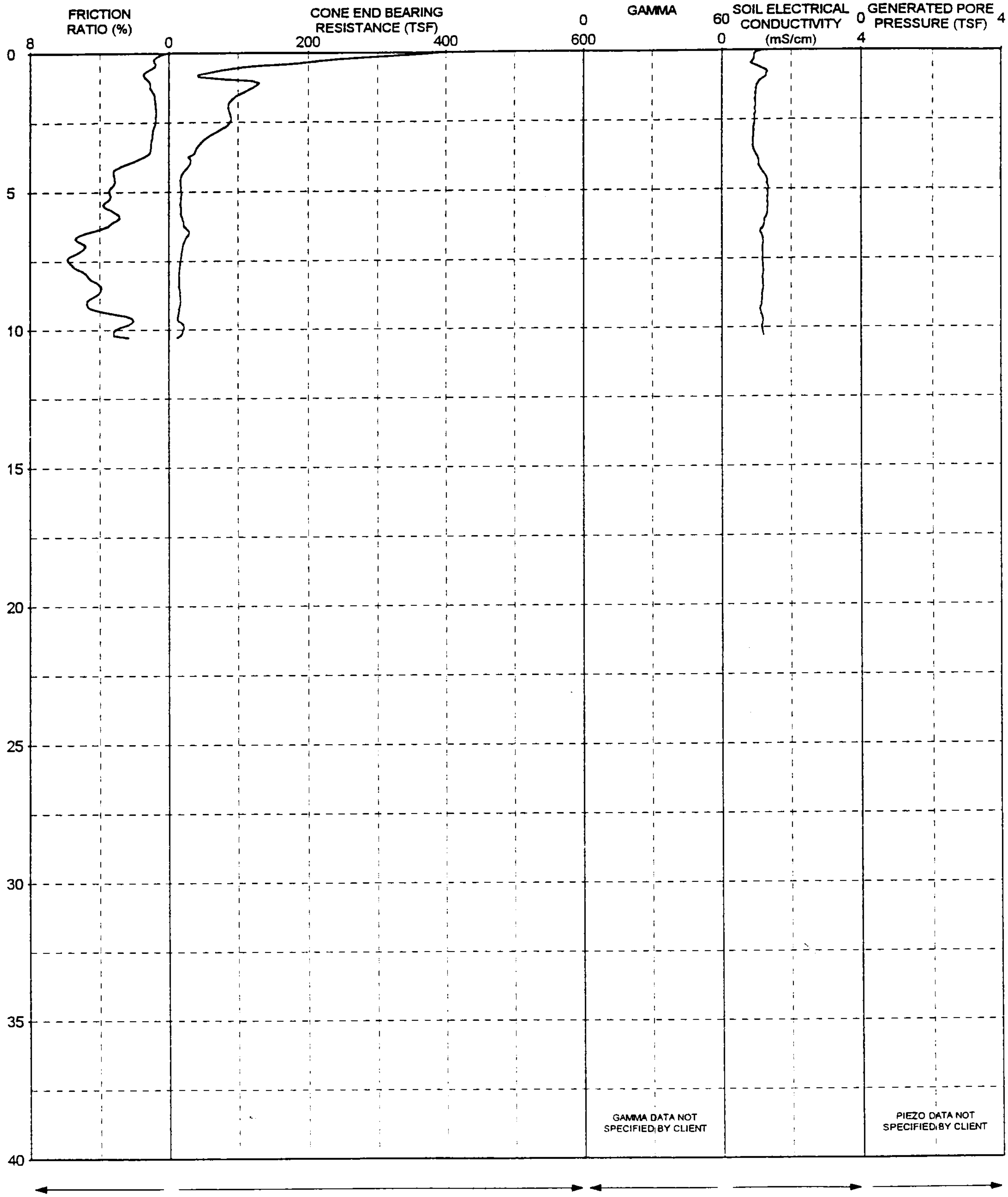
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP093

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp093

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	116.3	187.4	1.4	1.2		1236	Dense, Sand to silty sand	42-46	60-80				37 - 45	60 - 72
1.5	102.5	156.1	1.0	0.8		980	Med dense, Sand to silty sand	42-46	40-60				26 - 30	40 - 46
2.0	86.6	126.4	0.7	0.8		970	Med dense, Sand to silty sand	40-42	40-60				23 - 27	33 - 40
2.5	88.9	125.5	0.7	0.8		948	Med dense, Sand to silty sand	40-42	40-60				23 - 28	33 - 40
3.0	58.9	80.9	0.7	1.0		925	Med dense, Sand to silty sand	37-40	40-60				15 - 17	20 - 23
3.5	39.7	53.1	0.5	1.1		918	Med dense, Silty sand to sandy silt	37-40	40-60				9 - 11	12 - 15
4.0	31.1	40.7	0.8	2.4		1063	V stiff, Sandy silt to sandy clay			25	2.47	1.61	11 - 13	15 - 17
4.5	17.4	22.3	0.7	3.2		1242	Stiff, Sandy clay to silty clay *			20	1.71	1.45	5 - 8	7 - 10
5.0	18.1	22.8	0.6	3.5		1342	Stiff, Sandy clay to silty clay *			20	1.78	1.21	8 - 10	10 - 12
5.5	17.1	21.2	0.7	3.8		1326	Stiff, Silty clay to clay *			20	1.68	1.38	8 - 10	10 - 12
6.0	20.1	24.6	0.7	3.0		1284	Stiff, Sandy clay to silty clay *			20	1.97	1.38	8 - 10	10 - 12
6.5	29.7	35.8	1.2	4.9		1114	V stiff, Silty clay to clay *			25	2.35	2.47	25 - 27	30 - 33
7.0	19.9	23.7	1.2	4.9		1185	Stiff, Silty clay to clay *			20	1.95	2.32	14 - 17	17 - 20
7.5	17.1	20.0	1.1	5.8		1177	Stiff, Silty clay to clay *			20	1.66	2.15	14 - 17	17 - 20
8.0	14.8	17.2	0.7	4.8		1198	Stiff, Silty clay to clay *			15	1.91	1.49	9 - 10	10 - 12
8.5	15.2	17.5	0.6	3.9		1197	Stiff, Silty clay to clay *			15	1.96	1.25	6 - 9	7 - 10
9.0	16.8	19.1	0.8	4.7		1155	Stiff, Silty clay to clay *			20	1.63	1.56	11 - 13	12 - 15
9.5	13.6	15.3	0.4	2.6		1132	Stiff, Sandy clay to silty clay *			15	1.74	0.82	4 - 5	4 - 6
10.0	21.2	23.6	0.6	3.1		1167	V stiff, Sandy clay to silty clay *			20	2.06	1.11	9 - 11	10 - 12

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CPT-EC LOG

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP094

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp094

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	89.4	144.0	1.6	0.8		458	Med dense, Sand to silty sand	40-42	40-60				25 - 29	40 - 46
1.5	15.9	24.2	1.2	3.0		737	Stiff, Sandy clay to silty clay *			20	1.58	2.49	7 - 8	10 - 12
2.0	10.4	15.1	0.6	4.7		829	Stiff, Silty clay to clay *			15	1.37	1.26	5 - 7	7 - 10
2.5	7.7	10.9	0.4	4.4		868	Stiff, Silty clay to clay *			15	1.01	0.85	3 - 4	4 - 6
3.0	7.3	10.1	0.4	4.4		896	Firm, Silty clay to clay *			15	0.95	0.71	3 - 4	4 - 6
3.5	6.0	8.0	0.2	2.1		917	Stiff, Clayey silt to silty clay			10	1.16	0.42	1 - 2	1 - 3
4.0	23.7	31.0	0.3	1.2		768	Loose, Silty sand to sandy silt	27-31	20-40				5 - 5	6 - 7
4.5	24.8	31.9	0.3	1.1		710	Loose, Silty sand to sandy silt	36-37	20-40				5 - 5	6 - 7
5.0	7.9	10.0	0.1	0.6		757	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
5.5	5.5	6.8	0.1	0.8		846	Stiff, Sandy silt to clayey silt			10	1.03	0.11	1 - 2	1 - 3
6.0	6.5	7.9	0.1	1.2		821	Stiff, Sandy silt to clayey silt			10	1.22	0.18	1 - 2	1 - 3
6.5	6.6	7.9	0.0	0.4		857	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
7.0	7.6	9.0	0.3	3.0		857	Stiff, Silty clay to clay			10	1.43	0.52	1 - 3	1 - 3
7.5	8.1	9.5	0.4	4.2		856	Stiff, Silty clay to clay *			15	1.02	0.78	3 - 5	4 - 6
8.0	9.8	11.3	0.5	4.0		857	Stiff, Silty clay to clay *			15	1.24	0.90	3 - 5	4 - 6
8.5	10.0	11.4	0.6	4.5		814	Stiff, Silty clay to clay *			15	1.26	1.11	5 - 6	6 - 7
9.0	12.8	14.5	0.9	3.3		837	Stiff, Silty clay to clay *			15	1.63	1.83	5 - 6	6 - 7
9.5	55.3	62.0	0.9	2.4		757	Dense, Silty sand to sandy silt	27-31	60-80				20 - 27	23 - 30
10.0	20.3	22.6	0.9	2.4		759	Stiff, Sandy silt to sandy clay			20	1.97	1.71	5 - 6	6 - 7
10.5	19.5	21.6	0.8	3.3		771	Stiff, Sandy clay to silty clay *			20	1.89	1.58	9 - 11	10 - 12
11.0	24.7	27.2	0.9	3.7		712	V stiff, Sandy clay to silty clay *			20	2.40	1.77	14 - 15	15 - 17
11.5	17.1	18.8	0.7	3.0		812	V stiff, Sandy clay to silty clay *			15	2.19	1.37	5 - 6	6 - 7
12.0	16.0	17.4	0.5	2.8		899	V stiff, Sandy clay to silty clay *			15	2.03	0.97	6 - 6	6 - 7
12.5	15.7	17.1	0.5	3.0		930	Stiff, Sandy clay to silty clay *			15	2.00	1.08	6 - 6	6 - 7
13.0	12.0	13.0	0.5	3.4		1025	Stiff, Silty clay to clay *			15	1.50	0.97	4 - 6	4 - 6
13.5	10.7	11.5	0.5	4.4		1296	Stiff, Silty clay to clay *			15	1.32	1.08	6 - 6	6 - 7
14.0	11.0	11.8	0.6	5.0		1285	Stiff, Silty clay to clay *			15	1.36	1.11	6 - 7	6 - 7

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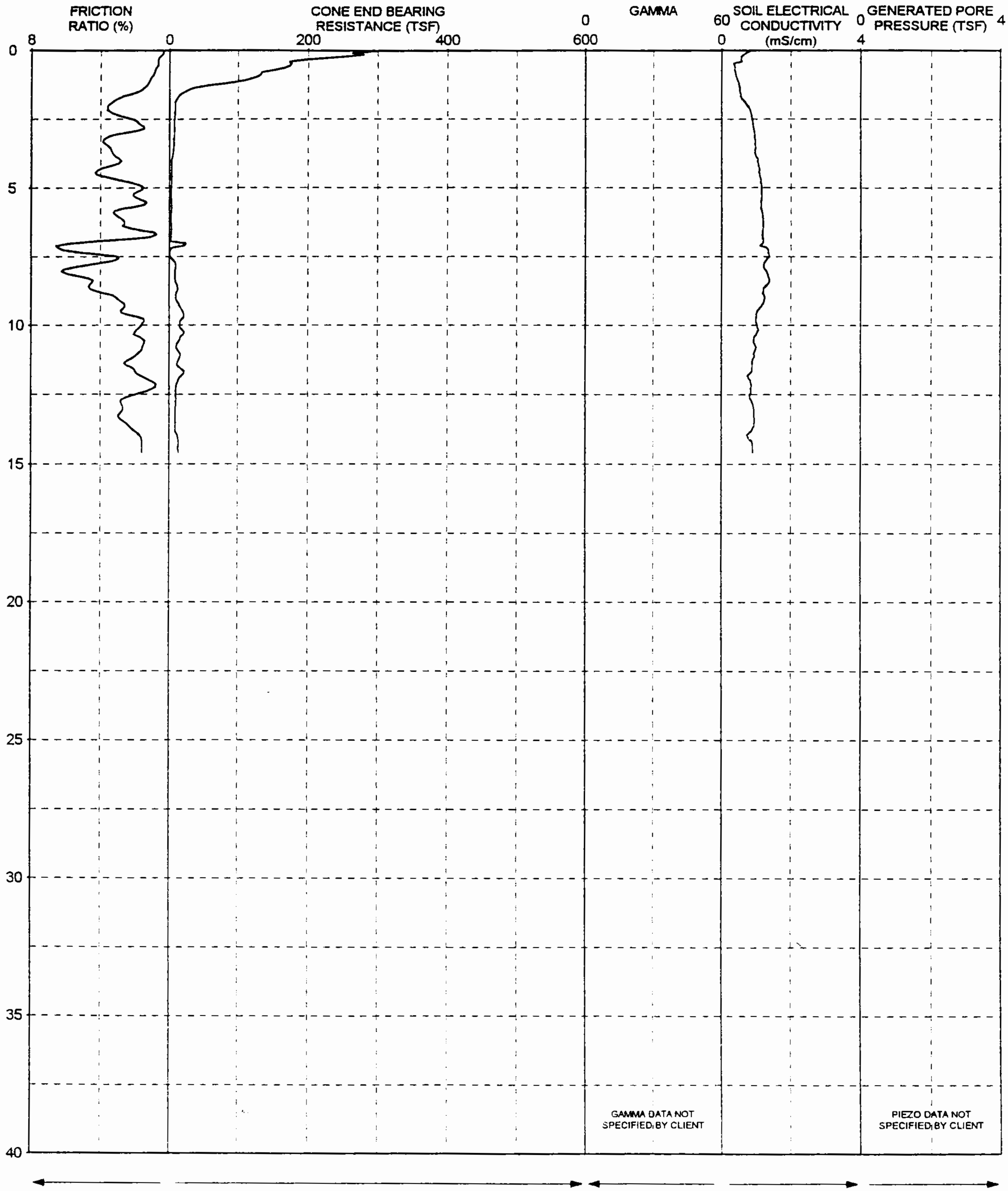
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP095

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp095

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	124.5	200.5	1.6	1.1		433	Dense, Sand to silty sand	42-46	60-80				37 - 45	60 - 72
1.5	23.9	36.4	1.2	1.8		548	Med dense, Silty sand to sandy silt	27-31	40-60				7 - 8	10 - 12
2.0	8.6	12.5	0.5	3.5		730	Stiff, Silty clay to clay *			15	1.13	0.91	3 - 4	4 - 6
2.5	7.7	10.9	0.2	2.2		892	Stiff, Clayey silt to silty clay			15	1.01	0.35	1 - 2	1 - 3
3.0	7.5	10.3	0.2	2.5		957	Firm, Clayey silt to silty clay			15	0.98	0.41	1 - 2	1 - 3
3.5	6.6	8.8	0.2	3.5		984	Stiff, Silty clay to clay			10	1.27	0.49	2 - 3	3 - 4
4.0	3.7	4.8	0.1	2.8		1053	Soft, Silty clay to clay			18	0.38	0.30	1 - 2	1 - 3
4.5	3.6	4.6	0.2	4.2		1102	Soft, Clay			18	0.37	0.30	1 - 2	1 - 3
5.0	3.1	3.9	0.0	1.5		1159	Soft, Sensitive fine grained soil			18	0.31	0.10	1 - 2	1 - 3
5.5	3.1	3.9	0.0	1.5		1154	Soft, Sensitive fine grained soil			18	0.31	0.09	0 - 1	0 - 1
6.0	2.8	3.5	0.1	3.1		1189	Soft, Silty clay to clay			18	0.27	0.19	1 - 2	1 - 3
6.5	3.4	4.1	0.1	2.1		1199	Soft, Clayey silt to silty clay			18	0.34	0.17	1 - 2	1 - 3
7.0	15.9	18.9	0.5	5.2		1208	Stiff, Silty clay to clay *			20	1.55	0.94	10 - 13	12 - 15
7.5	1.5	1.8	0.2	3.1		1376	V soft, Sensitive fine grained soil			25	0.08	0.45	0 - 1	0 - 1
8.0	9.4	10.9	0.6	6.2		1281	Stiff, Silty clay to clay *			14	1.27	1.17	6 - 9	7 - 10
8.5	11.0	12.6	0.5	4.6		1335	Stiff, Silty clay to clay *			15	1.40	1.07	5 - 6	6 - 7
9.0	9.8	11.1	0.5	3.1		1250	Stiff, Clayey silt to silty clay			15	1.23	0.90	3 - 4	3 - 4
9.5	20.5	23.0	0.6	2.8		1048	Stiff, Sandy clay to silty clay *			20	1.99	1.13	6 - 9	7 - 10
10.0	15.8	17.5	0.3	1.6		1033	V stiff, Sandy silt to clayey silt			15	2.02	0.63	3 - 4	3 - 4
10.5	16.6	18.4	0.3	1.6		945	Loose, Silty sand to sandy silt	27-31	20-40				3 - 4	3 - 4
11.0	15.3	16.8	0.2	1.8		957	Stiff, Sandy silt to clayey silt			15	1.95	0.49	3 - 4	3 - 4
11.5	14.0	15.3	0.4	2.3		897	Stiff, Clayey silt to silty clay			15	1.77	0.84	4 - 5	4 - 6
12.0	13.7	15.0	0.2	1.1		834	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
12.5	10.1	11.0	0.2	1.9		836	Stiff, Clayey silt to silty clay			15	1.25	0.41	1 - 3	1 - 3
13.0	9.7	10.5	0.3	2.7		940	Stiff, Clayey silt to silty clay			15	1.19	0.54	1 - 3	1 - 3
13.5	9.6	10.3	0.3	2.6		957	Stiff, Clayey silt to silty clay			15	1.17	0.51	1 - 3	1 - 3
14.0	12.8	13.8	0.2	1.7		758	Stiff, Sandy silt to clayey silt			15	1.60	0.46	1 - 3	1 - 3
14.5	13.7	14.6	0.1	1.6		910	Stiff, Sandy silt to clayey silt			15	1.71	0.19	3 - 4	3 - 4

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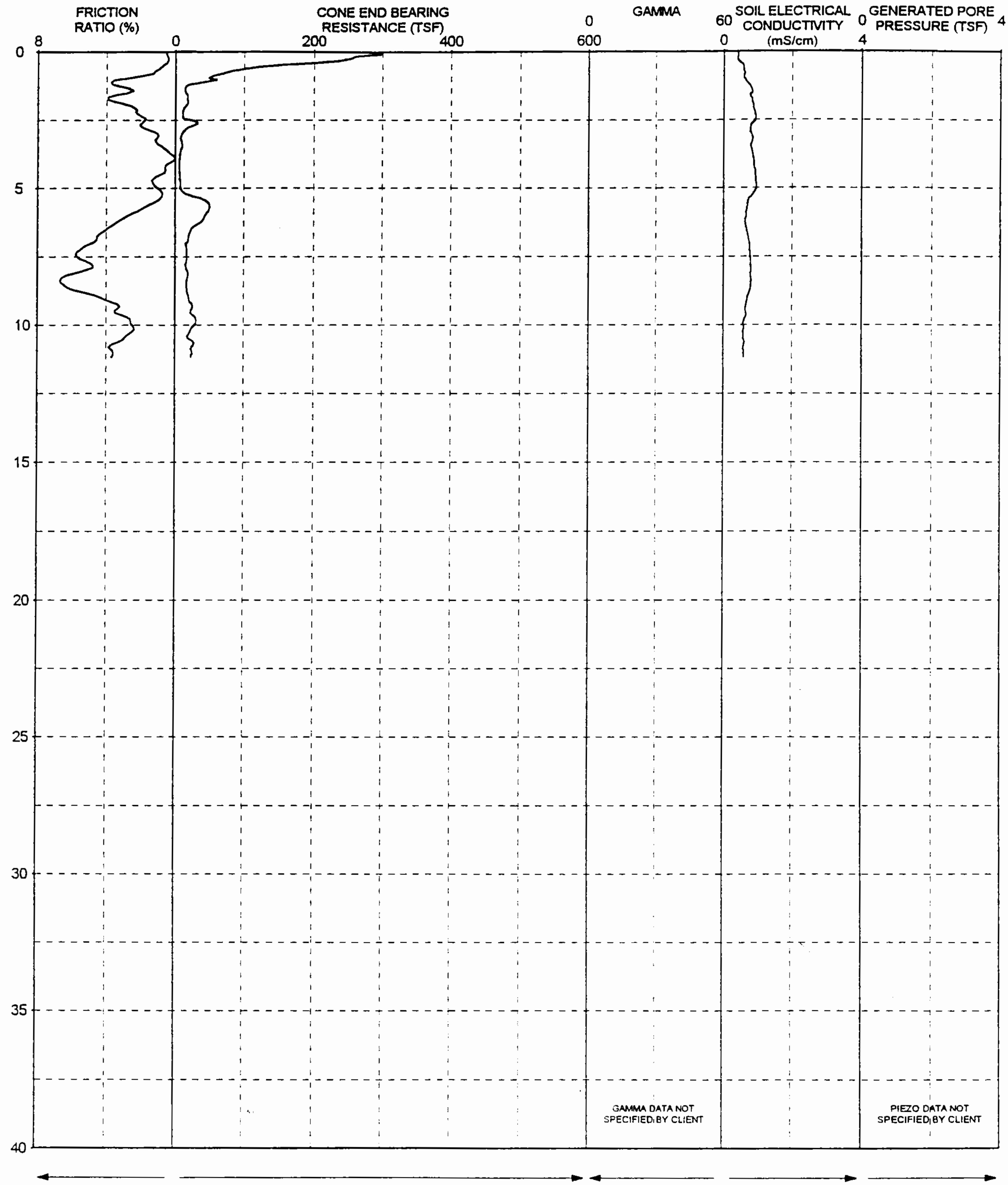
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230
DATE: 10/03/96
SOUNDING NUMBER: CP096

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp096

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	68.6	110.6	2.9	3.4		626	Hard, Gr cl sand to gr sa silt			30	4.57	5.72	45 - 61	72 - 99
1.5	15.3	23.2	0.7	2.7		852	Stiff, Sandy clay to silty clay *			20	1.52	1.32	5 - 7	7 - 10
2.0	14.7	21.4	0.4	2.6		884	Stiff, Sandy clay to silty clay *			20	1.46	0.84	4 - 5	6 - 7
2.5	20.3	28.6	0.3	1.7		939	Med dense, Silty sand to sandy silt	27-31	40-60				5 - 7	7 - 10
3.0	9.9	13.5	0.2	1.1		813	Loose, Silty sand to sandy silt	27-31	20-40				1 - 2	1 - 3
3.5	9.5	12.7	0.1	0.7		803	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
4.0	6.0	7.8	0.0	0.1		895	, Sensitive fine grained soil	27-31	6				1 - 2	1 - 3
4.5	6.5	8.4	0.1	0.8		936	Stiff, Sandy silt to clayey silt			10	1.25	0.11	1 - 2	1 - 3
5.0	7.7	9.7	0.2	1.0		958	Stiff, Sandy silt to clayey silt			10	1.48	0.47	1 - 2	1 - 3
5.5	46.9	58.2	0.5	1.2		724	Med dense, Silty sand to sandy silt	37-40	40-60				12 - 14	15 - 17
6.0	44.2	54.0	1.3	2.7		668	V stiff, Sandy silt to sandy clay			25	3.51	2.60	19 - 25	23 - 30
6.5	23.7	28.5	1.4	4.0		681	V stiff, Silty clay to clay *			20	2.33	2.76	14 - 17	17 - 20
7.0	16.1	19.2	1.0	4.8		764	Stiff, Silty clay to clay *			20	1.57	1.92	10 - 13	12 - 15
7.5	16.7	19.5	0.9	5.7		793	Stiff, Silty clay to clay *			20	1.62	1.88	13 - 14	15 - 17
8.0	17.5	20.3	0.9	5.2		809	Stiff, Silty clay to clay *			20	1.71	1.85	13 - 15	15 - 17
8.5	16.5	19.0	1.2	6.5		817	Stiff, Silty clay to clay *			18	1.78	2.35	15 - 17	17 - 20
9.0	20.0	22.7	1.0	4.3		708	Stiff, Silty clay to clay *			20	1.95	1.98	11 - 13	12 - 15
9.5	23.0	25.9	1.0	3.5		662	V stiff, Sandy clay to silty clay *			20	2.25	1.98	11 - 13	12 - 15
10.0	28.6	31.7	0.7	2.5		595	V stiff, Sandy silt to sandy clay			20	2.80	1.39	11 - 14	12 - 15
10.5	19.1	21.2	0.7	3.0		583	Stiff, Sandy clay to silty clay *			20	1.85	1.43	6 - 9	7 - 10
11.0	24.7	27.2	0.7	3.6		603	V stiff, Sandy clay to silty clay *			20	2.41	1.45	14 - 15	15 - 17

NOTES:
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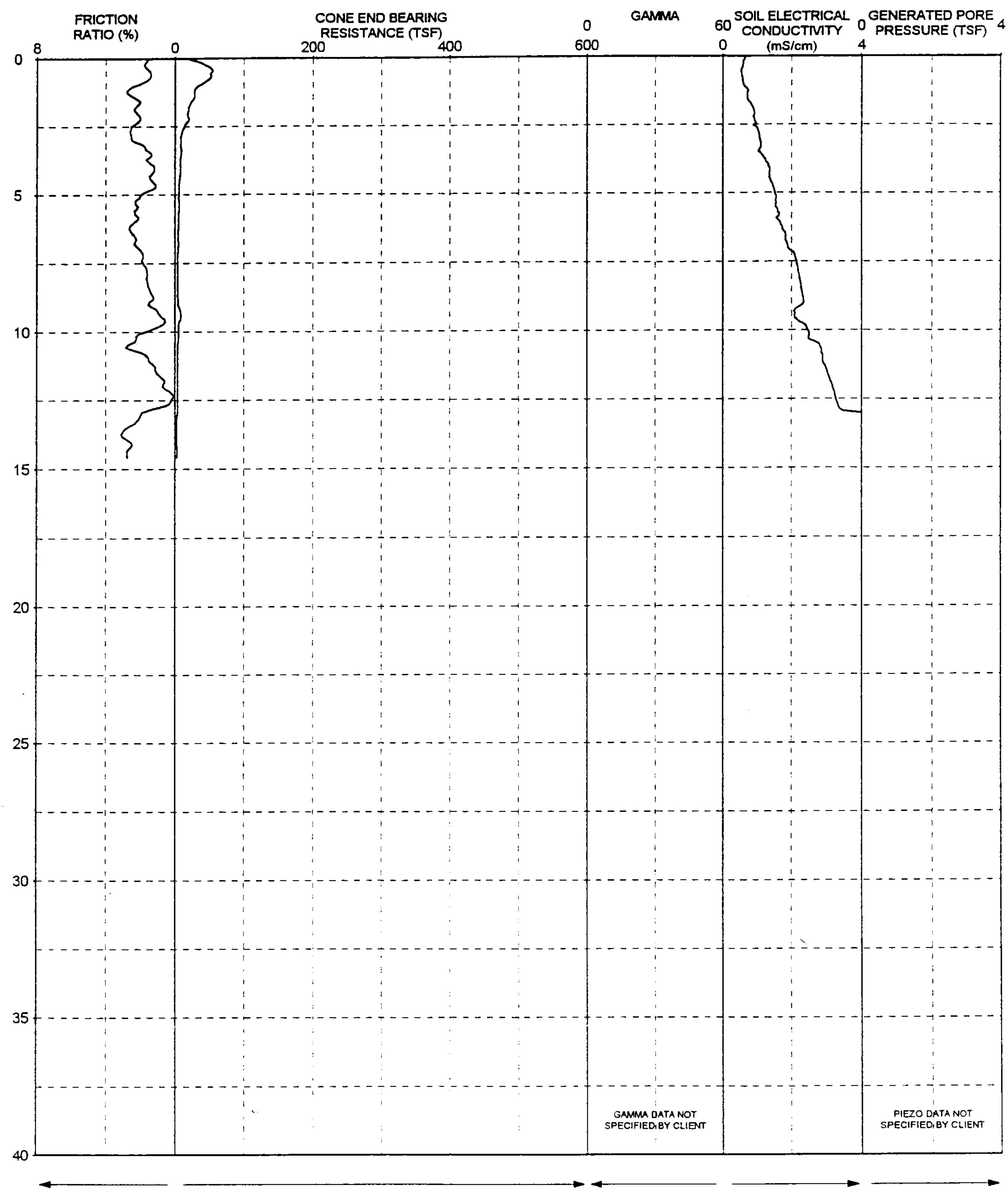
Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/03/96
SOUNDING NUMBER: CP097

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp097

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	34.3	55.3	1.1	2.3		581	Dense, Silty sand to sandy silt	27-31	60-80				12 - 14	20 - 23
1.5	26.7	40.6	0.6	2.2		710	Med dense, Silty sand to sandy silt	27-31	40-60				10 - 11	15 - 17
2.0	19.0	27.8	0.5	2.2		912	Stiff, Sandy silt to sandy clay			20	1.89	0.99	5 - 7	7 - 10
2.5	14.5	20.5	0.5	2.5		924	Stiff, Sandy silt to sandy clay			15	1.91	0.91	4 - 5	6 - 7
3.0	8.7	11.9	0.3	2.5		1081	Stiff, Clayey silt to silty clay			15	1.13	0.55	2 - 3	3 - 4
3.5	9.6	12.9	0.1	1.4		1052	Stiff, Sandy silt to clayey silt			15	1.25	0.24	1 - 2	1 - 3
4.0	7.8	10.2	0.1	1.2		1320	Stiff, Sandy silt to clayey silt			10	1.51	0.20	1 - 2	1 - 3
4.5	6.7	8.7	0.1	1.3		1370	Stiff, Sandy silt to clayey silt			10	1.29	0.20	1 - 2	1 - 3
5.0	5.7	7.2	0.1	1.9		1507	Stiff, Clayey silt to silty clay			10	1.09	0.24	1 - 2	1 - 3
5.5	6.2	7.7	0.1	2.2		1536	Stiff, Clayey silt to silty clay			10	1.18	0.25	1 - 2	1 - 3
6.0	5.5	6.7	0.1	2.3		1610	Stiff, Clayey silt to silty clay			10	1.02	0.25	1 - 2	1 - 3
6.5	4.8	5.8	0.1	2.4		1835	Firm, Clayey silt to silty clay			10	0.88	0.24	1 - 2	1 - 3
7.0	5.0	5.9	0.1	2.1		1905	Firm, Clayey silt to silty clay			10	0.91	0.20	1 - 3	1 - 3
7.5	3.8	4.5	0.1	1.9		2143	Soft, Clayey silt to silty clay			18	0.38	0.16	1 - 3	1 - 3
8.0	4.0	4.7	0.1	1.6		2223	Soft, Clayey silt to silty clay			18	0.39	0.14	1 - 3	1 - 3
8.5	4.2	4.8	0.1	1.5		2291	Soft, Clayey silt to silty clay			18	0.41	0.13	1 - 3	1 - 3
9.0	4.8	5.4	0.1	1.5		2362	Soft, Clayey silt to silty clay			18	0.47	0.25	1 - 3	1 - 3
9.5	8.6	9.7	0.0	0.7		2096	V loose, Silty sand to sandy silt	27-31	0-20				1 - 3	1 - 3
10.0	5.1	5.6	0.1	1.7		2475	Soft, Clayey silt to silty clay			18	0.50	0.22	1 - 3	1 - 3
10.5	4.3	4.8	0.1	2.8		2802	Soft, Silty clay to clay			18	0.41	0.29	1 - 3	1 - 3
11.0	3.9	4.3	0.1	1.5		2901	Soft, Clayey silt to silty clay			18	0.36	0.12	1 - 3	1 - 3
11.5	3.7	4.1	0.0	1.1		3033	Soft, Sensitive fine grained soil			18	0.34	0.08	0 - 1	0 - 1
12.0	3.8	4.1	0.0	0.7		3169	Soft, Sensitive fine grained soil			18	0.34	0.06	0 - 1	0 - 1
12.5	3.7	4.0	0.0	0.2		3269	Soft, Sensitive fine grained soil			18	0.33	0.01	0 - 1	0 - 1
13.0	3.7	4.1	0.1	2.0		3998	Soft, Clayey silt to silty clay			18	0.33	0.15	1 - 3	1 - 3
13.5	2.8	3.0	0.1	2.8		4441	V soft, Silty clay to clay			18	0.22	0.17	0 - 1	0 - 1
14.0	3.0	3.2	0.1	2.6		4757	V soft, Silty clay to clay			18	0.24	0.16	0 - 1	0 - 1
14.5	3.2	3.4	0.1	2.8		5269	Soft, Silty clay to clay			18	0.26	0.16	1 - 3	1 - 3

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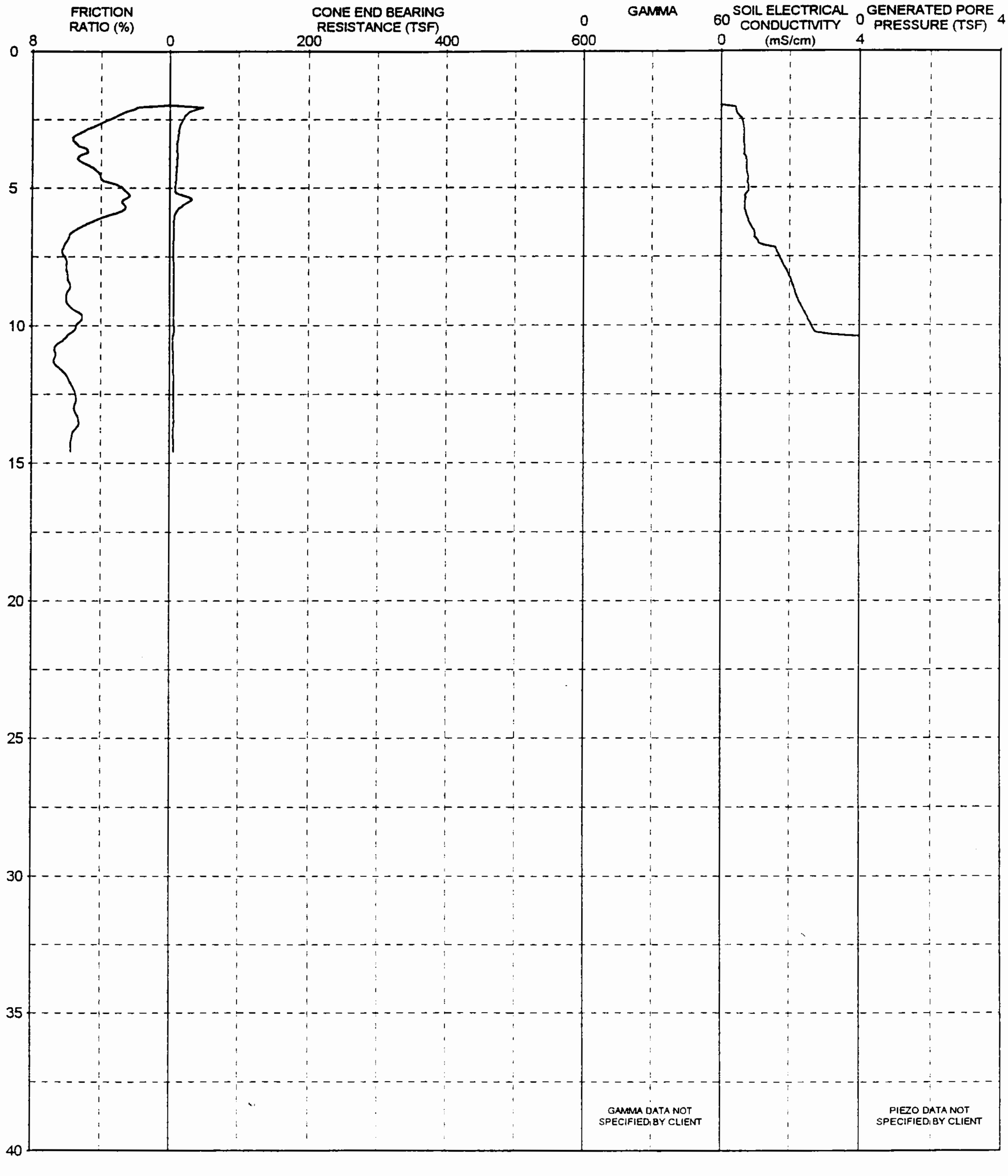
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230
DATE: 10/03/96
SOUNDING NUMBER: CP100

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp100

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.00	PREPUNCH													
1.50	PREPUNCH													
2.0	8.5	12.4	0.3	0.3		75	V loose, Silty sand to sandy silt	31-36	0-20				1 - 2	1 - 3
2.5	19.6	27.6	1.1	3.5		613	Stiff, Sandy clay to silty clay *			20	1.94	2.17	8 - 11	12 - 15
3.0	13.2	18.2	0.8	5.2		667	Stiff, Silty clay to clay *			15	1.74	1.60	9 - 11	12 - 15
3.5	10.6	14.2	0.6	5.2		682	Stiff, Silty clay to clay *			15	1.39	1.25	5 - 7	7 - 10
4.0	10.8	14.2	0.6	5.3		748	Stiff, Silty clay to clay *			15	1.41	1.17	8 - 9	10 - 12
4.5	9.4	12.1	0.4	4.0		769	Stiff, Silty clay to clay *			15	1.22	0.82	5 - 5	6 - 7
5.0	8.2	10.4	0.5	2.8		802	Stiff, Clayey silt to silty clay			15	1.06	0.95	2 - 3	3 - 4
5.5	29.0	36.0	0.5	2.7		702	V stiff, Sandy silt to sandy clay			25	2.29	1.09	12 - 14	15 - 17
6.0	7.7	9.4	0.5	3.5		745	Firm, Silty clay to clay			15	0.98	1.07	2 - 3	3 - 4
6.5	5.8	7.0	0.3	5.4		933	Stiff, Clay			10	1.08	0.69	2 - 3	3 - 4
7.0	5.6	6.7	0.4	6.1		1102	Firm, Clay			12	0.87	0.70	3 - 5	4 - 6
7.5	5.5	6.5	0.4	6.1		1700	Firm, Clay			12	0.84	0.70	3 - 5	4 - 6
8.0	5.9	6.8	0.3	6.0		1914	Firm, Clay			12	0.90	0.70	3 - 5	4 - 6
8.5	5.8	6.7	0.3	5.8		2086	Firm, Clay			12	0.89	0.69	3 - 5	4 - 6
9.0	6.0	6.8	0.4	6.0		2220	Firm, Clay			12	0.91	0.72	4 - 5	4 - 6
9.5	5.7	6.4	0.3	5.4		2426	Stiff, Clay			10	1.03	0.64	3 - 4	3 - 4
10.0	6.4	7.1	0.3	5.5		2630	Stiff, Clay			10	1.15	0.68	4 - 5	4 - 6
10.5	4.8	5.3	0.4	6.1		4103	Firm, Clay			12	0.69	0.74	3 - 4	3 - 4
11.0	5.1	5.7	0.4	6.7		4342	Firm, Clay			12	0.75	0.71	4 - 5	4 - 6
11.5	5.5	6.1	0.4	6.6		4585	Firm, Clay			12	0.81	0.75	4 - 5	4 - 6
12.0	5.8	6.3	0.3	5.9		4794	Firm, Clay			12	0.85	0.69	3 - 4	3 - 4
12.5	5.9	6.4	0.3	5.5		4973	Firm, Clay			12	0.86	0.66	3 - 4	3 - 4
13.0	6.1	6.6	0.3	5.6		5140	Firm, Clay			12	0.88	0.69	3 - 4	3 - 4
13.5	6.3	6.8	0.3	5.3		5291	Stiff, Clay			10	1.11	0.66	3 - 4	3 - 4
14.0	5.6	6.0	0.3	5.7		5548	Firm, Clay			12	0.80	0.67	3 - 4	3 - 4
14.5	5.8	6.2	0.4	5.8		6375	Firm, Clay			12	0.82	0.79	3 - 4	3 - 4

NOTES:
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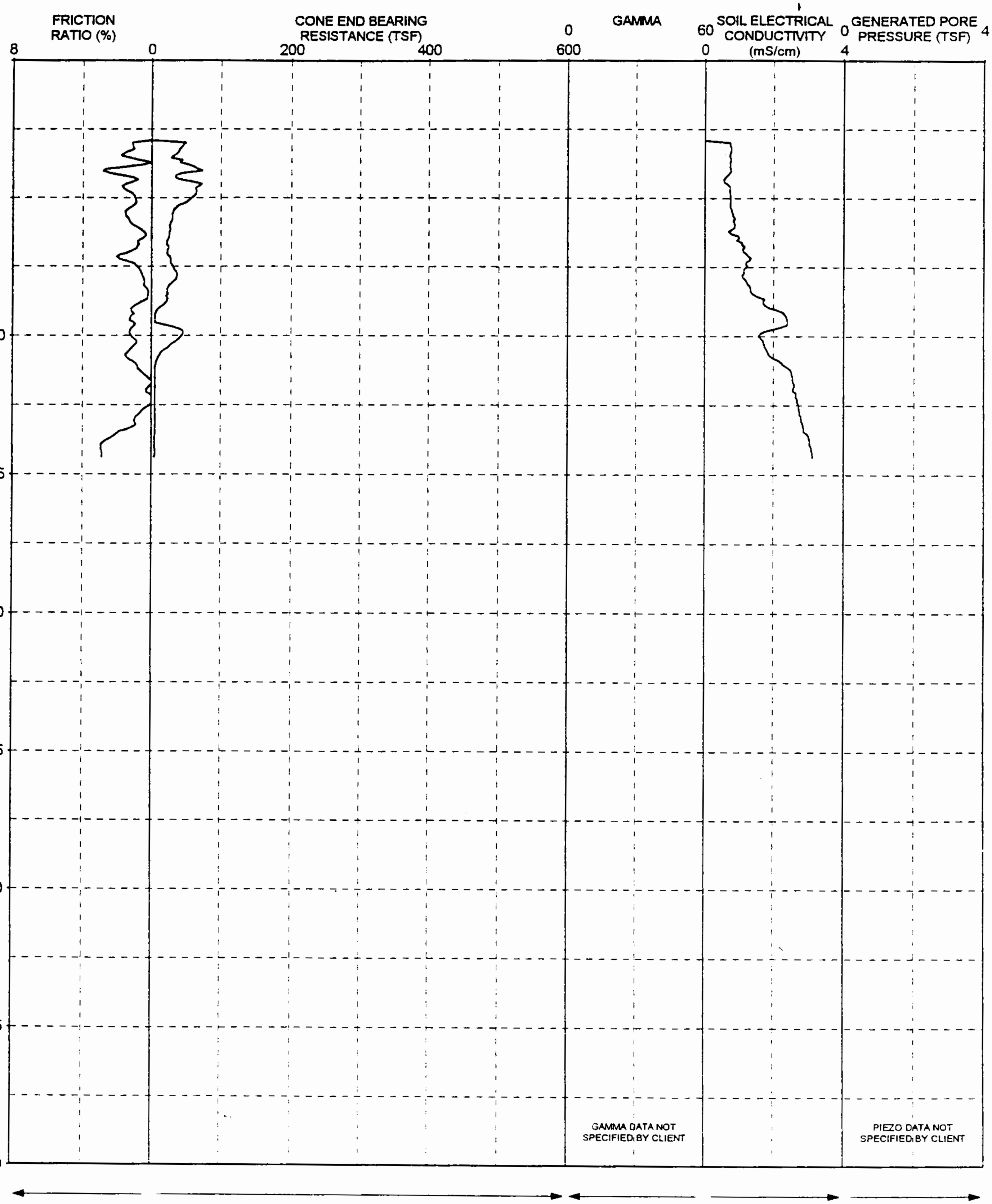
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/04/96
SOUNDING NUMBER: CP104

STRATIGRAPHICS

JOB NO: '96-110-230

JOB NAME: Zone D, F, and G Charleston Naval Base

SOUNDING NO: cp104

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.00	PREPUNCH													
1.50	PREPUNCH													
2.00	PREPUNCH													
2.50	PREPUNCH													
3.0	47.6	65.3	0.7	1.1		710	Med dense, Sand to silty sand	37-40	40-60				12 - 15	17 - 20
3.5	30.9	41.4	0.8	1.6		737	Med dense, Silty sand to sandy silt	36-37	40-60				7 - 9	10 - 12
4.0	71.0	93.0	1.5	2.8		767	V dense, Silty sand to sandy silt	36-37	80-100				35 - 46	46 - 60
4.5	72.6	93.3	1.1	1.5		675	Med dense, Silty sand to sandy silt	37-40	40-60				23 - 26	30 - 33
5.0	58.3	73.5	0.6	0.9		749	Med dense, Sand to silty sand	37-40	40-60				13 - 16	17 - 20
5.5	31.6	39.3	0.7	1.5		795	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 10	10 - 12
6.0	26.5	32.4	0.3	1.1		882	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
6.5	24.1	29.1	0.2	0.6		971	Loose, Silty sand to sandy silt	36-37	20-40				3 - 5	4 - 6
7.0	22.7	27.0	0.4	1.4		1202	Loose, Silty sand to sandy silt	27-31	20-40				5 - 6	6 - 7
7.5	30.8	36.2	0.2	0.8		1219	Loose, Silty sand to sandy silt	36-37	20-40				5 - 6	6 - 7
8.0	34.2	39.6	0.1	0.4		1194	Loose, Sand to silty sand	37-40	20-40				5 - 6	6 - 7
8.5	24.2	27.7	0.1	0.2		1418	V loose, Sand to silty sand	36-37	0-20				3 - 3	3 - 4
9.0	11.8	13.3	0.2	1.1		1932	Loose, Silty sand to sandy silt	27-31	20-40				1 - 3	1 - 3
9.5	5.2	5.8	0.3	1.1		2390	Firm, Sandy silt to clayey silt			18	0.51	0.61	1 - 3	1 - 3
10.0	44.0	48.8	0.4	1.2		1594	Med dense, Silty sand to sandy silt	36-37	40-60				11 - 14	12 - 15
10.5	19.7	21.8	0.4	1.2		1798	Loose, Silty sand to sandy silt	27-31	20-40				4 - 5	4 - 6
11.0	6.8	7.5	0.1	0.9		2242	Stiff, Sandy silt to clayey silt			10	1.23	0.20	1 - 3	1 - 3
11.5	5.1	5.6	0.0	0.2		2551	Soft, Sensitive fine grained soil			18	0.49	0.03	1 - 3	1 - 3
12.0	5.3	5.8	0.0	0.3		2590	Firm, Sensitive fine grained soil			18	0.51	0.04	1 - 3	1 - 3
12.5	5.3	5.8	0.0	0.0		2711	, Sensitive fine grained soil	27-31	18				1 - 3	1 - 3
13.0	5.2	5.6	0.1	0.9		2795	Soft, Sandy silt to clayey silt			18	0.49	0.10	1 - 3	1 - 3
13.5	5.4	5.8	0.1	2.0		2908	Firm, Clayey silt to silty clay			10	0.91	0.21	1 - 3	1 - 3
14.0	5.0	5.4	0.2	2.9		3063	Firm, Silty clay to clay			10	0.83	0.30	1 - 3	1 - 3

NOTES:

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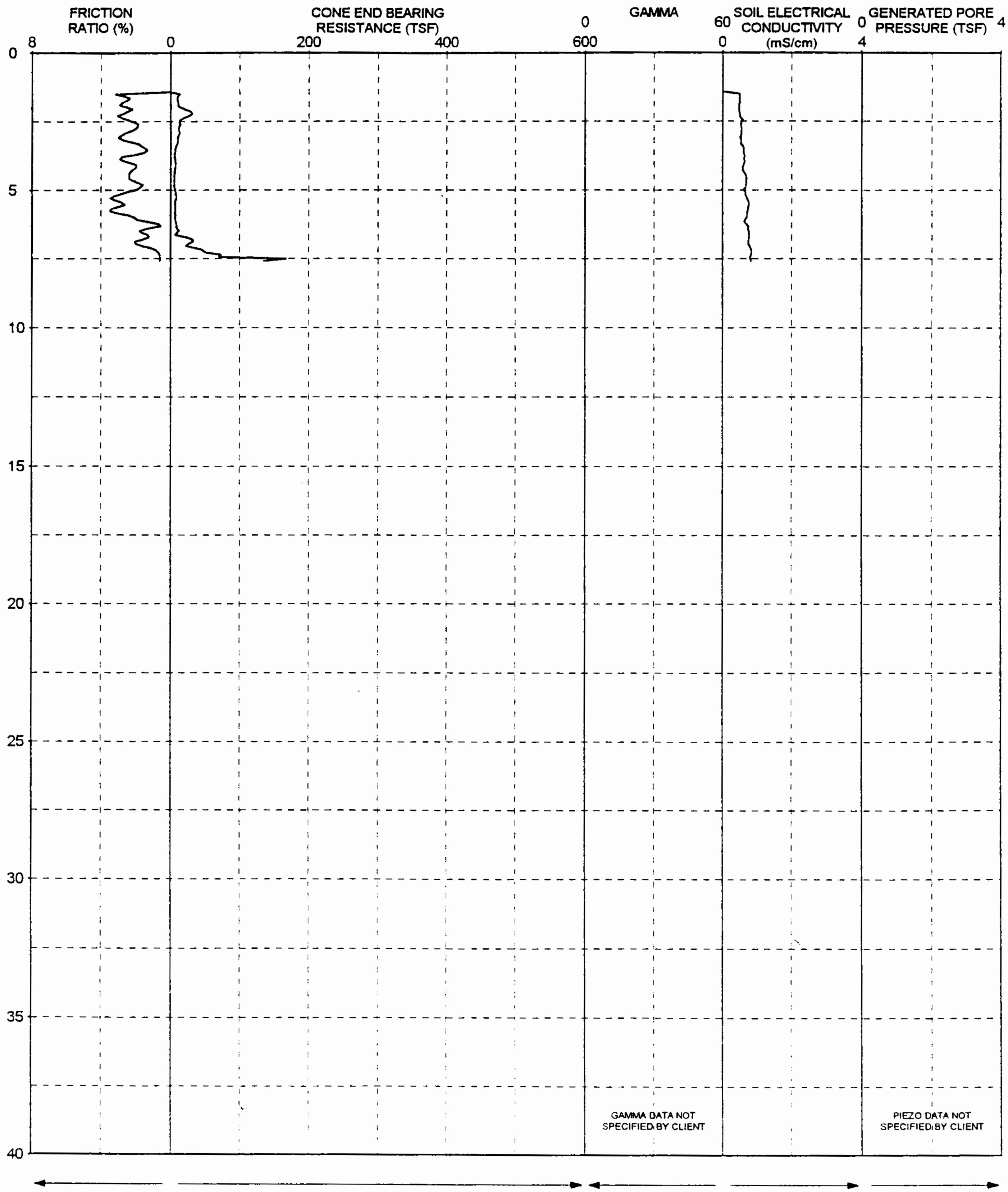
CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/04/96
SOUNDING NUMBER: CP106

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp106

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.00	PREPUNCH													
1.5	10.3	15.7	0.5	2.5		391	Stiff, Clayey silt to silty clay			15	1.37	1.04	3 - 4	4 - 6
2.0	14.1	20.7	0.5	2.5		482	Stiff, Sandy silt to sandy clay			15	1.87	1.03	4 - 5	6 - 7
2.5	13.2	18.7	0.5	2.2		577	Stiff, Sandy silt to sandy clay			15	1.74	0.95	3 - 4	4 - 6
3.0	12.2	16.7	0.4	2.8		544	Stiff, Sandy clay to silty clay *			15	1.60	0.70	4 - 5	6 - 7
3.5	7.2	9.7	0.1	1.5		610	Stiff, Sandy silt to clayey silt			10	1.40	0.30	1 - 2	1 - 3
4.0	7.5	9.8	0.2	2.5		641	Firm, Clayey silt to silty clay			15	0.97	0.31	1 - 2	1 - 3
4.5	5.7	7.3	0.1	2.4		687	Stiff, Clayey silt to silty clay			10	1.09	0.30	1 - 2	1 - 3
5.0	6.5	8.3	0.1	2.0		610	Stiff, Clayey silt to silty clay			10	1.25	0.30	1 - 2	1 - 3
5.5	6.6	8.1	0.2	2.7		771	Stiff, Clayey silt to silty clay			10	1.25	0.36	1 - 2	1 - 3
6.0	6.9	8.4	0.2	2.2		713	Stiff, Clayey silt to silty clay			10	1.31	0.33	1 - 2	1 - 3
6.5	12.6	15.1	0.4	1.8		770	Stiff, Sandy silt to clayey silt			15	1.62	0.85	2 - 3	3 - 4
7.0	25.2	29.9	1.0	1.9		777	Med dense, Silty sand to sandy silt	27-31	40-60				6 - 8	7 - 10
7.5	141.7	166.3	0.8	0.6		824	Med dense, Sand to silty sand	42-46	40-60				34 - 39	40 - 46

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CPT-EC LOG

STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/05/96
SOUNDING NUMBER: CP111

STRATIGRAPHICS

JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp111

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.0	254.9	410.6	5.0	2.1		240	V dense, Sa gravel to si gr sand	40-42	+100				+ 62	+ 100
1.5	206.7	314.7	'3.1	1.4		283	V dense, Sand to silty sand	42-46	80-100				+ 66	+ 100
2.0	130.4	190.5	2.9	1.6		322	Dense, Sand to silty sand	40-42	60-80				41 - 49	60 - 72
2.5	86.1	121.6	2.1	2.1		390	Dense, Silty sand to sandy silt	37-40	60-80				42 - 51	60 - 72
3.0	96.2	132.0	1.2	1.4		367	Dense, Sand to silty sand	40-42	60-80				34 - 44	46 - 60
3.5	54.1	72.4	1.0	1.4		437	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 17	20 - 23
4.0	50.0	65.5	0.5	1.0		455	Med dense, Sand to silty sand	37-40	40-60				11 - 13	15 - 17
4.5	50.6	65.0	0.3	0.7		463	Loose, Sand to silty sand	37-40	20-40				9 - 12	12 - 15
5.0	29.1	36.7	0.5	1.4		534	Loose, Silty sand to sandy silt	36-37	20-40				6 - 8	7 - 10
5.5	37.8	47.0	0.4	1.1		513	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 10	10 - 12
6.0	22.4	27.4	0.2	0.7		550	Loose, Silty sand to sandy silt	36-37	20-40				3 - 5	4 - 6
6.5	7.1	8.5	0.2	1.2		694	Stiff, Sandy silt to clayey silt			10	1.34	0.31	1 - 2	1 - 3
7.0	5.8	6.9	0.0	0.6		829	Stiff, Sandy silt to clayey silt			10	1.07	0.07	1 - 3	1 - 3
7.5	4.8	5.7	0.0	0.0		1057	, Sensitive fine grained soil	27-31	10				1 - 3	1 - 3
8.0	5.1	5.9	0.0	0.1		1121	, Sensitive fine grained soil	27-31	3				1 - 3	1 - 3
8.5	5.1	5.8	0.0	0.8		1350	Firm, Sandy silt to clayey silt			18	0.51	0.08	1 - 3	1 - 3
9.0	4.3	4.9	0.0	0.7		1463	Soft, Sensitive fine grained soil			18	0.42	0.06	1 - 3	1 - 3
9.5	4.8	5.4	0.0	1.0		1558	Soft, Sandy silt to clayey silt			18	0.47	0.09	1 - 3	1 - 3
10.0	4.4	4.9	0.0	0.5		1663	Soft, Sensitive fine grained soil			18	0.43	0.04	1 - 3	1 - 3

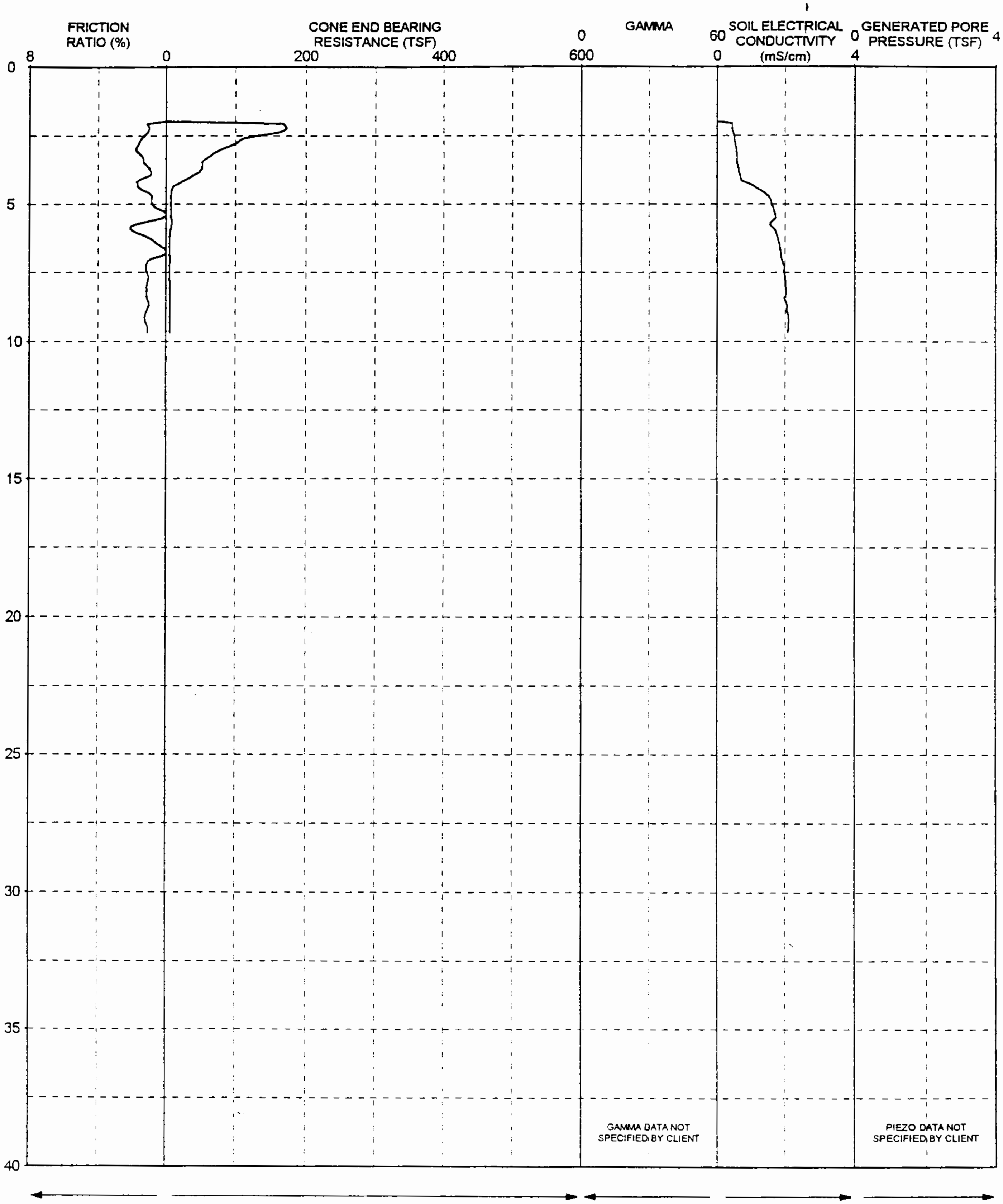
NOTES:

* Indicates lightly overconsolidated soil
** Indicates heavily overconsolidated or cemented soil

Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

CPT-EC LOG



STRATIGRAPHICS

PROJECT NAME: Zone D, F, and G Charleston Naval Base
PROJECT NUMBER: 96-110-230

DATE: 10/05/96
SOUNDING NUMBER: CP114

STRATIGRAPHICS
JOB NO: '96-110-230
JOB NAME: Zone D, F, and G Charleston Naval Base
SOUNDING NO: cp114

DEPTH (FT)	CONE (TSF)	NORM CONE (TSF)	FRICTION (TSF)	AVERAGED FRICTION RATIO (%)	GENERATED PORE WATER PRESSURE (TSF)	SOIL CONDUCTIVITY (uS/cm)	SOIL TYPE	DRAINED FRICTION ANGLE (DEG)	RELATIVE DENSITY (%)	Nc	UNDRAINED SHEAR STRENGTH (KSF)	UNDRAINED LARGE STRAIN SHEAR STRENGTH (KSF)	SPT (N)	NORM SPT (N1)
1.00	PREPUNCH													
1.50	PREPUNCH													
2.0	36.0	52.5	0.4	0.2		96	Loose, Sand to silty sand	37-40	20-40				5 - 7	7 - 10
2.5	133.3	188.3	2.0	1.3		496	Dense, Sand to silty sand	42-46	60-80				42 - 51	60 - 72
3.0	81.2	111.5	1.8	1.8		572	Dense, Silty sand to sandy silt	37-40	60-80				29 - 34	40 - 46
3.5	52.6	70.5	0.9	1.3		592	Med dense, Silty sand to sandy silt	37-40	40-60				15 - 17	20 - 23
4.0	37.0	48.4	0.5	1.1		689	Med dense, Silty sand to sandy silt	36-37	40-60				8 - 9	10 - 12
4.5	8.7	11.2	0.3	1.4		1277	Stiff, Sandy silt to clayey silt			15	1.12	0.56	1 - 2	1 - 3
5.0	7.4	9.4	0.1	0.8		1600	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
5.5	7.7	9.5	0.0	0.2		1718	V loose, Silty sand to sandy silt	27-31	0-20				1 - 2	1 - 3
6.0	6.4	7.8	0.2	1.9		1724	Stiff, Clayey silt to silty clay			10	1.21	0.31	1 - 2	1 - 3
6.5	5.4	6.5	0.0	0.5		1840	Stiff, Sensitive fine grained soil			10	1.01	0.05	1 - 2	1 - 3
7.0	5.8	6.8	0.1	0.7		1903	Stiff, Sandy silt to clayey silt			10	1.07	0.10	1 - 3	1 - 3
7.5	5.5	6.4	0.1	1.1		1984	Stiff, Sandy silt to clayey silt			10	1.00	0.13	1 - 3	1 - 3
8.0	5.8	6.7	0.1	1.1		2022	Stiff, Sandy silt to clayey silt			10	1.06	0.14	1 - 3	1 - 3
8.5	5.8	6.7	0.1	1.1		1993	Stiff, Sandy silt to clayey silt			10	1.06	0.13	1 - 3	1 - 3
9.0	6.0	6.8	0.1	1.2		2075	Stiff, Sandy silt to clayey silt			10	1.09	0.14	1 - 3	1 - 3
9.5	5.8	6.6	0.1	1.1		2099	Stiff, Sandy silt to clayey silt			10	1.05	0.10	1 - 3	1 - 3

NOTES:

* Indicates lightly overconsolidated soil
** Indicates heavily overconsolidated or cemented soil

Mixed soils containing both granular and fine grained particles (e.g. clayey sands) may undergo partial drained failure during CPT. Both undrained and drained parameters can be estimated for these soils.

Structure rate of loading should be considered in choosing which strength parameters to use for design. Drained and undrained parameters must not be combined as such combination will result in significant overprediction of in situ shear strength.

APPENDIX A

TABLE OF CONTENTS

A1.0 EVALUATION OF GEOTECHNICAL PARAMETERS

STRATIGRAPHICS provides computerized evaluation of geotechnical parameters from CPT results. CPT data have been correlated with soil type, drained friction angle, undrained shear strength, relative density, and equivalent SPT blowcounts, among others.

Correlations of CPT data with these parameters have been developed on the basis of: 1) side-by-side CPT and laboratory testing on drilled samples; 2) side-by-side CPT and other in situ testing, such as vane and pressuremeter; 3) laboratory CPT testing on large scale samples of known composition; and 4) classical bearing capacity and cavity expansion theory. Site specific information, where available, is used to fine tune correlations.

A two parameter correlation scheme has proved most useful for CPT data interpretation. The logarithm of the CPT cone end bearing resistance exhibits well defined trends when plotted versus friction ratio. Increased grain size increases cone end bearing resistance, while increased plasticity and compressibility increases friction ratio. A generalized chart illustrating these and other trends is presented in Figure A2. A discussion of CPT data evaluation is presented in Douglas and Olsen, 1981.

<u>A1.1 CPT Soil Behavior Types</u> CPT soil behavior type correlations have been developed from geotechnical theory and comparisons of borehole data with CPT data (Douglas and Olsen, 1981). The CPT soil behavior type tabulations are indicative of the response of the soil to the large shear deformations imposed on the soil during penetrometer advance. Soil shear response is not entirely controlled by grain size distribution. However, it has been found that soil types defined by CPT generally agree with classifications based on soil grain size distribution methods such as the Unified Soil Classification System (USCS). The generalized soil classification chart used for this study is presented in Figure A3.

<u>A1.2 CPT Relative Density</u> Relative densities of granular soils are correlated with CPT data on the basis of laboratory CPT on large scale samples of known composition (Schmertmann, 1978, and Villet and Mitchell, 1981). The effect of soil fines content has been empirically accounted for by extrapolating trends in the two parameter correlation model (Douglas and Strutynsky, 1984). The generalized chart used for correlation of CPT data to relative density is presented in Figure A4.

<u>A1.3 CPT Drained Static Strength</u> Drained friction angles have been correlated with CPT results on the basis of CPT soundings and laboratory tests on drilled samples, and on theoretical analyses of the cone end bearing capacity problem (Schmertmann, 1978, Durgunoglu and Mitchell, 1974, and Villet and Mitchell, 1981). The effect of soil fines content on friction angles has been accounted for by extrapolating trends in the two parameter correlation model, as was done for the relative density correlation. The generalized chart used to correlate CPT data with drained friction angles is presented along with the relative density correlation in Figure A4.

A1.4 CPT Undrained Static Strength

Low Strain, Undisturbed Strength The correlation between CPT data and undrained shear strength has been extensively studied (Douglas and others, 1984, Lunne and others, 1976, Sanglerat, 1972, and Schmertmann, 1978). The following bearing capacity equation is used for computing undrained shear strength from CPT data:

qu = (Su * Nc) + Sv (Eq. A1);

where: qu = ultimate bearing capacity;
Su = undrained shear strength;
Nc = a dimensionless bearing capacity factor; and
Sv = the estimated total vertical stress.

By setting qu equal to the cone end bearing resistance, qc, and rearranging the equation, a value of the undrained shear strength can be computed from CPT data:

Su = (qc - Sv) / Nc (Eq. A2).

The primary difficulty in using this equation has been the selection of Nc applicable to cone penetration in a particular soil. Bearing capacity and cavity expansion theory and other in situ and laboratory test results performed adjacent to CPT soundings have been used to calculate Nc values. These Nc values have ranged from 5 to over 25, but are most often between about 12 and 20. Higher Nc values are typically associated with overconsolidated clays and lower plasticity clays and clayey silts.

A compilation of Nc values as a function of cone end bearing resistance and friction ratio is presented in Figure A5. This figure was developed from comparisons of CPT to results of laboratory consolidated-undrained (CU) strength tests. This is important to note as undrained shear strength is not a unique property of a soil - it is test type and stress path dependent.

Many design methodologies have been developed using a particular strength test result on a particular type of sample. These semi-empirical design methods are successfully used by experienced designers. Engineering judgement must be applied in using the results of any type of testing - whether in situ or laboratory - to assure both adequate safety and design economy.

High Strain, Remolded Strength Another measure of the in situ undrained shear strength is provided by the CPT friction sleeve resistance. The friction sleeve interacts with soil that has already undergone bearing capacity failure induced by the tip of the penetrometer. Thus, the friction sleeve resistance is a measure of soil large strain, remolded strength. The ratio between undrained strengths calculated from the cone end bearing and from the friction sleeve is indicative of soil sensitivity.

In moderately to highly overconsolidated, non-sensitive clays, friction sleeve resistances can indicate higher strengths than those calculated using the cone end bearing resistance. This often reflects the dilative (strain hardening) nature of shear failure in overconsolidated soils. Engineering judgement must be applied in deciding which strain level, and thus which strength, is representative for the particular design problem to be solved.

Due to the variability in overburden normalization curves and the relatively shallow depths of the soundings for this study, no specific correction for overburden pressure on friction ratio has been recommended or used for this study. For this study, effective stresses in Equation A4 were computed using assumed water tables and soil unit weights.

A3.0 TEST DRAINAGE CONDITION

The CPT loading rate is such that drained and undrained conditions exist during penetration of sands and clays, respectively. Partial drainage may occur in mixed soils. Lack of boundary drainage control during any in situ test complicates data analysis, especially in mixed soils, as both frictional and cohesive behavior can be exhibited during testing.

CPTU piezometric data indicate that minor differences in cone end bearing and friction ratio response can correspond with major changes in pore water pressure response during the test (Douglas and others, 1985). The complex volumetric strain field around the penetrometer (Davidson and Boghrat, 1983) precludes reliable geotechnical effective stress analysis of CPTU results in partially drained soil at the present time.

Empirical estimates of either drained or undrained parameters can be made in soils composed of mixtures of granular and fine grained particles. These parameters must not be combined - they are to be used alternatively. Combination of the drained and undrained parameters for geotechnical analysis will result in significant overestimation of in situ shear strength.

Structure rate of loading will help determine which geotechnical parameters, whether drained or undrained, should be appropriate for design use. Depending on project needs and extent of such soils at a site, geotechnical laboratory testing including CU tests with pore pressure measurements and consolidation tests will also be useful in assigning appropriate design parameters. Field instrumentation during construction using low volume change piezometers may be appropriate for some projects.

A4.0 RECOMMENDED PRACTICES

The STRATIGRAPHICS parameter evaluation program tracks the CPT data through a series of correlation charts, Figures A2 through A6. Parameters are computer evaluated and tabulated at discrete intervals. Some practices are recommended when reviewing tabulated data and correlated parameters:

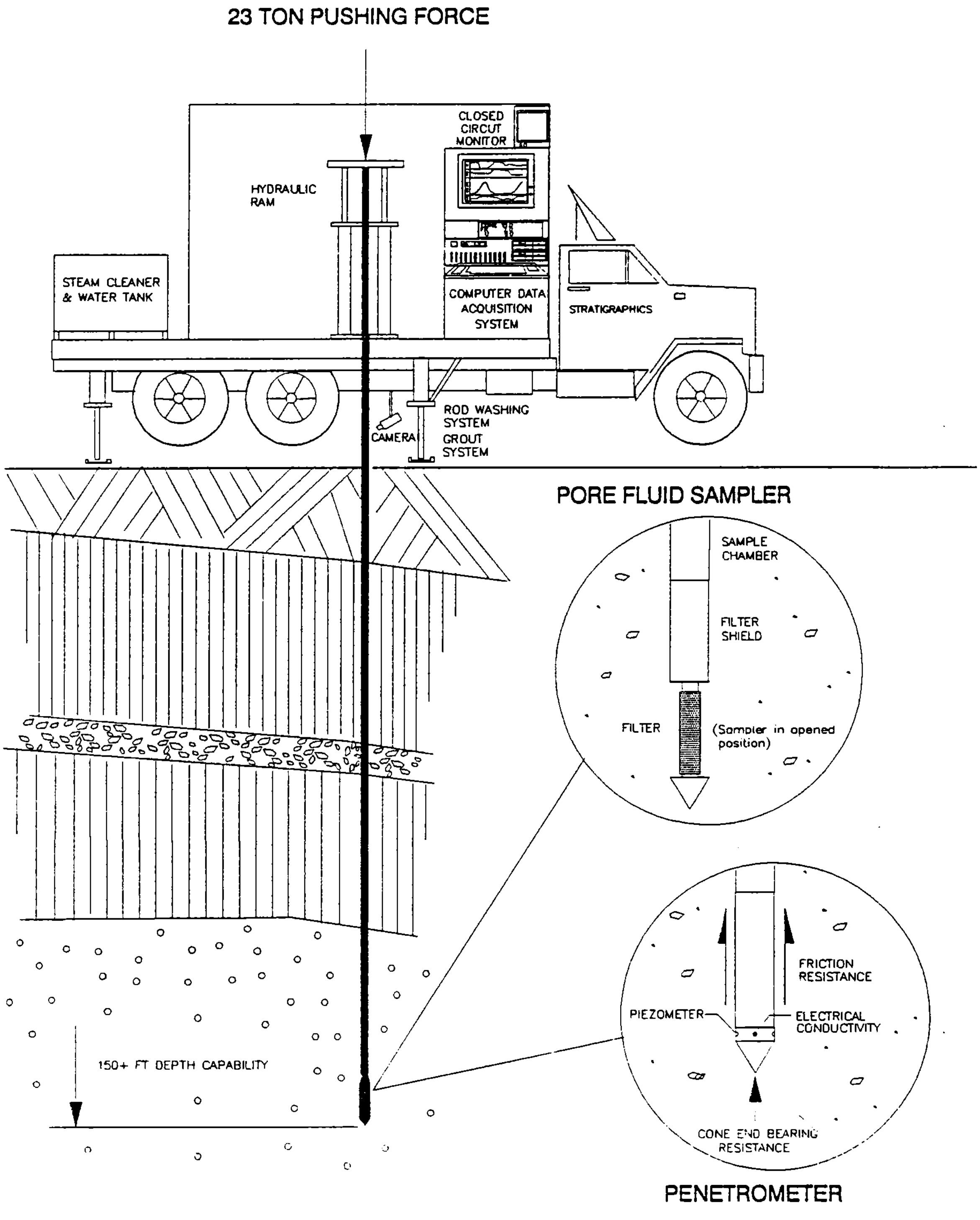
1) stratigraphic units should be defined on the basis of the continuous sounding logs and project requirements. The tabulations are then used to provide layer properties. Use of the tabulations without the review of the continuous sounding logs can lead to the choice of non-representative parameters, especially in interlayered deposits. It should be noted that taking discontinuous borehole soil samples also often provides a poor representation of subsurface conditions;

2) CPT correlations have been developed using empiricism. The empirical data base is world-wide, and includes decades of CPT experience. However, unique local conditions may differ from those in the global data base. Thus, the tabulations should be viewed as indicating trends rather than as the exact equivalent of specific laboratory tests performed under boundary and drainage controlled conditions; and

3) while CPT suffers from none of the effects of sample disturbance as found during drilled investigations, boundary conditions are not well defined during any in situ test such as CPT. The derived parameters are not intended to replace appropriate drilling and undisturbed sampling, other in situ and laboratory testing, and use of engineering judgement.

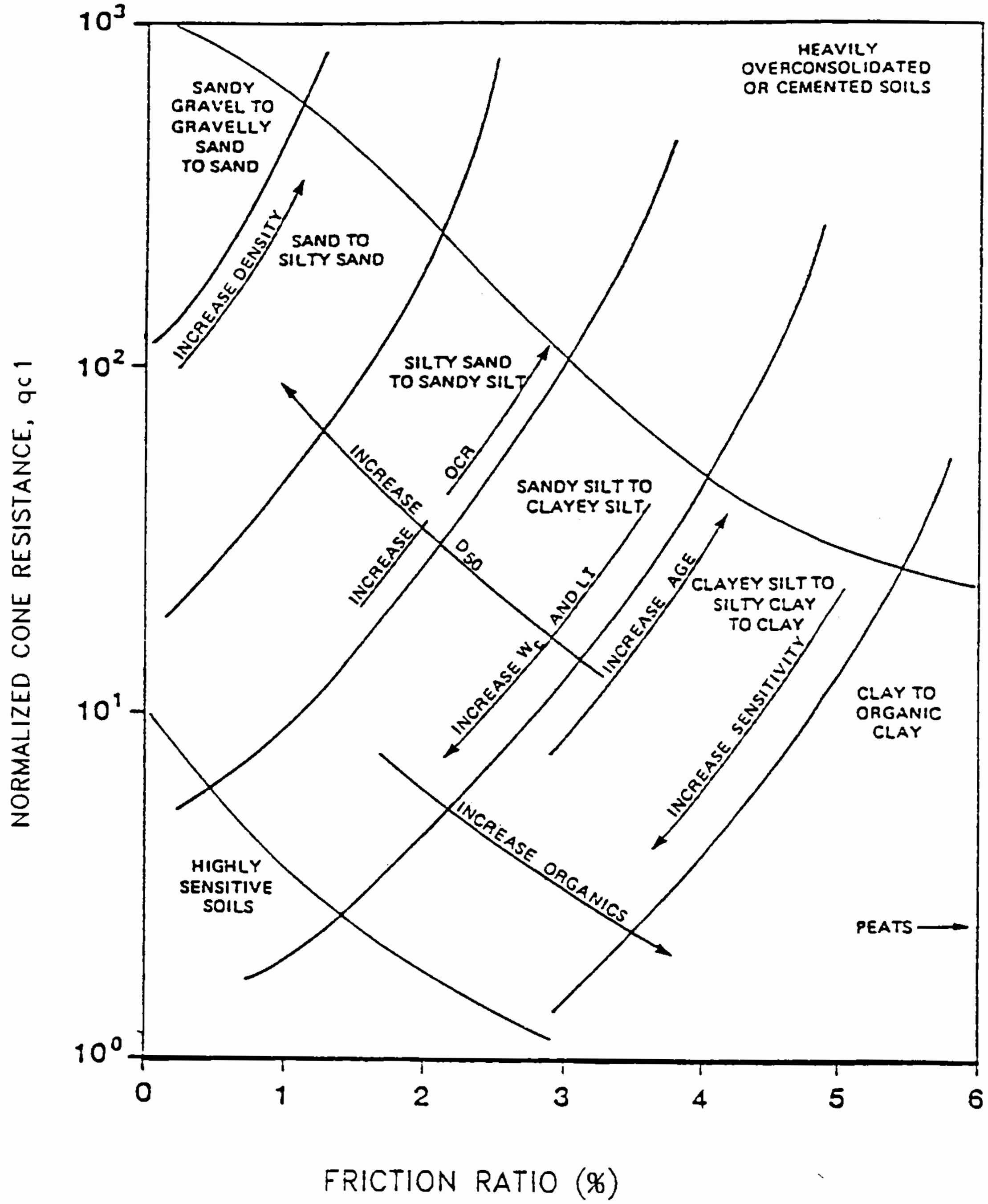
Review of CPT results and project requirements is used to define the need for additional information. Zones delineated by CPT (or, in fact, any other test) providing low factors of safety should be further investigated.

Select undisturbed sampling followed by geotechnical triaxial and consolidation testing may be indicated for low strength cohesive or partially drained mixed soil strata. Monitoring wells may be installed or groundwater samples taken in CPT(U) identified high permeability strata during geo-environmental investigations. Laboratory and other test results can then be extrapolated across the site based on CPT(U) defined stratigraphy.



PENETROMETER SUBSURFACE EXPLORATION SYSTEM

STRATIGRAPHICS

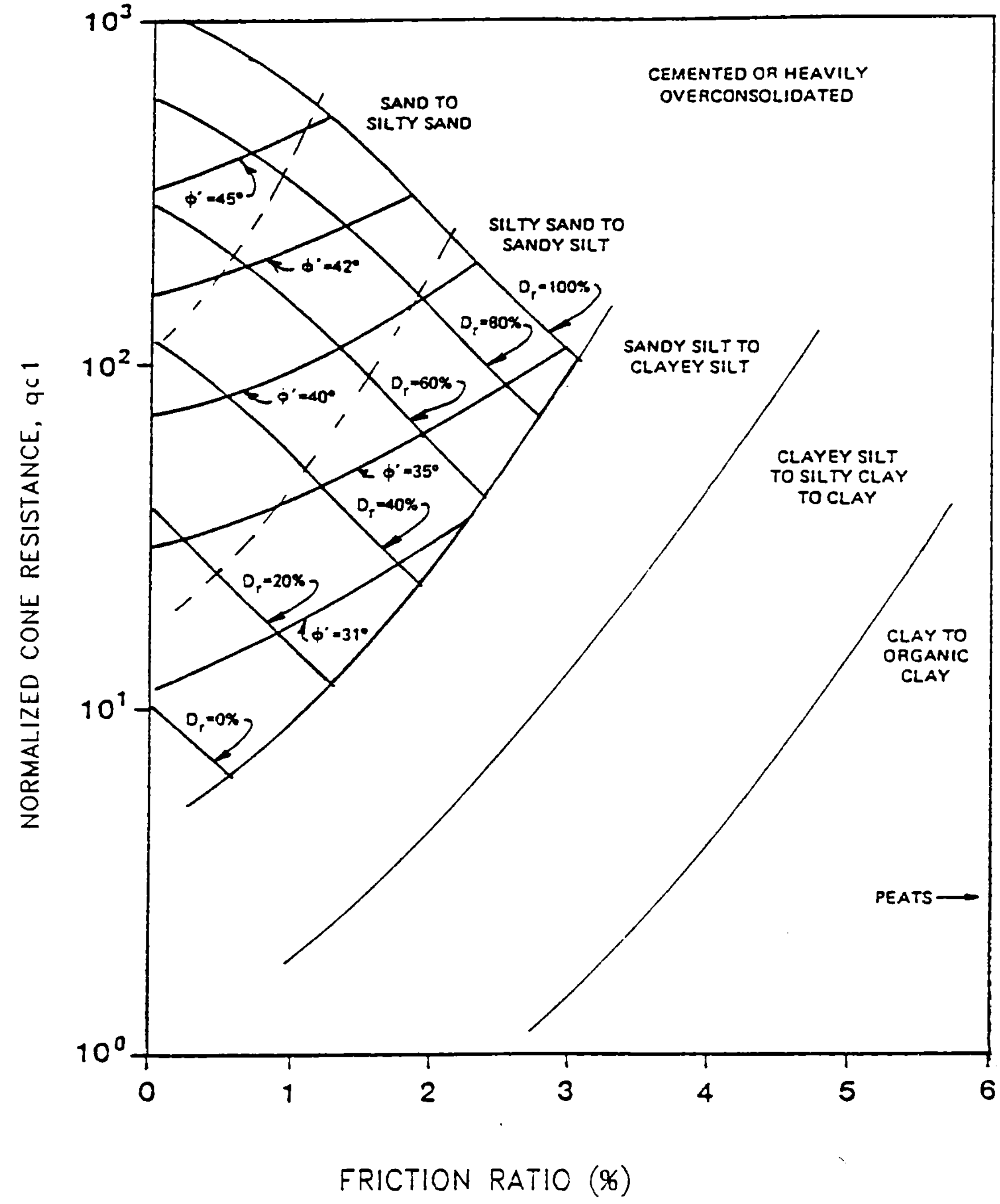


SOIL BEHAVIOR TYPE CLASSIFICATION CHART

After Douglas and Olsen, 1981

STRATIGRAPHICS

Figure 2

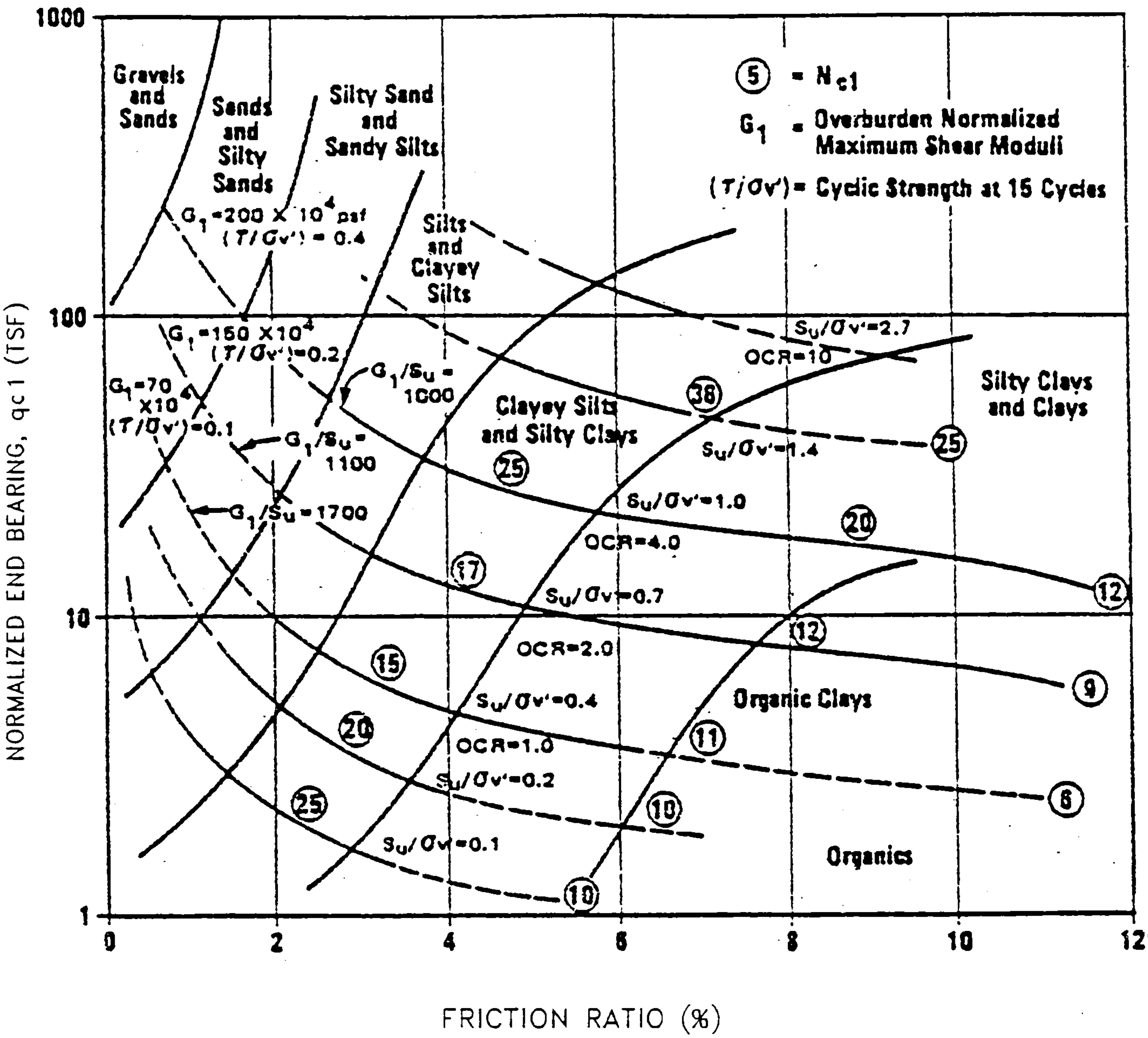


EXPANDED SOIL BEHAVIOR TYPE CLASSIFICATION CHART WITH EQUIVALENT OVERBURDEN NORMALIZED FRICTION ANGLE AND RELATIVE DENSITY TRENDS

After Douglas and Strutynsky, 1984

STRATIGRAPHICS

Figure 4

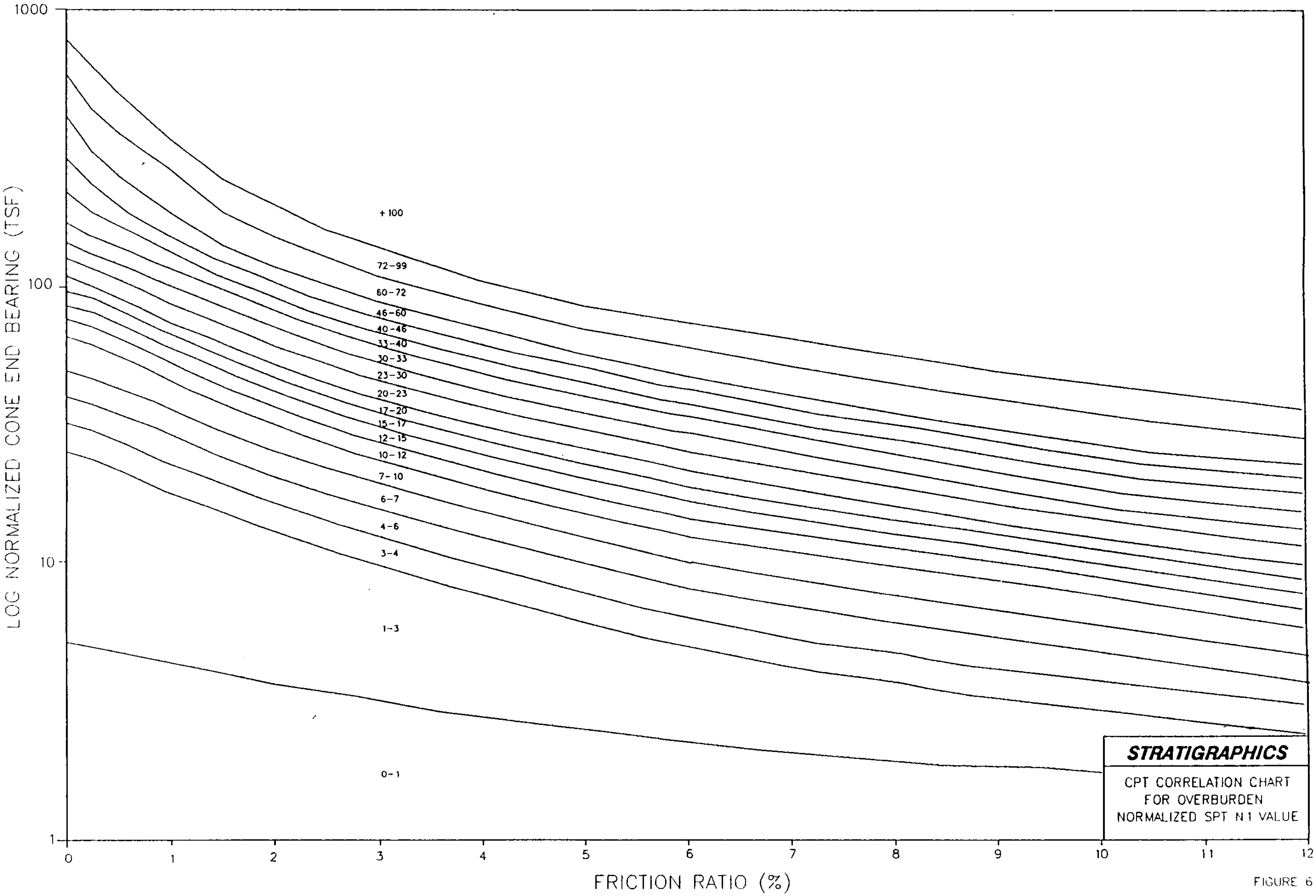


COMPOSITE TRENDS IN UNDRAINED SOIL PROPERTIES

After Douglas, Strutynsky, et. al., 1985

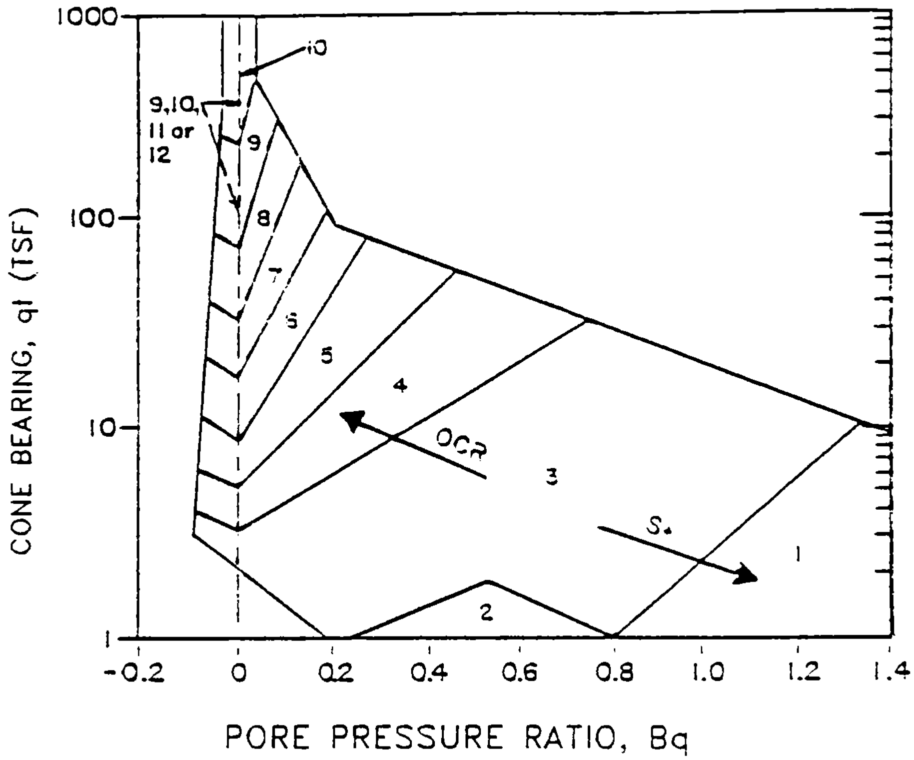
STRATIGRAPHICS

Figure 5



STRATIGRAPHICS
CPT CORRELATION CHART
FOR OVERBURDEN
NORMALIZED SPT N1 VALUE
LOG NORMALIZED CONE END BEARING (TSF)
FRICTION RATIO (%)
1000
100
10
1
0
1
2
3
4
5
6
7
8
9
10
11
12
+100
72-99
60-72
46-60
40-46
33-40
30-33
23-30
20-23
17-20
15-17
12-15
10-12
7-10
6-7
4-6
3-4
1-3
0-1

FIGURE 6



ZONE	SOIL BEHAVIOR TYPE
1	ORGANIC MATERIAL
2	CLAY
3	CLAY
4	SILTY CLAY TO CLAY
5	CLAYEY SILT TO SILTY CLAY
6	SANDY SILT TO CLAYEY SILT
7	SILTY SAND TO SANDY SILT
8	SAND TO SILTY SAND
9	SAND
10	GRAVELLY SAND TO SAND
11	VERY STIFF FINE GRAINED (*)
12	SAND TO CLAYEY SAND (*)
(*)	OVERCONSOLIDATED TO CEMENTED

After Robertson & Others, 1986

STRATIGRAPHICS

Figure 7

APPENDIX B

Excerpt from Baligh, M.M. and J. Levadoux, "Pore Pressure Dissipation After Cone Penetration," Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1980.

6.2.4 Evaluation of c_h (probe)

At a given degree of consolidation, the predicted horizontal coefficient of consolidation c_h (probe) is obtained from the expression

$$c_h \text{ (probe)} = R^2T/t \tag{6.2}$$

where R is the radius of the cone shaft, t is the measured time to reach this degree of consolidation; and T is the time factor. Table 5.1 provides values of T for different probe types at various degrees of consolidation.

An analytical method * to check the validity of the prediction method consists of determining c_h at different dissipation stages, i.e., different u. Large differences between c_h at various degrees of consolidation indicate an inadequate initial distribution of excess pore pressure or significant coupling, or creep behavior.

The estimated values of c_h (probe) at 50% dissipation can be used in foundation problems involving horizontal water flow due to unloading or reloading of clays above the maximum past pressure. For problems involving vertical water flow in the overconsolidated range, the vertical

* Equivalent to the graphical method described in Section 6.2.3.

coefficient of consolidation, c_v(probe), can be estimated from the expression:

$$c_v \text{ (probe)} = (k_v/k_h)\ c_h \text{ (probe)} \qquad (6.3)$$

where k_v and k_h are the vertical and horizontal coefficients of permeability, respectively. Reliable estimates of the in situ anisotropy of clays as expressed by the ratio k_h/k_v is difficult to determine in the laboratory because of the effects of sample size, sample disturbance, ... etc. and is the subject of controversy (Rowe, 1972; Casagrande and Poulos, 1969). In situ tests to determine k_h/k_v are almost nonexistent. Table 6.2 provides rough estimates of k_h/k_v for different clays.

6.2.5 Prediction of k_h (probe)

Approximate estimates of the horizontal coefficient of permeability, k_h (probe), can be obtained from the expression:

$$k_h \text{ (probe)} = (g_w/2.3s_{vo}) * RR\text{(probe)} * c_h \text{ (probe)} \qquad (6.4)$$

where s_{vo} is the initial vertical effective stress (kg/cm^2); g_w is the unit weight of water (=10^{-3} kg/cm^3); and, RR(probe) is the recompression ratio during early stages of consolidation around the probe (50% dissipation, say).

Results in both the upper and lower Boston Blue Clays indicate that:

$$\text{the average RR(probe)} = 10^{-2} \quad (6.5)$$

$$\text{and generally } 0.5 * 10^{-2} < \text{RR(probe)} < 2 * 10^{-2} \quad (6.6)$$

6.2.6 Prediction of $c_v(NC)$

For foundation clays consolidated in the normally consolidated range, estimates of the coefficients of consolidation can be obtained from c_h (probe) by means of the expressions:

$$c_h(NC) = (RR(probe)/CR) * c_h\,(probe) \quad (6.7)$$

for horizontal water flow, and

$$c_v(NC) = (RR(probe)/CR) * (k_v/k_h) * c_h(probe) \quad (6.8)$$

for vertical water flow.

The compression of ratio CR is the average slope of the strain vs. log effective stress plot in the appropriate effective stress range expected during consolidation of the foundation clay. Values of CR should be obtained from good quality samples carefully tested in the laboratory. Table 6.2 provides rough estimates of CR based on empirical correlation with index properties of various clays.

1. Compression Ratio CR (from Ladd, 1973)

$CR = C_c/1+e_o$ = slope of the strain vs. log stress curve

e_o = initial void ratio

c_c = virgin compression index = slope of e vs. log stress

w_L = liquid limit

w_N = natural water content

$c_c = 0.009\ (w_L\% - 10\%)$ Terzaghi and Peck (1967)

$C_c = 0.54\ (e_o - 0.35)$ Nishida (1958)

$C_c = 0.01$ to $0.15\ (w_N\%)$ MPMR (1958)

$C_c = 0.6\ (e_o - 1)$ for $e_o < 6$

$C_c = 0.6\ (e_o - 1)$ for $e_o < 6$

(Kapp, 1966)

$= 0.85\ (e_o - 2)$ for $6 < e_o < 14$

2. Anisotropic Permeability of Clays (from Ladd, 1976)

Nature of Clay	k_h/k_v
1. No evidence of layering	1.2 +- 0.2
2. Slight layering, e.g., sedimentary clays with occasional silt dustings to random lenses	2 to 5
3. Varved clays in north-eastern U.S.	10 +- 5

Table 6.2 Empirical Correlation and Typical Properties of Clays.

APPENDIX C

USE OF PIEZOMETRIC CONE PENETRATION TESTING AND PENETROMETER GROUNDWATER SAMPLING FOR VOLATILE ORGANIC CONTAMINANT PLUME DETECTION

Andrew I. Strutynsky, P.E., STRATIGRAPHICS, Inc., Glen Ellyn, Illinois
Timothy J. Sainey, P.G., ERM-Midwest, Inc., Columbus, Ohio

ABSTRACT

Piezometric Cone Penetration Testing (CPTU) and penetrometer groundwater sampling were used in locating a volatile organic contaminant plume at an industrial site in southern Ohio. Nine CPTU tests (soundings) were performed to determine site hydrostratigraphy in real-time. On-site chemical analysis of penetrometer groundwater samples provided near real-time detection of contaminants. These results were used to define subsequent exploration points. Using this investigation approach, drilling operations to set monitor wells began as penetrometer exploration ended. Program quality increased, while exploration costs decreased by using this combination penetrometer-drilling rig approach.

INTRODUCTION

Tricholoroethene (TCE), an industrial solvent, along with other volatile organic compounds, was identified in the groundwater at a manufacturing site in rural southern Ohio. Contamination was initially found in four monitor wells, located around a suspected source. The immediate soils consist of mixed sand, silt, and clay, overlying granular strata, which overlie bedrock. The water table is located at El. 550 ft, or 8 to 20 ft below the surface.

To define the limits of contamination, a soil gas survey was performed using a hand-held hammer drill to drive probes 5 ft into the ground. Probing traced contamination to an off-site agricultural field and defined the general direction of contaminant movement (Figure 1). As the survey expanded, indications of volatiles abruptly stopped. It was suspected that a thicker clay unit was masking volatiles that might be present in the groundwater. The limits of contamination still had to be determined, but additional exploration was subject to the following constraints:

- Contamination was determined to be moving off-site, where stratigraphy was uncertain.
- The off-site property owner did not want drilled boreholes and monitor wells in his field.
- Poor weather conditions prevailed during the late winter months of 1990.
- Agency deadlines and budgetary limitations influenced the scope and schedule.

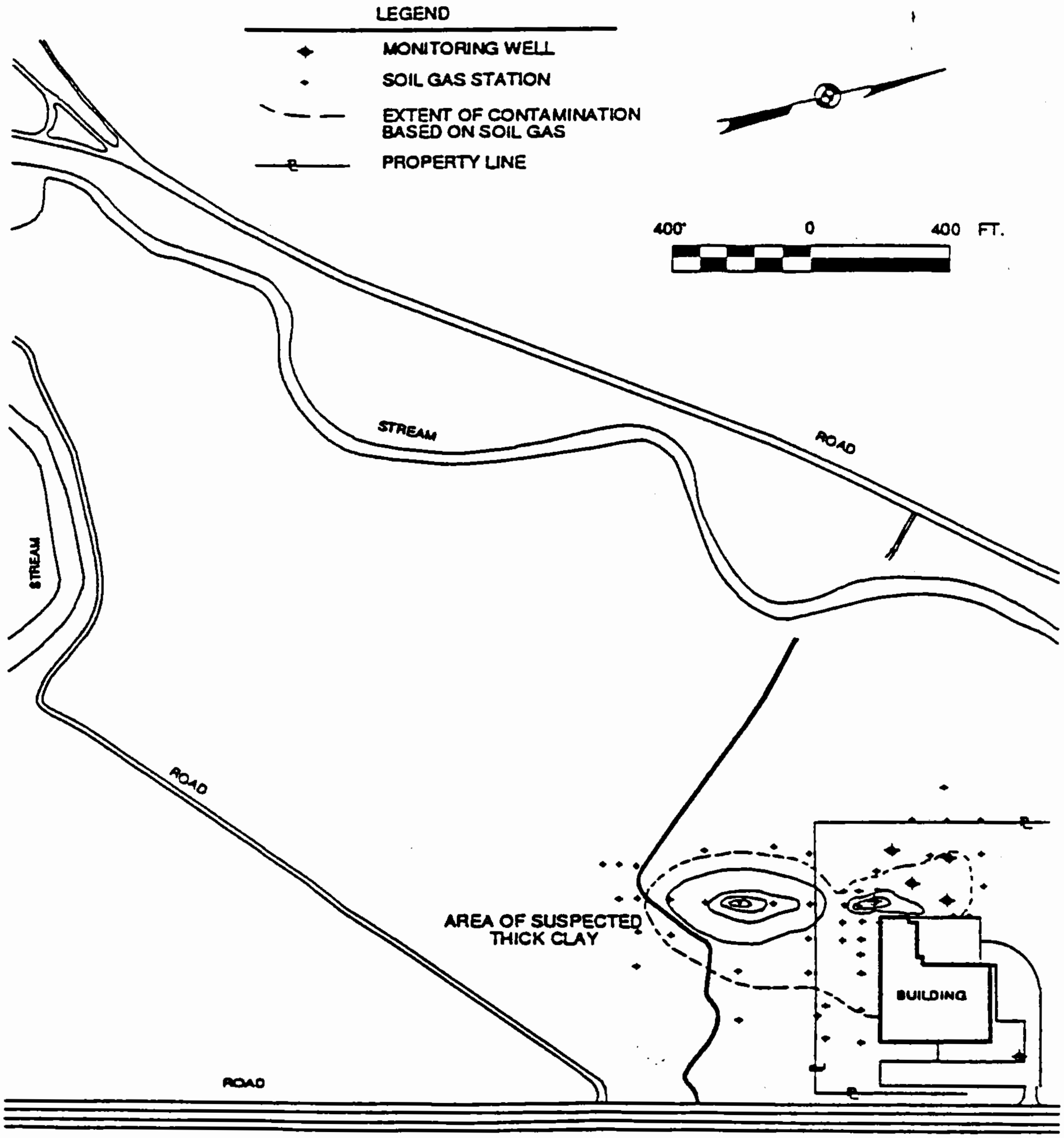


FIGURE 1 - EXTENT OF CONTAMINATION BASED ON SOIL GAS SURVEY, APRIL 1988

The needs of the off-site property owner had to be met while still allowing exploration to proceed. His concerns were addressed by negotiating permission to set a maximum of nine wells to monitor the extent of contamination, with assurances of minimal surficial disturbance to future crop cultivation.

A possible solution to the constraints of the agreement was to use a drilling rig to split-spoon sample soils, and to sample groundwater by using either a Hydropunch sampler or wellpoints. The exploration boreholes would be drilled and plugged until the extent of contamination had been determined. At this point, the monitor wells would be set. However, the cost of drilling and plugging numerous exploratory boreholes, and the overall ineffectiveness of drilling rigs to advance the Hydropunch in dense sands and gravels, made the use of a drill rig less than optimal.

Another solution was to use a cone penetrometer rig to explore subsurface conditions followed by conventional drilling to set monitor wells. This plan had the following advantages:

- The penetrometer rig has an enclosed work area so that bad weather does not significantly impact productivity.
- It is capable of collecting high quality, continuous stratigraphic information in real-time, both allowing for efficient penetrometer groundwater sampling and allowing a drill rig to eventually set monitor wells without additional physical sampling.
- It can be used to hydraulically push groundwater samplers into sands and fine gravels, under suitable conditions.
- Penetrometer operations do not generate possibly contaminated drill cuttings or fluids that require expensive disposal.
- The method does not result in large diameter holes that require extensive grouting to seal.
- Penetrometer operations are more rapid and thus less expensive than drilling operations.

Use of the penetrometer exploration/drill rig well installation approach was decided upon as the most cost- and performance-effective solution for this project. An analytical laboratory was set up on-site allowing for successive exploration points to be optimally chosen on the basis of contaminant plume detection, rather than on an arbitrary grid pattern.

PENETROMETER TECHNIQUE AND EQUIPMENT

Penetrometer methods are being used with increasing frequency, and they provide significant advantages for geo-environmental exploration. The technique uses a large hydraulic ram to push small (1.5 to 2.5 inch) diameter probes into the ground without drilling a borehole (Figure 2). Instrumented probes, called penetrometers, provide semi-direct and direct information on geotechnical, hydrogeological, and geochemical site conditions. Penetrometer samplers are used to obtain physical samples of subsurface materials.

Penetrometer methods are used to their greatest advantage in sand, silt and clay deposits. Penetrometer profiling (Figure 3) is continuous and accurate, and measurements (sounding

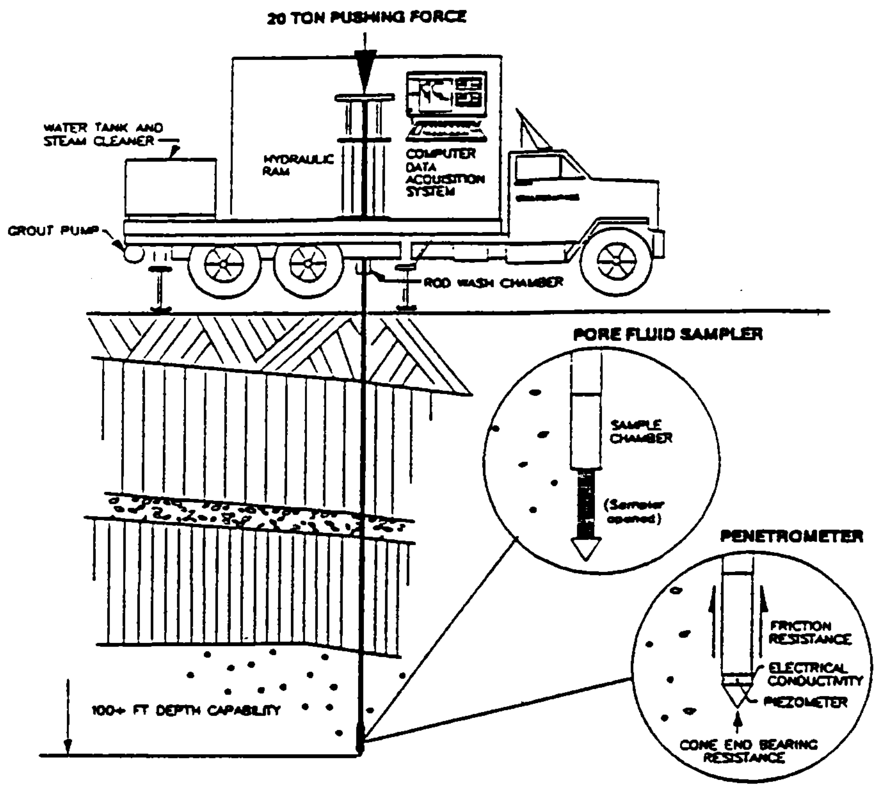


FIGURE 2 - PENETROMETER SUBSURFACE EXPLORATION SYSTEM

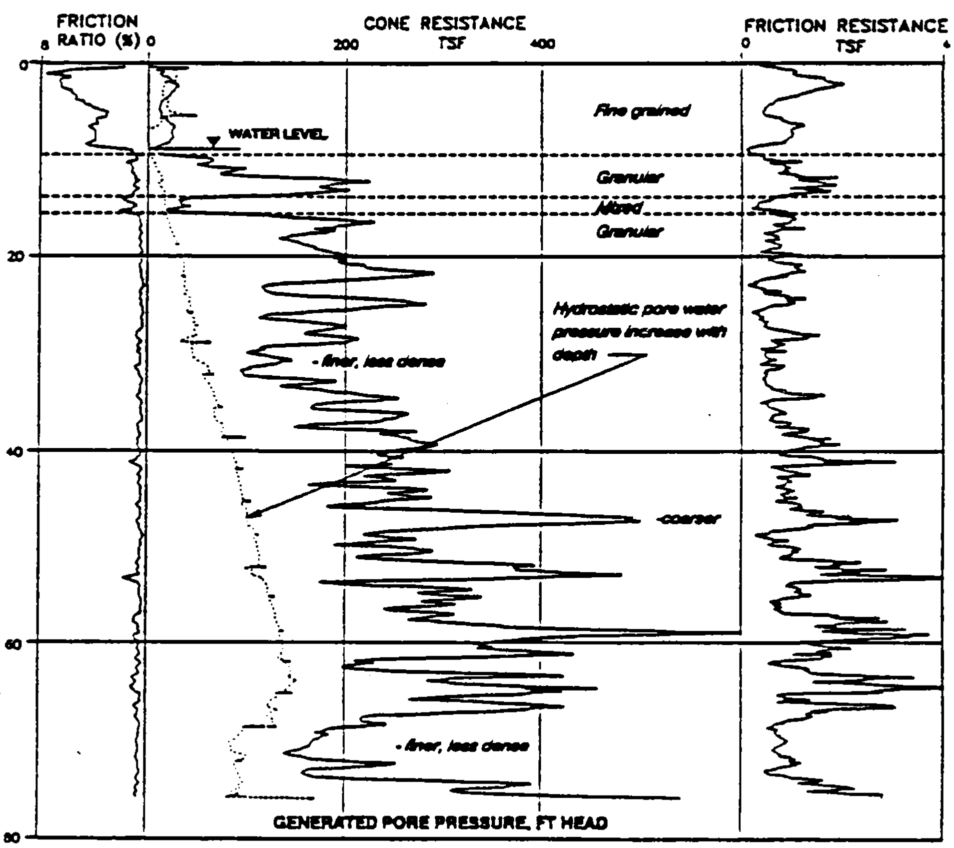


FIGURE 3 - CPTU SOUNDING LOG C-7

logs) are reliably interpreted for definition of aquifers and confining layers. Lateral continuity of layers is readily apparent from a series of adjacent penetrometer soundings.

Site disturbance and waste material disposal is minimized because no cuttings or drilling fluids are generated during penetrometer operations. Downhole equipment is steam cleaned during retrieval. Personnel exposure to contaminants is much less than exposures during drilling. Heaving sands pose little problem, as no open hole actually exists during penetrometer advance.

Three hundred to 900 ft of geotechnical soundings can be performed in a day, depending on access and project requirements. The special demands of geo-environmental investigations decrease daily footage, but productivity is still significantly higher than that using drilling rigs. Sounding depths in excess of 100 ft can be achieved, depending on site stratigraphy.

The penetrometer is mounted at the end of a series of heavy-wall sounding rods. A hydraulic ram is used to push the penetrometer into the ground at a rate of 4 ft per minute. Electronic signals from downhole sensors are transmitted by a cable, strung through the sounding rods, to a computer inside the penetrometer rig. Data are recorded at depth intervals of 3/8 to 3/4 inch. A real-time data display is monitored for evaluation of test performance and for immediate definition of site conditions. At the end of a sounding, the penetrometer and sounding rods are retrieved and decontaminated. Open hole can be grouted where cross-contamination between layers may occur. Open hole was allowed to collapse at the end of each sounding for this project, due to the lack of confining layers at the site.

A special truck is used to house, transport, and deploy the penetrometer. Twenty tons of truck weight and ballast are used to counteract the thrust of the hydraulic ram. The work area is enclosed and includes heating and air conditioning. Computers, penetrometers, samplers, electrical power, lighting, compressed air, grout and water pumps, steam cleaner for equipment decontamination, 275 gal water tank, tools and spare parts are all included within the penetrometer truck, providing for self-contained operations.

Instrumentation

The basic electronic penetrometer consists of two separate soil shear resistance sensors, and is used to acquire information on soil strength and stratigraphy. Tests conducted with this penetrometer are called Cone Penetration Tests (CPT) and are specified by ASTM Standard D3441. Electronic CPT has been used for geotechnical engineering projects for more than 25 years, while less sophisticated, uninstrumented versions of the test (Dutch cone test) have been used since the 1930s.

Two laboratory grade, strain gage loadcells, mounted inside the penetrometer, are used to measure the soil shear resistance to penetration acting on the conical tip and along the cylindrical sides of the CPT penetrometer. CPT measurements are continuous, accurate and repeatable. The tip or cone end bearing resistance can respond to soil seams as thin as 2 to 4 inches. The side or friction resistance measurement has a resolution of about 6 inches.

A pressure transducer is added to the CPT penetrometer to additionally measure the soil pore water pressure response to penetration; this is called a Piezometric Cone Penetration Test (CPTU). CPTU piezometric data allow for the evaluation of soil saturation, water tables, potentiometric surfaces, and soil horizontal permeability in both aquifers and aquitards. The CPTU piezometric measurement has a resolution of about 1 inch.

Another penetrometer has been used to measure the shear resistance, piezometric response, electrical conductivity and temperature of penetrated soils. This penetrometer is useful in detecting free hydrocarbon product on groundwater. This test type is termed CPTU-EC. Additional details on penetrometer instrumentation can be found in Strutynsky, et al., 1985 and 1991.

Groundwater Samplers

The Hydropunch and BAT penetrometer samplers were used to sample groundwater for this project. The Hydropunch sampler (Figure 4) consists of a stainless steel, shielded wellpoint and sample barrel assembly (Edge and Cordry, 1989); it is deployed using the heavy-wall penetrometer sounding rod. The shield prevents contamination of the sampler while pushing. When the shield is retracted, groundwater flows under in situ pressure conditions into the 500 ml sample barrel.

A water level indicator can be lowered to the top of the Hydropunch in order to determine sampler filling. The sample is isolated in the barrel by two ball check valves. The entire sampler is retrieved to the surface to pour off the sample and for sampler decontamination. The tip of the Hydropunch sampler must be at least 4 ft below the water table to acquire a sample.

The BAT sampling system (Figure 5) consists of a wellpoint that is internally sealed with a septum (Torstensson, 1984). After pushing the wellpoint to depth, an evacuated 35 or 70 ml vial, also sealed with a septum, is wirelined down the casing. A double-ended hypodermic needle, mounted in an adapter below the vial, pierces both the wellpoint and the sample vial septa, and allows fluids to flow into the vial. The septa seal as the sample vial is retrieved to the surface, maintaining the sample at in situ pressure conditions. This procedure may be repeated to develop the wellpoint and to obtain increased sample volumes.

The BAT Enviroprobe and Mk. 2 wellpoints were used during this study. The Enviroprobe is shielded, while the Mk. 2 tip is unshielded. The Mk. 2 filter is exposed to possible cross-contamination during deployment. A thin-wall AQ drill rod is used to deploy the BAT samplers, as the heavy-wall penetrometer sounding rods are too small to pass the BAT sample vial.

PENETROMETER DATA INTERPRETATION

Correlations between penetrometer data and soil type have been developed from observational criteria on adjacent CPT soundings and drilled and sampled boreholes (Douglas and Olsen, 1981). CPT soil classifications reflect the shear response of a soil to penetration. Soil shear response is not entirely controlled by grain size distribution. However, soil types evaluated from CPT data generally agree with those classifications based on soil grain size distribution methods, such as the Unified Soil Classification System (USCS).

The CPT cone end bearing resistance increases exponentially with increases in grain size. The cone end bearing resistance in dense sands ranges from about 150 to 300 tons per square foot (TSF), while the cone end bearing resistance in a stiff clay ranges from about 7 to 15 TSF. The proportion of CPT friction to cone end bearing resistance, termed friction ratio, is related to the fines content of a soil. The friction ratio is low in sands and high in clays. CPT measurements are computer analyzed using CPT soil classification charts (Figure 6) to quickly define site stratigraphy.

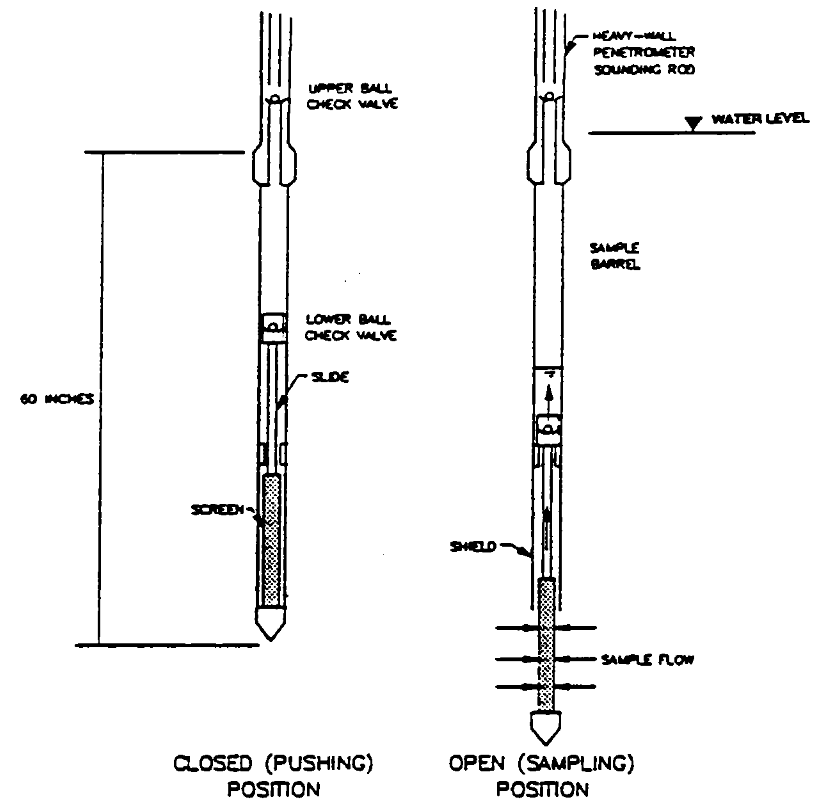


FIGURE 4 - HYDROPUNCH GROUNDWATER SAMPLER

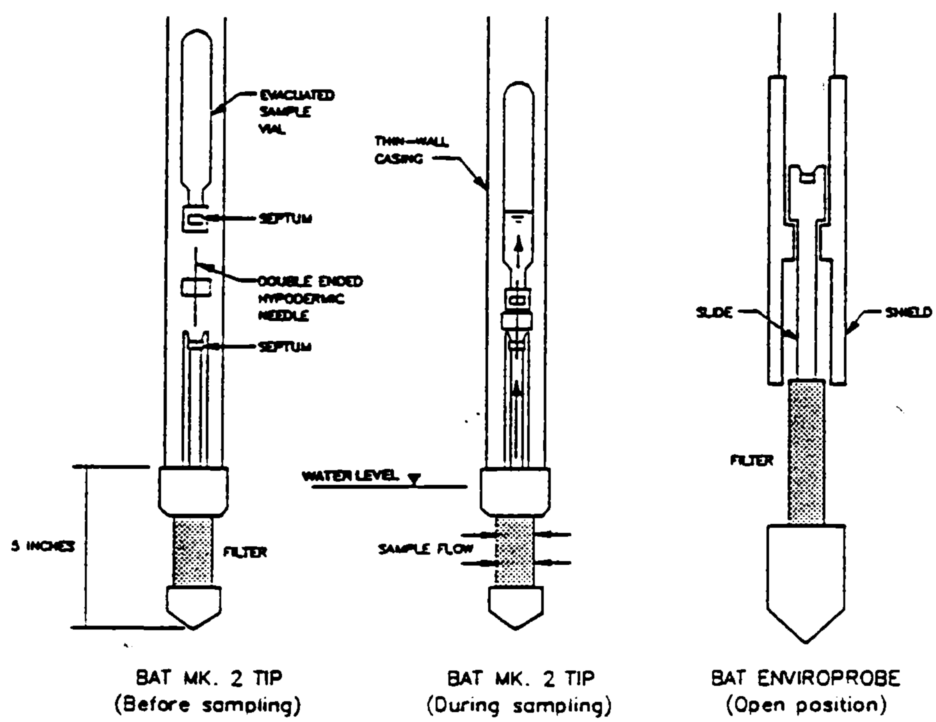


FIGURE 5 - BAT GROUNDWATER SAMPLING SYSTEM
Note: All dimensions approximate

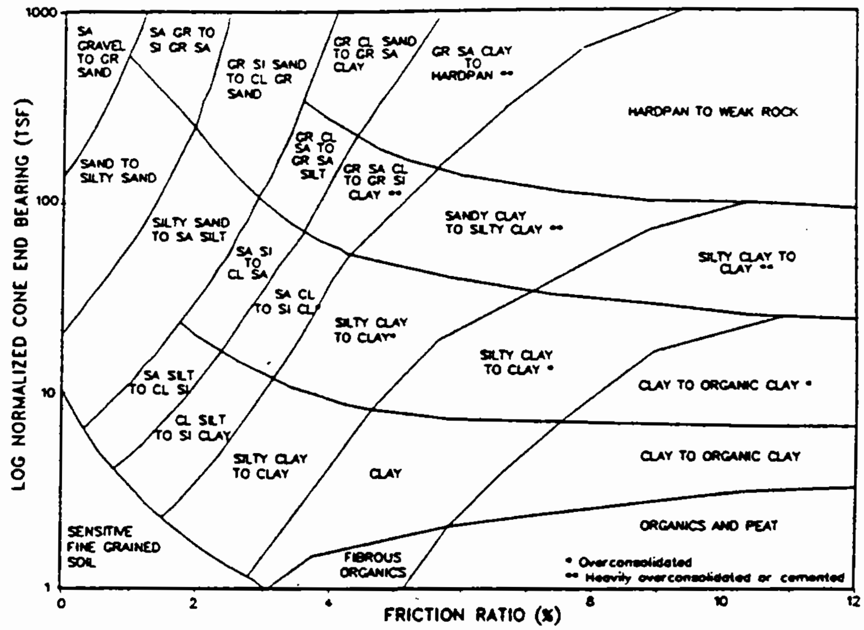


FIGURE 6 - CORRELATION CHART FOR CPT SOIL TYPES

The penetration of a saturated soil generates a localized pore water pressure field, in excess of equilibrium, around the penetrating probe. This generated pressure field dissipates quickly in soils of high permeability, so only the equilibrium pore water pressure field is measured in clean sands and gravels during Piezometric Cone Penetration Testing (CPTU). In low permeability soils, excess pore pressures require a significant amount of time to dissipate (Saines, et al., 1989). The dissipation of excess pore water pressure can be recorded as a function of time by pausing in the penetration process; this is termed a CPTU dissipation test. If the pauses are sufficiently long for all excess pressures to dissipate, measurements can be obtained of equilibrium potentiometric surfaces at multiple depths.

A CPTU dissipation test is somewhat similar to a falling head slug test, and can be used to calculate a value of soil horizontal permeability. However, tens to hundreds of feet of excess pore water pressure are induced in low permeability soils by penetrometer advance, as compared to several feet of head induced in a well during slug testing. The greater pressure changes during CPTU dissipation testing require soil compressibility effects to be included in analyses. The CPT cone end bearing resistance provides an index of compressibility for permeability computations.

ON-SITE LABORATORY

A Hewlett-Packard HP 589OA gas chromatograph (GC) with two electron capture detectors (ECD) was selected as the on-site analytical instrument for this project. It has the advantage of:

- Achieving laboratory results in the parts per billion (ppb) range
- Having a programmable oven which provides better separation of the eluting compounds for more accurate identification
- Qualifying and quantifying compounds as compared to internal reference standards

For the analysis of volatile organics, U.S. EPA SW-846 Method 3810 Headspace was used. Calibration procedures were performed using standard mixtures to establish the internal standard curve. Sample analysis consisted of pouring collected water samples into a 1.0 ml syringe, and injecting this sample into a nitrogen purged 40 ml septum vial. The sample was then heated in a 70 deg C water bath for 15 minutes; 100 ml of headspace was drawn from the center of the septum vial and injected into the GC for analysis.

For quality control (QC), every 10th unknown was run, per a modified U.S. EPA Method 3810. Modifications are to allow samples to equilibrate to 70 deg C, to use 40 ml vials with Teflon face septa, and to inject 100 ml of headspace gas. For each 10th unknown, four samples were injected to determine the quality of data. These consisted of a:

- Sample containing reagent water that had been carried through all stages of sample collection of unknown constituents
- Sample containing reagent water spiked with known amount of target analytes
- Sample containing unknown constituents
- Sample containing unknown constituents spiked with known amount of target analytes

In addition to the field analyses, select duplicate samples were sent to an off-site analytical laboratory for verification. Sample preparation, standards and QC were assisted by an analytical subcontractor.

PROGRAM RESULTS

CPTU soundings were performed at nine locations (Figure 7) during the period of February 6 to 13, 1990, for a total of 699 ft of test. Only partial days were worked on February 6 and 9, and no field work was done on February 10 when bulldozer support for access to locations in the wet, recently plowed field was not available. Twenty seven groundwater sampling attempts, with 22 successfully recovered samples, were also performed during this period. The sequence of penetrometer operations was as follows:

1) The penetrometer rig was set up, and a CPTU sounding was performed to determine hydrostratigraphy. The field sounding log was analyzed immediately to determine groundwater sampling depths.

2) The penetrometer rig was moved to provide about 5 ft of offset between the sounding and sampling hole to avoid vertical cross-contamination of samples.

3) Where sands were especially dense, or contained a high gravel content, a prepunch tool was pushed to nearly the sampling depth in order to facilitate sampler deployment.

4) The sampler was pushed to depth. Three groundwater samples were typically taken at each location at successively deeper penetrations (Figure 8), from shallow (15-31 ft), to intermediate (37-47 ft), to deep (68-90 ft). Three Hydropunch samplers were available on site, so as a sampler was being deployed, the others were being decontaminated.

The CPTU soundings revealed site soil conditions to have general lateral continuity, as can be seen on a stratigraphic cross-section (Figure 9). Site stratigraphy is summarized in Table 1.

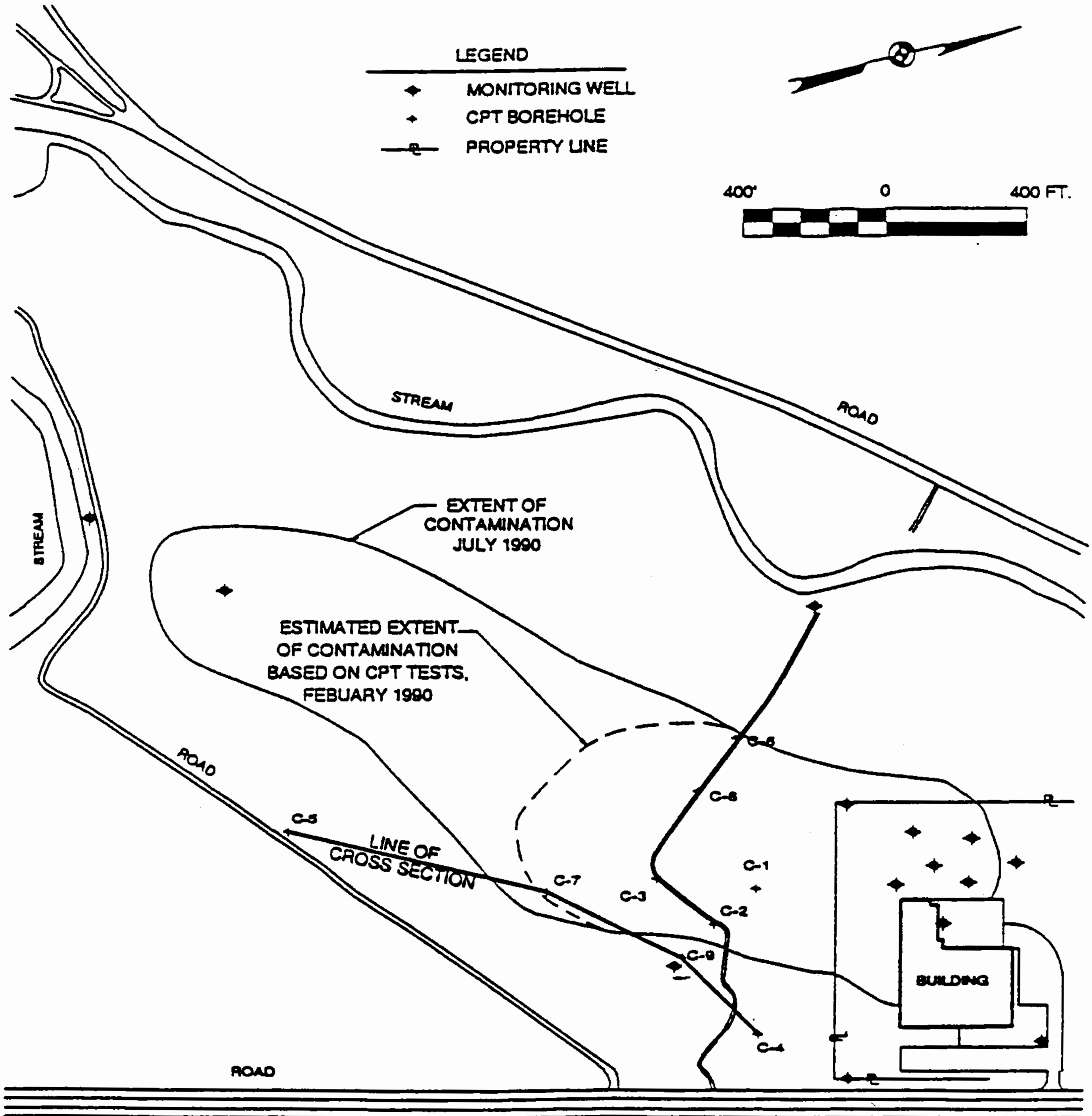


FIGURE 7 - LOCATION OF CPT TESTS, MONITOR WELLS, LINE OF CROSS SECTION AND EXTENT OF TCE CONTAMINATION AT THE TOP OF GROUNDWATER

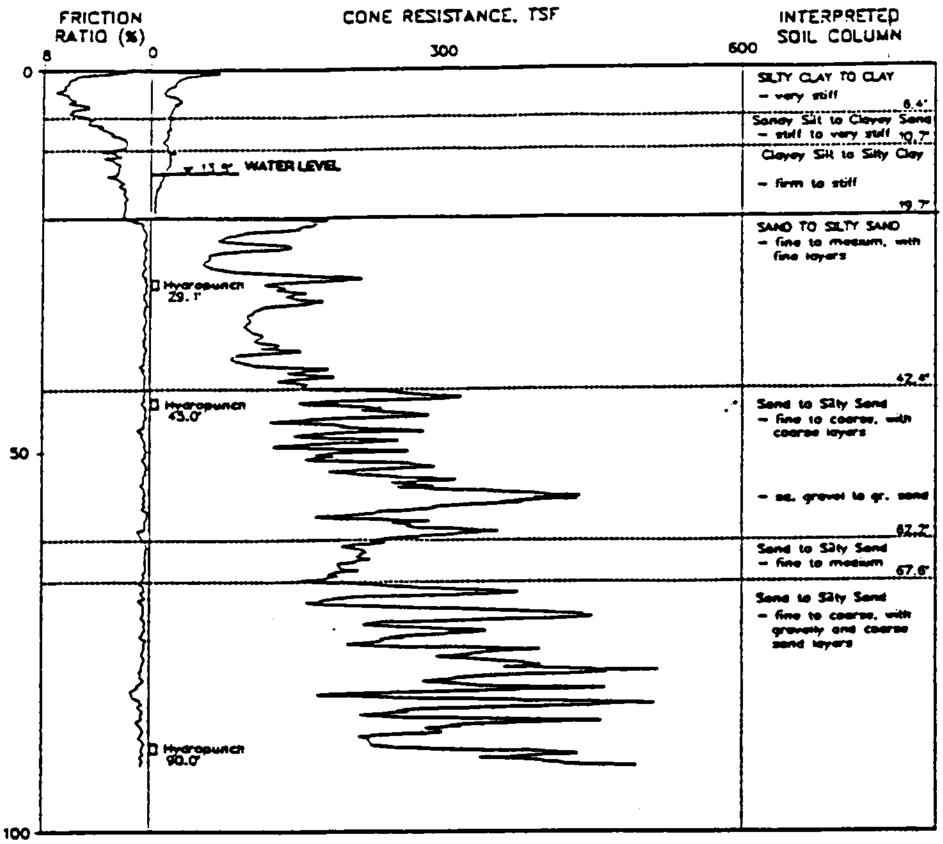


FIGURE 8 - INTERPRETED CPT SOUNDING LOG C-3 WITH SAMPLING DEPTHS

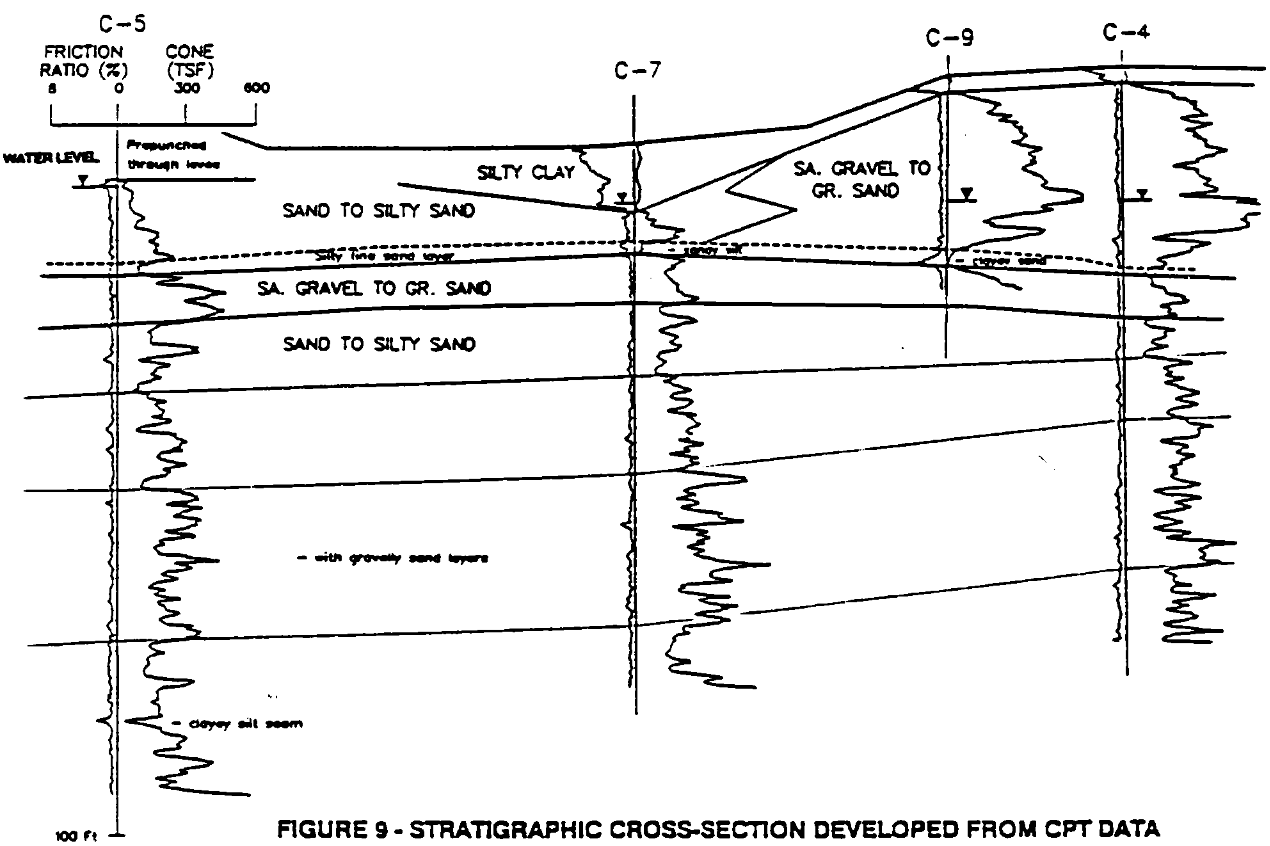


FIGURE 9 - STRATIGRAPHIC CROSS-SECTION DEVELOPED FROM CPT DATA

TABLE 1
CPTU SOIL STRATIGRAPHY

STRATUM NUMBER	DEPTH	DESCRIPTION	INCLUSIONS
1	0 ft to 2-3 ft (0 ft to 9-20 ft in C-3, C-7 & C-8)	Very stiff to firm sandy clay to clayey silt, with increasing silt content with depth	
2	2-3 ft to 75-94 ft (completion depth)	Medium dense to dense sand to silty sand, with layers of gravelly sand and sandy gravel.	a) a seam of cl. silt at 84 ft at C-5 b) sa. silt from 13.8 to 15.5 ft at C-7 c) cl. sand from 24.4 to 26.6 ft at C-9

A highly detailed characterization of the site geology was obtained from the CPTU sounding logs. Split-spoon sampling during drilled investigations often results in poor recovery in sands and gravels, which make detailed description impossible. In contrast, the CPTU data provided a continuous record of the material being penetrated, thus allowing even minor changes to be recorded accurately (Figures 3, 8 and 9). The high resolution of the CPTU data was important in finding zones of higher permeability for future groundwater remediation and also verified the lack of confining layers at the site. The assumption of a thick, surficial clay zone interfering with the soil gas survey was verified by soundings C-3, C-7 and C-8 (Figures 3, 8 and 9).

Groundwater conditions were measured using CPTU piezometric data (Figures 8 and 9). Water table measurements were also taken using a water level indicator lowered into the open hole left after a sounding. The potentiometric surface at one groundwater sampling depth was measured by allowing the sounding rod string to fill through the Hydropunch sampler.

The Hydropunch sampler was successfully used in obtaining 22 groundwater samples out of 27 attempts. In general, the Hydropunch sampler worked well, especially in regards to depth capacity. Some disadvantages of the Hydropunch sampler were:

- Lack of definitive feedback as to whether the shield opened
- Minor galling and seizing of sampler parts as is common with unlubricated stainless steel assemblies
- Slight bending of the sample barrel during pushing with forces in excess of 10 tons

The BAT groundwater samplers were used during two sampling attempts at the site. The thin-wall deployment casing buckled while pushing the Mk. 2 wellpoint through the shallow gravelly sands at location C-2, which precluded taking a sample. The Enviroprobe was successfully used at location C-5 and illustrated some of the features of the BAT system, including the retrieval of multiple samples and rapid feedback as to wellpoint shield opening.

Groundwater samples were analyzed at the on-site laboratory for four organic volatiles that had been identified in the groundwater. TCE was found to be the most prevalent contaminant. Several samples were sent to an off-site laboratory for verification of the field results. On-site analytical results were consistently lower than results generated in the off-site laboratory. However, the on-site laboratory results were sufficiently accurate to guide the location of successive exploration locations.

CONCLUSIONS

The approach of using a truck-mounted penetrometer rig, CPTU soundings, penetrometer groundwater samplers and an on-site GC laboratory to conduct geo-environmental site characterization studies, in combination with drill rigs to set monitor wells, proved to be highly advantageous in terms of:

- Minimal site disturbance and generation of wastes
- Collection and analysis of high quality, high resolution hydrostratigraphic data, with little or no downtime
- Optimal positioning of drill rig installed monitor wells, with little additional split-spoon sampling or geotechnical laboratory testing
- Meeting deadlines and budgetary constraints

Based on the results of the penetrometer investigation, monitor wells were installed using drill rigs along the downstream perimeter of the contaminant plume. Little split-spoon sampling was performed during well installation as stratigraphy had already been defined to a high degree by the CPTU sounding data. Several rounds of monitor well sampling have verified the accuracy of penetrometer groundwater sampling and the use of field analytical testing.

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AUTHORS

Andrew I. Strutynsky, P.E., the Technical Director of STRATIGRAPHICS, is responsible for all penetrometer operations at the company. He designs custom penetrometer equipment and performs research and development on new techniques. He was a speaker at the First International Symposium on Penetration Testing (1988), and conducted a Piezometric Cone Penetration Test (CPTU) workshop at the Third Outdoor Action Conference (1989), sponsored by the NWWA. He has over 10 years of subsurface exploration experience, eight of which have been exclusively devoted to penetrometer exploration projects. He has worked throughout the United States, in the Far East, the Middle East, Central America, Europe, and the High Arctic. He has performed penetrometer research for a major oil company and both the U.S. Geological Survey and the National Science Foundation. He has authored various papers on penetrometer equipment and interpretation of penetrometer data. He has the B.S. and M.S. degrees from the University of Illinois.

Timothy J. Sainey, P.G., is Senior Project Geologist at ERM-Midwest, Inc. With more than 17 years of geologic experience, his specialties include OVA/GC instrumentation, soil gas surveys and subsurface geophysical testing methods. While at ERM, Mr. Sainey has managed numerous environmental assessment, site remediation and closure projects, involving soil and groundwater sampling, well construction, installation and monitoring, and the evaluation of remedial actions. Previously, he managed a geotechnical laboratory that specialized in ASTM testing. Also, he worked as an exploratory geologist for an oil company. Mr. Sainey received his B.S. and M.S. in geology from Ohio University in 1969 and 1973.

Ground Water Management Number 4

A journal for rapid dissemination of ground water research.

Proceedings of

Petroleum Hydrocarbons and Organic Chemicals in Ground Water:

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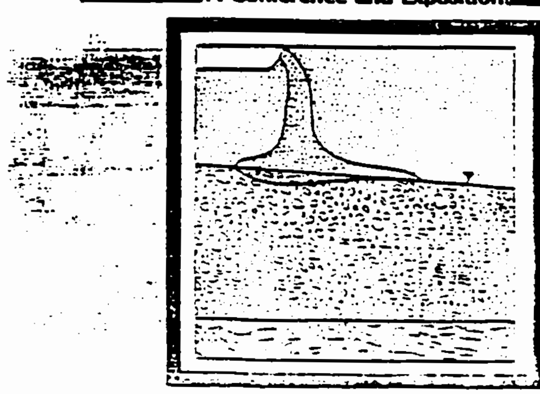

October 31 – November 2, 1990
The Westin Galleria
Houston, Texas

Presented by The Association of Ground Water Scientists and Engineers (division of NWWA) and The American Petroleum Institute

USING INNOVATIVE SAMPLE COLLECTION AND FIELD ANALYTICAL TECHNIQUES TO RAPIDLY CHARACTERIZE MULTIPLE PETROLEUM HYDROCARBON SITES

ABSTRACT

Innovative exploration methods and advanced on-site field analytical techniques identified the presence or absence of petroleum hydrocarbon constituents (PHCs) in the soil and groundwater at multiple sites, quickly and effectively. Where present, the vertical and horizontal extent of PHCs was identified. The field program was completed using two terraprobe systems, a cone penetrometer unit, and two mobile laboratories in a four-week time frame.

Piezometric Cone Penetrometer Tests with soil Electrical Conductivity (CPTU-EC) measurements were used to rapidly assess site hydrostratigraphy. Three CPTU-EC soundings were typically performed at each site. Aquifer and aquitard units were identified in real time. Soil and electrical conductivity measurements were used to evaluate whether free-phase products were present at each site. Small diameter piezometers were installed in each CPTU-EC hole to identify the direction of ground water flow and to allow for sampling of ground water. Penetrometer soil and ground water sampling were performed when lighter weight geoprobe units could not penetrate to desired depths. The penetrometer truck was able to complete exploration work at one and one-half sites per day, on average.

Using a phased approach, soil and ground water samples were analyzed for PHCs in the field, providing quality real-time data. During Phase I, all soil samples were analyzed for total petroleum hydrocarbons (TPH) by infrared (IR) spectroscopy, using a modification of USEPA Method 418.1. Data from these initial locations directed subsequent soil and ground water sampling, both horizontally and vertically. Approximately 30 percent of the samples underwent subsequent analysis (Phase II)

using a gas chromatograph (GC) for the specific analyte determination of benzene, toluene, ethylbenzene, and xylenes (BTEX), and fuel fingerprint identification.

INTRODUCTION

Corporate policy requires environmental assessment of all properties considered for acquisition or divestiture. One objective of these assessments is to determine the extent, if any, to which soil and ground water have been impacted by past operations. The knowledge is required to determine financial exposure and environmental obligations.

In 1992, approximately 400 miles of product pipeline in northern Illinois, Indiana, and western Ohio was investigated. Environmental assessments were required at seven pumping stations and three terminals associated with this pipeline. In addition, eight old spill sites at various locations along the pipeline right-of-way were investigated. Table 1 is a summary of site activities. Timing associated with negotiations and the desired close-date resulted in a 12-week window in which to complete the environmental assessments.

In response to a request for proposal, proposals ranging for $600,000 to $1,200,000 were received. The scope of work addressed in these proposals included the determination of the presence or absence of PHCs in soil and ground water and, if present, the vertical and horizontal extent. Both traditional (soil borings, monitoring wells, and off-site laboratory analyses) and innovative methods were proposed. Traditional assessment methods were rejected for the following reasons:

1. Time constraints did not allow the use of slower methods.

2. Data quality objectives did not require USEPA Level IV data.

3. Cost.

The plan that proposed the use of a cone penetrometer truck (CPT), two geoprobe units and field based analytical procedures was selected for the following reasons:

1. CPT techniques offered acquisition of stratigraphic and hydrologic data.

2. Geoprobe soil and ground water sample collection methods offered the collection of a large number of samples in a short amount of time.

3. Use of the CPTU-EC and geoprobe did not result in the generation of soil cuttings and monitoring well purge water requiring off-site disposal.

4. The field analytical plan best suited corporate requirements and was backed with directly relevant experience.

5. The proposed project schedule was credible and met corporate requirements.

6. Use of the proposed innovative techniques substantially reduced the cost of the project.

TABLE 1
Project Summary

Number of Sites	Total Number of Explorations	Total Number of Samples Collected	Total Number of Analyses[1]
18	575	913	1,498

NOTES:
1 The total number of analysis includes quality control samples and multiple analysis of a single sample.

TECHNICAL APPROACH

Three key elements used in the alternate approach to the 18 site investigations were CPT, geoprobe, and field analysis. This combination of innovative collection and on-site analytical techniques enabled the subsurface investigations of each site to be quick, thorough, and cost-effective.

Cone Penetrometer. The penetrometer technique provides various advantages during geo-environmental studies. These include a relatively nondestructive test procedure generating no cuttings or drilling fluids; real-time, computerized data acquisition and presentation; continuous profiling capability; minimal exposure of personnel to possible contaminants; and higher productivity with lower cost as compared to borehole techniques.

CPTU-EC soundings were performed at several locations within each study area. On-site personnel used these soundings to investigate stratigraphy, to determine the depth to ground water, and to identify soil sample collection depths. Each CPTU-EC sounding generated physical data about subsurface soil conditions interpreted from cone tip and friction sleeve-bearing resistance, generated pore pressure, and electrical conductivity.

CPTU-EC penetrometer testing consisted of using a large hydraulic ram to push a small diameter (1.7-inch) instrumented probe (penetrometer) into the ground while measuring the soil shear resistance to penetration. In addition to shear resistance, a pressure transducer and a soil electrical conductivity sensor were mounted on the cone tip. The pressure transducer was used to measure the water pressure response of the saturated soil. Time-dependent measures (dissipation tests) were used to calculate in situ hydraulic conductivities. Soil electrical conductivity primarily depends on pore fluid chemistry (identifying possible locations of nonconductive PHC layers[1]), soil saturation, and clay content. Downhole sensors transmitted electrical signals to an uphole computer for real-time display allowing immediate interpretation of subsurface conditions. Both soil and ground water samples could be collected by CPT techniques[2] when depths exceeded geoprobe capabilities.

The CPTU-EC data were reviewed before sample collection activities, and used to locate subsequent subsurface soil collection depths. Information about soil saturation and electrical conductivity was of particular interest for indicating the probable whereabouts of subsurface PHCs.

Piezometer Installation. Several small diameter (3/4-inch nominal) polyvinyl chloride (PVC) piezometers were installed at each site. All piezometers were screened across the water table in an attempt to intercept any hydrocarbon layer that might be present. The 15-foot-long slotted PVC screen was covered with a geofabric before installation to reduce infiltration of fines.

At each piezometer location, the CPT rig pushed a steel casing to the required depth (approximately 20 feet below ground surface [bgs]). The PVC screen and riser were placed inside the casing, which was then retracted leaving the piezometer material below the water table. The piezometer installation was completed with a protective casing to minimize tampering. All downhole equipment and PVC piezometer materials were steam-cleaned prior to installation.

All penetrometer downhole equipment was automatically decontaminated during retrieval by passing it through a sealed rodwashing chamber, mounted below the hydraulic ram, and connected to the onboard steam cleaner. The open hole was grouted using a proprietary system that continuously pumped grout into the annular space.

Geoprobe. The geoprobe is a hydraulic pushing system mounted on a truck that can push 1.25-inch sampling rods to a depth of approximately 30 feet bgs. By using the geoprobe system to collect soil and ground water samples, a reduction in time and cost was realized. Each geoprobe unit was able to collect 10 to 15 soil samples a day from 8 to 10 explorations. Additionally, this technique did not generate soil cuttings. The geoprobe unit is relatively small and lightweight compared to traditional drill rigs making it easier to access congested terminal locations.

Initial subsurface sampling locations were sited next to potential source locations; subsequent explorations were placed downgradient from the potential sources. The specific locations for subsequent sampling were based on information obtained during the initial sample collection and analytical data from the mobile laboratory. By directing the exploration program in the field, only necessary samples were collected and analyzed. This reduced the number of samples necessary to characterize the site. Generally, soils were collected from strata exhibiting depressed electrical conductivity and from the area around the water table.

DATA QUALITY OBJECTIVES

Data generated during field activities were characterized as USEPA Level I and Level II (USEPA, 1987).

With respect to the pipeline project, Level I data were qualitative and semi-quantitative and provided information on the presence or absence of contamination. Data included measurements from handheld photoionization detectors, pH meters, and specific conductivity probes. Level II data were those data generated by an on-site laboratory and were both qualitative or quantitative. Level II data collected during this investigation included TPH by IR detection, volatile organic compounds (VOCs) by GC (mainly BTEX), and petroleum fingerprints using GC.

FIELD ANALYTICAL METHODS

The detection of fuel-related hydrocarbons in site soils and ground water was performed using a combination of two analytical techniques: IR spectroscopy and gas chromatography. All soil samples were analyzed for TPH by IR; approximately 30 percent of the samples were also analyzed using GC.

Total Petroleum Hydrocarbons by Infrared Analysis. TPH were analyzed by IR spectroscopy as outlined in USEPA Method 418.1. The modified procedure[3] combined solvent extraction and silica gel cleanup into a rapid single step micro-extraction that uses smaller volumes of both solvent and sample. As many as 90 samples were analyzed in a single day by the two field operators. The analytical detection limit for this modified procedure is 50 milligrams per kilogram (mg/kg).

Gas Chromatography Analysis. GC was used for the specific determination of individual volatile aromatic hydrocarbons including BTEX[4], and to generate fuel "fingerprints" for selected mixtures of fuels through Carbon-28 (C_{28}). Generated fuel fingerprints were compared to known fuel products for both identification and quantitation and interpreted against current standards described in ASTM Method D 3328-78. The detection limit for the individual target fuel components in soil was one to two mg/kg, while the fuel mixtures had detection limits ranging from 10 to 100 mg/kg.

Quality Control. Quality Control for the aforementioned analytical methods was performed to a degree sufficient to evaluate data precision and accuracy and system performance while not inhibiting the ability to generate real-time data and maintain high sample throughput.

COMPARATIVE ANALYSIS

Tables 2 and 3 contrast and compare a traditional approach to site investigations (i.e., drilling and off-site laboratory analysis) with the innovative approach used during this program. Through the use of innovative collection and analytical techniques, the overall cost and schedule of the program was reduced without compromising the data quality needed to meet project objectives.

Impact On Program. Table 2 presents the actual cost incurred by the innovative program. Table 3 is an estimate of the costs that would have been incurred if a more traditional approach had been followed. Table 4 is a comparison of the two methods illustrating the cost savings for each unit item. However, possibly the greatest savings is much more difficult to measure - is the reduction in cycle-time that shortened the schedule significantly.

CASE STUDY

Investigation results for a terminal of approximately 37 acres is presented as a case study to illustrate the cost savings. The on-site review and historical data

TABLE 2
Project Cost Summary
Innovative Approach

	No. of Explorations	No. of Samples	Mob/ Demob[1]	Average Unit Cost	No. of Days	Total Cost
Geoprobe	508	757	$5,000	$335/ Exploration	43	$170,180[3]
CPT	64	53	$2,200	$1,471/ Exploration	19	$94,150[4]
Field Analysis	--	1,498[2]	$46,900	$151/Analysis	43	$226,198[5]
Drilling	3	0	$1,600	$13,850/Well	8	$41,550[6]
Reporting	18 Reports	--	--	$5,933/Report	16	$106,796
Project Management	--	--	--	$2,931/Site	70	$52,758
Totals	575	--	$55,700	--	--	$691,632

Average Cost per Site - $38,456

Notes:
1 This includes the cost of staging, moving equipment and personnel to and from all locations.
2 Includes samples collected by other means (i.e., surface soils, sediments, surface water, and a smaller number of quality control samples).
3 Cost includes all labor (2-person crew).
4 Cost includes 51, 3/4-inch piezometer and all labor (2-person crew plus 1 inspector).
5 Cost includes all labor (2-person crew).
6 Cost includes three 4-inch PVC monitoring wells, and labor for a 2-person crew plus 1 inspector (monitoring wells were necessary because of a very thick gravel deposit (approximately 45 feet of gravel to the water table).

TABLE 3
Estimated Project Cost Summary
Traditional Approach

	Total No. of Explorations/Analysis	Mob/ Demob	Est. Cost Per Unit	Subtotal Cost	Est. No. of Drums	Estimated Cost for Drum Disposal	Total Cost
Soil Boring[1]	508	$1,750	$600[4]/ Boring	$306,550	127 soil[2]	$209,550	$516,100
Monitoring Well Installation	54	$2,200	$1,815[5]/ Monitoring Well	$92,565 Plus $41,550 three gravel wells see Table 1	14 soil[2] Plus 27 drums of purge water[3]	$31,065	$165,180
Off-Site Laboratory Analysis	1,498 Analyses IR - 806 BTEX plus Finger Print - 346	$4,300 Shipping Cost	IR - $180 BTEX plus Fuel Finger Print- $600[6]	IR - $145,080 BTEX plus Fuel Finger Print - $207,600	--	--	$356,980
Reporting[7]	18 Reports	--	--	$5,933/ Report	--	--	$106,794
ProjectManagement[7]	--	--	--	$2,931/ Site	--	--	$52,758
Totals	562 Explorations; 1,498 Analysis	--	--	--	168	$240,615	$1,197,812

Average Cost per Site - $94,655

Notes:

1 Average depth of soil exploration from Table 1 is 12 feet.

2 Drill cuttings disposal. Assume one soil drum for every 4 soil borings requires off-site disposal and analysis: RCRA Characteristics $210 [reactivity $130, corrosivity $15, ignitability $65], TCLP analysis at $1,200, TPH at $60, Total BTEX at $100, trucking at $35/drum and bioremediation at $45/drum. Total cost per soil drum estimated at $1,650.

3 Purge water disposal. Assume one drum of purge water for every four wells requires off-site disposal. Analysis required: TPH at $60, Total BTEX at $100, Total BTEX at $100, and trucking at $35/drum, and treatment at $100/drum. Total estimated cost per purge water drum at $295.

4 Assume 4.25-inch hollow stem augers (HSA) with 5-foot sampling. Cost estimated at $35/foot and bentonite grout at $15/foot combined estimated cost of $50/foot. Labor cost included in footage rate.

5 Assumed 6.25-inch HSA 5-foot sampling at $35/foot and well material (4-inch PVC riser, $6/foot; 15-foot PVC screen, $32/foot; grout, $15/foot; protective casing $250 each) estimated cost per 25-foot installation $1,815. Labor cost included in footage rate.

6 Assume 24-hour turnaround is 3 times the cost of non-expedited analysis.

7 Cost for Reporting and Project Management assumed to be the same as presented in Table 2.

Table 4
Cost Summary
Innovative Compared To Traditional Approach

	Average Cost Per Site	Average Cost Per Exploration	Average Cost Per Analysis	No. Of Days	Totals
Innovative Approach	$38.456	$532[1]	$151[2]	70	$692.223
Traditional Approach	$94.655	$1.185[3]	$238[4]	120	$1.197.812
Savings Using Innovative Approach	$56,199	$653	$87	50	$505.589

Notes:

1 Average cost per exploration includes cost of geoprobe, CPT, and Drilling from Table 2 for 575 explorations.
2 Average cost per sample includes IR, BTEX, and fuel fingerprinting from Table 2 for 1,498 analysis.
3 Average cost per exploration includes cost for Soil Borings and Monitoring Well Installation from Table 3 for 575 explorations.
4 Average cost per sample includes IR, BTEX, and fuel fingerprinting from Table 3 for 1,498 analysis.

provided indicated that the pipeline manifold/sump area, the large aboveground breakout tanks, the railroad and truck-loading racks, and the warehouse were potential sources. The soil sampling and piezometer locations were placed using this information (Figure 1). Physical and chemical data from soils and ground water were collected at the Terminal site using a combination of cone penetrometer and geoprobe system sample collection techniques. All samples were analyzed using a combination of IR spectroscopy and GC. This work was completed including sample analysis and preliminary data evaluation in approximately five geoprobe/field laboratory days and two CPT days.

Stratigraphy and Hydrogeology. The terminal is located on a small hill. The large aboveground breakout tanks are located at the top of the hill, whereas the manifold area, loading racks and warehouse are at the bottom of the hill. The soils are interbedded sands, silts, and clays (Figure 2). There are two aquifers below the site, a perched system below the breakout tanks, and a regional sand and gravel aquifer.

Data Interpretation. Eighty-six soil, ten groundwater, five sediment, and four surface water samples were collected and analyzed for the presence and quantitation of petroleum hydrocarbons. PHCs were found in 44 of the soil samples associated with the loading racks and east of the large aboveground breakout tanks (see Figure 1). Sediment samples collected along the site boundary contained detectable concentrations of PHCs. No PHCs were reported in any surface waters associated with these sediment samples. Four of the ten ground water samples collected contained PHCs.

The apparently upgradient ground water sample (PW-0709) contained PHCs identified as weathered gasoline at 0.34 milligrams per liter (mg/L). The source area for these compounds was undetermined, and may have been related to an unidentified off-site source. The two ground water samples (PZ-0706 and PW-0707) collected downgradient from the bermed area (large aboveground breakout tanks) contained BTEX and a fuel fingerprint identified as gasoline at 9.4 and 83 mg/L, respectively. Gasoline was also identified in the ground water sample collected from the upper perched system (PZ-0704) at 0.94 mg/L (see Figure 2).

The soils data suggest that the bermed area, the manifold/sump area, and the two loading racks were probable source areas for the hydrocarbons present. The presence of PHCs in soils adjacent to the site boundaries and in the ground water suggested that PHCs may have migrated beyond the terminal boundary. Additionally, it appeared that PHCs may also have been migrating onto the site from an unidentified source area.

RESULTS

The results of applying the innovative techniques described in this paper are as follows:

1. Corporate environmental assessment requirements were fulfilled and meet the negotiated divestiture time schedule.

2. A total of 18 sites (seven pumping stations, three terminals, and eight spill sites) were assessed in four weeks of field work. Total project duration was 12 weeks.

3. The concentration and extent of PHCs in soil and ground water were mapped for each spill site. The concentration and extent of PHCs in soil and ground water mapping did not extend beyond property boundaries.

4. Environmental assessment costs were substantially reduced by utilizing innovative rather than traditional techniques.

CONCLUSIONS

By utilizing a cone penetrometer truck, two geoprobe units and field analytical procedures, the concentration of petroleum hydrocarbon constituents in soil and ground water was determined at 18 sites in a short time period and at reduced price. The extent of petroleum hydrocarbons in soil and ground water was mapped for each site. Mapping was limited to property boundaries for pumping stations and terminals. The successful completion of the environmental assessment fulfilled corporate requirements and met the negotiation divestiture time table.

ACKNOWLEDGEMENTS

ARCO Pipe Line Company acknowledges ABB Environmental Services and Stratographics Geotechnical Data Acquisition Corporation for their professional and exemplary conduct during this project. In addition, the authors thank their respective companies for the opportunity to publish this work.

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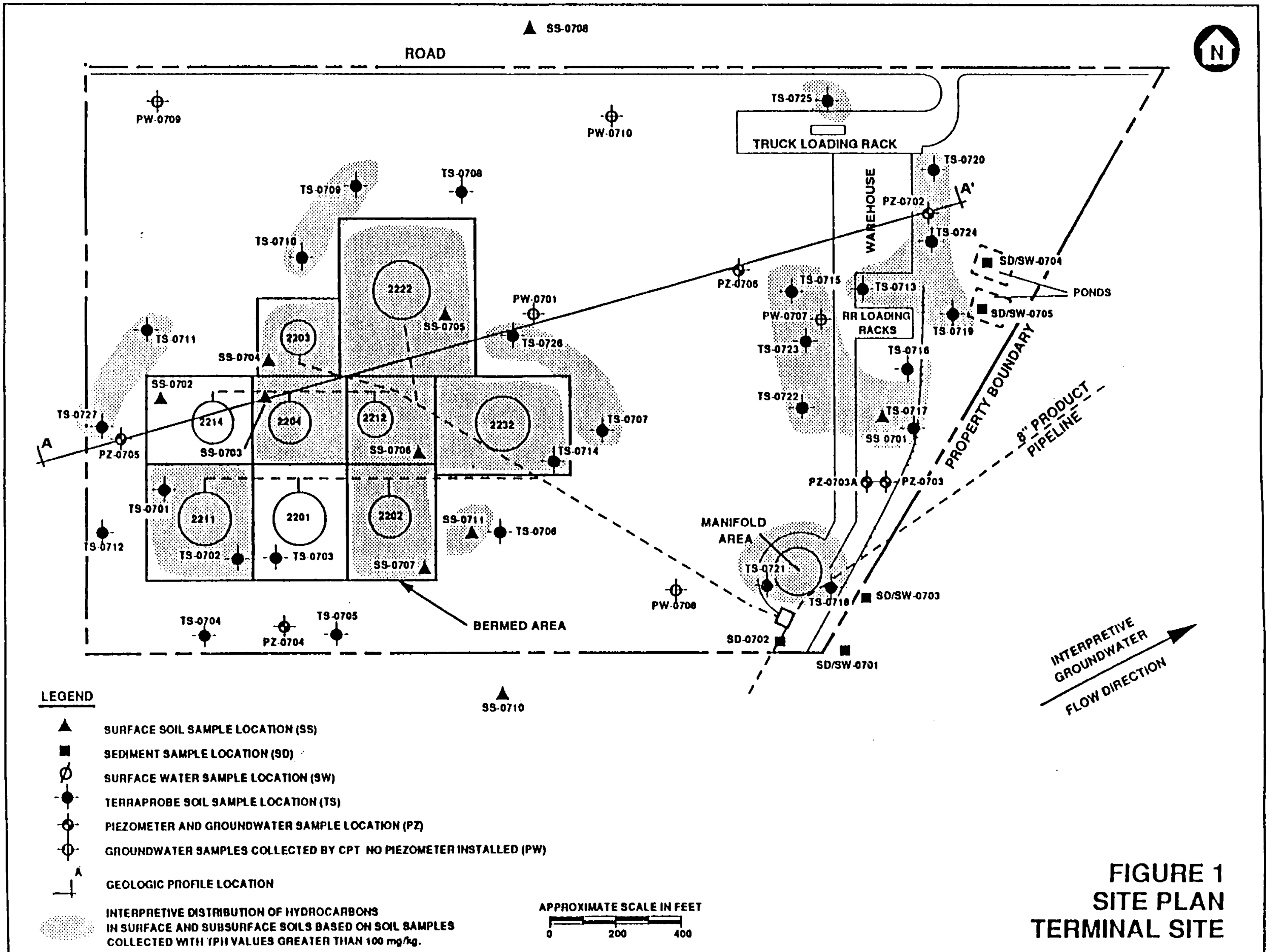

FIGURE 1
SITE PLAN
TERMINAL SITE

9212075D (A)

9212075D

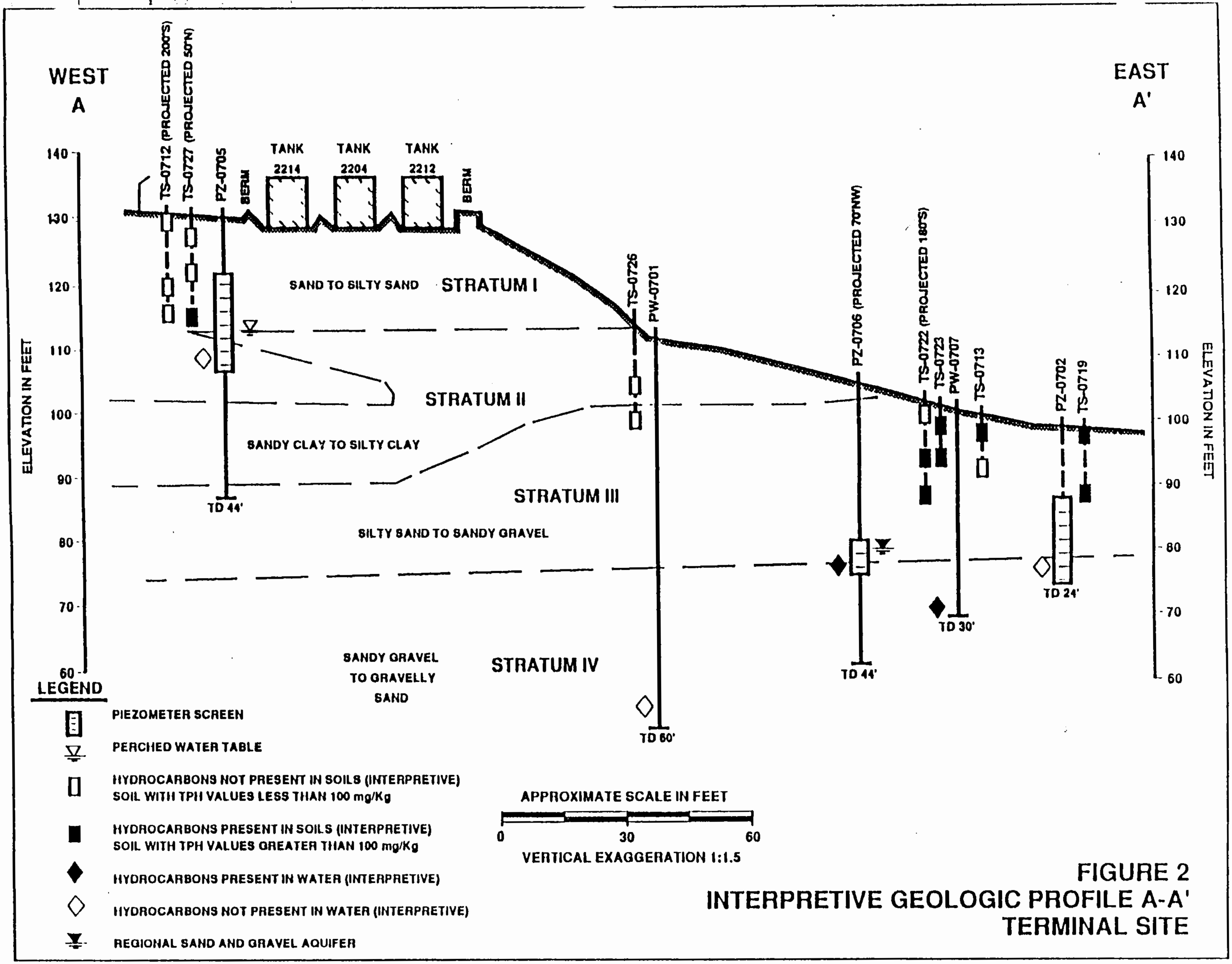

FIGURE 2
INTERPRETIVE GEOLOGIC PROFILE A-A'
TERMINAL SITE

Andrew I. Strutynsky, Raymond E. Sandiford, and Dennis Cavaliere

USE OF PIEZOMETRIC CONE PENETRATION TESTING WITH ELECTRICAL CONDUCTIVITY MEASUREMENTS (CPTU-EC) FOR THE DETECTION OF HYDROCARBON CONTAMINATION IN SATURATED GRANULAR SOILS

REFERENCE: Strutynsky, A.I., Sandiford, R.E., and Cavaliere D., "Use of Piezometric Cone Penetration Testing with Electrical Conductivity Measurements (CPTU-EC) for the Detection of Hydrocarbon Contamination in Saturated Granular Soils," Current Practices in Ground Water and Vadose Zone Investigations, ASTM STP 1118, David M. Nielsen, Martin N. Sara, Editors, American Society for Testing Materials, Philadelphia, 1991.

ABSTRACT: Piezometric Cone Penetration Testing with soil Electrical Conductivity measurements (CPTU-EC) was used for the detection of hydrocarbon saturated granular soils at two airport fuel storage areas. Details of the CPTU-EC equipment and site subsurface conditions are provided. Test program phases, including laboratory testing, field insitu testing and CPTU-EC data interpretation are described. Comparisons are made between CPTU-EC and adjacent monitor well data. Limitations to the CPTU-EC method are discussed.

KEY WORDS: Piezometric Cone Penetration Test, Soil Electrical Conductivity, free phase petroleum, hydrocarbon product contamination, airport fuel tank farms, computerized data acquisition, continuous soil profiling.

INTRODUCTION

Programs to remediate ground water accumulations of free phase petroleum hydrocarbon products, consisting primarily of aviation jet fuels, are ongoing at the fuel tank farms at John F. Kennedy (JFKIA), La Guardia, and Newark International Airports, in and around the city of New York. The Port Authority of New York and New Jersey (Port Authority) frequently requires supplemental ground water information in addition to that acquired in monitor wells at the sites.

Andrew Strutynsky, PE, is the Technical Director of STRATIGRAPHICS, 439 Taylor Ave., Glen Ellyn, IL 60137. Raymond Sandiford, PE, is a Senior Geotechnical Engineer and Dennis Cavaliere is a Geotechnical Engineer at the Port Authority of New York and New Jersey, 1 World Trade Center, New York, NY 10048.

STRATIGRAPHICS, a consulting company specializing in penetrometer data acquisition, was retained by Port Authority to evaluate the use of penetrometer soil electrical conductivity measurements (CPTU-EC) to delineate the accumulations of hydrocarbon products in the subsurface at the sites. STRATIGRAPHICS personnel had previously conducted similar studies on using penetrometer conductivity measurements for the detection of hydrocarbon contaminated soils and for the detection of ground water ice crystals in Arctic permafrost soils (Reference 1).

The penetrometer technique provides various advantages during geo-environmental subsurface investigations. These advantages include a relatively non-destructive test procedure; immediate, computerized data reporting and interpretation; continuous profiling; a high degree of exploration personnel safety; and lower exploration costs and higher productivity as compared to borehole techniques.

The experimental program for evaluating the applicability of penetrometer soil electrical conductivity measurements for the detection of free phase petroleum hydrocarbon products in ground water consisted of two phases. The first was a laboratory study using typical site soils, ground water, and jet fuel. A series of 60 tests was performed in order to establish a range of expected field measurements. The initial laboratory study was followed by field studies at the Satellite and Bulk Fuel Farms at JFKIA.

CPTU-EC soundings were performed adjacent to monitor wells for comparisons between penetrometer and monitor well data. CPTU-EC soundings were also performed at intermediate locations for correlation to the areal distribution of hydrocarbon product accumulations. A total of 48 CPTU-EC soundings were performed during the field study (Figures 1 and 2).

SOIL ELECTRICAL CONDUCTIVITY

Soil electrical conductivity is controlled by the conductance of the system of soil particles and fluids occupying the soil pore spaces. Factors affecting soil electrical conductivity, especially for sand aquifers, include:

<u>Mineralogy</u> Siliceous sand grains are essentially non-conductive, so granular soil electrical conductance is dependent on the quantity and conductance of the soil pore fluid. Clay minerals have some electrical conductance due to adsorbed water and ionic charges, thus clay conductance depends on both mineralogy and pore fluid characteristics.

<u>Pore Fluid</u> The electrical conductance of pore fluids plays the major role in granular soil electrical conductivity. Sands saturated with conductive fluids, such as saline water or landfill leachates, have a relatively high conductivity. Sands saturated with petroleum hydrocarbon products typically have low electrical conductivity because most petroleum hydrocarbon products are poor conductors.

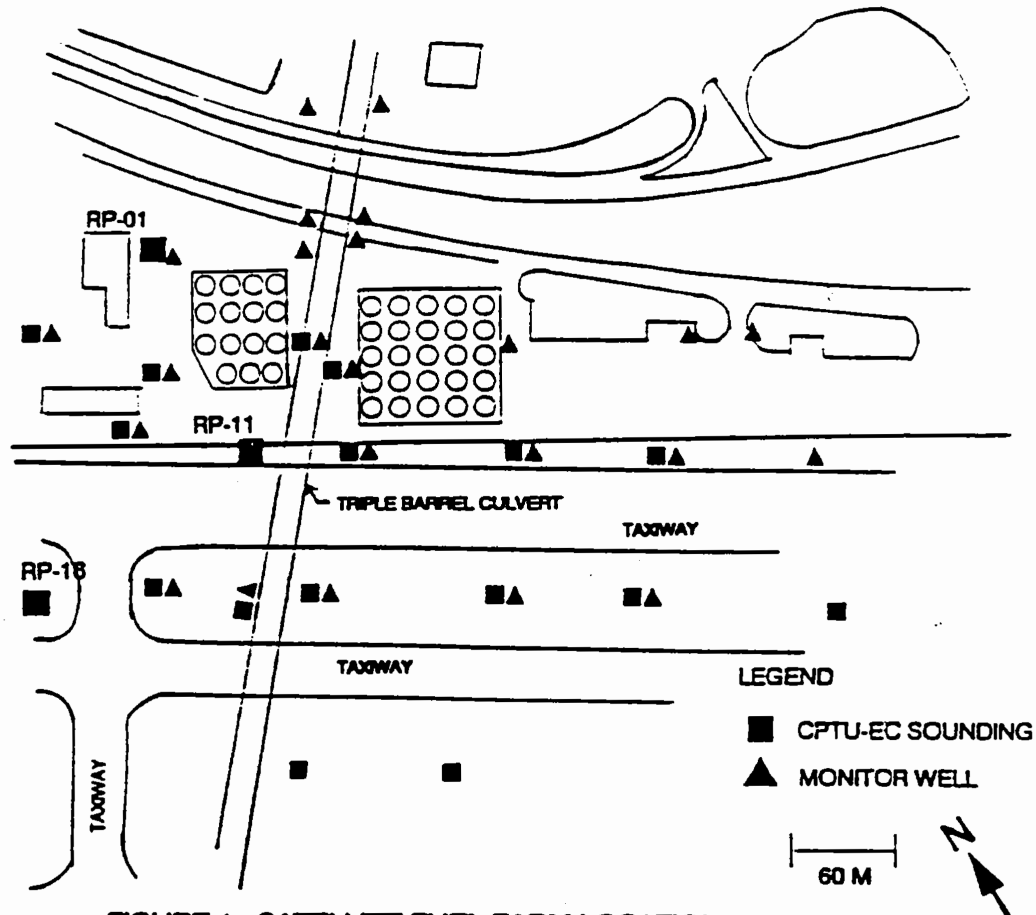

FIGURE 1 - SATELLITE FUEL FARM LOCATION PLAN

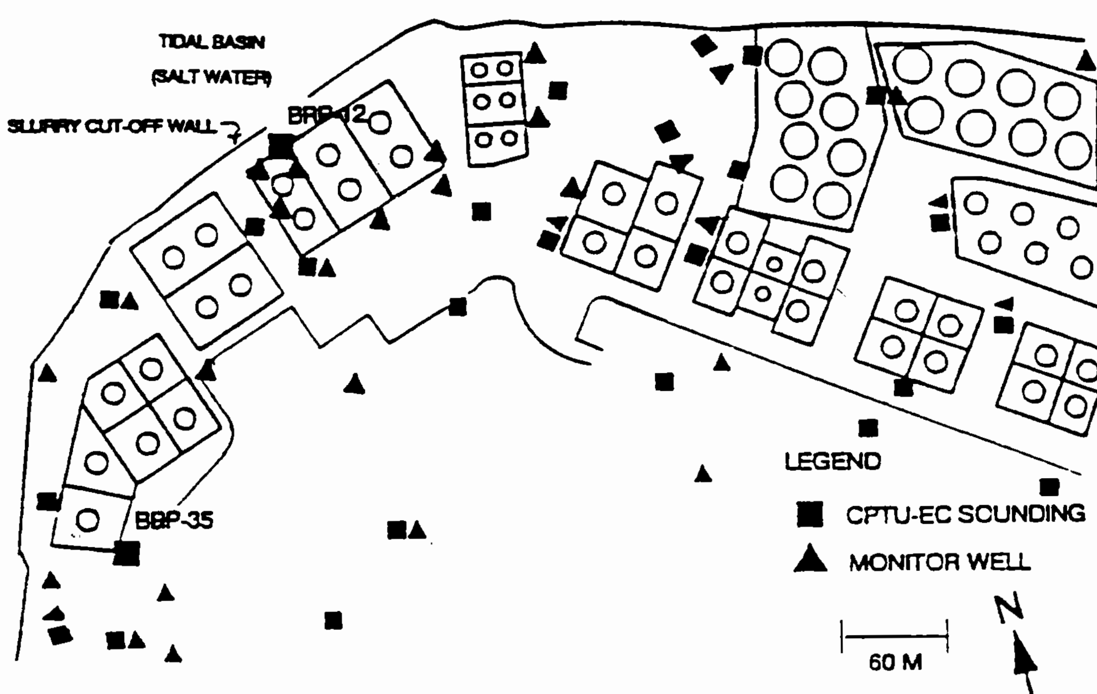

FIGURE 2 - BULK FUEL FARM LOCATION PLAN

Saturation The degree of soil saturation has a pronounced effect on soil electrical conductivity. Conductivity increases with increases in water saturation. Partially saturated sands have low electrical conductivity.

Porosity Soil porosity has an affect on soil electrical conductivity (Reference 2). Less pore fluid is required to fully saturate the pore space of a low porosity (dense) soil, resulting in lower soil electrical conductivity.

LABORATORY PROGRAM

The laboratory program to determine the effects of free phase petroleum hydrocarbon contamination on granular soil electrical conductivity included a total of 60 tests. Samples of soils from JFKIA site excavations, brackish (salty) ground water from site monitor wells, and samples of jet fuel were used to provide a range of variables that might be encountered during field testing. Soil samples were compacted to different porosities (densities) to determine the sensitivity of test results to porosity changes. Over the range of porosities expected to be representative for field conditions, the effects of porosity variation on soil electrical conductivity were considered to be relatively minor when compared to the changes in soil conductivity induced by variation in hydrocarbon content.

Laboratory testing showed that the electrical conductivity of the JFKIA sand samples depended primarily on the amount of water filling the soil pore spaces (degree of water saturation). Soil conductivity decreased with increasing substitution of pore water by jet fuel (Figure 3). A jet fuel saturated sand sample had an electrical conductivity similar to that of a dry sand sample.

The laboratory study indicated that in order to discriminate between dry sands above the water table, and free phase petroleum hydrocarbon product saturated sands below the water table, data on soil saturation was also required. A pore water pressure transducer, used during Piezometric Cone Penetration Testing (CPTU), was added to the CPTU-EC penetrometer to determine soil saturation.

Soil stratigraphy defined by Cone Penetration Test (CPT) measurements can be used to distinguish between the effects of soil type and pore fluid chemistry on measured soil conductivities. Thus, the soil shear resistance measurements of the CPT penetrometer, the piezometric measurement of the CPTU penetrometer, and soil electrical conductivity measurements were all combined in a CPTU-EC penetrometer in order to provide sufficient data to define petroleum hydrocarbon product contamination of saturated granular soils.

PENETROMETER TECHNIQUE

CPTU-EC penetrometer testing consists of smoothly pushing a small diameter (0.044 m - 1.7 inch), instrumented probe (penetrometer) directly into the ground, while a computer data acquisition system displays and records the soil shear resistance, pore water pressure response and soil electrical conductivity during penetration (Figure 4).

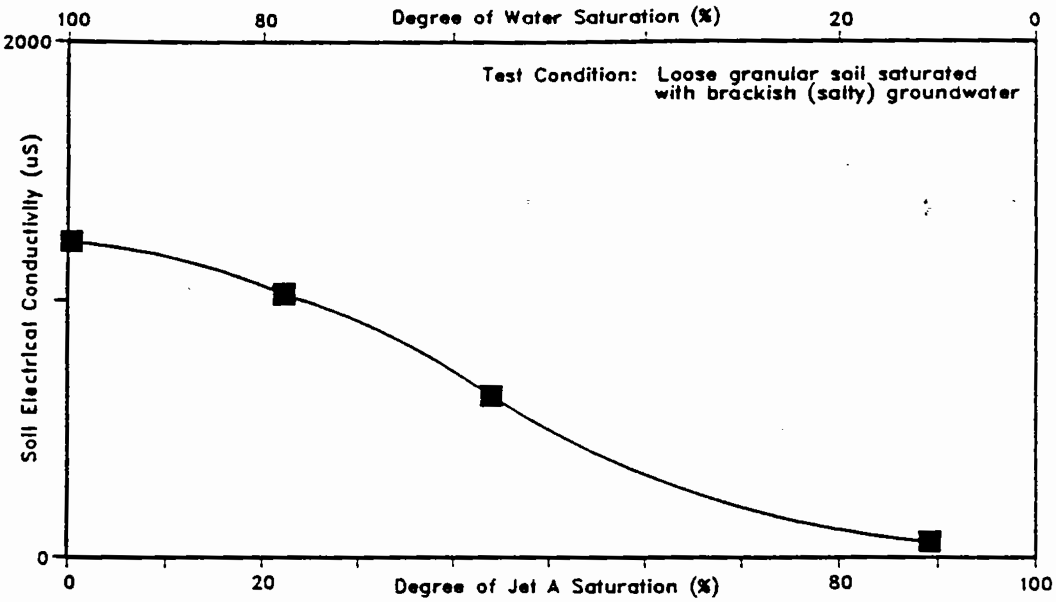

FIGURE 3 – EFFECT OF JET A PRODUCT CONTAMINATION ON GROUNDWATER SATURATED GRANULAR SOIL ELECTRICAL CONDUCTIVITY

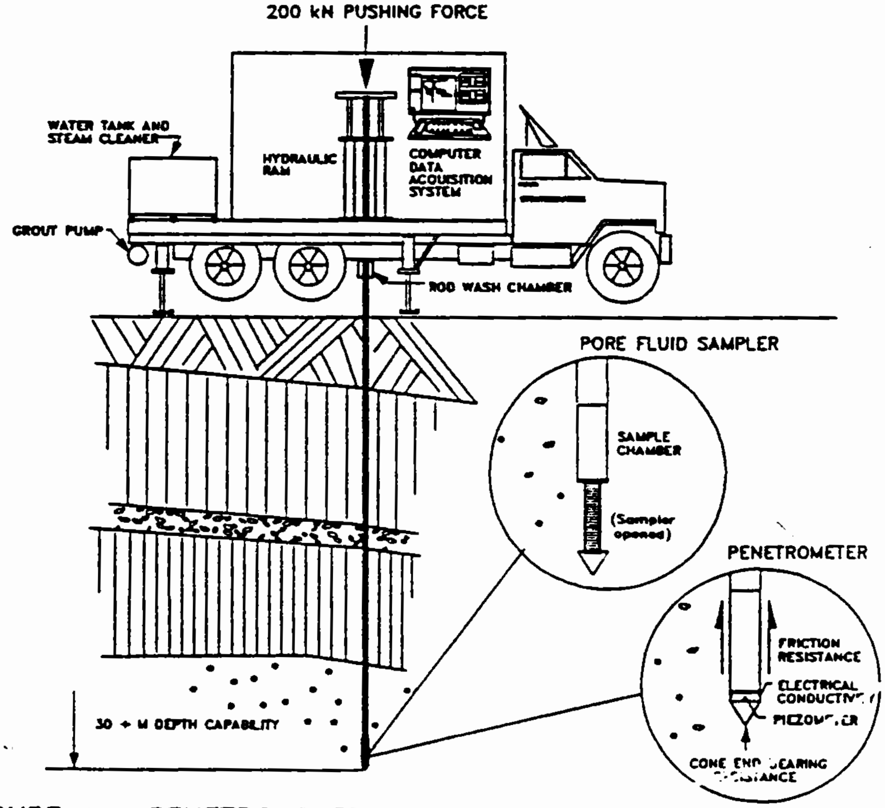

FIGURE 4 – PENETROMETER SUBSURFACE _)RATION SYSTEM

The penetrometer is mounted at the downhole end of a string of sounding rods. A hydraulic ram is used to smoothly push the penetrometer and rod string directly into the ground, without drilling a borehole, at a constant rate of 0.02 m/sec (4 ft per minute). Electronic signals from downhole sensors inside the penetrometer are transmitted by a cable, strung through the hollow sounding rods, to a data acquisition and display computer system at the surface.

CPTU-EC data are used to develop continuous profiles of geotechnical, hydrogeological, and gross geochemical soil conditions rapidly, accurately and economically. Penetrometer samplers can be used to obtain ground water or soil samples for laboratory testing (Reference 3).

Site disturbance is minimized since no borehole cuttings or drilling fluids are generated during penetrometer operations. Personnel exposure to contaminated soil is significantly less than exposures during drilling and sampling. Penetrometer downhole equipment is easily decontaminated by steam cleaning during retrieval. The small open hole left in soils above the water table after penetrometer retrieval is readily grouted.

CPTU-EC PENETROMETER MEASUREMENTS

The CPTU-EC penetrometer incorporates cone resistance, friction sleeve resistance, piezometric, thermal and soil electrical conductivity sensors. The resistance of a soil to penetration is measured on the tip and along the sides of the CPTU-EC penetrometer. The soil resistance acting on the cone tip is controlled primarily by soil grain size and porosity. The cone resistance measurement has a resolution of about 0.05 to 0.10 m (2 to 4 inches). The sliding friction between the soil and the penetrometer is measured along a sleeve mounted just behind the cone tip. The CPT-EC friction sleeve resistance measurement has a resolution of about 0.15 m (6 inches).

A pressure transducer in the tip of the penetrometer is used to measure the soil pore water pressure response to penetration. Pore water pressure response is primarily controlled by the degree of saturation, potentiometric surface, compressibility and horizontal permeability of the penetrated soil (Reference 4). The CPTU-EC piezometric measurement has a resolution of about 0.03 m (1 inch).

The soil electrical conductivity is measured between two electrodes also mounted in the tip of the CPTU-EC penetrometer. The electrodes are insulated from the steel body of the penetrometer by plastic insulators. The CPT-EC soil electrical conductivity measurement has a resolution of about 0.04 m (1.5 inches). A thermistor inside the CPTU-EC penetrometer provides data on downhole equipment temperatures. These data can be used to adjust the measured soil conductivity to a corrected conductivity at a reference temperature of 25 degrees C.

CPTU-EC data are acquired as analog signals from the transducers inside the penetrometer. The analog signals are transmitted by cable strung through the sounding rod string to a computerized data acquisition system inside the penetrometer truck. The data acquisition system translates the analog signal to a digital value using a 16-bit, analog to digital (A/D) converter. The 16-bit conversion provides a digital data resolution of 1 part in 32,768.

The CPTU-EC data are logged at a 2 Hz frequency. This logging frequency provides insitu soil data at about 0.01 m (3/8 inch) depth intervals. Data appear on a high resolution, color computer monitor in real time. Real time data display allows for the immediate definition of site conditions. Data are logged on hard disk for permanent storage. A preliminary, hard copy sounding log is generated at the conclusion of each test. Recorded data are computer processed to develop interpretations of site conditions.

GENERAL CPTU-EC DATA INTERPRETATION

Correlations between penetrometer data and soil type classifications have been developed from geotechnical soil bearing capacity theory, and observational criteria from adjacent CPT soundings and drilled and sampled boreholes (Reference 5). The CPT cone resistance increases exponentially with increases in soil grain size. The CPT friction ratio (the friction sleeve resistance divided by the cone resistance) increases with increases in the fines content of a soil. A correlation scheme based on the cone resistance and friction ratio values (Figure 5) has proved most useful in interpreting soil types from CPT measurements.

Soil saturation is evaluated using the CPTU-EC piezometric data. Atmospheric (zero) water pore pressure is measured in unsaturated soils. Hydrostatic pore water pressures are generally recorded in high permeability, granular soils below the water table. High pore water pressures are recorded in saturated, fine grained soils during penetrometer advance.

CPTU-EC FIELD TESTING PROGRAM

A total of 48 CPTU-EC soundings were performed at the JFKIA Satellite and Bulk Fuel Farms. The stratigraphy at the two sites is somewhat similar. The surficial soils at both sites consist of a hydraulically placed, fine to medium sand fill, ranging in thickness from about 1.5 to 4.6 m (5 to 15 ft).

At the Satellite Fuel Farm site, this sand fill overlies a discontinuous tidal flat deposit, which consists of about 0 to 1.5 m (0 to 5 ft) of silty clay and peat. At the Bulk Fuel Farm, heterogeneous deposits of refuse and silt interlayer the hydraulic sand fill and tidal flat deposits. Underlying the tidal flat deposits at both sites is a fine to medium sand stratum in excess of 30.5 m (100 ft) thick.

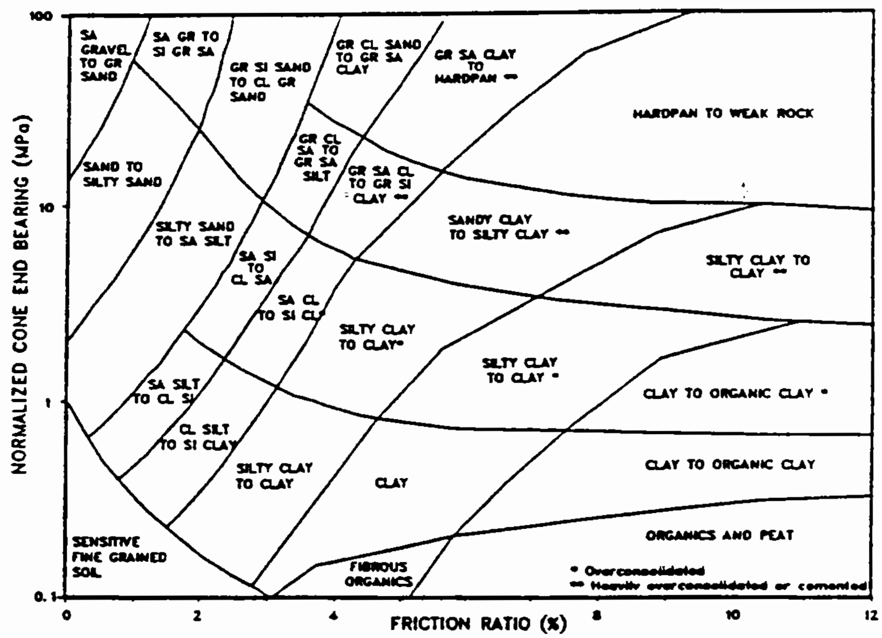

FIGURE 5 – CORRELATION CHART FOR CPT SOIL TYPES

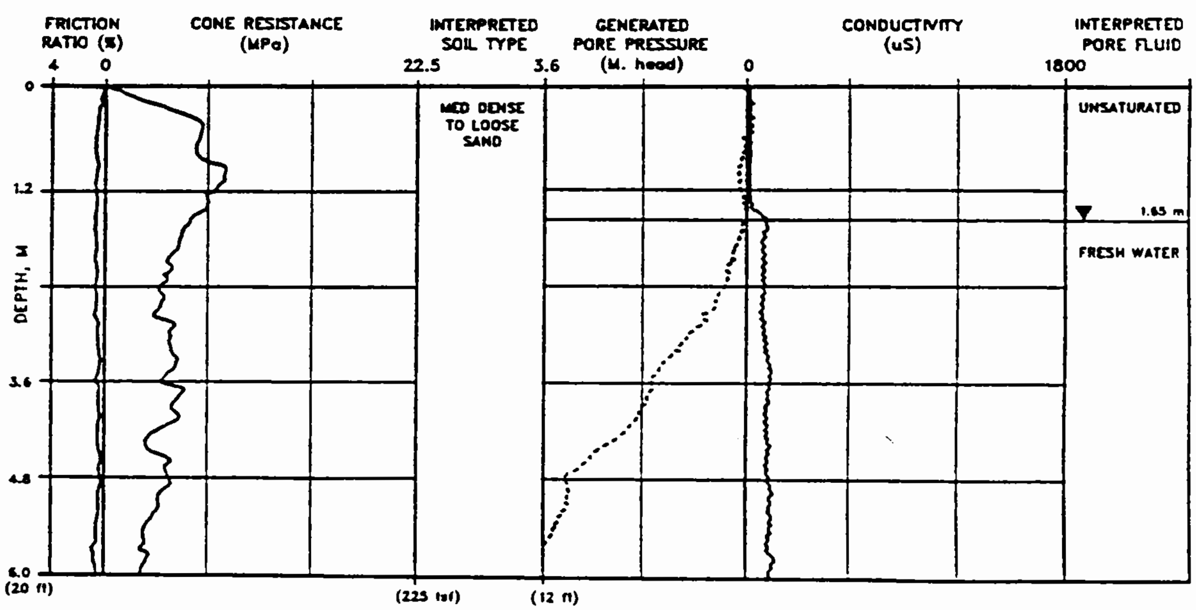

FIGURE 6 – CPTU–EC SOUNDING RP–16

The tidal flat deposits form discontinuous aquitards across the sites, resulting in both locally perched and water table (unconfined) aquifer ground water conditions. At the Bulk Fuel Farm site, the ground water has been partially contained by a slurry cut-off wall. The deeper ground water at both sites is brackish (somewhat salty) with moderate electrical conductivity. Shallow ground water is typically less salty and less conductive, probably reflecting a recent rainwater origin.

The JFKIA Satellite and Bulk Fuel Farms have significant subsurface accumulations of aviation jet fuel, as determined in monitor wells at the two sites. For the Satellite Fuel Farm, free phase petroleum hydrocarbon product thicknesses interpreted from CPTU-EC data were compared to product thicknesses measured in nearby monitor wells. This comparison showed that the general thickness patterns were very consistent, but that the insitu CPTU-EC data indicated product thicknesses to be generally 25 to 50% less than the monitor well product thicknesses.

These results confirm the hypothesis that monitor wells generally contain a thicker accumulation of free phase petroleum hydrocarbon product than is actually present in the soil. This occurs because most products float on the capillary zone above the water table. Thus, the product fills a monitor well for the thickness of the capillary zone and for a depth below the ground water table required to achieve buoyancy equilibrium between the product and ground water.

An uncontaminated, water table (unconfined) aquifer is indicated by the CPTU-EC sounding log at the Satellite Fuel Farm Location RP-16 (Figure 6). The shallow stratigraphy consists of a homogeneous sand stratum. The piezometric measurements indicate the sand to be of medium to high permeability, and indicate a water table at a depth of 1.65 m (5.4 ft).

The soil electrical conductivity increases just above the water table, reflecting increasing soil water content. Soil conductivities are relatively low and constant below the water table, reflecting low ground water salinity conditions. It was subsequently determined that a nearby water main was leaking, and the fresh water leakage was probably responsible for the low soil electrical conductivity measurements.

An accumulation of free phase petroleum hydrocarbon product is indicated by the CPTU-EC sounding log at the Satellite Fuel Farm Location RP-01 (Figure 7). The piezometric measurements indicate a free fluid surface at 1.83 m (6.0 ft) of depth. The very low soil conductivity between 1.83 and 2.10 m (6.0 and 6.9 ft) depths indicates a thin layer of product. Increasing soil conductivity below the product layer indicates increasing ground water salinity and density with depth.

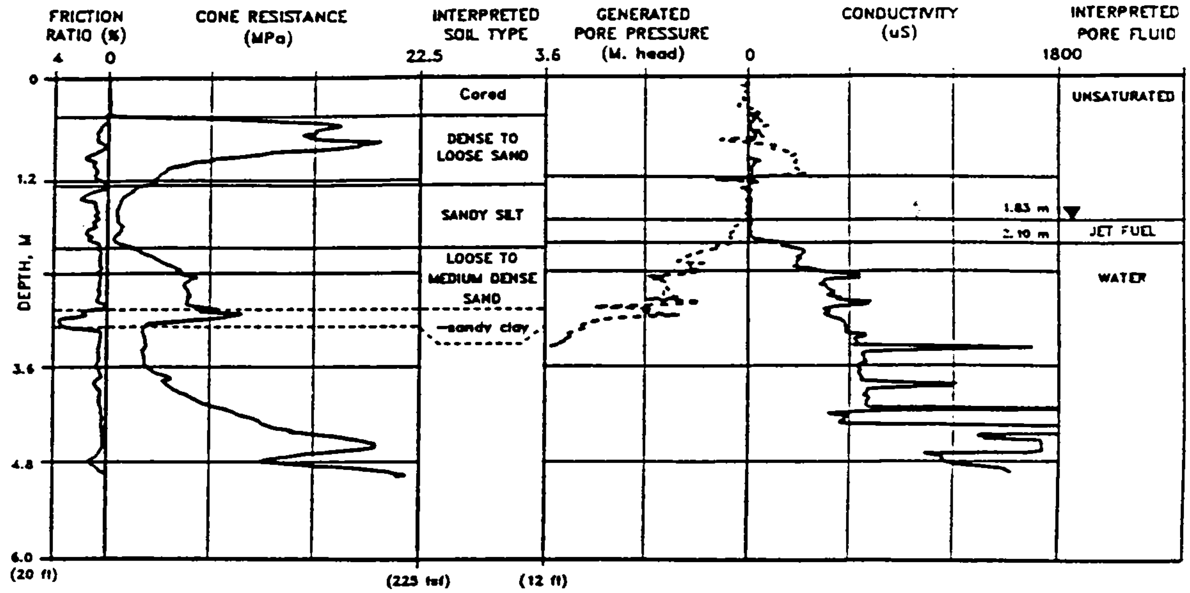

FIGURE 7 – CPTU–EC SOUNDING RP–01

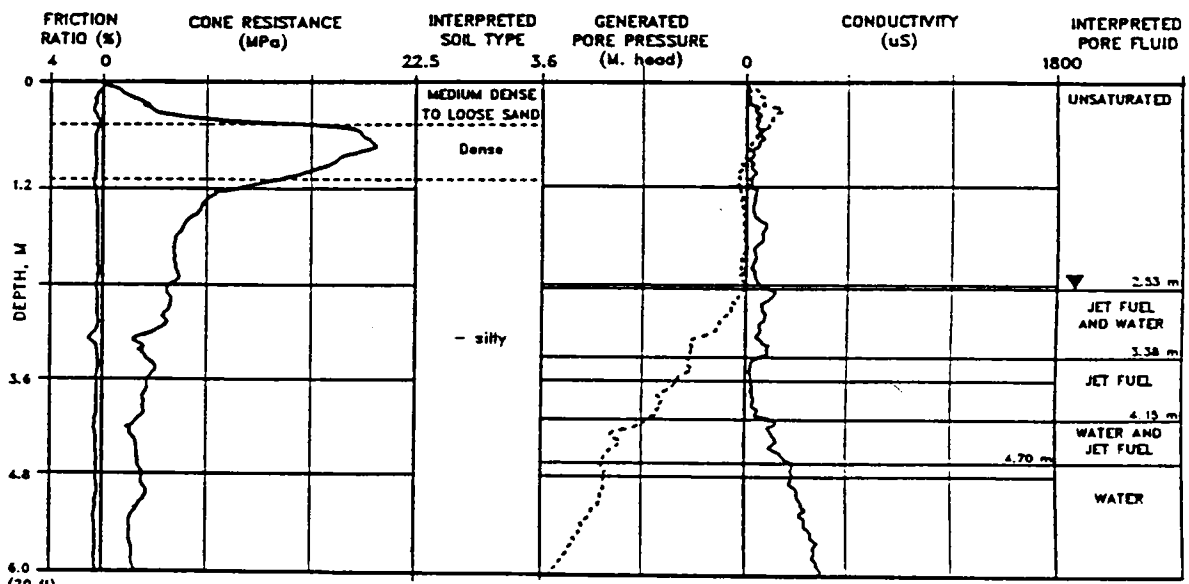

FIGURE 8 – CPTU–EC SOUNDING RP–11

Unusual results were obtained at the Satellite Fuel Farm Location RP-11 (Figure 8) next to a product recovery well. The CPTU-EC data indicate 0.85 m (2.8 ft) of a ground water-petroleum hydrocarbon product mixture, overlying a 0.76 m (2.5 ft) thick layer of product. The product layer overlies another mixed layer, which in turn overlies ground water.

This unexpected sequence is thought to be due to rapidly changing ground water conditions. Record rainfalls during the autumn of 1989 are conjectured to have both raised the locally depressed water table and filled in the cone of depression created by the nearby recovery well. The former surficial product layer became inundated. It is interpreted that due to soil permeability effects, insufficient time had passed prior to the December, 1989 CPTU-EC study for fluid density equilibrium between product and ground water to have been re-established .

This interpretation has been corroborated by CPTU-EC soundings combined with penetrometer ground water sampling at other project sites with similar rapidly changing ground water conditions. A monitor well, typically screened 1.5 m (5 ft) above and 3.0 m (10 ft) below the water table, would provide no hint of this phenomenon, because density equilibrium would occur almost instantaneously in the monitor well riser pipe.

Many of the CPTU-EC sounding logs at the Bulk Fuel Farm were not as definitive as those at the Satellite Fuel Farm. Product thickness trends from the CPTU-EC soundings did generally correspond with monitor well defined trends. However, the presence of perched ground water and product, numerous trapped product lenses, and complex ground water flow conditions caused by the slurry cut-off wall and the discontinuous aquitard, caused CPTU-EC data interpretation to be much more subjective than at the Satellite Fuel Farm.

Ground truthing the CPTU-EC data, acquired at 0.01 m (3/8 inch) intervals to monitor wells screened over 5 m (15 ft) lengths may not be appropriate for the complex site conditions at the Bulk Fuel Farm. The CPTU-EC sounding log at Location BRP-12 (Figure 9) illustrates some of the difficulties in interpreting data at sites with a complex hydrostratigraphy.

The CPTU-EC results were definitive in areas of the Bulk Fuel Farm where uniform conditions existed. The presence of free phase petroleum hydrocarbon product overlying a water table aquifer is indicated by the CPTU-EC sounding log at Location BRP-35 (Figure 10). Soil electrical conductivity is very low between the free fluid surface at a depth of 2.80 m (9.2 ft) and a depth of 3.29 m (10.8 ft), indicating a 0.49 m (1.6 ft) thick layer of product. A 0.15 m (0.5 ft) thick transition zone underlies the product layer and probably consists of soil saturated with both product and ground water.

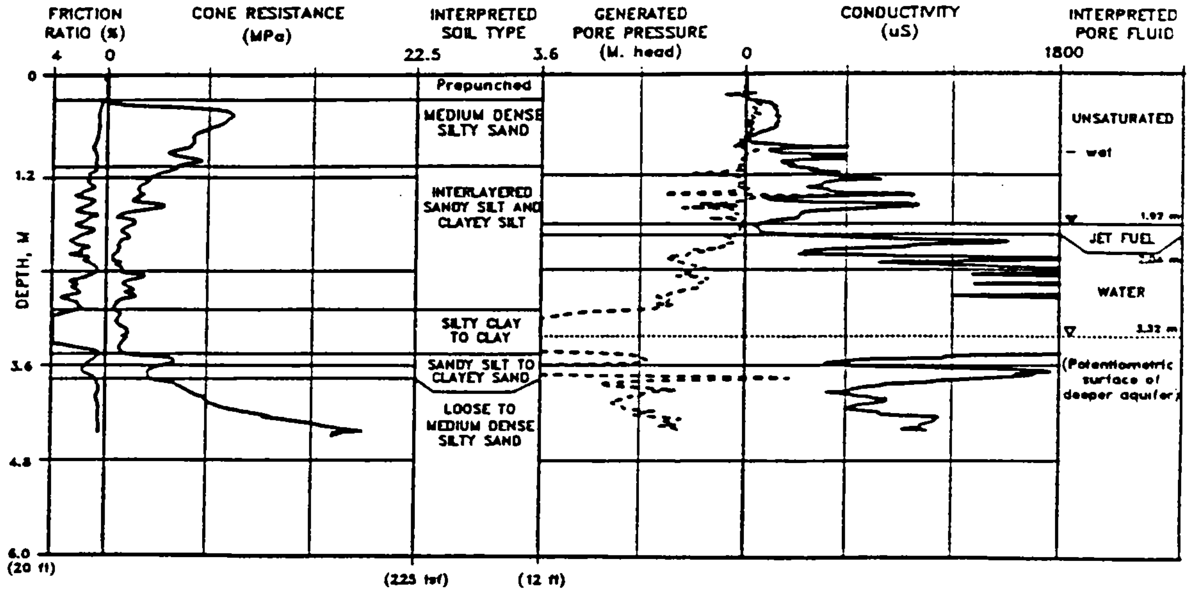

FIGURE 9 – CPTU-EC SOUNDING BRP-12

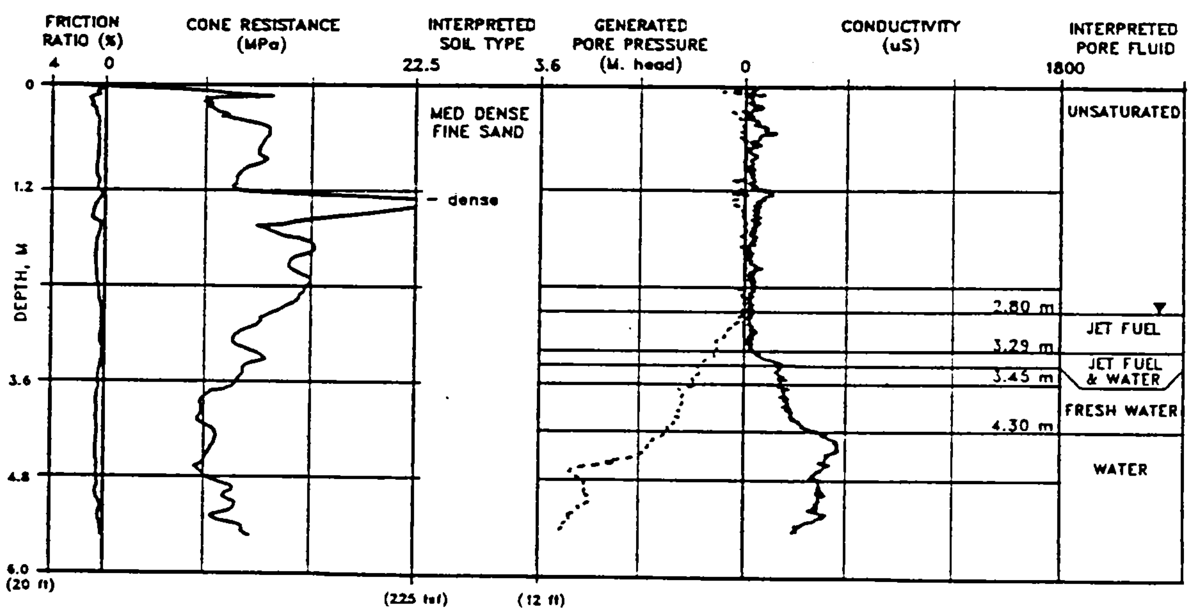

FIGURE 10 – CPTU-EC SOUNDING BRP-35

CPTU-EC COSTS AND PRODUCTIVITY

A comparison of production rates and costs for CPTU-EC and conventional monitor well surveys is as follows:

	CPTU-EC	Monitor Wells
Production Rate	8 to 12/day	1 to 2/day
Unit Cost	$66/m ($20/ft)	$131/m ($40/ft)
Cost per location, 6.1 m (20 ft) depth	$485/ea.*	$1066/ea.*

* includes data interpretation or inspection.

The CPTU-EC method provides a more rapid means of surveying an area, and is less than one half the cost of conventional monitor well survey methods on a per location basis.

CONCLUSIONS

The CPTU-EC penetrometer method has been shown to provide a rapid means of surveying sand aquifers for free phase petroleum hydrocarbon product contamination. In areas of more complex stratigraphy, additional testing is necessary to verify the applicability of CPTU-EC methods. Monitor wells with long screened lengths may not provide the best method of ground truthing CPTU-EC measurements at sites with complex hydrostratigraphic conditions.

Penetrometer ground water sampling should be included in CPTU-EC field investigation programs to provide direct samples of CPTU-EC identified anomalous ground water zones. Sensitive CPTU-EC piezometric transducers should be used to provide high accuracy in water table location.

The rapidity and the relative non-destructive nature of the CPTU-EC method especially provides advantages in areas of high priority usage or sensitivity, such as active apron areas of airport terminals, or in residential areas surrounding contamination sources. The CPTU-EC method in many cases, allows for more rapid and better definition of the true thickness of free phase petroleum hydrocarbon products in ground water. Cost savings in initial survey work should translate into better placement of permanent monitor and recovery wells, resulting in decreased overall remediation/investigation program costs.

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USE OF PIEZOMETRIC CONE PENETRATION TESTING IN HYDROGEOLOGIC INVESTIGATIONS

By M. Saines, A. Strutynsky, and G. Lytwynyshyn

Presented at the

First USA/USSR Hydrogeology Conference
Moscow, USSR
July, 1989

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USE OF PIEZOMETRIC CONE PENETRATION TESTING IN HYDROGEOLOGIC INVESTIGATIONS

Marvin Saines, Ph.D.
Senior Hydrogeologist
Donohue & Associates, Inc.
111 North Canal Street, Suite 305
Chicago, Illinois 60606

Andrew I. Strutynsky
Technical Director
STRATIGRAPHICS
The Geotechnical Data Acquisition Corporation
439 Taylor Avenue
Glen Ellyn, Illinois 60137

George R. Lytwynyshyn
Manager
Environmental Services Department
Donohue & Associates, Inc.
111 North Canal Street, Suite 305
Chicago, Illinois 60606

ABSTRACT

Piezometric Cone Penetration Testing (CPTU) is a powerful exploration tool for hydrogeologic investigations. CPTU consists of pushing a 1.4 to 1.7-inch diameter (3.6 - 4.4 cm) penetrometer to depths of 150 feet (45 m) or more in unconsolidated deposits of clay, silt, and sand. Sensors mounted inside the penetrometer provide data for the instantaneous evaluation of the following hydrogeologic parameters:

1) stratigraphy and lithology - identification of aquifers, aquitards, and definition of the lateral continuity of these units;

2) the position of the water table/potentiometric surface in sands and the water table-capillary fringe in silts and clays;

3) the hydraulic head in confined aquifers;

4) the slope of the water table or potentiometric surface, and therefore the direction of groundwater movement;

5) the vertical gradient by determining the head at various depths in each CPTU sounding; and

6) the permeability and transmissivity of aquifers.

The CPTU penetrometer is hydraulically pushed into the ground using a 20 ton (180 kN) truck. CPTU data are gathered by an on-board computer as continuous functions of both depth and time. Data consist of cone end bearing resistance, friction sleeve resistance, penetrometer deviation from vertical, and pore water pressure response to penetration. Lithologies are obtained by computer processing of CPTU sounding data using observational classification criteria based on an extensive library of comparisons between CPTU and drilled and sampled boreholes. Small diameter standpipe piezometers may also be installed using 20 ton CPTU equipment at a significant savings of time and money compared to drilling methods.

The continuous CPTU sounding yields accurate hydrogeologic data quickly and at low cost without drilling, sampling or laboratory testing. Test production rates vary from about 300 feet (90 m) to over 800 feet (250 m) per day, depending on project requirements. Cost comparisons are presented illustrating possible savings of up to 85 percent over continuously sampled and tested borings, and cost savings of 35-65 percent over the cost of borings with samples and laboratory tests at 5-foot intervals.

Limitations of the Piezometric Cone Penetration Test method include penetrometer refusal by coarse gravels, cobbles, and bedrock, or excessive friction on sounding rods during deep soundings. Depths of as much as 150 to 230 feet (45 to 70 m) can be reached with 20 ton CPTU equipment, depending on site stratigraphy.

INTRODUCTION

In unconsolidated deposits of sand, silt, and clay, Piezometric Cone Penetration Testing (CPTU) provides excellent hydrogeologic data accurately, quickly, and inexpensively. CPTU consists of smoothly pushing a small diameter instrumented probe (penetrometer) into the ground using a hydraulic ram (Figure 1). High technology sensors mounted inside the penetrometer provide data for the evaluation of soil type, soil strength, and pore water response of penetrated soils. Testing is rapid and precise. In environmental investigations there is lessened exposure of personnel to potentially contaminated soil and groundwater. Small diameter, standpipe piezometers can also be installed using CPTU equipment; these piezometers can be tested for permeability, sampled for water quality, and monitored for water level changes over time.

Traditional site characterization studies have involved performing numerous soil boring, soil sampling and piezometer and/or observation well installations. These studies can be expensive, time consuming and yield somewhat subjective results. For example:

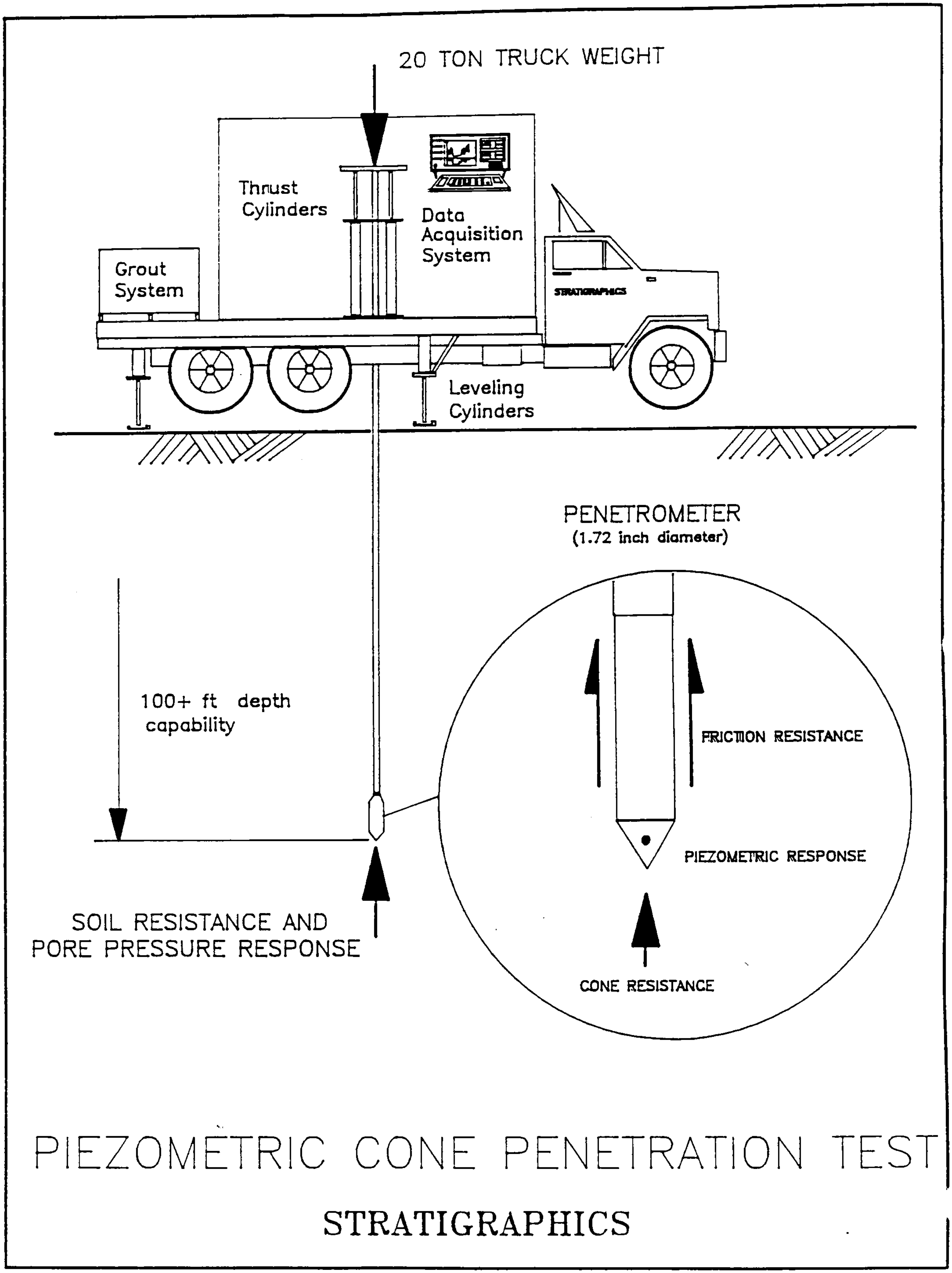


FIGURE 1 — SCHEMATIC OF ELECTRONIC PIEZOCONE PENETRATION TESTING

1) traditional discontinuous soil sampling is expensive, while continuous sampling is very expensive;

2) sample reliability is often degraded by poor recovery or other drilling problems;

3) transporting, handling, cataloging, classifying, testing and storing soil samples is both time consuming and expensive;

4) drilling and sampling results in disturbed soil samples;

5) field soil classification and geological logging are often subjective;

6) hydrogeological characterization requires expensive drilled well installations and testing;

7) long lag times, days or weeks, are often required for drilled wells to reach equilibrium conditions in low permeability soils; and

8) large quantities of fluids and cuttings are brought to the surface during drilling operations; in contaminated areas these fluids and cuttings require expensive handling and disposal.

CPTU suffers from none of these disadvantages. CPTU used independently for initial studies or in conjunction with a limited boring program, results in a less costly but more detailed site characterization study. (Olsen and Farr, 1986.)

A major benefit of using CPTU soundings for stratigraphic correlation is that the data are objective, whereas a geologist's visual log is subjective and dependent upon the quality of recovered samples. CPTU sounding data can delineate very small features (+/- 1 inch or 2.54 cm) which can be missed if sample quality is poor in continuously sampled boreholes; much thicker units, of course, are regularly missed in discontinuously sampled boreholes.

CPTU soundings are also more reliable than geophysical logging. CPTU response is directly related to primary soil characteristics such as grain size, void ratio, and permeability. Geophysical logs, such as natural gamma and electrical logs, reflect secondary soil properties such as radioactivity and electrical conductivity. Geophysical logging may also be affected by borehole characteristics and geometry, and groundwater chemistry.

PRINCIPLES OF PIEZOMETRIC CONE PENETRATION TESTING

Data Acquisition

Test Equipment and Procedures. CPTU consists of pushing an instrumented penetrometer into the ground while continuously recording the soil resistance and pore pressure response to penetration. A profile of the in situ soil mechanical properties is obtained rapidly and accurately. The penetrometer advance rate of 4 ft/min (2 cm/sec) is such that drained and undrained conditions exist while penetrating sands and clays, respectively. Both American ASTM and European ISSMFE standards specify various aspects of penetrometer test procedures.

The penetrometer is mounted at the end of a series of sounding rods. A set of hydraulic rams is used to push the penetrometer and rods into the soil at a constant rate. The thrust of the rams automatically varies according to soil resistance. A self-contained, 20 ton (180 kN) dead weight truck is used to counteract the thrust of the hydraulic rams, and to house and transport the test equipment (Figure 1). Test production rates vary from about 300 feet (90 m) to over 800 feet (250 m) per day, depending on terrain, pore pressure dissipation monitoring requirements, and hole grouting.

All work is performed from inside the vehicle, so testing can efficiently proceed in all types of weather. Additionally, the enclosed work space shields activities from onlookers, resulting in a much lower visual presence than that associated with drill rig operation.

The use of CPTU should not be planned for sites with shallow bedrock, or extensive boulder, cobble and coarse gravel deposits. Practical depths of penetration are typically limited by the reaction eight of the truck carrying the equipment. Twenty ton dead weight systems can be expected to have sufficient thrust to penetrate as deep as 150 to 230 feet (45 to 70 m) at many sites.

Penetrometer. The penetrometer soil mechanical load sensors consist of a conical tip and cylindrical sleeve. The conical tip has a 60 degree apex angle and a projected cross sectional area of 15 square centimeters; the cylindrical sleeve has a surface area of 200 square centimeters. Elements with other sizes are also in common use.

The interior of the penetrometer consists of two strain gauge load cells that allow simultaneous measurement of cone tip and sleeve loads during penetration. Continuous electrical signals from the downhole load cells are transmitted by an electrical cable strung through the hollow sounding rods to the field computer inside the CPTU truck. The technician monitors a real time display of subsurface soil resistance, pore pressure response, and penetrometer deviation from vertical, for evaluation of test performance.

Piezometer. A miniature diaphragm type pressure transducer is mounted inside the conical tip of the penetrometer. This transducer is coupled to the soil through a fluid filled porous filter, and is used to measure soil pore pressure response as a function of depth during penetration. The dissipation of excess pore pressures can be recorded as a function of time by stopping the penetration process at any particular depth. By allowing sufficient time to pass, a measurement can be obtained of the equilibrium hydraulic head at that depth.

Signal Conditioning and Recording. Data are digitally recorded using a 16 bit A/D (1 part in 32,728) data logger and field computer. Data is displayed in real time on the computer screen during testing, allowing for immediate evaluation of test performance. Preliminary hard copy is provided at the end of a test. Additional quality assurance procedures and report ready data presentation processing are performed in-house after completion of field work. Measurement accuracy and data processing are greatly enhanced using this high resolution digital system.

A schematic of the CPTU equipment is presented in Figure 1. Further details of instrumentation and other sensors that can be used in conjunction with CPTU are presented in Strutynsky and others (1985).

Data Reduction

Measured data consist of depth, time, cone end bearing and friction sleeve resistances, total load on penetrometer, pore pressure response, and penetrometer inclination. Data are recorded and plotted at a 1 Hz frequency, or at about 0.7-inch (2 cm) intervals. The following parameters are computed at each depth increment to enhance test interpretation:

Friction ratio, FR, in percent

$$FR = fs/qc \times 100 \qquad \text{(Eq. 1)}$$

Pore pressure ratio, Bq:

$$Bq = (u-uh)/(qc-Sv) \qquad \text{(Eq. 2)}$$

where:

fs is the measured sleeve resistance, in TSF (tons per square foot);

qc is the measured cone resistance, in TSF;

u is the measured generated pore pressure response, in TSF;

uh is the measured or estimated equilibrium hydraulic head, in TSF; and

Sv is the estimated total soil overburden pressure, in TSF.

Data Interpretation

Sounding Log. The continuous plot of CPTU data versus depth (sounding log) provides direct information on subsurface conditions. Layering is readily apparent, along with relative soil strength and consistency. Inspection of a series of continuous CPTU sounding logs helps to define site stratigraphy with greater ease and more accuracy than most borehole or geophysical techniques. Stratigraphic correlations are most easily made by comparing and overlaying consecutive CPTU soundings on a light table. Characteristic data signatures are visually matched, resulting in tracing of layer continuity across the site.

CPTU Soil Classification. CPTU classifications are based on at least 30 years of observational criteria from great numbers of side by side penetrometer soundings and drilled and sampled boreholes. In general, soils that exhibit high cone resistance and low friction ratio are sands while layers with low end bearing and high friction ratio are clays. Mixed soils, such as clayey sands and silts, exhibit intermediate trends. A detailed description of the use of CPT (no pore pressure measurement) data for soil classification is presented in Douglas and Olsen (1981). An example CPT classification chart is presented in Figure 2. An extension of these classification techniques to include results of CPTU (CPT with pore pressure measurements) is presented in Robertson and others (1986); an example CPTU classification chart is presented in Figure 3.

Cone End Bearing Resistance (qc). A measurement of a soil's bearing capacity is provided by the output of the load cell connected to the conical tip of the penetrometer. Soil bearing capacity depends primarily on grain size, and on the effects of grain size on permeability and compressibility.

Bearing capacity increases exponentially with grain size. Clays have low bearing capacity, while silt bearing capacity is typically somewhat higher. Sands have very high bearing capacity - the bearing capacity of a sand is from one to two orders of magnitude greater than that of a clay. Thus, the cone end bearing resistance is extremely sensitive to sand content.

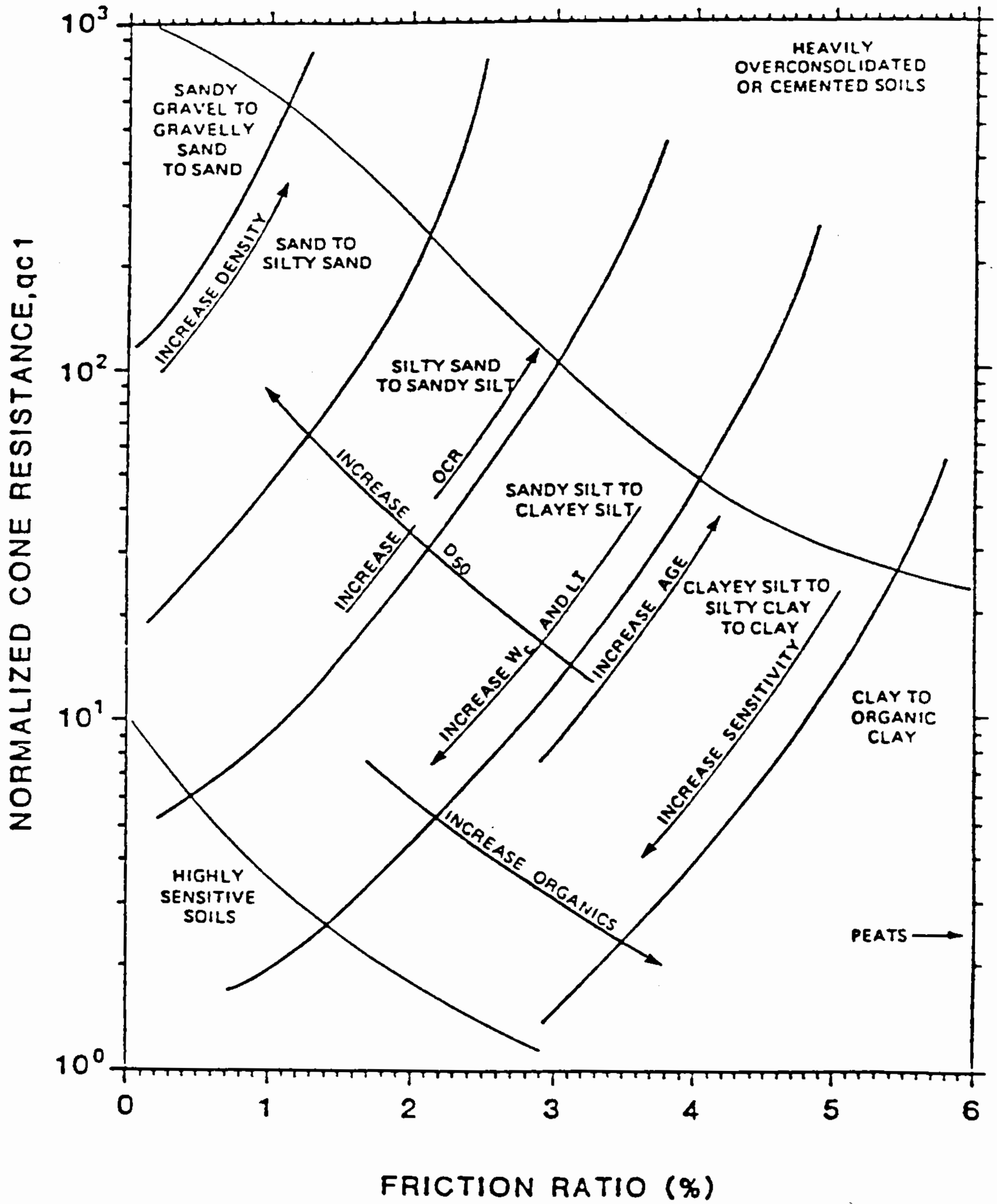
Typical cone end bearing measurements are:

1) 2 - 12 TSF (0.2 - 1.2 MN) in Holocene clays, depending on depth;

2) 20 - 40 TSF (2 - 4 MN) in desiccated clays, and in preloaded Pleistocene and older clays;

3) 5 - 50 TSF (0.5 - 5 MN) in clayey silts to sandy silts;

4) 30 - 60 TSF (3 - 5 MN) in loose fine sands;

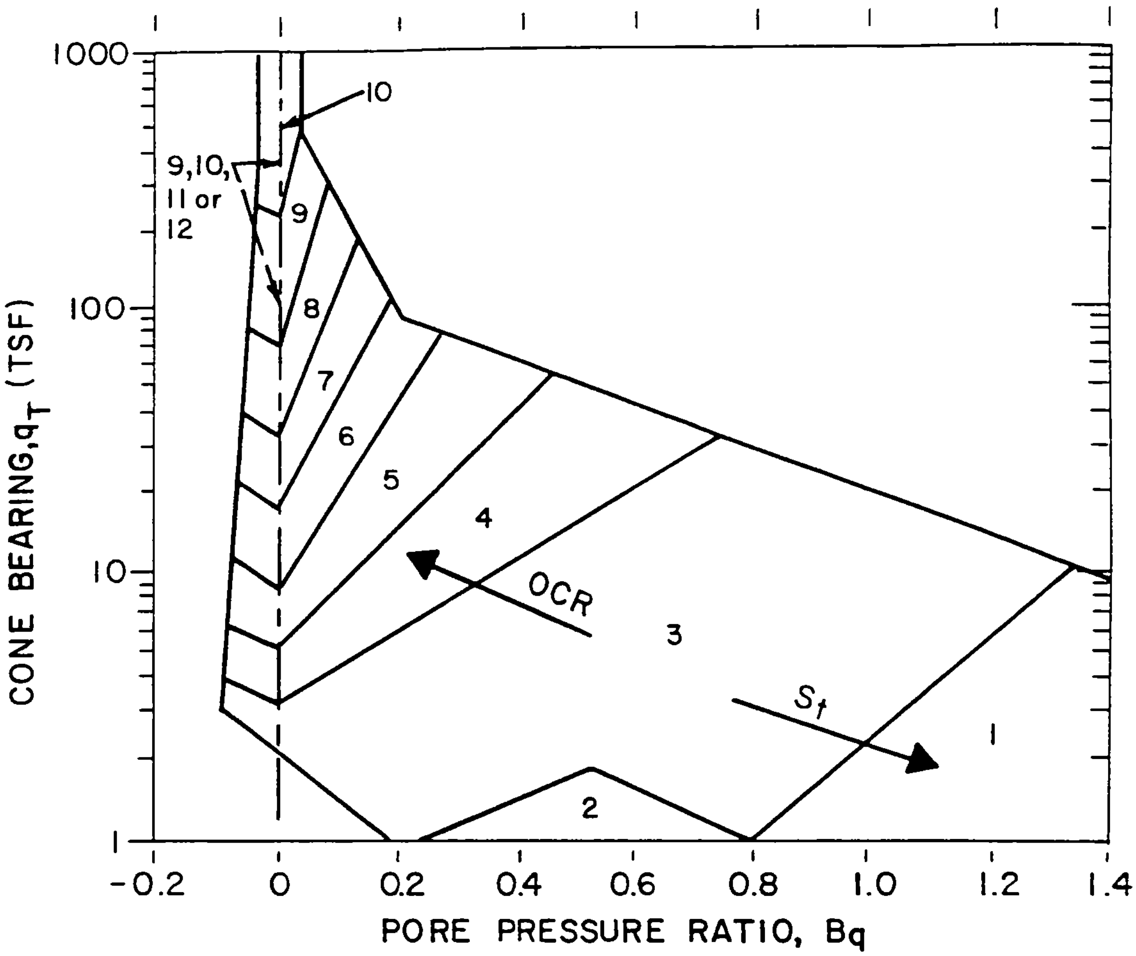


SOIL BEHAVIOR TYPE CLASSIFICATION CHART

After Douglas and Olsen (1981)

STRATIGRAPHICS

FIGURE 2 — CPT SOIL BEHAVIOR TYPE CLASSIFICATION CHART



ZONE	SOIL BEHAVIOUR TYPE
1	SENSITIVE FINE GRAINED
2	ORGANIC MATERIAL
3	CLAY
4	SILTY CLAY TO CLAY
5	CLAYEY SILT TO SILTY CLAY
6	SANDY SILT TO CLAYEY SILT
7	SILTY SAND TO SANDY SILT
8	SAND TO SILTY SAND
9	SAND
10	GRAVELLY SAND TO SAND
11	VERY STIFF FINE GRAINED (*)
12	SAND TO CLAYEY SAND (*)
(*)	OVERCONSOLIDATED OR CEMENTED

SOURCE: ROBERTSON & OTHERS (1986)

FIGURE 3 — PROPOSED SOIL BEHAVIOR TYPE CLASSIFICATION SYSTEM FROM CPTU DATA

5) 150 - 400 TSF (15 - 40 MN) in dense sands; and

6) 200 - 800 TSF (20 - 80 MN) in gravelly sands and gravels.

Friction Sleeve Resistance (fs). The friction sleeve resistance of a soil varies approximately as a linear function of grain size and is inversely proportional to porosity. This measurement does not vary as dramatically as the cone end bearing resistance in stratified deposits. The friction sleeve resistance reflects soil large strain (disturbed) properties, as the sleeve interacts with soil that has already undergone bearing capacity failure, induced by the cone tip.

Friction Ratio (FR). The friction ratio is calculated by dividing the friction sleeve resistance by the cone end bearing resistance, expressed as a percentage (Equation 2). The friction ratio is low (0.5 - 2 percent) in sands due to the very high cone end bearing in sand. The friction ratio is high in clays (3 - 8 percent), and intermediate (1 - 5 percent) in mixed soils such as clayey silts and sandy clays.

Generated Pore Pressure (u). The soil water pressure response to penetrometer insertion depends on soil saturation, permeability and compressibility. The pore pressure response in unsaturated soils is zero. No pore pressures in excess of equilibrium are generated, or the dissipation of generated excess pressures occurs much more rapidly than the 1 second response time of the CPTU piezometer-data acquisition system in high or medium permeability (k greater than about 1.0×10^{-4} cm/sec) soils. Thus in saturated, permeable, clean sands the CPTU pore pressure response provides a direct measurement of the hydraulic head at that depth.

As soil permeability decreases below about 1.0×10^{-4} cm/sec, soil volumetric distortion due to penetrometer advance results in excess pore pressure generation. These generated excess pressures dissipate much more slowly than the response time of the piezometer system. Generated pore pressures in saturated low to very low permeability soils reflect both permeability and compressibility effects. High generated pore pressures are measured in both low compressibility dirty sands or high compressibility clays.

Pore Pressure Ratio (Bq). The pore pressure ratio is calculated as the generated pore pressure (in excess of equilibrium) divided by the cone end bearing resistance (Equation 2). This normalized parameter is useful in discrimination of soil compressibility and permeability effects. Due to the high cone end bearing in low compressibility, dirty sands, the pore pressure ratio typically ranges from about 0.05 to 0.20 in these soils. In saturated, high compressibility clays, the pore pressure ratio typically ranges from about 0.4 to over 1.0. Thus, the CPTU pore pressure ratio is useful, along with cone end bearing and friction ratio, in classifying lower permeability soils.

Pore Pressure Dissipations. By stopping the penetration process and monitoring the decay of generated pore pressure versus time, an in situ measurement is obtained of the equilibrium hydraulic head at that particular depth. The dissipation rate also reveals information on soil compressibility and permeability. Thus, another discrimination between dirty sands and clays can be based on the amount of time required to dissipate generated excess pore pressures. Long dissipation times are associated with clays, while short times indicate sands.

EXAMPLES OF THE USE OF PIEZOMETRIC CONE PENETRATION TESTING IN HYDROGEOLOGICAL INVESTIGATIONS

Stratigraphy

At a landfill in northeastern Illinois, CPTU soundings were used to investigate the hydrogeological conditions at proposed monitoring well locations. CPTU data were used to predetermine well design without expensive drilled continuous sampling. Stratigraphic continuity was quickly evaluated at the site by doing a series of CPTU soundings. The depths to the uppermost aquifer, extent of aquitards and locations of discontinuous sand lenses were readily identified on cross-sections developed from the CPTU sounding logs. Permanent monitoring wells were later constructed with hollow stem augers in the uppermost aquifer at the depths indicated by the CPTU soundings.

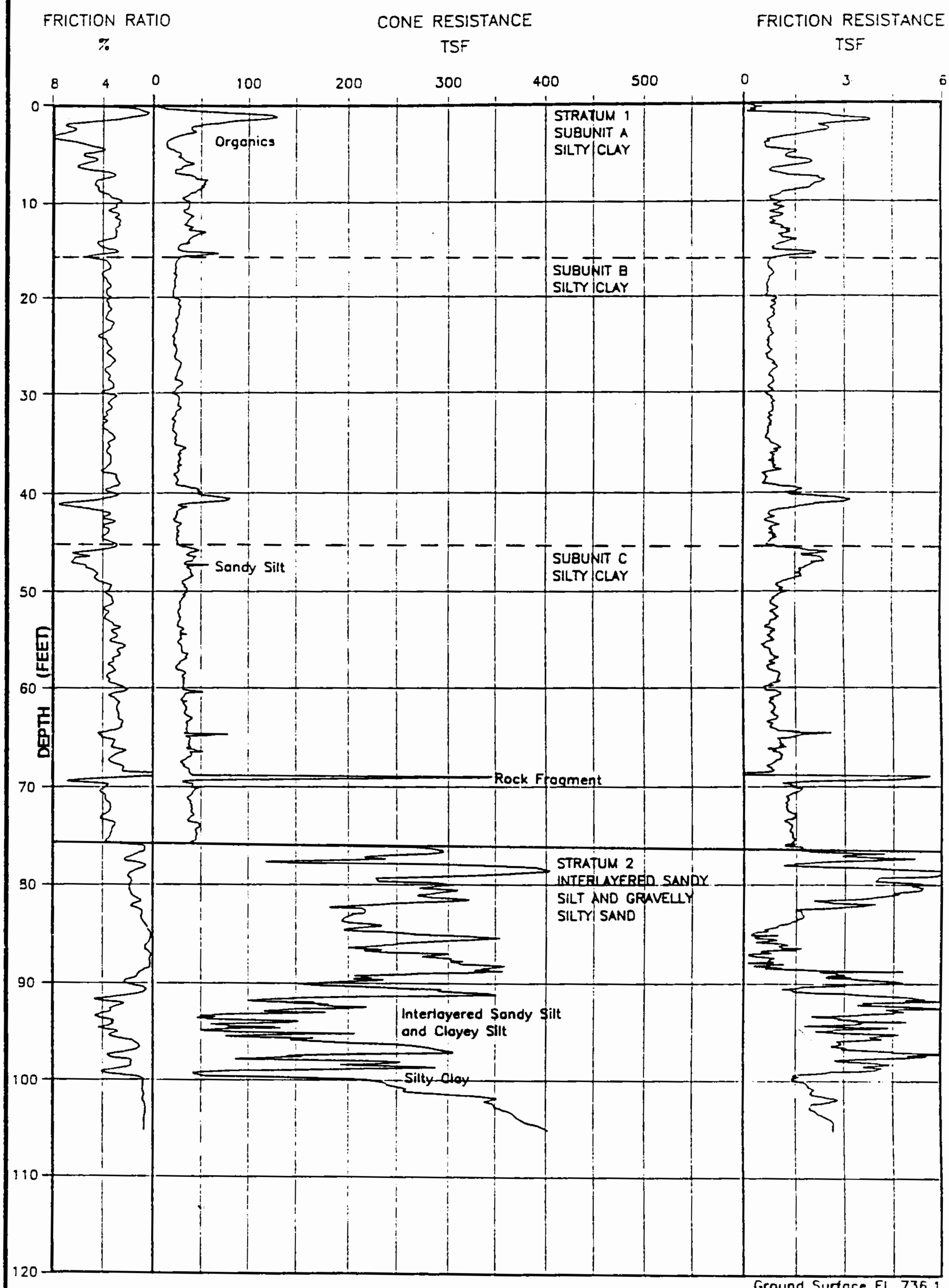
The CPTU soundings clearly defined the site stratigraphy - clay till overlying a sandy silt to silty sand aquifer. A plot of the cone resistance and friction ratio versus depth is shown in Figure 4 for CPTU Sounding D-6. Note the abrupt decrease in the friction ratio and large increase in the cone end bearing resistance at a depth of 76 feet indicating a sharp clay to sand transition. This sand unit was identified as the uppermost aquifer at the site.

The contrast between the clay till and sand is also very clear on the plot of the pore pressure ratio, Bq, versus cone end bearing resistance for the same sounding (Figure 5). The pore pressure ratio, Bq, is high in saturated clays and low in sands. Above 76 feet, the high pore pressure ratio and low cone end bearing resistance indicate a saturated clay, while the sand unit below 76 feet exhibits a low pore pressure ratio and high cone end bearing resistance.

Position of the Water Table or Capillary Fringe

CPTU soundings can be used to determine the position of the water table or zone of saturation. Figure 6 shows the water table in a thick sand unit as interpreted from the generated pore pressure plot of Sounding P-17 at JFK Airport, New York, New York. A CPTU sounding log in a clay till is presented in Figure 7. The position of the top of the fully saturated zone in the clay was about 7 feet below the ground surface at this location.

CONE PENETRATION TEST



STRATIGRAPHICS

FIGURE 4 — FRICTION RATIO VERSUS CONE RESISTANCE FOR CPTU SOUNDING D–6, WINTHROP HARBOR, ILLINOIS

CONE PENETRATION TEST

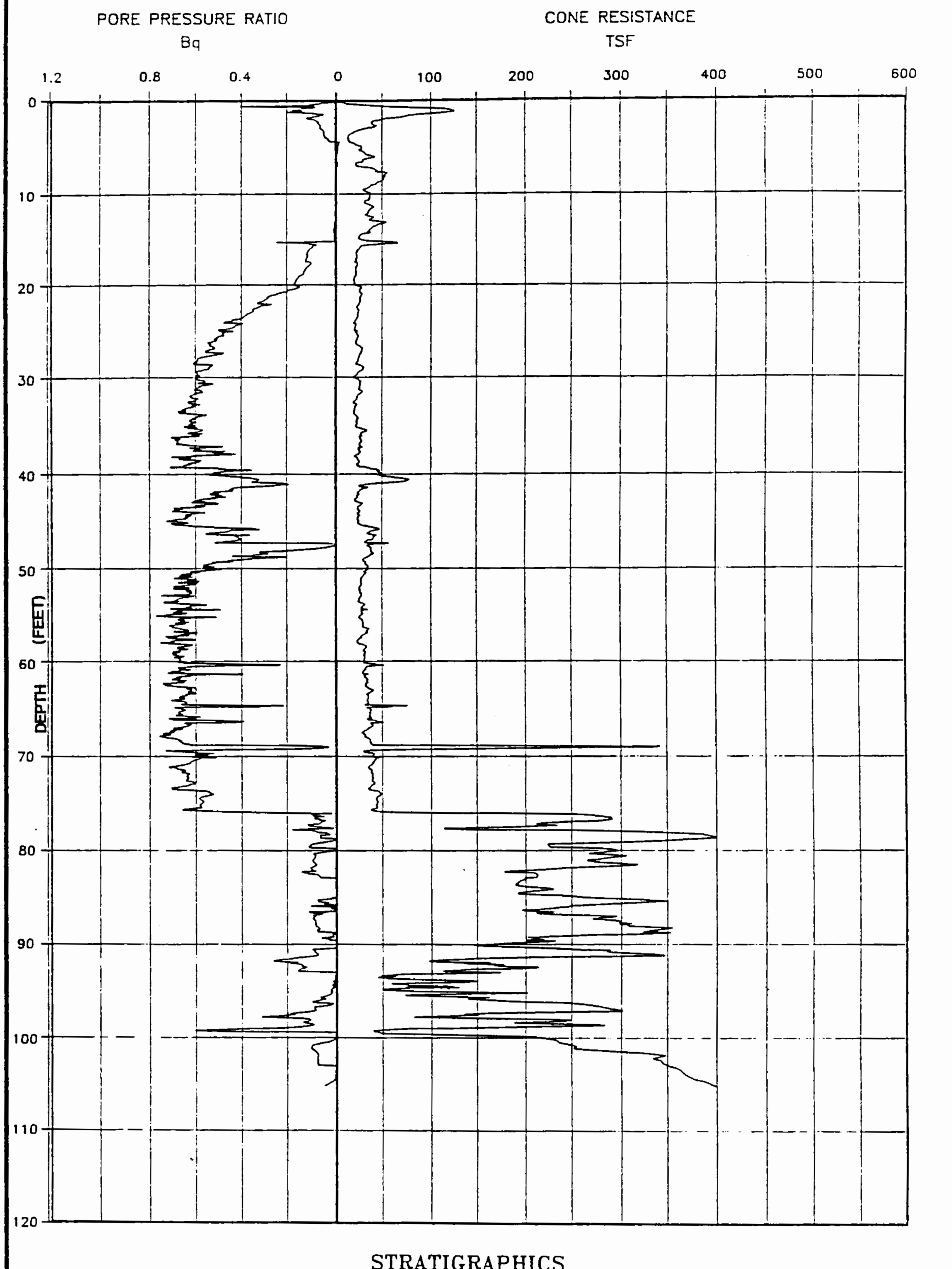
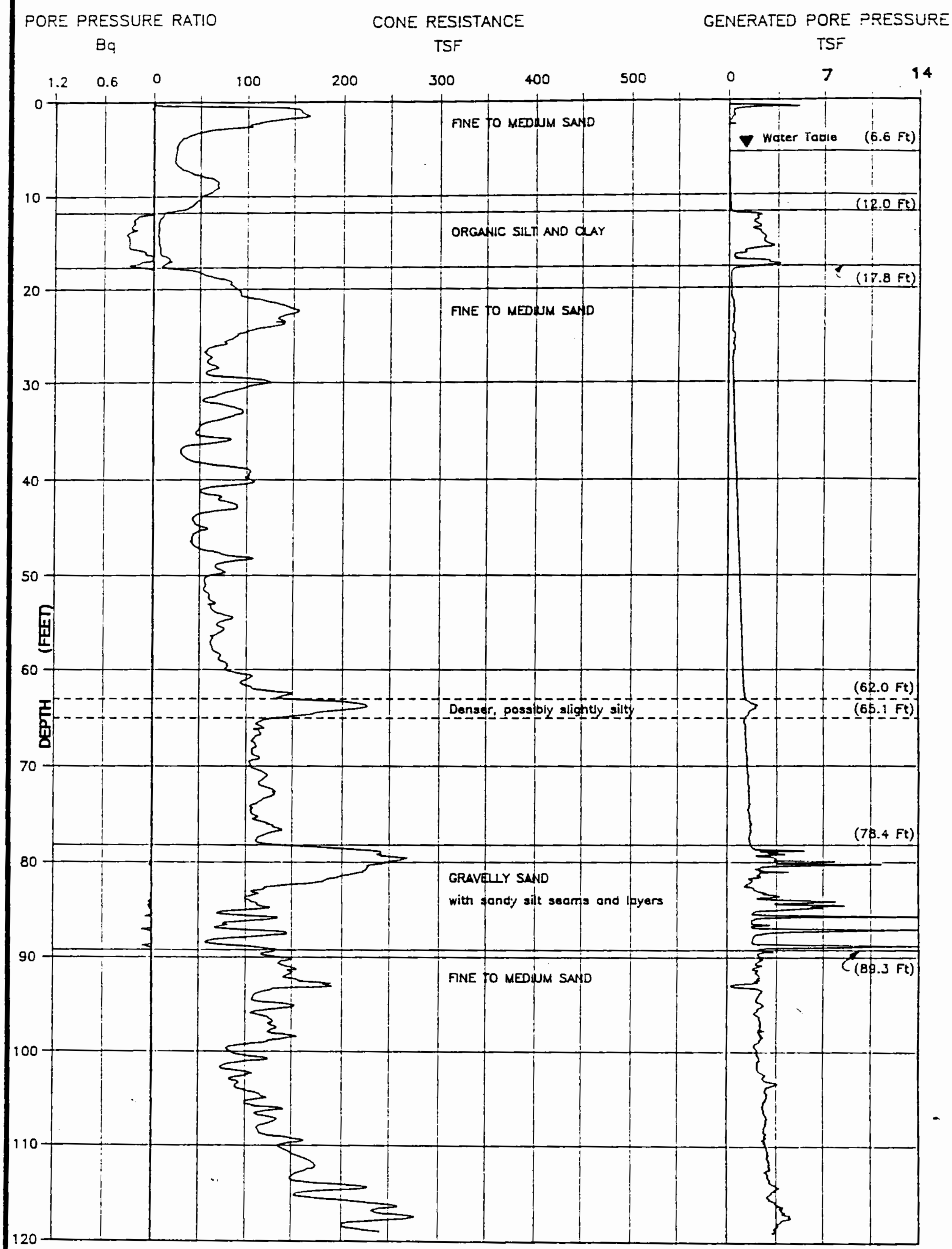


FIGURE 5 — PORE PRESSURE RATIO VERSUS CONE RESISTANCE FOR CPTU SOUNDING D–6, WINTHROP HARBOR, ILLINOIS

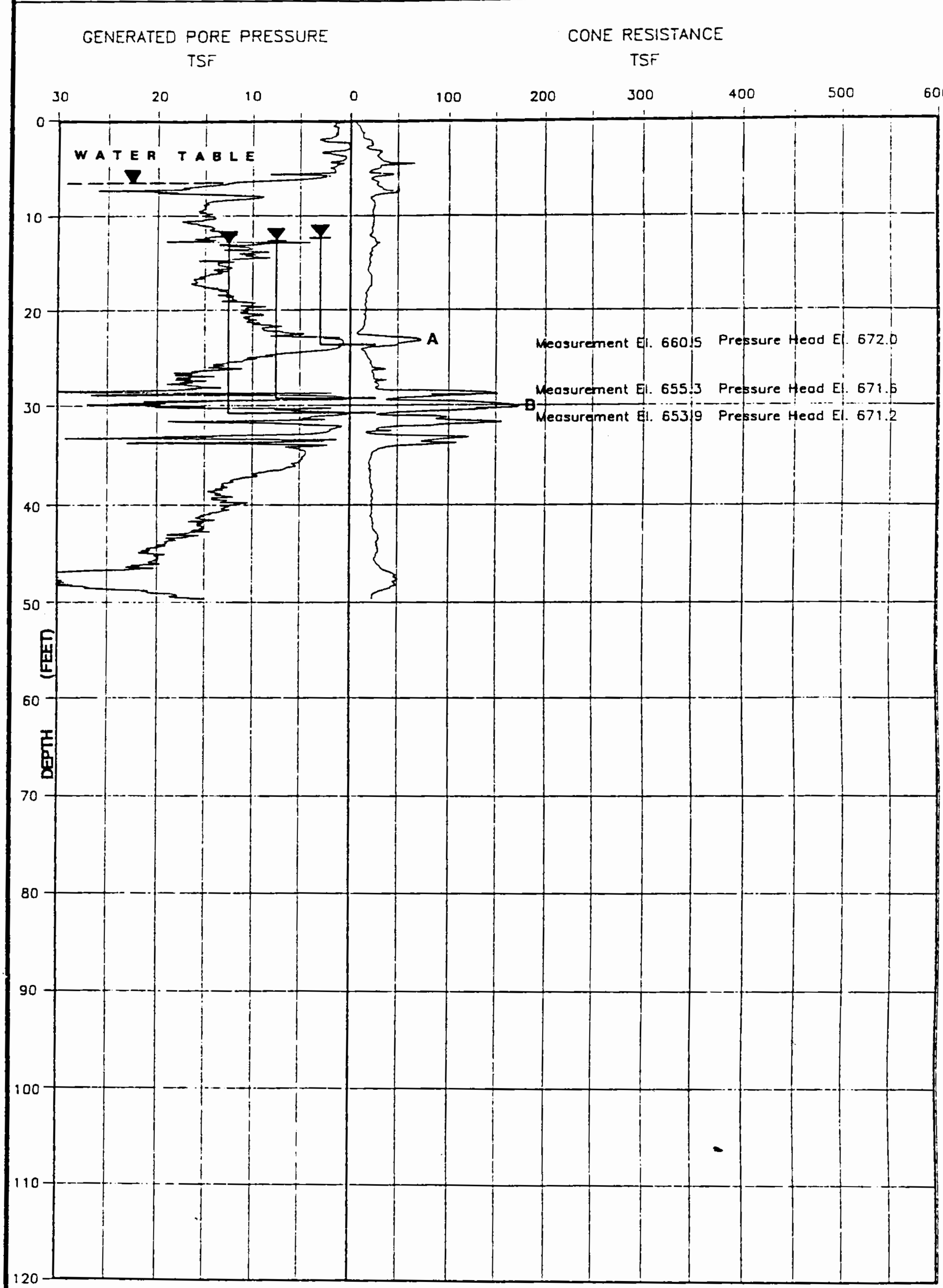
PIEZOMETRIC CONE PENETRATION TEST



STRATIGRAPHICS

FIGURE 6 — PORE PRESSURE RATIO VERSUS CONE RESISTANCE AND GENERATED PORE PRESSURE FOR CPTU SOUNDING P–17 , NEW YORK CITY

CONE PENETRATION TEST



A AND B ARE SANDY UNITS

STRATIGRAPHICS

FIGURE 7 – GENERATED PORE PRESSURE VERSUS CONE RESISTANCE FOR CPTU SOUNDING D–1, WINTHROP HARBOR, ILLINOIS

Change of Hydraulic Head with Depth

By pausing in the penetration process and allowing generated pore pressures to dissipate to equilibrium conditions, the potentiometric surface (as would be measured in a fixed piezometer) is obtained at any particular depth. Therefore, vertical gradients and hydraulic head relationships can be investigated in one CPTU sounding without the significant time and cost expenditure associated with a cluster of fixed piezometers.

At the landfill in northeastern Illinois, it was important to determine if the uppermost aquifer discharged to a nearby swamp. CPTU Sounding D-1 indicated that the hydraulic head in a discontinuous sand unit (indicated by "A" in Figure 7) above the aquifer, was lower than the surface elevation of the overlying swamp. Also, the head in this unit was 0.5 feet greater than the hydraulic head in the aquifer (indicated by "B" in Figure 7) itself. These data indicate a downward gradient, showing that the swampy area of Sounding D-1 was a recharge area for the aquifer, rather than being a discharge area from the aquifer to the swamp.

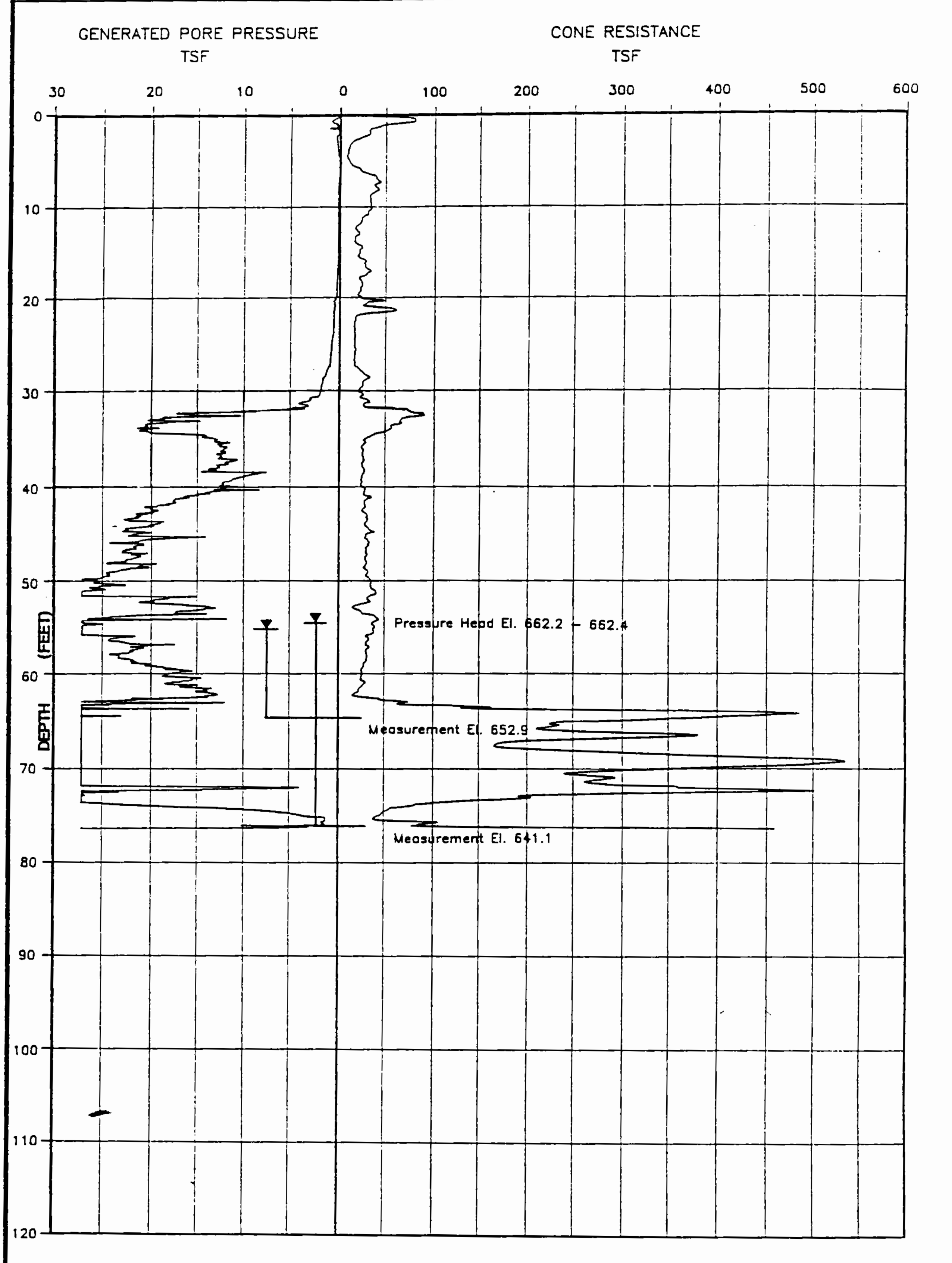
The determination of lateral flow is also important in that it identifies the sand unit as a continuous aquifer with lateral extent. Areas of lateral flow are indicated by constant hydraulic heads with depth. In CPTU Sounding D-4 (Figure 8) at the landfill in northeastern Illinois, the hydraulic head measured at different depths in the uppermost aquifer was approximately the same, indicating a region of predominantly lateral flow.

The CPTU piezometric sounding is useful not only in locating the aquifers but in determining the head in confined aquifers before installing wells. The pore pressure in Sounding D-6 indicated that the head in the aquifer was just above the top of the unit (Figure 9). This low head was confirmed by the drilled monitoring well which was installed based on the CPTU-defined stratigraphy.

Direction of Groundwater Flow and Gradient

The United States Environmental Protection Agency generally requires a minimum of one up-gradient well and three down-gradient wells to monitor a landfill. In many cases the direction of groundwater flow is not known and must be determined before the monitoring well system can be designed and developed. Usually, several drilled test wells or piezometers are installed and surveyed to obtain this information. Groundwater levels are measured after the wells/piezometers have stabilized. This process can take days or weeks, depending upon site conditions. If the terrain is suitable and the water table is within the depth capability of the equipment, use of CPTU can result in a more detailed characterization and at less cost than a drilled investigation. A map of the water table or potentiometric surface can be rapidly made from the CPTU data utilizing surveyed ground surface elevations of the sounding locations.

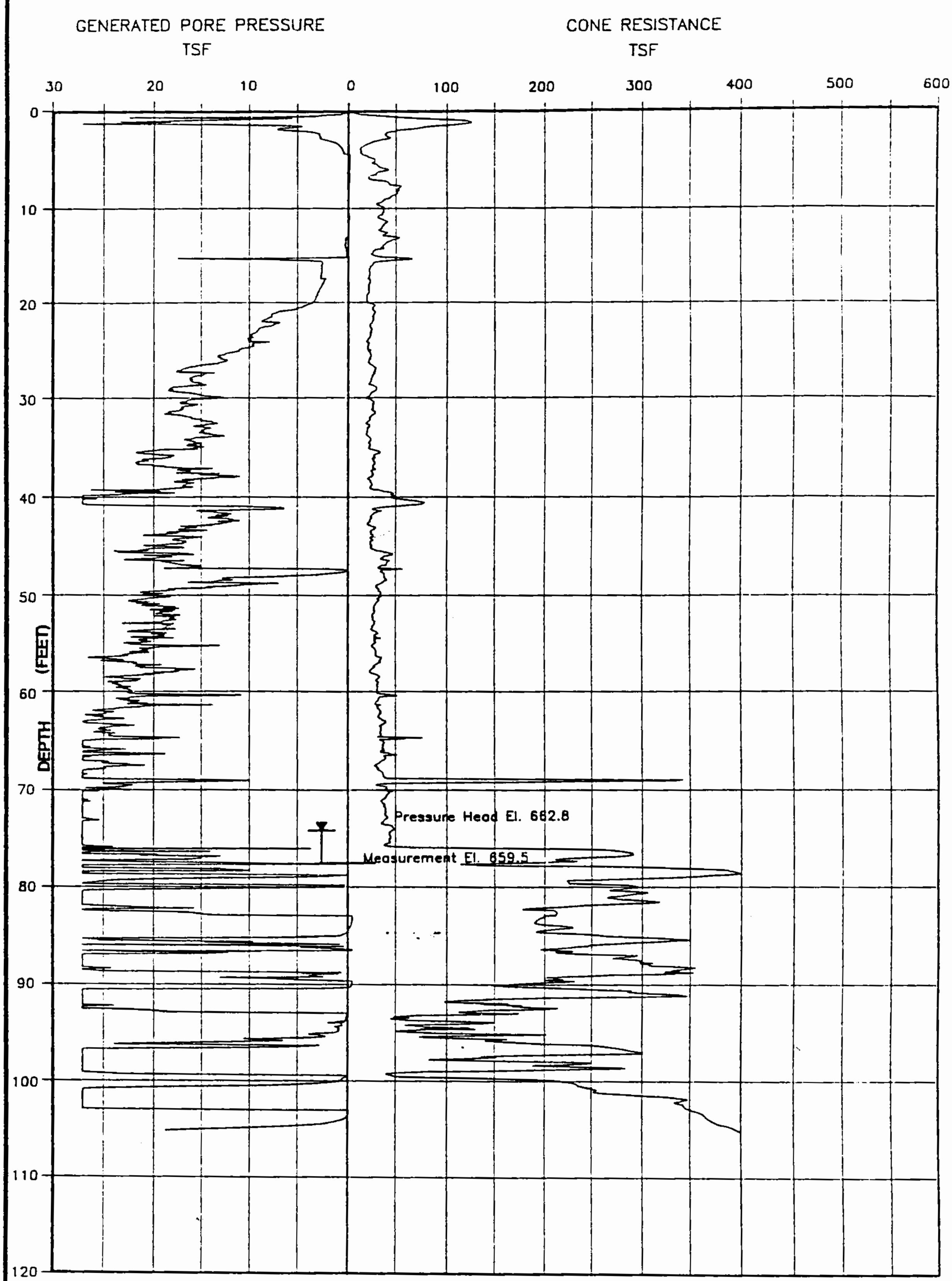
CONE PENETRATION TEST



STRATIGRAPHICS

FIGURE 8 — GENERATED PORE PRESSURE VERSUS CONE RESISTANCE FOR CPTU SOUNDING D-4, WINTHROP HARBOR, ILLINOIS

CONE PENETRATION TEST



STRATIGRAPHICS

FIGURE 9 — GENERATED PORE PRESSURE VERSUS CONE RESISTANCE FOR CPTU SOUNDING D–6, WINTHROP HARBOR, ILLINOIS

The gradient of the water table or potentiometric surface is related to the transmissivity. Other factors being equal, areas of flatter gradient are generally more transmissive (Table 1). The areas of flatter gradient are evident from the water table or potentiometric map. The gradient can be calculated by dividing the head loss by the distance across which the head is lost. Along with the other hydrogeological information the gradients derived from the CPTU data may be used in groundwater exploration before test drilling, as there is a direct relationship between transmissivity and water supply potential (well yield).

Aquifer Coefficients

Permeability and Transmissivity Estimates. An estimate of the permeability can be made from the CPTU classification of the soil encountered. For example, in CPTU Sounding D-6 (Figure 4) at the northeastern Illinois landfill, a silty sand aquifer was identified below 76 feet. According to Tables 2 and 3, the permeability of silty sands is in the range of 1.0×10^{-3} to 1.0×10^{-5} cm/sec. A slug test conducted subsequently in a drilled monitoring well constructed at the D-6 location, indicated a permeability of 1.8×10^{-4} cm/sec, which was within the estimated range.

By using permeability values estimated from CPTU soil classifications, and multiplying by the thickness of the unit as determined by the CPTU sounding, an approximate value of transmissivity can be obtained before drilling and pump testing. This estimate of transmissivity can be an important factor in deciding whether or not to drill a test well at the sounding location during a groundwater exploration investigation.

Pore Pressure Dissipation Permeability Values. By pausing during the penetration process, and allowing the pore pressures generated by penetrometer insertion to dissipate with time, a horizontal permeability value at the depth of the penetrometer can be obtained based on the measured time rate of dissipation. Computed permeabilities from CPTU pore pressure dissipations are representative of the disturbed soil immediately in contact with the CPTU piezometric filter. This zone has a vertical extent of only 1/4 to 1 inch (0.6 - 2.5 cm). An assumption of soil compressibility is also required to compute permeability from CPTU data.

Examples of measured dissipation curves are provided in Figure 10. The evaluation of horizontal permeability is performed using normalized dissipation plots, as shown in Figure 11, and procedures detailed in Baligh and Levandoux (1980) or Robertson et al (1986). The normalized dissipation data (Figure 11) from 20.5 and 50.0 feet were obtained in the silty clay tills in CPTU Sounding D-1 at the landfill in northeastern Illinois. These data indicate horizontal permeabilities of about 1.0×10^{-6} cm/sec in the silty clay till. This value is in good agreement with slug test results in monitoring wells finished in the same stratum.

TABLE 1

AQUIFER HORIZONTAL GRADIENTS

.0005 - .002	good aquifers
about .01	poor aquifers
>.05	aquitards

Source: Mandel and Shiftan (1981, p. 172).

TABLE 2

ESTIMATED HYDRAULIC CONDUCTIVITY OF TYPICAL GEOLOGIC MATERIALS IN ILLINOIS

Geologic material	cm/sec	gpd/ft²	Comments
Clean sand and gravel	$>1 \times 10^{-3}$	>20	May be highly permeable
Fine sand and silty sand	1×10^{-5} to 1×10^{-3}	0.2 to 20	—
Silt (loess, colluvium, etc.)	1×10^{-6} to 1×10^{-4}	1×10^{-1} to 2	—
Gravelly till, less than 10% clay	1×10^{-7} to 1×10^{-5}	2×10^{-3} to 2×10^{-1}	Often contains gravel/sand lenses or zones
Till, less than 25% clay	1×10^{-8} to 1×10^{-6}	2×10^{-4} to 2×10^{-2}	Often contains gravel/sand lenses or zones
Clayey tills, greater than 25% clay	1×10^{-9} to 1×10^{-7}	2×10^{-5} to 2×10^{-3}	Often contains gravel/sand lenses or zones
Sandstone	$>1 \times 10^{-4}$	>2	—
Cemented fine sandstone	1×10^{-7} to 1×10^{-4}	2×10^{-3} to 2	Frequently fractured
Fractured rock	$>1 \times 10^{-4}$	>2	May have extremely high hydraulic conductivity
Shale	1×10^{-11} to 1×10^{-7}	2×10^{-7} to 2×10^{-3}	Often fractured
Dense limestone/dolomite (unfractured)	1×10^{-11} to 1×10^{-8}	2×10^{-7} to 2×10^{-4}	—

Source: Berg and Others (1984)

TABLE 3

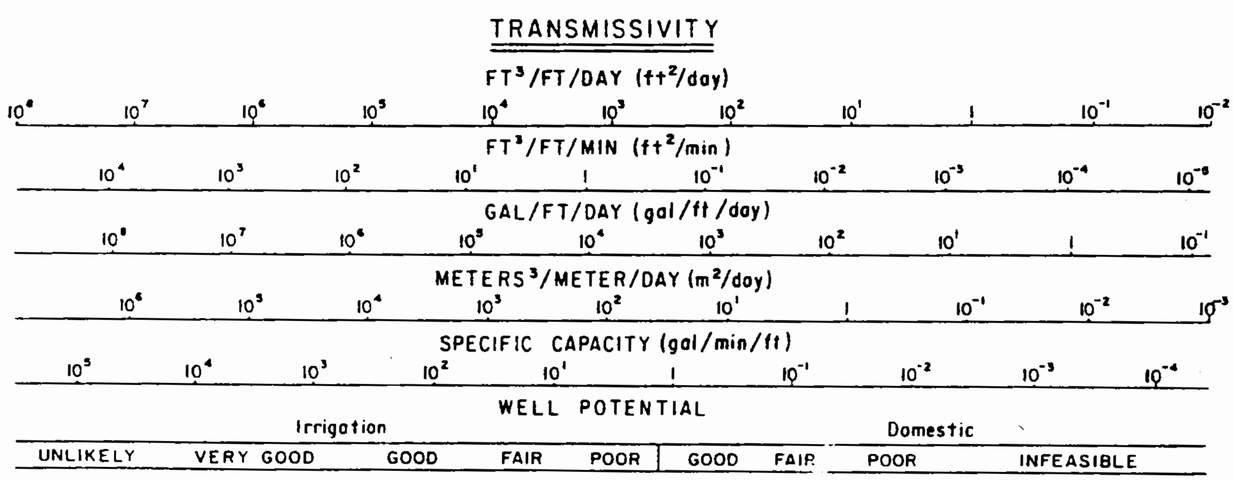
RELATIVE VALUES OF PERMEABILITY

Relative Permeability	Values of k (cm/sec)	Typical Soil
Very permeable	Over 1×10^{-1}	Coarse gravel
Medium permeability	1×10^{-1} to 1×10^{-3}	Sand, fine sand
Low permeability	1×10^{-3} to 1×10^{-5}	Silty sand, dirty sand
Very Low permeability	1×10^{-5} to 1×10^{-7}	Clay
Impervious	Less than 1×10^{-7}	Clay

Source: Sowers and Sowers (1970, p.93)

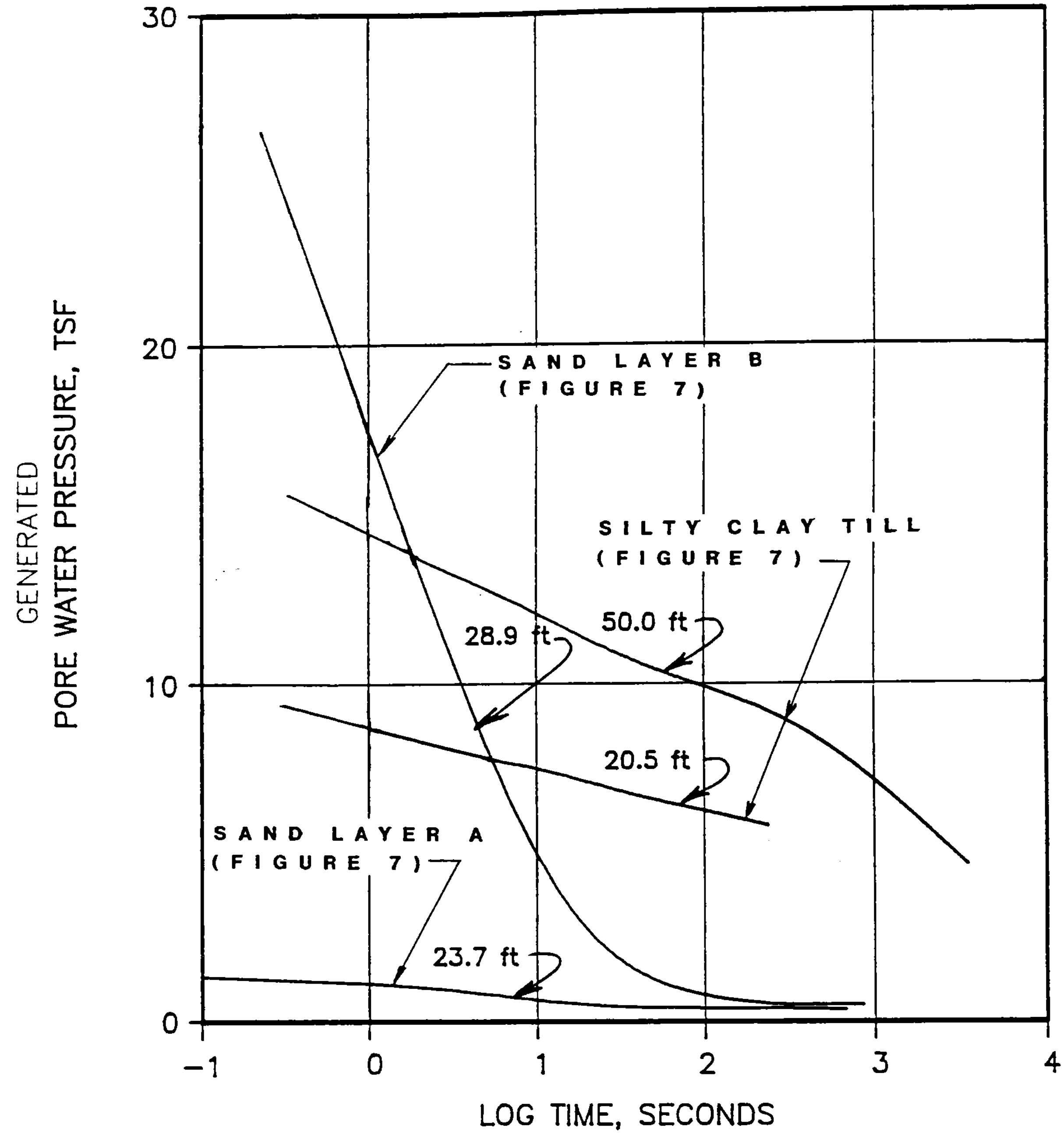
TABLE 4

COMPARISON OF TRANSMISSIVITY, SPECIFIC CAPACITY, AND WELL POTENTIAL



NOTES: Transmissivity (T) = KM where
K = Permeability
M = Saturated thickness of the aquifer
Specific capacity values based on pumping period of approximately 8-hours but are otherwise generalized.

Source: U.S. Bureau of Reclamation (1977, Figure 2-4)



CPT SOUNDING D−1

STRATIGRAPHICS

CPT DISSIPATION DATA

LAKE COUNTY, IL

FIGURE 10 — GENERATED PORE WATER PRESSURE, CPTU SOUNDING D−1, WINTHROP HARBOR, ILLINOIS

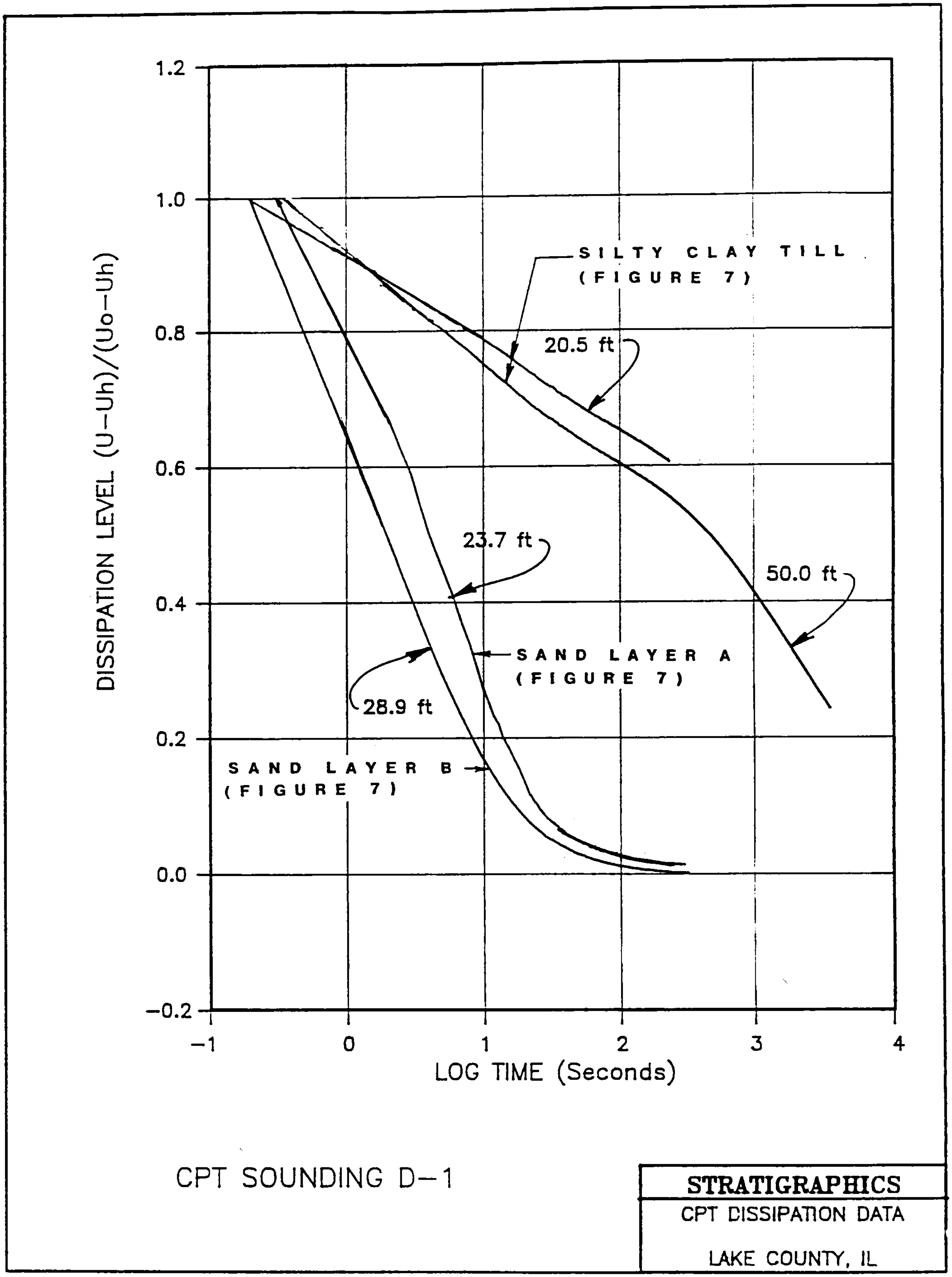


FIGURE 11 – PORE WATER PRESSURE DISSIPATION LEVEL, CPTU SOUNDING D−1, WINTHROP HARBOR, ILLINOIS

The other dissipation data in Figure 11 were obtained in a discontinuous silty sand layer in CPTU Sounding D-1, at 23.8 feet, and in the silty sand uppermost aquifer at 28.9 feet. These horizontal permeabilities are indicated by the CPTU dissipation data to range from about 1.5 x 10^{-5} to 7.0 x 10^{-5} cm/sec. A slug test in the uppermost aquifer in a monitoring well drilled at location D-1 indicated a permeability of about 2.0 x 10^{-5} cm/sec, in the lower range of values determined from CPTU. The monitoring well screen, at a depth of 27 to 35 feet, was set opposite interbedded silty sand and silty clay layers.

Example of Estimation of Potential Well Yield From CPTU Sounding Data

A potential well yield of at least 2.0 gpm (0.13 liters/sec) was estimated from CPTU data in a thin water table sand in Evanston, Illinois. Interpretation of the CPTU Sounding NW-1 (Figure 12) indicated a saturated, clean, fine to medium sand from 12.7 to 20 feet below the surface. Based on Tables 2 and 3, the permeability of this zone was estimated as about 5.0 x 10^{-3} cm/sec. Multiplying the saturated thickness by the permeability gives a transmissivity (T) of 10 square meters/day or 800 gpd/ft. According to Table 4, this T is in the range of good aquifers for domestic supplies, but not for irrigation supplies. The specific capacity is estimated from Figure 13. Using a water table coefficient of storage of 0.2 and a T of 800 gpd/ft, the specific capacity was estimated as 0.8 gpm/ft of drawdown.

The lower third of a water table aquifer is screened in typical installations. A better design in this thin aquifer would be installing a 5-foot screen with a pump set one foot above the bottom. Allowing one foot for the pump and 3 feet to cover the pump, the remaining available drawdown is only 2.5 feet. Multiplying by the specific capacity of 0.8 gpm/ft indicates an estimated yield of 2.0 gpm.

Examination of the CPTU Sounding NW-1 (Figure 12) indicates 4 feet of fine sand and silt below the aquifer which could also contribute to the well yield. Therefore, the estimate is considered conservative. By prior estimation of potential well yields using CPTU data, decisions regarding the locations of expensive test wells and pumping tests can be more intelligently made.

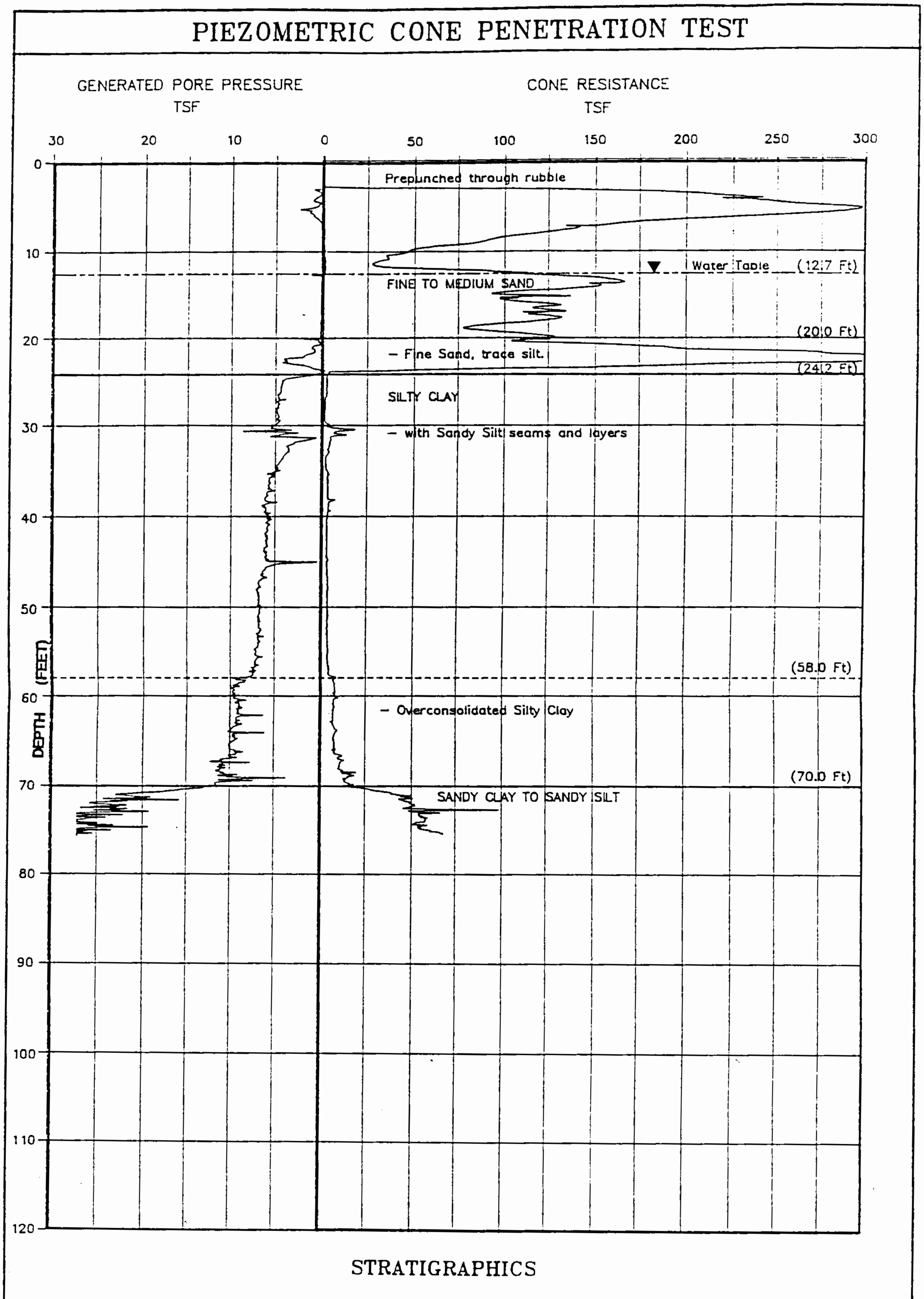
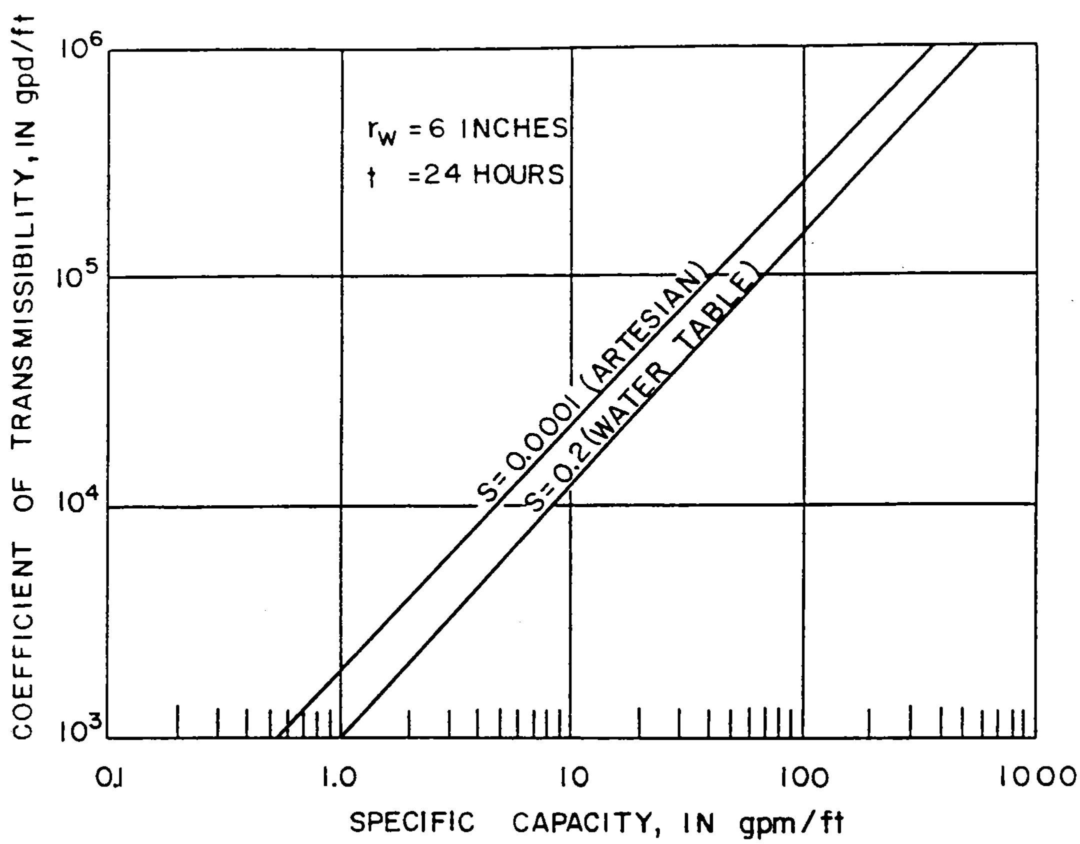


FIGURE 12 – GENERATED PORE PRESSURE VERSUS CONE RESISTANCE FOR CPTU SOUNDING NW–1, EVANSTON, ILLINOIS



SOURCE: WALTON (1970, FIG. 5.8)

FIGURE 13 — GRAPH OF SPECIFIC CAPACITY VERSUS TRANSMISSIVITY AFTER 24 HOURS OF PUMPING

Installation of Piezometers in CPTU Sounding Holes

Small diameter, standpipe piezometers may be installed in CPTU sounding holes, in many places, at a significant savings of time and money compared to drilling methods. Four installation methods are available for placing standpipe piezometers using CPTU equipment. These four methods are: 1) pushed 1 1/4-inch (nominal) steel well point, 2) PVC riser in temporarily cased hole, 3) PVC riser in open hole, and 4) pushed 2-inch (nominal) steel well point.

Of the four methods, the 1 1/4-inch (nominal) steel well point is most preferred. The advantages of this installation technique are: 1) depth of installation nearly equal to the depth of a CPTU sounding; 2) rapid installation with minimal personnel contact with possibly contaminated soils; 3) exceptional sealing of risers to formation, with excellent isolation of well screen; and 4) low labor cost due to rapid installation with moderate material cost. One disadvantage of this technique is that no sand or gravel pack can be used as a well screen filter other than that which may naturally occur at the screened interval. Another is the diameter, which is too small for a submersible pump.

The second CPTU standpipe piezometer installation technique consists of the following steps: a small diameter hole is punched to the desired depth, either during CPTU, or by using an uninstrumented conical tip. A 2-inch (nominal) steel casing is then pushed down the pre-punched hole to the required depth. The end of this casing is closed with a slip-on cap, which remains in the soil after casing withdrawal. Three-quarter inch (nominal) PVC well screen and risers are lowered to the bottom of the casing. Sand pack is poured down the annulus, tamped with a long thin steel rod around the well screen, as the casing is slowly withdrawn, leaving the riser down-hole. A bentonite seal is placed above the sand pack to isolate the well point. The advantages of this technique are: 1) low cost for PVC well materials; 2) moderate labor time during installation; and 3) hole kept open by temporary casing. A disadvantage of this technique is that the completion depth is limited due to the use of the relatively large diameter 2-inch casing. The maximum depth of installation depends on site stratigraphy, but is certainly much less than the depth that can be achieved with the CPTU sounding itself. Also the small diameter riser (0.83-inch ID) makes the well difficult to develop if the water level is deeper than the lift of a suction pump. It must then be developed and sampled with a bailer.

The third technique, PVC riser in open hole, is the least expensive, both in installation time and materials, but is potentially also the least reliable. A 3/4-inch or 1-inch (nominal) PVC well screen and riser is lowered into the open hole left by the penetrometer. In squeezing soils, the hole may be enlarged using a 2-inch uninstrumented cone tip. After the PVC is lowered, sand pack is poured down the annulus and tamped around the screen, followed by a bentonite seal.

Advantages to this technique are: 1) low labor cost; 2) very low material cost; and 3) rapid installation. The disadvantage of this technique is that installation in an open hole is less reliable than in a cased hole. Caving sands or squeezing clays can affect both sand pack and grout seal. Caving sands and squeezing clays can also preclude deep installations. Again the small diameter of the riser pipe is a disadvantage.

The fourth technique of setting fixed piezometers with CPTU equipment involves pushing a 2-inch (nominal) steel pipe and well screen to the required depth. An enlarged hole is pre-punched with a 2-inch uninstrumented cone tip to facilitate well riser insertion. Advantages to this method are that the inner diameter of the riser is greater than 2 inches, and moderate labor and material costs. The diameter allows use of a submersible pump for development and water sampling. The disadvantage to this technique is limited depth capacity due to the relatively large diameter of the riser.

The ability to install fixed piezometers or small diameter wells in CPTU sounding holes gives the CPTU method a powerful versatility. In many environmental and geotechnical projects, shallow piezometers can be located at the proper depth and installed with the CPTU rig, without bringing in a drilling rig. In groundwater supply projects for domestic and rural village water supplies, sand aquifers can be located, estimates of potential well yield can be made, and steel well points installed quickly by using CPTU equipment alone, without drilling rigs.

<u>Testing and Sampling</u>. Standpipe piezometer installations with 2-inch (5 cm) risers can be developed and sampled and pump tested with a submersible pump. Standpipe piezometer installations with risers at least one inch (2.54 cm) in inside diameter are readily developed, tested, and sampled with a bailer. After development, a bailer or slug test may be conducted to determine the permeability of the material opposite the screen. Water samples may be bailed from the well for chemical analysis. The 0.83-inch ID (3/4-inch nominal) PVC riser can also be bailed with a specially made slim bailer. Small diameter piezometers may be pumped if the water level is shallow enough, and the intake pipe of a suction pump can fit inside the riser. Water levels, of course, can readily be obtained in all of these standpipe piezometers.

COST COMPARISON BETWEEN CPTU AND DRILLING AND SAMPLING

CPTU can be an efficient tool to obtain critical geotechnical and hydrogeological information. The key element is that the CPTU sounding provides a continuous log of the subsurface soil conditions and properties. To obtain a continuous log of subsurface conditions using traditional drilling techniques is costly and time consuming. For example, 100 feet of data using CPTU or drilling and sampling may cost approximately:

A) $1,000-$1,400 for CPTU, with interpretation, pore pressure dissipation, and hole grouting

B) $8,000-$10,200 for continuously sampled boring/analysis (including laboratory testing)

C) $1,850-$3,900 for conventional boring/analysis (non-continuous sampling/testing at 5-foot intervals)

The drilling/boring costs do not include a field technician which may add $500 to $750 to the cost of Alternatives B and C. Thus, CPTU may result in a cost savings of about 85 percent as compared to continuous boring/sampling/analysis and about 35 to 65 percent when compared to the cost of conventional boring/sampling/analysis.

Use of CPTU saved an estimated $4,000 (U.S.) in the monitoring well installation program for the landfill project in northeastern Illinois. By having the continuous CPTU sounding logs defining site stratigraphy, and knowing exactly at what depth the aquifer would be encountered, it was possible to install the monitoring wells using hollow stem augers, without expensive continuous sampling. Additionally, fewer geotechnical laboratory tests on the samples were required. and less geological supervision and logging time was necessary to complete the well installations.

CPTU standpipe piezometer installations are also less expensive than drilled piezometers. Both CPTU and drilled borehole techniques were used at another site in northern Illinois to provide data for site characterization and for shallow piezometer installations. The total cost for the drilled portion of the investigation was about $6,900; the cost for about the same amount of work based on CPTU methods was only $3,300, or less than half of the drilled cost. The drilling cost did not include the cost of the geologist who supervised the drilling and logged the samples. No geological supervision was required with the CPTU method, resulting in additional savings.

CONCLUSIONS

Piezometric Cone Penetration Testing (CPTU) provides a cost effective, accurate, and rapid means to determine hydrogeologic properties at suitable sites, including stratigraphy, saturation, hydraulic head, lateral gradient, vertical gradient, position of the water table, position of the potentiometric surface, slope of the water table, direction of groundwater movement, and permeability and transmissivity. This information is readily defined in a short period of time using computerized data acquisition techniques. Data are objective, and analysis is straight forward as CPTU test results directly reflect soil characteristics of grain size, void ratio and permeability. Costs of CPTU can be as much as 85 percent less than costs associated with a drilled borehole with continuous sampling and laboratory testing.

Small diameter, standpipe piezometers can also be installed using CPTU equipment after completion of a sounding. At contaminated sites, lessened personnel exposure and greatly decreased generation of cuttings and drilling fluids characterize CPTU exploration techniques.

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BIOGRAPHICAL SKETCHES

Marvin (Nick) Saines is Senior Hydrogeologist and Scientific Services Discipline Manager at Donohue & Associates, Chicago Office. Dr. Saines has over 20 years of consulting experience in the fields of hydrogeology and engineering geology. He has worked on groundwater supply projects in the U.S., Guyana, Malaysia, and the Sultanate of Oman; and has worked on damsite and reservoir hydrogeology and engineering geology projects in the U.S., Iran, Afghanistan and Jordan. Currently he is working mainly on environmental projects dealing with solid and hazardous waste landfills in the U.S. He has published or presented over 20 papers, and taught hydrogeology as an adjunct professor at the University of Illinois (Chicago).

Andrew I. Strutynsky is the Technical Director of STRATIGRAPHICS, responsible for all in situ testing, field operations, and data interpretation. He designs custom in situ test equipment and performs research and development of new test techniques. He was recently a speaker at the First International Symposium on Penetration Testing (ISOPT-1), and conducted CPTU workshops at the Third National Outdoor Conference on Aquifer Restoration, Ground-Water Monitoring and Geophysical Methods (1989), sponsored by the NWWA. He has over ten years of exploration expertise, gathered on both domestic and international projects, onshore, offshore and off of the Arctic ice cap. He was formerly responsible for all in situ test projects at the Earth Technology Corporation. He developed CPTU testing procedures and analytic routines, and performed research for both the USGS and the National Science Foundation. He has authored various papers on CPT equipment and interpretation of CPT data. He has both B.S. and M.S. degrees from the University of Illinois.

George R. Lytwynyshyn is a geologist/engineer with over 14 years of experience. His areas of specialty include waste management related geological/hydrogeological investigations, remedial investigations/ feasibility studies (RI/FS), remedial action design studies, geotechnical/geological investigations, and project administration/ management. He serves as the department head for the Environmental Services Department at Donohue's Chicago, Illinois office. The Environment Services Department provides scientific and engineering services on solid and hazardous waste projects. His responsibilities include development, planning and management of projects in the Chicago office. Mr. Lytwynyshyn earned a B.S. degree in geological sciences and an M.S. degree in Civil Engineering, both from Northwestern University in Evanston, Illinois. He has published and presented several papers dealing with hydrogeology, waste management and rock mechanics.

Appendix B

Fuel Distribution System
Monitoring Well Construction Diagrams

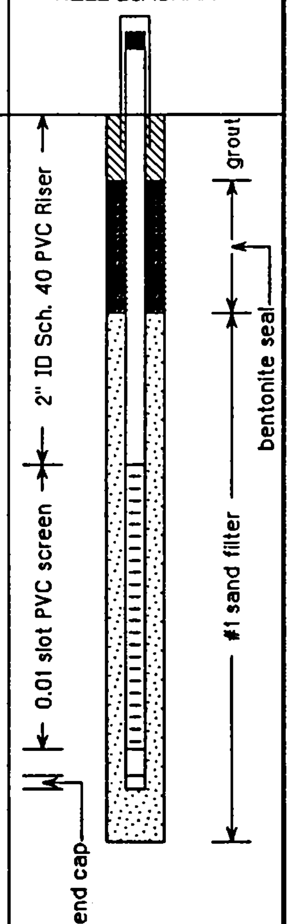
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS01A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2322779.89 E, 371894.80 N*
Location: *Charleston, SC*	Surface Elevation: *7.4 feet msl*
Started at *0915 on 1-07-97*	TOC Elevation: *9.75 feet msl*
Completed at *1130 on 1-07-97*	Depth to Groundwater: *9.74 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *0.01 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *10.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *5.3 to 9.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass.	
							FILL	Cuttings 0-2' bgs: Fill: sand, silt, and gravel; loose; petroleum odor.	5.4
									4.4
							OL/OH	Clay: black; silty; little sand; moist; petroleum odor.	3.4
5			1	50	360				2.4
							SC/OL	Sand: dark gray; fine to medium; silty; clayey; loose; saturated; stong petroleum odor.	1
			2	70	40				
							OL	Clay: gray; silty; soft; saturated.	-1.6 / -1.9
10							SM	Sand: gray; medium to very coarse; little silt and clay; loose; saturated; grades into soft, clayey silt from 9.4-9.7'.	
			3	90	50				-3.4
15									
20									

WELL DIAGRAM



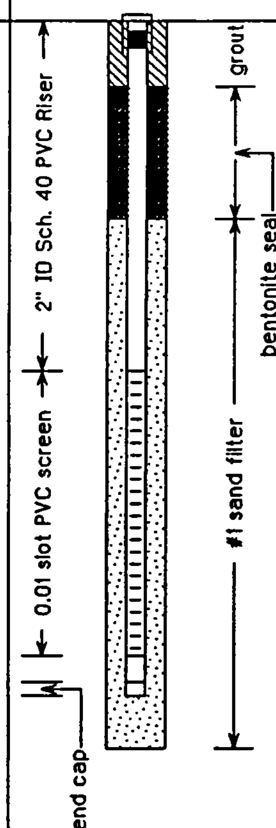
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS01B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2322803.81 E, 371861.32 N*
Location: *Charleston, SC*	Surface Elevation: *7.9 feet msl*
Started at *1230 on 1-07-97*	TOC Elevation: *7.69 feet msl*
Completed at *1400 on 1-07-97*	Depth to Groundwater: *4.42 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.27 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *10.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *5.3 to 9.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt. Cuttings logged below. Please refer to Boring Log NBCGFDS01A for detailed lithologic descriptions.	
							FILL	Cuttings 2-4' bgs: Fill: black silt, sand, and loose gravel.	5.9
5							SM	Cuttings 4-11' bgs: Sand: black; fine to medium; silty; loose; saturated.	3.9
10									3.1
15									
20									

WELL DIAGRAM



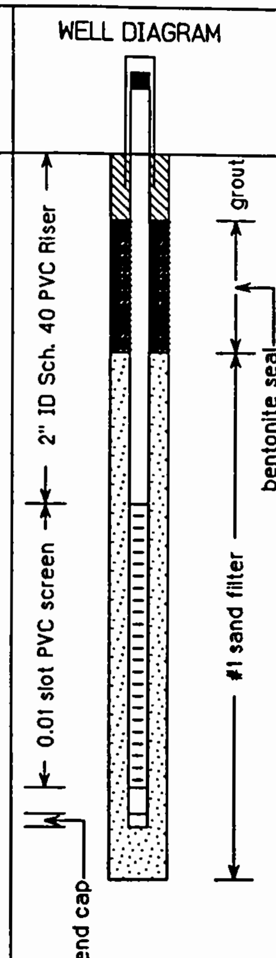
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS01C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2322821.31 E, 371906.41 N*
Location: *Charleston, SC*	Surface Elevation: *6.8 feet msl*
Started at *1445 on 1-07-97*	TOC Elevation: *9.30 feet msl*
Completed at *1545 on 1-07-97*	Depth to Groundwater: *6.24 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.06 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *10.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *5.3 to 9.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–3							SM	Surface conditions: Gravel. Cuttings logged below. Please refer to Boring Log NBCGFDS01A for detailed lithologic descriptions. Cuttings 0-3' bgs: Sand: gray; fine to medium; silty; loose; dry.	3.8
3–4							OL	Clay; black; high organic content; soft; moist.	2.8
4–5.3							SP SM	Shelby tube: Bottom: Sand: gray; fine to coarse; trace silt; loose.	1.5
5.3–6	X		ST-1	65					.8
6–11							SP SM	Cuttings 6-11' bgs: Sand: as above.	-4.2

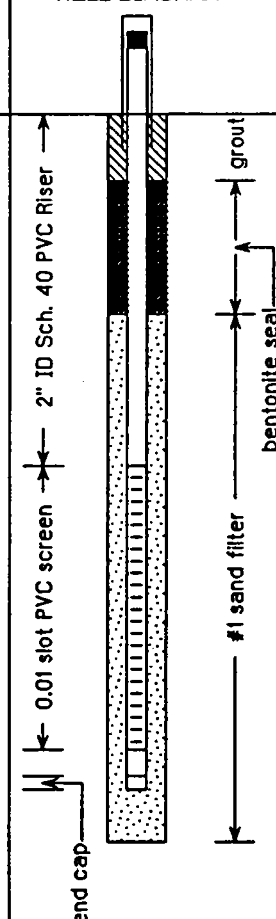
Depth scale: 5, 10, 15, 20



EnSafe/Allen & Hoshall	Monitoring Well NBCGFDS01D
Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2322824.96 E, 371887.21 N*
Location: *Charleston, SC*	Surface Elevation: *7.1 feet msl*
Started at *0800 on 1-08-97*	TOC Elevation: *9.46 feet msl*
Completed at *0910 on 1-08-97*	Depth to Groundwater: *6.36 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.10 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *10.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *5.3 to 9.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0								Surface conditions: Grass.	
								Cuttings logged below. Please refer to Boring Log NBCGFDS01A for detailed lithologic descriptions.	
								Cuttings from 0-11' bgs: Sand: black; fine to coarse; silty; loose; moist.	
5							SM/ML		
10									
11									-3.9
15									
20									

WELL DIAGRAM



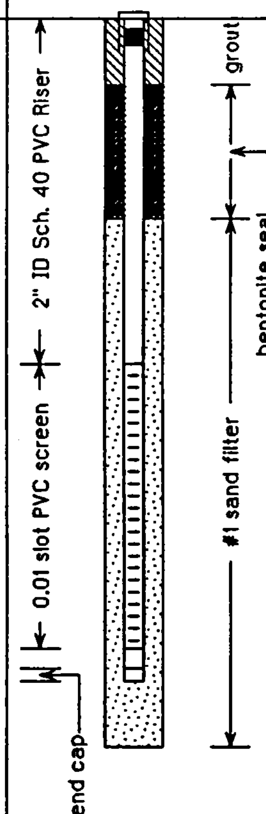
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS01E

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2322667.69 E, 371918.64 N*
Location: *Charleston, SC*	Surface Elevation: *7.0 feet msl*
Started at *1340 on 1-22-97*	TOC Elevation: *6.84 feet msl*
Completed at *1455 on 1-22-97*	Depth to Groundwater: *4.64 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.20 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *10.0 feet bgs*
Geologist: *D. Felter*	Well Screen: *5.2 to 9.5 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–10							OL	Surface conditions: Grass. Cuttings logged below. Please refer to Boring Log NBCGFDS01A for detailed lithologic descriptions. Cuttings from 0-10' bgs: Clay: dark gray; organic; marsh clay.	
10									-3
15									
20									

WELL DIAGRAM



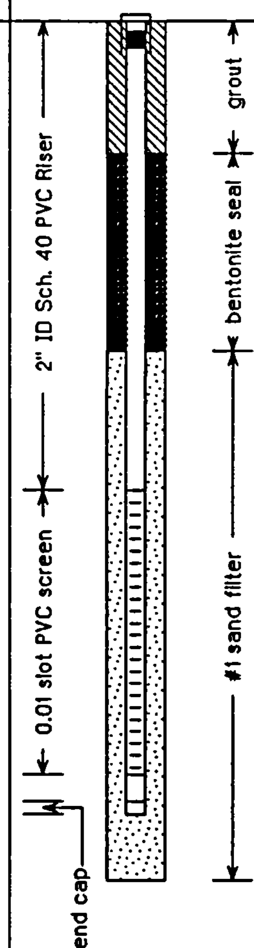
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS02A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321722.44 E, 371988.57 N*
Location: *Charleston, SC*	Surface Elevation: *7.6 feet msl*
Started at *1230 on 1-07-97*	TOC Elevation: *7.45 feet msl*
Completed at *1456 on 1-07-97*	Depth to Groundwater: *3.82 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.63 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
							ML	Surface conditions: Asphalt Cuttings 0-3': Silt: red-brown; clayey; sandy.	4.6
							SW	Sand: brown; fine to coarse; silty to gravelly; moist.	3.6
5			1	60			CL	Clay: red; silty sandy mixture; trace gravel; moist.	3.4 2.6
							SM	Sand: brown to black; fine to coarse; silty; little gravel; moist to saturated; petroleum odor.	1.1
			2	75					1.4
10							ML	Silt: olive green; clayey with trace of fine to medium sand; medium plasticity; soft; moist.	1.6 -3.4
			3	8			OL	Clay: Gray; silty; very soft; low to medium plasticity; organic.	
			2	100					-5.4
15									
20									

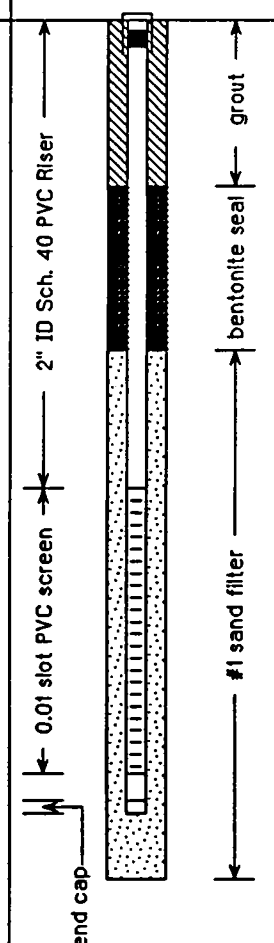
WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCGFDS02B
Project: *Fuel Distribution System - Naval Base Charleston*	Coordinates: *2321773.76 E, 372119.06 N*
Location: *Charleston, SC*	Surface Elevation: *7.4 feet msl*
Started at *0800 on 1-08-97*	TOC Elevation: *7.24 feet msl*
Completed at *1020 on 1-08-97*	Depth to Groundwater: *4.12 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.12 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–5							SM	Surface conditions: Asphalt Cuttings logged below. Please refer to Boring Log NBCGFDS02A for detailed lithologic descriptions. Cuttings from 0-5' bgs: Sand: brown; silty; shelly.	
5									2.4
5–10							ML	Cuttings from 5-10' bgs: Silt: olive-green; sandy.	
10									2.6
10–13							ML/CL	Cuttings from 10-13' bgs: Clay: olive-green to gray; sandy; silty.	
13									5.6
15									
20									

WELL DIAGRAM



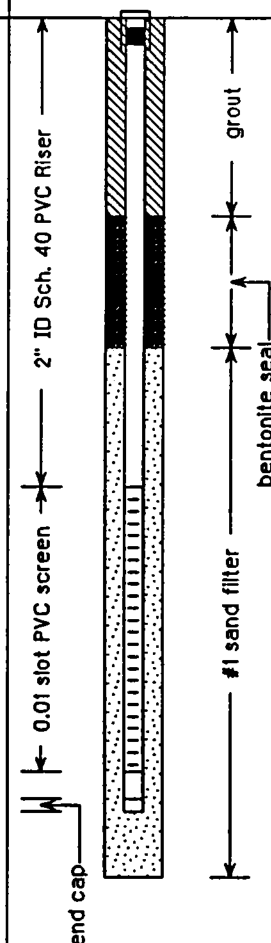
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS02C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321790.97 E, 371993.34 N*
Location: *Charleston, SC*	Surface Elevation: *7.9 feet msl*
Started at *1520 on 1-07-97*	TOC Elevation: *7.57 feet msl*
Completed at *1730 on 1-07-97*	Depth to Groundwater: *3.90 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.67 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
							SM/SC	Cuttings logged below. Please refer to Boring Log NBCGFDS02A for detailed lithologic descriptions.	
								Cuttings 0.5–2.5' bgs: Sand: brown to red; silty; clayey; gravel at 2.5' bgs.	5.4
5								Cuttings 2.5–13' bgs: Clay: dark gray; silty.	
10							OL		
									-5.1
15									
20									

WELL DIAGRAM

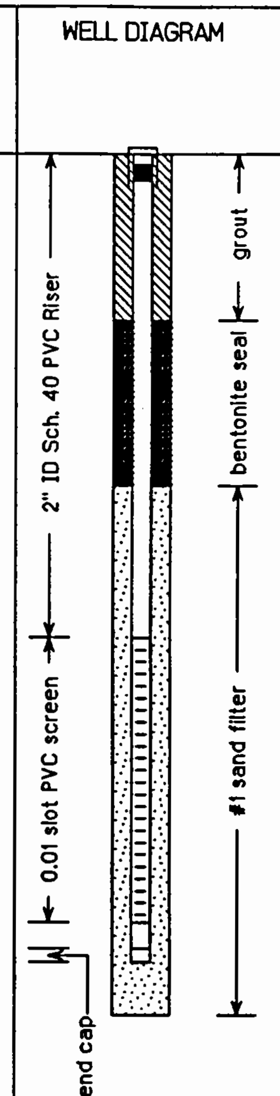


EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS03A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321606.25 E, 372118.52 N*
Location: *Charleston, SC*	Surface Elevation: *7.7 feet msl*
Started at *1030 on 1-08-97*	TOC Elevation: *7.59 feet msl*
Completed at *1200 on 1-08-97*	Depth to Groundwater: *4.52 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.07 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *7.3 to 11.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
								Cuttings logged below. Please refer to Boring Log NBCGFDS03C for detailed lithologic descriptions.	6.7
							SM	Cuttings 1-4' bgs: Sand: brown to gray; fine to coarse; silty; loose; slightly moist.	
5							OL	Cuttings 4-6' bgs: Clay: black; silty; w/ fine to coarse sand; organic; moist.	3.7
10							ML SM	Cuttings 6-13' bgs: Silt: brown; w/ fine to coarse sand; soft; very moist.	1.7
15									-5.3
20									



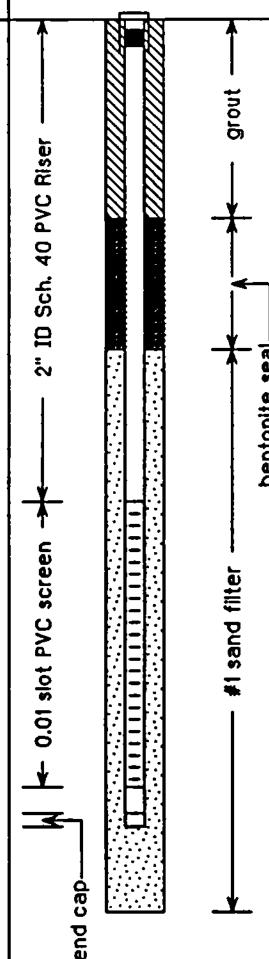
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS03B

Project: *ZONE G - Naval Base Charleston*	Coordinates: *2321584.42 E, 372053.65 N*
Location: *Charleston, SC*	Surface Elevation: *7.1 feet msl*
Started at *0815 on 1-10-97*	TOC Elevation: *7.00 feet msl*
Completed at *0945 on 1-10-97*	Depth to Groundwater: *3.93 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.07 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *7.3 to 11.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
								Cuttings logged below. Please refer to Boring Log NBCGFDS03C for detailed lithologic descriptions.	6.1
5							OL	Cuttings 1-6' bgs: Clay: black; silty; w/ fine to medium sand; high organic content; soft; some gravel and shell hash; moist.	
								Cuttings 6-7' bgs: Silt: black; clayey; some fine to coarse sand; soft; saturated.	.1
10							ML/SM	Cuttings 7-13' bgs: Silt: green-gray; very sandy (fine to coarse); trace clay; soft; saturated.	-6.4
15									
20									

WELL DIAGRAM



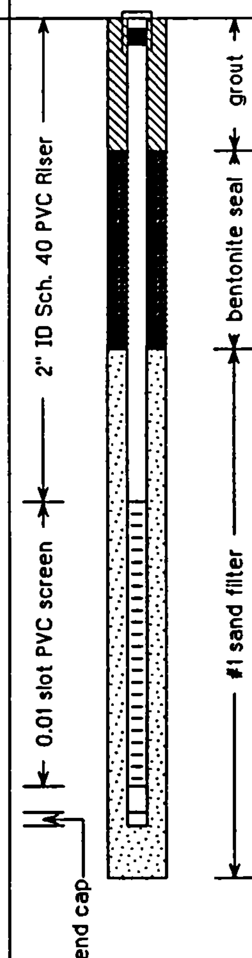
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS03C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321540.47 E, 372053.38 N*
Location: *Charleston, SC*	Surface Elevation: *6.6 feet msl*
Started at *1015 on 1-10-97*	TOC Elevation: *6.36 feet msl*
Completed at *1220 on 1-10-97*	Depth to Groundwater: *3.36 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.00 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *7.3 to 11.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0							FILL	Surface conditions: Asphalt. Cuttings 0-3' bgs: Fill: black; fine to very coarse sand with clay and silt, bricks and concrete; loose; moist.	
3							OL/CL	Cuttings 3-5' bgs: Clay: black; w/ very fine to coarse sand; soft; very moist.	3.6
5							OL	Clay: black; silty; trace fine to coarse sand; medium stiff; moist; organic.	1.6
			1	100	90				
							ML	Silt: brown to tan; clayey; medium stiff; saturated.	-1.7, -2
			2	100	90		SM	Sand: gray; medium to coarse; silty; loose; saturated.	-2.4
10							ML	Shelby tube: Silt: brown to tan; clayey; medium stiff; saturated.	-3.4, -3.6
			ST-1	12					
15									
20									

WELL DIAGRAM



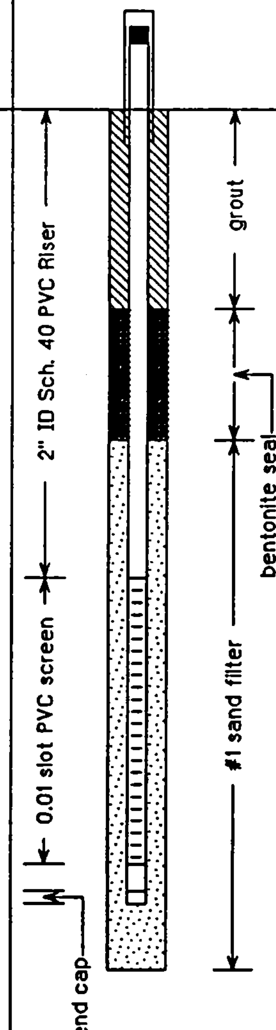
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS04A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321552.37 E, 372182.76 N*
Location: *Charleston, SC*	Surface Elevation: *7.7 feet msl*
Started at *1040 on 1-08-97*	TOC Elevation: *10.19 feet msl*
Completed at *1215 on 1-08-97*	Depth to Groundwater: *7.23 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.96 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

DEPTH IN FEET	SAMPLE NO.	% RECOVERY	PID (ppm)	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
					Surface conditions: Grass	
				SM	Cuttings 0-3' bgs: Sand: brown; silty; soil cover.	
				SM/CL	Sand: brown; silty; clayey; some gravel; loose; moist.	4.7 / 4.4
5	1	10	0	SM/CL	Sand: brown to tan to gray; fine to medium; silty; some clay; some gravel; loose; moist.	2.7
	2	75	50	OL	Clay: gray; silty; some very fine to medium sand; trace gravel; organic; laminated; petroleum stained at 6.5 feet bgs.	1.7 / 1.2
10				SC/SM	Sand: gray to gray-brown; silty; w/ low plasticity clay; trace gravel; saturated.	-1.3
	3	75	10	ML/SM	Silt: tan to olive; medium to coarse sandy stringers throughout; shell fragments; saturated.	-2.3 / -2.8
15						
20						

WELL DIAGRAM



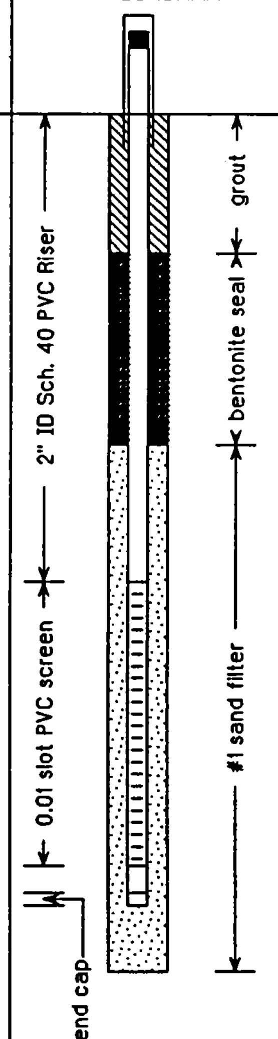
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS04B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321583.93 E, 372205.48 N*
Location: *Charleston, SC*	Surface Elevation: *7.2 feet msl*
Started at *1540 on 1-08-97*	TOC Elevation: *9.65 feet msl*
Completed at *0845 on 1-09-97*	Depth to Groundwater: *6.84 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.81 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

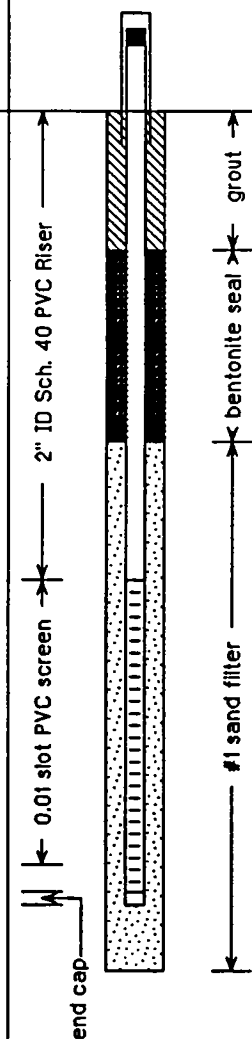
DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass	
5								Please refer to Boring Log NBCGFDS04A for detailed lithologic descriptions.	
	X						OL / CL	Shelby Tube: Clay: dark gray; silty.	.8
									2
10			ST-1	60					
15									
20									

WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCGFDS04C
Project: *Fuel Distribution System - Naval Base Charleston*	Coordinates: *2321612.70 E, 372197.30 N*
Location: *Charleston, SC*	Surface Elevation: *6.9 feet msl*
Started at *1330 on 1-08-97*	TOC Elevation: *9.42 feet msl*
Completed at *1455 on 1-08-97*	Depth to Groundwater: *6.58 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.84 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
								Surface conditions: Grass		
5										
								Please refer to Boring Log of NBCGFDS04A for detailed lithologic descriptions.		
10										
15										
20										



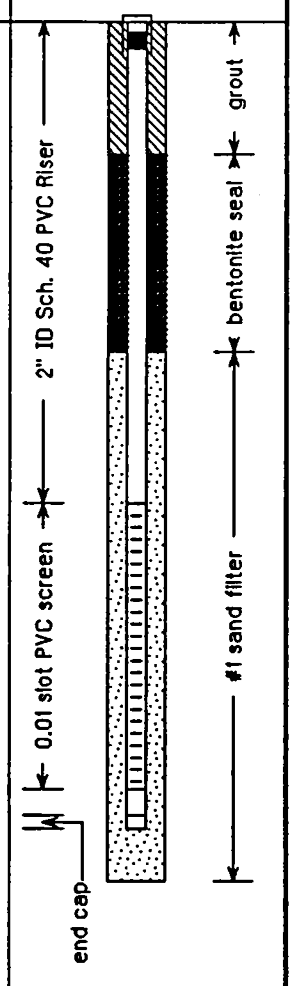
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS05A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321425.41 E, 372168.50 N*
Location: *Charleston, SC*	Surface Elevation: *6.4 feet msl*
Started at *1215 on 1-08-97*	TOC Elevation: *6.30 feet msl*
Completed at *1400 on 1-08-97*	Depth to Groundwater: *3.37 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.93 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *7.3 to 11.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt to 3.5' bgs.	
								Cuttings logged below. Please refer to Boring Log of NBCGFDS05D for detailed lithologic descriptions.	
									2.9
5							SM	Cuttings 3.5-7' bgs: Sand: brown; silty; loose; moist.	
									-.6
10							SW/SM	Cuttings 7-13' bgs: Sand: black; fine to coarse; silty; loose; soft; wood w/ creosote odor encountered.	
									-6.6
15									
20									

WELL DIAGRAM



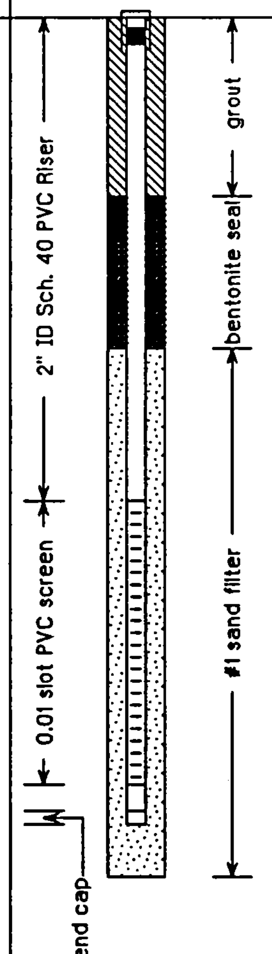
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS05B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321308.85 E, 372095.84 N*
Location: *Charleston, SC*	Surface Elevation: *6.0 feet msl*
Started at *1415 on 1-10-97*	TOC Elevation: *5.80 feet msl*
Completed at *1600 on 1-10-97*	Depth to Groundwater: *5.17 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *0.63 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *7.3 to 11.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–2							SM	Surface conditions: Asphalt. Cuttings 0-2' bgs: Sand: brown-gray; fine to medium; silty; loose; moist;	4
2–3							OL	Cuttings 2-3' bgs: Clay: black; silty.	3
3–5							SM	Cuttings 3-5' bgs: Sand: gray; fine to medium; silty; loose; moist.	1
5–7			1	100	220		OL	Clay: black; silty; soft; moist.	-1
7–10									-4
10–12			ST-1	100	220		SM	Shelby tube: Top: Sand: brown; fine to medium; silty; dense; saturated; Bottom: Sand: gray; coarse; some silt; loose; saturated.	-6
15									
20									

WELL DIAGRAM



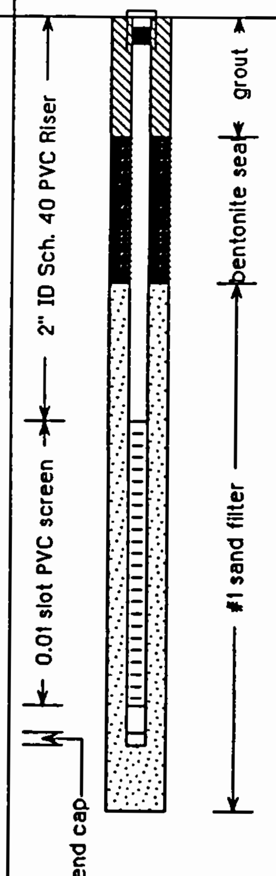
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS06A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321445.71 E, 372213.66 N*
Location: *Charleston, SC*	Surface Elevation: *7.2 feet msl*
Started at *0845 on 1-10-97*	TOC Elevation: *6.94 feet msl*
Completed at *1005 on 1-10-97*	Depth to Groundwater: *4.28 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.66 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *11.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *6.1 to 10.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0							SM	Surface conditions: Grass Cuttings 0-4' bgs: Sand: brown; silty; little gravel; petroleum odor	4.2
							SP/SC	Sand: tan to gray; fine to medium; some clay; loose; petroleum odor.	3.3
5			1	100	720		OH	Clay: gray; silty; trace sand; stiff; medium plasticity; organic; moist.	2.2
							SP/SC	Sand: gray; fine to medium; clayey; loose; saturated; petroleum odor.	1.3
							OH	Clay: gray; trace gravel and sand; stiff; medium plasticity; petroleum odor; saturated at ~6 feet bgs.	.7
			2	75	80				
10							OL/SM	Clay: gray; with silty sand lenses; soft; low plasticity.	-1.8
							ML	Silt: tan; silty; trace gravel.	-2.9
			3	85	20				-3.5
15									
20									

WELL DIAGRAM

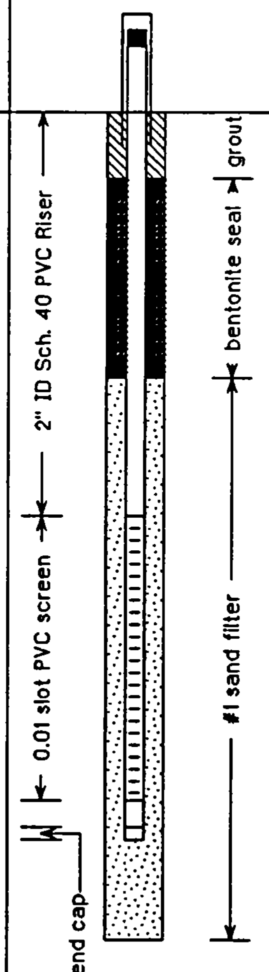


EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS06B

Project: *Fuel Distribution System - Naval Base Charleston*	Coordinates: *2321352.20 E, 372245.42 N*
Location: *Charleston, SC*	Surface Elevation: *7.0 feet msl*
Started at *1115 on 1-10-97*	TOC Elevation: *9.06 feet msl*
Completed at *1230 on 1-10-97*	Depth to Groundwater: *6.01 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.05 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *11.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *6.1 to 10.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
								Surface conditions: Grass		
								Please refer to Boring Log NBCGFDS06A for detailed lithologic descriptions.		
5										
								NOTE: free product (oily residue) seen on augers from 5-10 ft bgs.		
10										
15										
20										



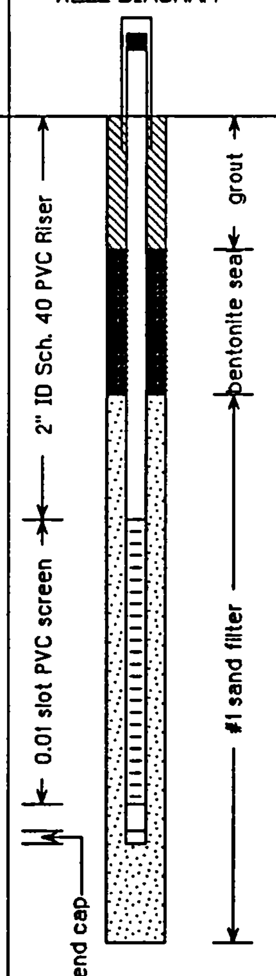
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS06C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2321411.04 E, 372266.04 N*
Location: *Charleston, SC*	Surface Elevation: *7.4 feet msl*
Started at *1425 on 1-10-97*	TOC Elevation: *9.76 feet msl*
Completed at *1530 on 1-10-97*	Depth to Groundwater: *7.44 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.32 feet msl*
Drilling Company: *GeoTek Drilling (SC cert. #794)*	Total Well Depth: *11.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *6.1 to 10.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass	
								Cuttings logged below. Please refer to Boring Log NBCGFDS06A for detailed lithologic descriptions.	6.4
							FILL	Cuttings 1-3' bgs: Fill: wet gravel.	
									4.4
5							OL	Cuttings 3-8' bgs: Clay: dark gray; silty; very soft.	
									-.6
10									
15									
20									

WELL DIAGRAM



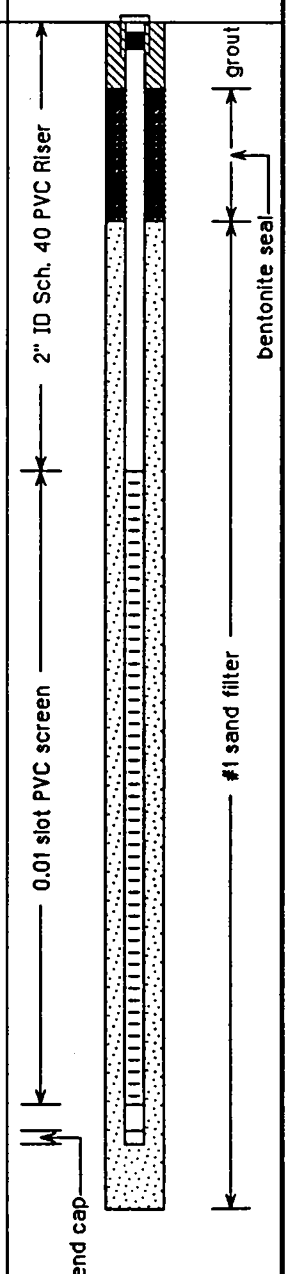
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS07A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320492.54 E, 372335.64 N*
Location: *Charleston, SC*	Surface Elevation: *5.7 feet msl*
Started at *1520 on 1-10-97*	TOC Elevation: *5.44 feet msl*
Completed at *1700 on 1-10-97*	Depth to Groundwater: *8.00 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *-2.56 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *17.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *6.8 to 16.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0							SM/SW	Surface conditions: Asphalt. NOTE: Upper 10' logged during first installation attempt. Lithology from 10-18' bgs logged during second well installation on 1/22/97. Cuttings 0-4' bgs: Sand: tan; medium to coarse; silty; gravelly; loose.	
							SP/SM	Sand; tan to olive green; fine to medium; micaceous; heavy minerals; moist.	1.7
5							CL	Clay: dark gray; sandy; trace gravel.	.9
							GW	Gravel: gray to black; debris; sandy; loose; saturated.	.5
			1	80	40				.1
							SM	Shelby Tube: Sand: olive green to brown; fine to medium; silty.	-2.3
10			ST-1	80					-3.9
							OL	Cuttings 10-18' bgs: Clay: dark gray; silty; organic; moist; marsh clay.	-4.3
15									
									-12.3
20									

WELL DIAGRAM



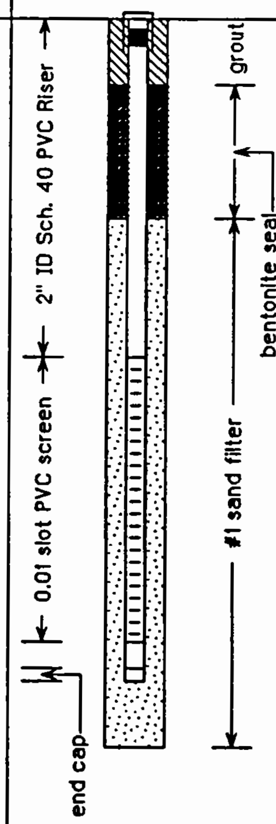
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS07B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320573.17 E, 372426.11 N*
Location: *Charleston, SC*	Surface Elevation: *4.6 feet msl*
Started at *1025 on 1-11-97*	TOC Elevation: *4.57 feet msl*
Completed at *1147 on 1-11-97*	Depth to Groundwater: *0.80 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.77 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *10.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.1 to 9.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
								Cuttings logged below. Please refer to Boring Log NBCGFDS07A for detailed lithologic descriptions.	
0.5–5							SM	Cuttings 0.5-5' bgs: Sand: dark brown; silty.	
5									-.4
5–11							ML	Cuttings 5-11' bgs: Silt: tan; wet; H_2S odor.	
10									
11									-6.4
15									
20									

WELL DIAGRAM



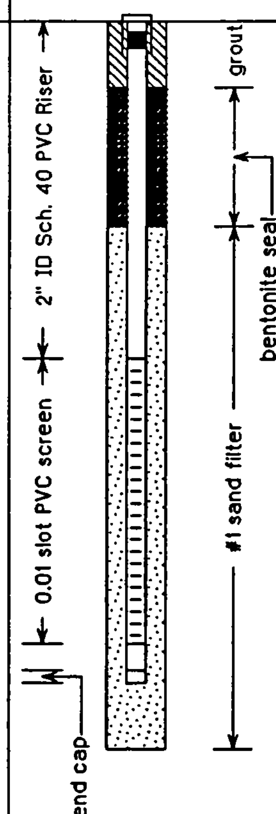
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS07C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320603.57 E, 372416.06 N*
Location: *Charleston, SC*	Surface Elevation: *4.7 feet msl*
Started at *0830 on 1-11-97*	TOC Elevation: *4.50 feet msl*
Completed at *1004 on 1-11-97*	Depth to Groundwater: *0.97 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *3.53 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *10.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.1 to 9.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–3							SC / SM	Surface conditions: Asphalt. Cuttings 0-3' bgs: Sand: brown; clayey; silty.	1.7
5								Please refer to Boring Log NBCGFDS07A for detailed lithologic descriptions.	
10									
15									
20									

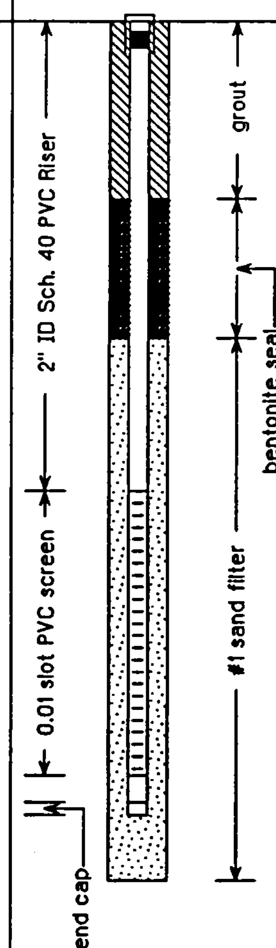
WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCGFDS07D
Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320674.44 E, 372491.81 N*
Location: *Charleston, SC*	Surface Elevation: *6.2 feet msl*
Started at *1333 on 1-11-97*	TOC Elevation: *6.06 feet msl*
Completed at *1505 on 1-11-97*	Depth to Groundwater: *1.41 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.65 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.1 to 11.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
5							SC SP	Sand: gray; fine to medium; clayey; shelly; loose; calcareous; saturated.	1.2 .9 .5
							SM	Sand: tan to brown; fine to medium; silty.	-.2
			1	70	70		WOOD	Wood: creosote preserved (post or timber).	
10							OL	Clay: dark gray to black; silty; some fine to medium sand; very soft; organics and wood present throughout; low plasticity; organic.	-2.8
			2	100	10		SC	Sand: brown to gray; fine to coarse; silty; some shells and wood fragments throughout; slight odor.	-4.8 -5
15									
20									

WELL DIAGRAM

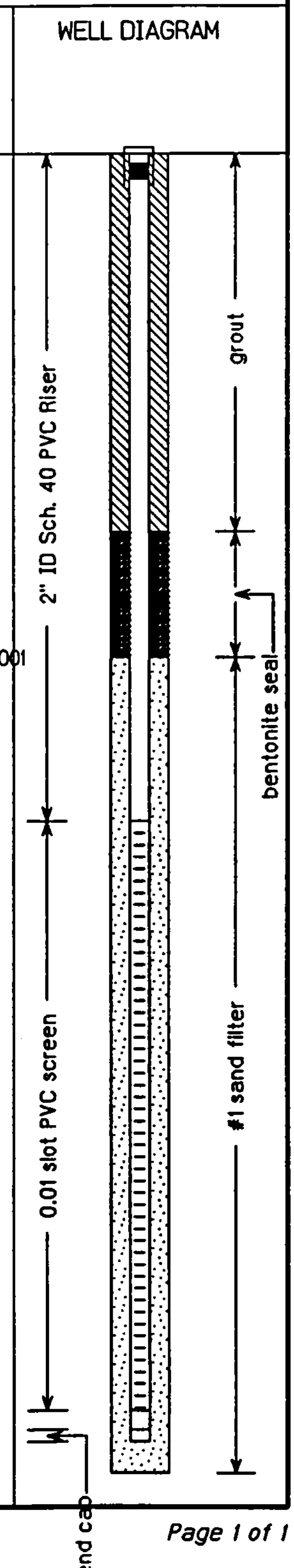


EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS08A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319455.19 E, 372225.10 N*
Location: *Charleston, SC*	Surface Elevation: *16.9 feet msl*
Started at *0800 on 1-11-97*	TOC Elevation: *16.68 feet msl*
Completed at *1020 on 1-11-97*	Depth to Groundwater: *8.32 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *8.36 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *20.5 feet bgs*
Geologist: *D. Doyle*	Well Screen: *10.6 to 20.0 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass.	
								Cuttings 0-8' bgs: Fill: brown to gray, fine to coarse sand; clayey; silty; medium dense; moist.	
5							FILL		
							SM	Sand: gray; fine to medium; silty; dense; saturated.	8.900001 / 8.5
10			1	40	0.0		OL	Clay: black; silty; high organic content; medium stiff; very moist.	6.9
							SW / SC	Shelby Tube: Top: Sand as above (likely slough); Bottom: Sand: gray; fine to coarse; clayey; dense; stiff; moist.	3.9
15			ST-1	100					1.9
							SM / CL	Sand: brown-gray; fine to coarse; silty; dense; saturated; interbedded w/ clay: gray; stiff; sandy; saturated.	1.1
20			2	100					-3.1



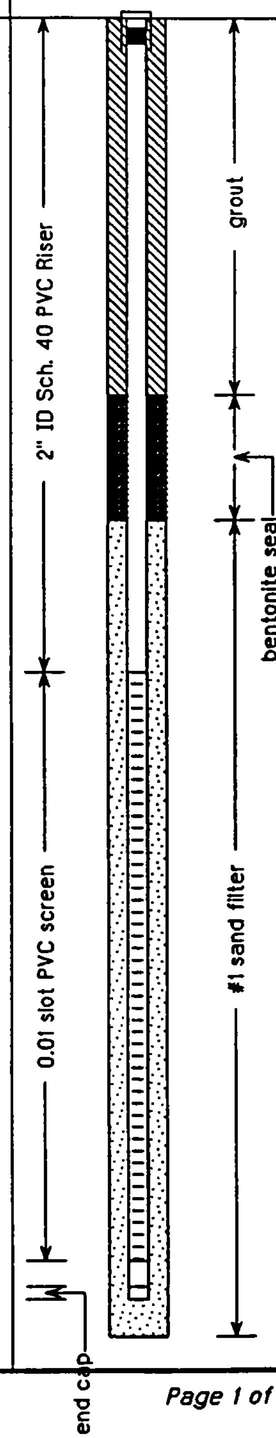
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS08B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319395.12 E, 372179.63 N*
Location: *Charleston, SC*	Surface Elevation: *16.2 feet msl*
Started at *1220 on 1-11-97*	TOC Elevation: *16.30 feet msl*
Completed at *1430 on 1-11-97*	Depth to Groundwater: *7.25 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *9.05 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *20.4 feet bgs*
Geologist: *D. Doyle*	Well Screen: *10.4 to 19.8 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass.	
								Cuttings logged below. Please refer to Boring Log NBCGFDS08A for detailed lithologic descriptions.	
							SM/SW	Cuttings 0.5-5' bgs: Sand: brown; fine to very coarse; silty; loose; moist.	
5								Cuttings from 5-21' bgs: Clay: black; very sandy (fine to very coarse); shell hash; soft; moist; saturated at 11' bgs and strong petro odor at that depth.	11.2
10									
							SM/OL		
15									
20									-4.8

WELL DIAGRAM



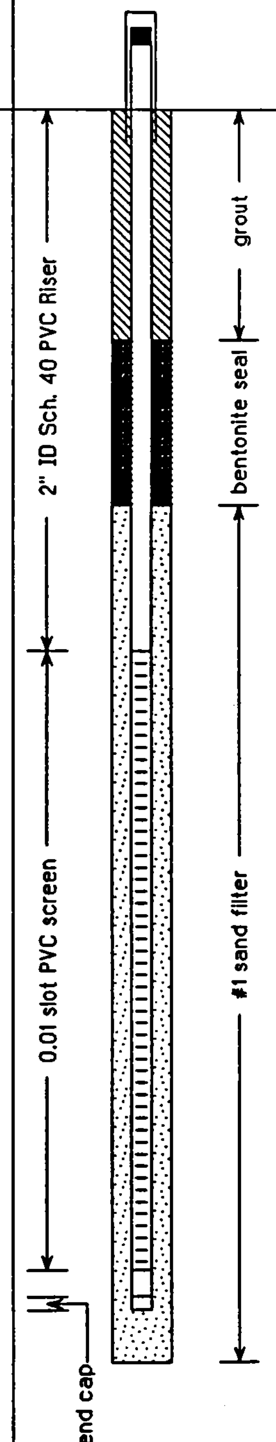
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS08C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319356.46 E, 372221.39 N*
Location: *Charleston, SC*	Surface Elevation: *13.8 feet msl*
Started at *0900 on 1-14-97*	TOC Elevation: *16.05 feet msl*
Completed at *1045 on 1-14-97*	Depth to Groundwater: *5.48 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *10.57 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *18.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *8.2 to 17.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
							CL	Surface conditions: Grass. Cuttings logged below. Please refer to Boring Log NBCGFDS08A for detailed lithologic descriptions.	
								Cuttings 0-2' bgs: Clay: brown; silty; stiff; moist.	11.8
	X		ST-1	75			CL/SW	Shelby Tube: Top: Clay: brown; silty; stiff; moist. Bottom: Sand: medium to very coarse; trace silt; dense; saturated.	10.3
5									7.8
10							SM/CL	Cuttings 6-16' bgs: Sand: black to dark gray; fine to coarse; silty; clayey; saturated.	
15									2.2
							SM/SW	Cuttings 16-19' bgs: Sand: black; fine to coarse; silty; wet.	-5.2
20									

WELL DIAGRAM



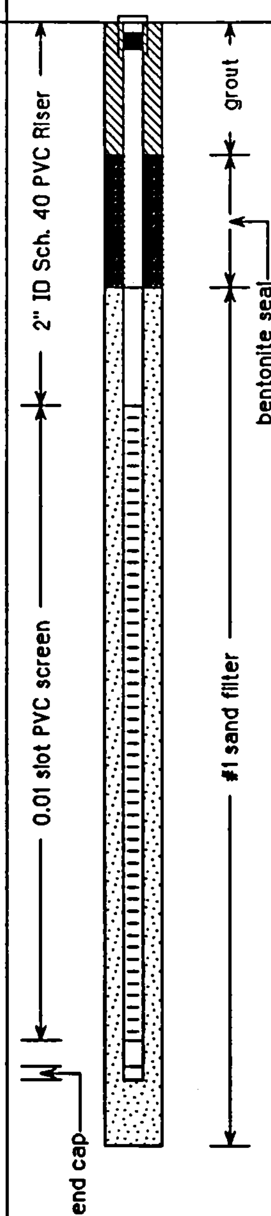
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS09A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320618.87 E, 372992.97 N*
Location: *Charleston, SC*	Surface Elevation: *4.9 feet msl*
Started at *0900 on 1-13-97*	TOC Elevation: *4.98 feet msl*
Completed at *1235 on 1-13-97*	Depth to Groundwater: *2.11 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.87 feet msl*
Drilling Company: *GeoTek Drilling (SC cert. #794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0								Surface conditions: Asphalt.	
							OL	Clay: gray; trace sand; few shells; soft; organic; medium plasticity; saturated sand section overlying clay.	.9 / .7
5			1	20	150				
							OL	Clay: gray; trace shell fragments; organic; soft; low plasticity; moist.	3.1
							SC	Sand: gray; clayey; very fine to medium; few shell fragments; wet.	4.1
10			2	100	80		SW		4.6
							OL	Sand: light gray; medium to coarse; shell fragments throughout; loose; wet; fining upward sequence.	5.1
			ST-1	100				Shelby Tube: Clay: gray; soft; low plasticity.	7.1
							SC	Sand: gray; shelly; clayey; loose; saturated.	8.1 / 8.5
15							OL	Clay: with trace sand and silt; organic; very soft; low plasticity.	
			3	90	0				10.9
20									

WELL DIAGRAM

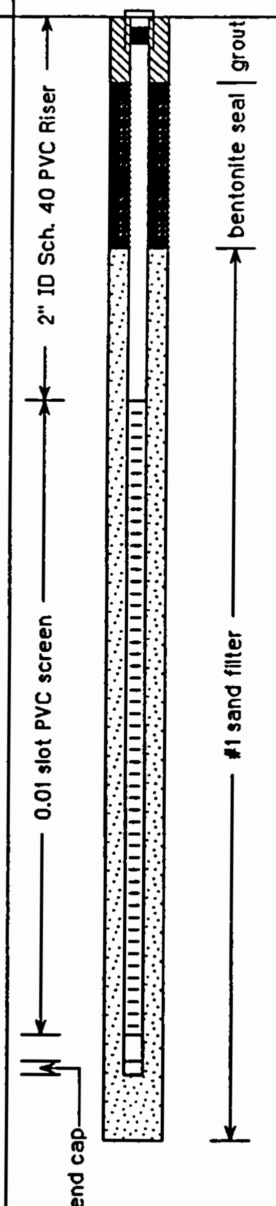


EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS09B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320689.62 E, 372954.93 N*
Location: *Charleston, SC*	Surface Elevation: *4.7 feet msl*
Started at *1430 on 1-13-97*	TOC Elevation: *4.76 feet msl*
Completed at *1600 on 1-13-97*	Depth to Groundwater: *1.85 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.91 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
								Surface conditions: Asphalt.		
5										
								Please refer to Boring Log NBCGFDS09A for detailed lithologic descriptions.		
10										
15										
20										

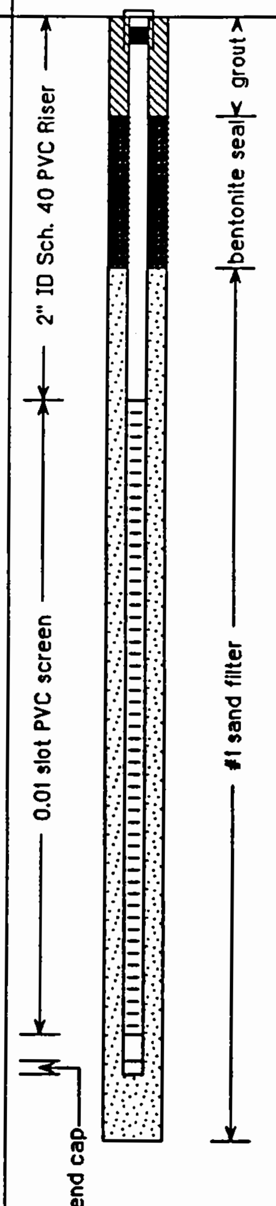


EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS09C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320614.54 E, 372948.25 N*
Location: *Charleston, SC*	Surface Elevation: *4.9 feet msl*
Started at *1620 on 1-13-97*	TOC Elevation: *4.78 feet msl*
Completed at *1715 on 1-13-97*	Depth to Groundwater: *1.96 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.82 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
								Surface conditions: Asphalt.		
5										
								Please refer to Boring Log NBCGFDS09A for detailed lithologic descriptions.		
10										
15										
20										



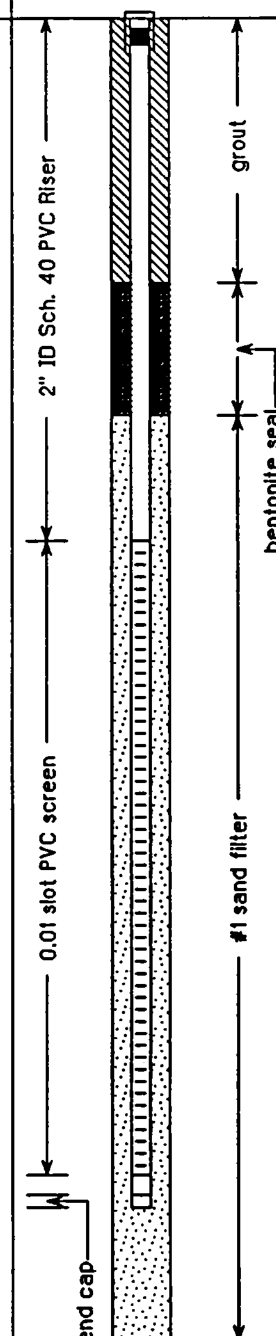
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS10A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320808.02 E, 373222.72 N*
Location: *Charleston, SC*	Surface Elevation: *5.5 feet msl*
Started at *1000 on 1-12-97*	TOC Elevation: *5.33 feet msl*
Completed at *1730 on 1-12-97*	Depth to Groundwater: *3.58 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *1.75 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *18.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.9 to 17.5 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–1								Surface conditions: Asphalt to 1' bgs.	4.5
1–4							CL / SC	Cuttings 1-4' bgs: Sand: black; clayey,	1.5
4–4.2							SM / SC	Sand: dark brown; fine to coarse; silty; clayey; some gravel; loose; moist.	1.3
4.2–6			1	90	0		ML / SM	Silt: tan; some gravel; some very fine to medium sand; stiff; dry.	.3 / .5
6–8			ST-1	100			ML	Shelby Tube: Silt: tan; sandy; stiff; dry.	2.5
10–11.8			2	90	0		ML	Silt: tan to brown; sandy; some gravel; sand lenses in lower section of spoon, medium to coarse, shelly; silt is moderately stiff; wet at 9 feet bgs.	4.5 / 6.3
14–15.7							ML	Silt: tan to olive green; sandy; some rock gravel and shell fragments; soft to medium stiff; wet.	8.5 / 10.2
15.7–16			3	100	190		GW	Gravel and Debris: black; metal throughout; wet.	10.5

WELL DIAGRAM



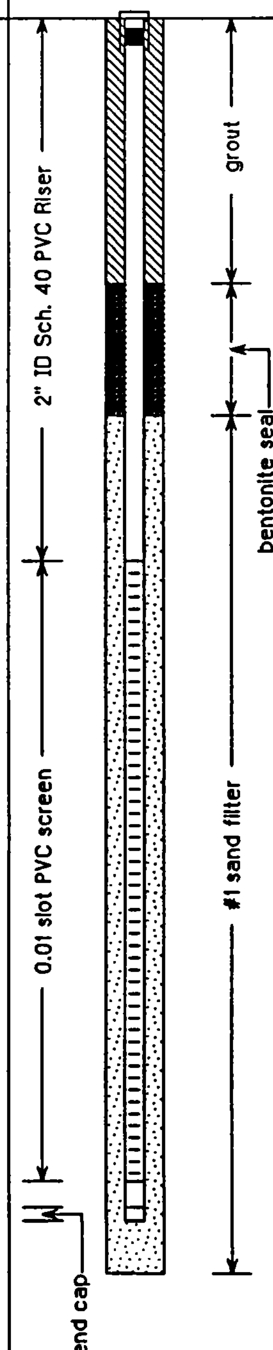
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS10B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320852.48 E, 373168.47 N*
Location: *Charleston, SC*	Surface Elevation: *5.2 feet msl*
Started at *0820 on 1-13-97*	TOC Elevation: *5.05 feet msl*
Completed at *0950 on 1-13-97*	Depth to Groundwater: *2.79 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.26 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *18.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *8.2 to 17.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
							SM	Cuttings logged below. Please refer to Boring Log NBCGFDS10A for detailed lithologic descriptions.	4.5
								Cuttings 0.5-1.5' bgs: Sand: black; fine to coarse; silty; loose	
5								Cuttings 1.5-6' bgs: Sand: blue-gray; fine to coarse; very silty; slightly moist.	
							SC	Cuttings 6-13' bgs: Sand: dark gray; fine to coarse; clayey; loose; moist.	-.8
10									
							SM	Cuttings 13-19' bgs: Sand: tan to black; fine to coarse; very silty; loose; saturated at 15' bgs.	-7.8
15									
									-13.8
20									

WELL DIAGRAM



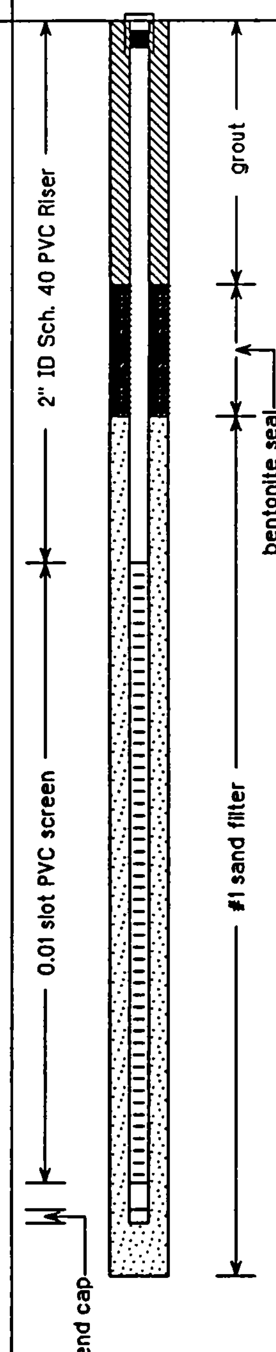
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS10C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2320904.96 E, 373105.56 N*
Location: *Charleston, SC*	Surface Elevation: *6.3 feet msl*
Started at *1050 on 1-13-97*	TOC Elevation: *6.06 feet msl*
Completed at *1230 on 1-13-97*	Depth to Groundwater: *3.92 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.14 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *18.2 feet bgs*
Geologist: *D. Doyle*	Well Screen: *8.2 to 17.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
							FILL	Cuttings logged below. Please refer to Boring Log NBCGFDS10A for detailed lithologic descriptions. Cuttings 0.5-4' bgs: Sand and Gravel: black; clayey; silty; loose; FILL.	2.3
5							CL/ML	Cuttings 4-8' bgs: Silt and Clay: dark green; sandy; soft; moist.	1.7
10								Cuttings 8-13' bgs: Sand: tan; fine to coarse; very silty; moist.	
15							SM	Cuttings from 13-19' bgs: Sand: black; as above but saturated.	12.7
20									

WELL DIAGRAM



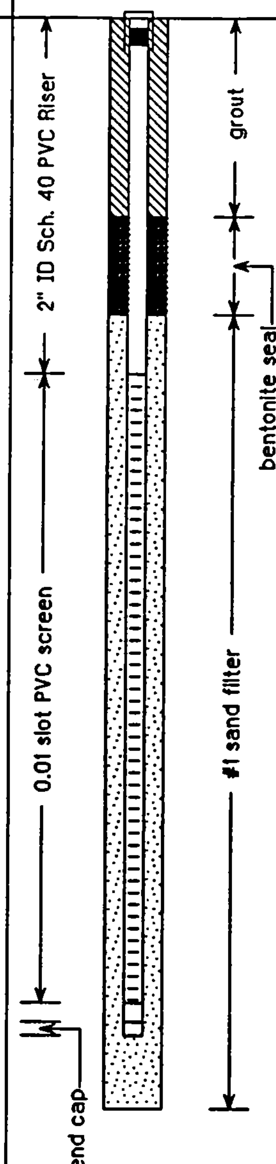
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS11A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319876.97 E, 372729.05 N*
Location: *Charleston, SC*	Surface Elevation: *7.7 feet msl*
Started at *1515 on 1-13-97*	TOC Elevation: *7.61 feet msl*
Completed at *1800 on 1-13-97*	Depth to Groundwater: *4.72 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.89 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15.4 feet bgs*
Geologist: *D. Doyle*	Well Screen: *5.4 to 14.9 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt.	
								Asphalt from ground to 4.0' below ground surface.	
5							SM	Sand: black; fine to medium; very dense; slightly moist; petroleum odor.	2.7
			1	100	30		SM	Sand: gray; fine to medium; silty; dense; saturated.	.7
								Sand: rust brown; fine to medium; silty; dense; saturated.	
			2	90	20				-1.1
10							OL	Shelby tube: Silt: black; clayey; organic; wood fragments; soft; saturated. (tube discarded).	-2.3
									-3
			3	35	45		OL	Cuttings 12-16' bgs: Silt: as above.	-4.3
15									
									-8.3
20									

WELL DIAGRAM



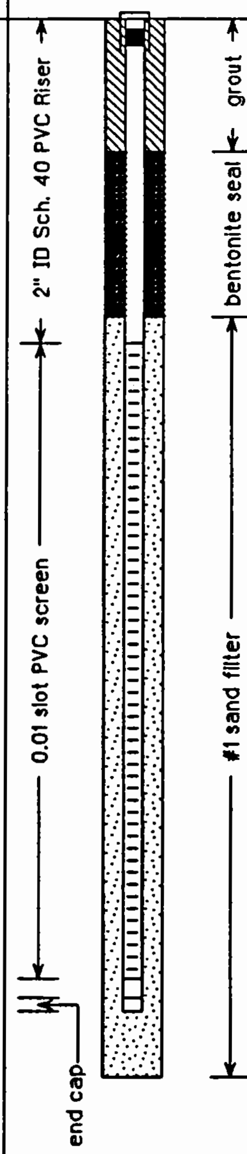
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS11B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319900.52 E, 372753.63 N*
Location: *Charleston, SC*	Surface Elevation: *7.4 feet msl*
Started at *1510 on 1-21-97*	TOC Elevation: *7.17 feet msl*
Completed at *1700 on 1-21-97*	Depth to Groundwater: *4.22 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.95 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15 feet bgs*
Geologist: *D. Felter*	Well Screen: *4.9 to 14.5 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt to 4' bgs. Cuttings logged below. Please refer to Boring Log NBCGFDS11A for detailed lithologic descriptions.	
5							SM/ML	Cuttings 4-12' bgs: Sand: gray; silty; moist to wet; petro odor	3.4
10									
15							OL	Cuttings 12-16' bgs: Clay: gray; silty; marsh clay.	-4.6
20									-8.6

WELL DIAGRAM



EnSafe/Allen & Hoshall

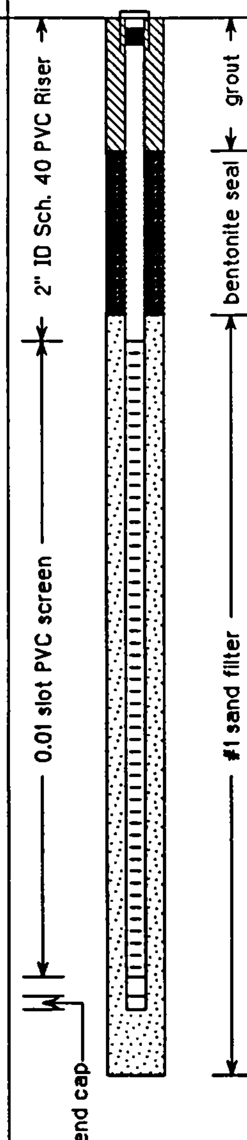
Monitoring Well NBCGFDS11C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319926.49 E, 372720.62 N*
Location: *Charleston, SC*	Surface Elevation: *7.0 feet msl*
Started at *1300 on 1-21-97*	TOC Elevation: *6.77 feet msl*
Completed at *1445 on 1-21-97*	Depth to Groundwater: *5.54 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *1.23 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15 feet bgs*
Geologist: *D. Felter*	Well Screen: *4.9 to 14.5 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–4								Surface conditions: Asphalt to 4' bgs. Cuttings logged below. Please refer to Boring Log NBCGFDS11A for detailed lithologic descriptions.	3
4–10							SM/ML	Cuttings 4-10' bgs: Sand: brown to gray; silty; alternating to sandy silt; moist.	-3
10–16							OL	Cuttings 10-16' bgs: Clay: dark gray; silty; marsh clay.	-9

Depth scale: 5, 10, 15, 20

WELL DIAGRAM



EnSafe/Allen & Hoshall

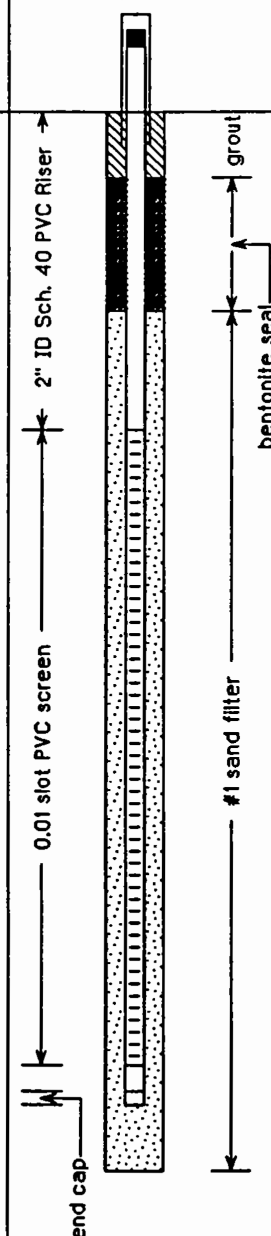
Monitoring Well NBCGFDS12A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318955.49 E, 372895.88 N*
Location: *Charleston, SC*	Surface Elevation: *9.9 feet msl*
Started at *0830 on 1-21-97*	TOC Elevation: *12.26 feet msl*
Completed at *1145 on 1-21-97*	Depth to Groundwater: *6.90 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *5.36 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15 feet bgs*
Geologist: *S. Parker*	Well Screen: *4.8 to 14.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0							Surface conditions: Grass.	
4–6	Yes		1	85	150	CL	Clay: gray to brown; very fine to fine sand; soft; medium plasticity; moist.	5.9 / 5.4
						SC	Sand: green-gray; fine to medium; clayey; low plasticity; wet.	5.1
						OL CL	Clay: dark to lt gray; interbedded w/ clayey sand; low plasticity; soft; wet; petroleum odor.	4.3
8–10	Shelby Tube		ST-1	100		OL SP	Shelby Tube: Clay and Sand: medium to coarse; soft; moist.	1.9 / .1
12–14	Yes		2	100	5	OL CL	Clay: dark gray; sandy; very soft; low plasticity.	2.1 / 2.4
						ML CL	Sandy Silt to Clayey Silt: light gray; mottled orange with coarse sand lenses throughout; wet.	2.9 / 3.2
						SC	Sand: brown to orange; fine to medium; wet.	4.1
						OH	Clay: gray w/ orange mottling; trace sand; stiff; high plasticity; organic.	

Depth scale: 5, 10, 15, 20

WELL DIAGRAM



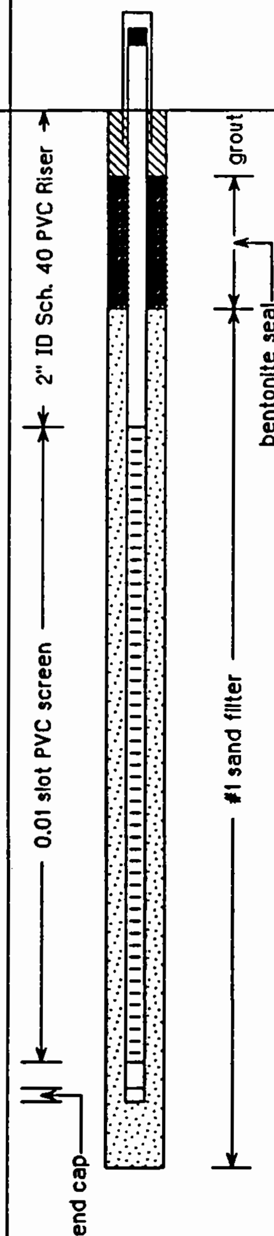
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS12B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318879.38 E, 372861.15 N*
Location: *Charleston, SC*	Surface Elevation: *9.0 feet msl*
Started at *1230 on 1-21-97*	TOC Elevation: *11.47 feet msl*
Completed at *1415 on 1-21-97*	Depth to Groundwater: *6.01 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *5.46 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *4.8 to 14.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass.	
5									
								Please refer to Boring Log NBCGFDS12A for detailed lithologic descriptions.	
10									
15									
20									

WELL DIAGRAM



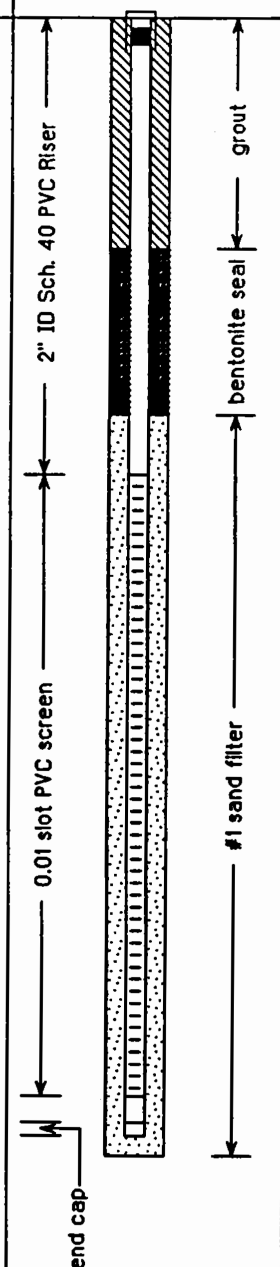
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS13A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318783.24 E, 372785.99 N*
Location: *Charleston, SC*	Surface Elevation: *9.1 feet msl*
Started at *1245 on 1-14-97*	TOC Elevation: *9.03 feet msl*
Completed at *1450 on 1-14-97*	Depth to Groundwater: *3.89 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *5.14 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16.9 feet bgs*
Geologist: *D. Doyle*	Well Screen: *6.9 to 16.3 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0								Surface conditions: Asphalt.	
								Cuttings logged below. Please refer to Boring Log NBCGFDS13D for detailed lithologic descriptions.	
5								Cuttings 0.5–17' bgs: Clay: black; silty; trace gravel and fine to coarse sand; medium stiffness; moist; saturated at 5' bgs.	
							OL		
10									
15									
17									-7.9
20									

WELL DIAGRAM



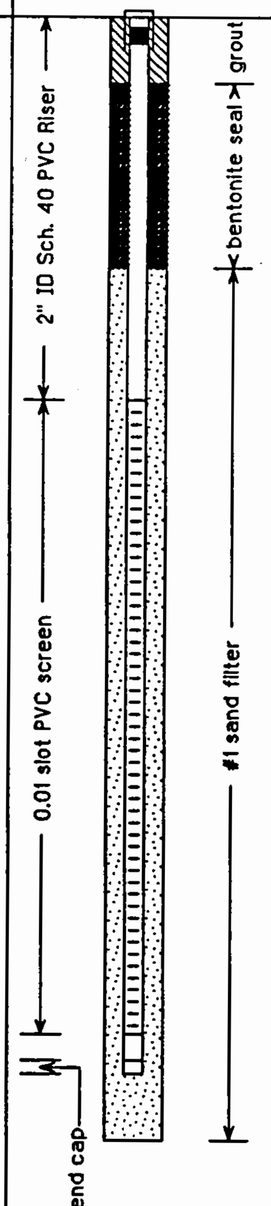
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS13B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318815.25 E, 372749.02 N*
Location: *Charleston, SC*	Surface Elevation: *9.1 feet msl*
Started at *1330 on 1-20-97*	TOC Elevation: *9.08 feet msl*
Completed at *1435 on 1-20-97*	Depth to Groundwater: *1.89 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *7.19 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0								Surface conditions: Asphalt. Please refer to Boring Log NBCGFDS13D for detailed lithologic descriptions.	
5									4.1
5–10							OL OH	Cuttings 5-10' bgs: Clay: black; medium to high plasticity; soft; moist.	
10									-.9
15									
20									

WELL DIAGRAM



EnSafe/Allen & Hoshall

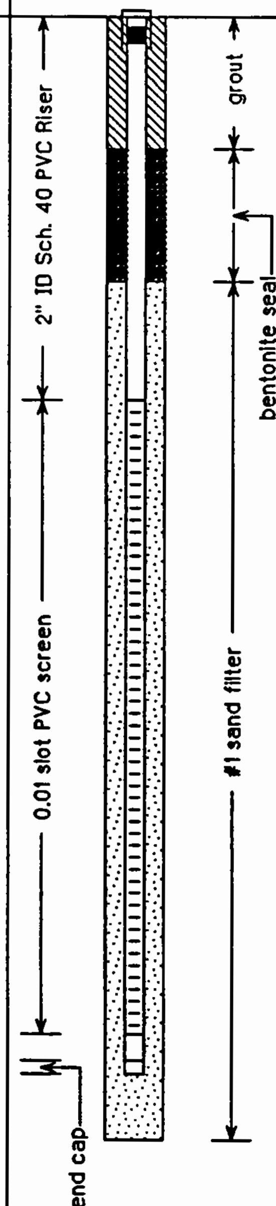
Monitoring Well NBCGFDS13C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318770.25 E, 372720.73 N*
Location: *Charleston, SC*	Surface Elevation: *9.6 feet msl*
Started at *1550 on 1-20-97*	TOC Elevation: *9.47 feet msl*
Completed at *1700 on 1-20-97*	Depth to Groundwater: *2.22 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *7.25 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–2								Surface conditions: Asphalt. Cuttings logged below. Please refer to Boring Log NBCGFDS13D for detailed lithologic descriptions.	7.6
2–10							OH	Cuttings 2-10' bgs: Clay: black; medium plasticity; soft.	.4
10–17							SC / SM	Cuttings 10-17' bgs: Sand: tan; very fine to medium; clayey; silty; wet.	-7.4

Depth scale: 5, 10, 15, 20

WELL DIAGRAM



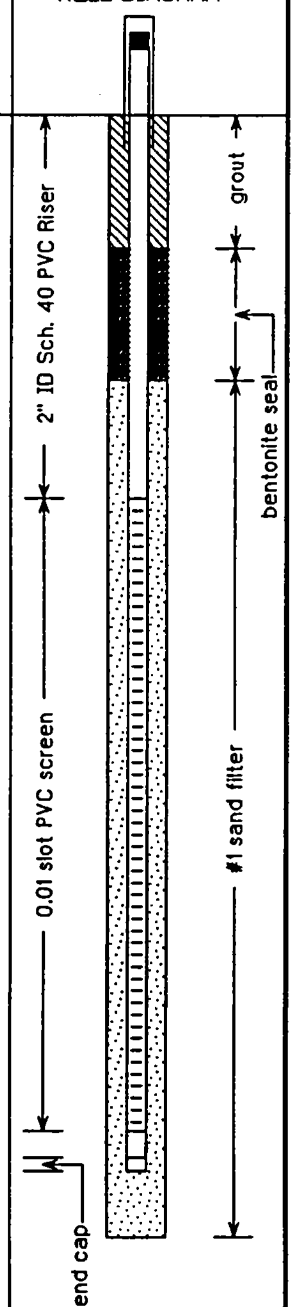
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS13D

Project: *Fuel Distribution System - Naval Base Charleston*	Coordinates: *2318712.74 E, 372765.79 N*
Location: *Charleston, SC*	Surface Elevation: *9.3 feet msl*
Started at *0945 on 1-20-97*	TOC Elevation: *11.83 feet msl*
Completed at *1525 on 1-20-97*	Depth to Groundwater: *5.53 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *6.30 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *D. Felter*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass.	
5							SC / CL	Clay: brown, orange and gray; mottled; sandy; stiff; dry.	4.3 / 3.1
			1	60					
10							CH	Shelby Tube: Top and bottom: Clay: brown and gray; stiff; dry.	.7 / 2.7
			ST-1	100					
15							CL	Clay: blue; sandy; wet. / Clay: gray; sandy; wet.	5.7 / 7.3
			2	80					
20									

WELL DIAGRAM



EnSafe/Allen & Hoshall

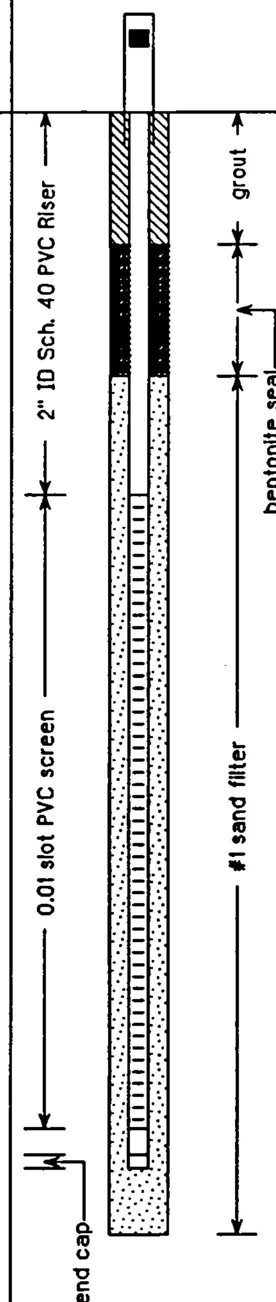
Monitoring Well NBCGFDS13E

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318585.24 E, 372789.50 N*
Location: *Charleston, SC*	Surface Elevation: *8.7 feet msl*
Started at *1550 on 1-20-97*	TOC Elevation: *10.97 feet msl*
Completed at *1805 on 1-20-97*	Depth to Groundwater: *5.54 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *5.43 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *D. Felter*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–6							CL / CH	Surface conditions: Grass. Cuttings logged below. Please refer to Boring Log NBCGFDS13D for detailed lithologic descriptions. Cuttings 0-6' bgs: Clay: brown; silty.	2.7
6–17							OL	Cuttings 6-17' bgs: Clay: black; sticky; saturated; mucky.	-8.3

Depth scale: 5, 10, 15, 20

WELL DIAGRAM



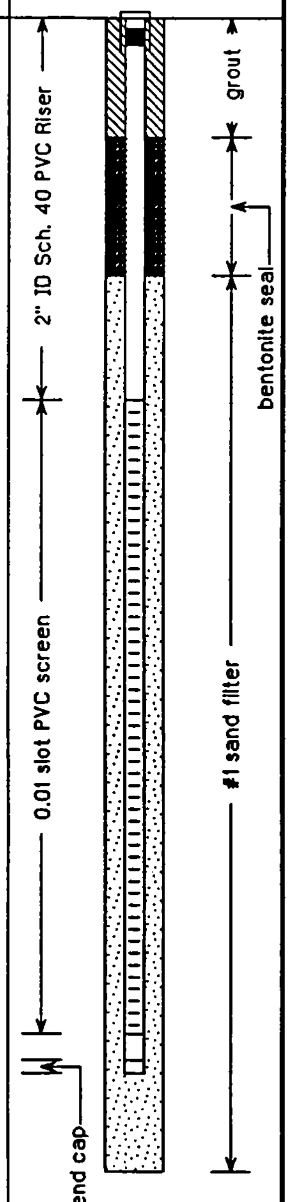
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS14A

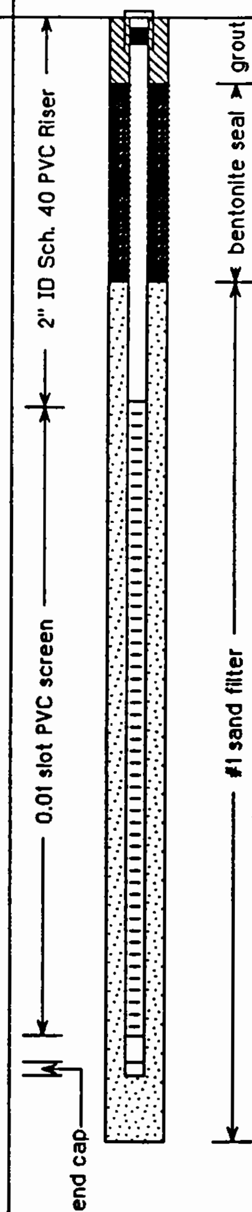
Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318668.14 E, 372641.11 N*
Location: *Charleston, SC*	Surface Elevation: *9.0 feet msl*
Started at *0930 on 1-14-97*	TOC Elevation: *8.87 feet msl*
Completed at *1200 on 1-14-97*	Depth to Groundwater: *2.35 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *6.52 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0							Surface conditions: Asphalt	
0–4						OL CL	Cuttings 0-4'bgs: Clay: black; sandy; silty; some gravel; medium plasticity; soft; moist.	5
4						SM SW	Sand: dark brown; silty; gravelly; loose; moist.	4.6
5						ML	Silt: tan to brown; sandy; some gravel; stiff; dry.	4.1
6			1	85	10	OL CL	Clay: dark gray to black; silty; medium to coarse sand lenses; medium plasticity; soft; moist.	3.1
8–10			ST-1	100		OL	Shelby tube: Clay: black; silty; trace sand; medium plasticity; soft; moist.	1 / -1
12						OL	Clay: black to dark gray; slightly silty w/ trace sand; low to medium plasticity; organic; soft; wet.	-3 / -4
13.8			2	80	5	PT OH	Peat and Clay: gray to brown; medium plasticity; organic; woody fragments; soft.	-4.8
15								
20								

WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCGFDS14B
Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318631.17 E, 372624.71 N*
Location: *Charleston, SC*	Surface Elevation: *8.4 feet msl*
Started at *1000 on 1-20-97*	TOC Elevation: *8.38 feet msl*
Completed at *1130 on 1-20-97*	Depth to Groundwater: *2.70 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *5.68 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)	WELL DIAGRAM
								Surface conditions: Asphalt		
5										
10								Please refer to Boring Log NBCGFDS14A for detailed lithologic descriptions.		
15										
20										

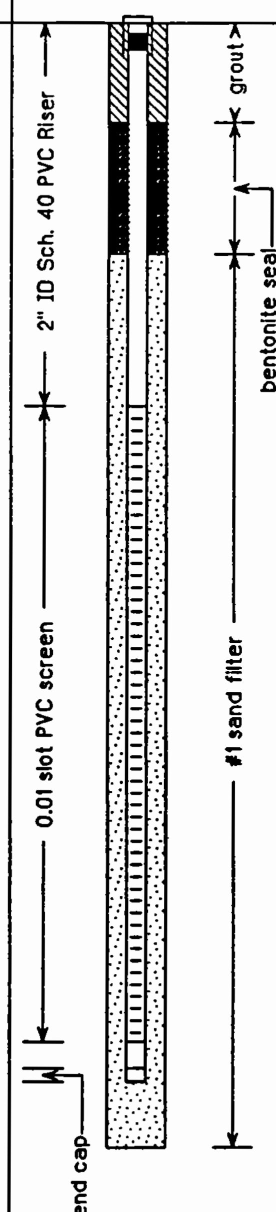
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS14C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318631.17 E, 372673.45 N*
Location: *Charleston, SC*	Surface Elevation: *8.4 feet msl*
Started at *1330 on 1-14-97*	TOC Elevation: *8.34 feet msl*
Completed at *1600 on 1-14-97*	Depth to Groundwater: *2.20 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *6.14 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. # 794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt Concrete to depth of 2.5' bgs.	
5									
10								Please refer to Boring Log NBCGFDS14A for detailed lithologic descriptions.	
15									
20									

WELL DIAGRAM



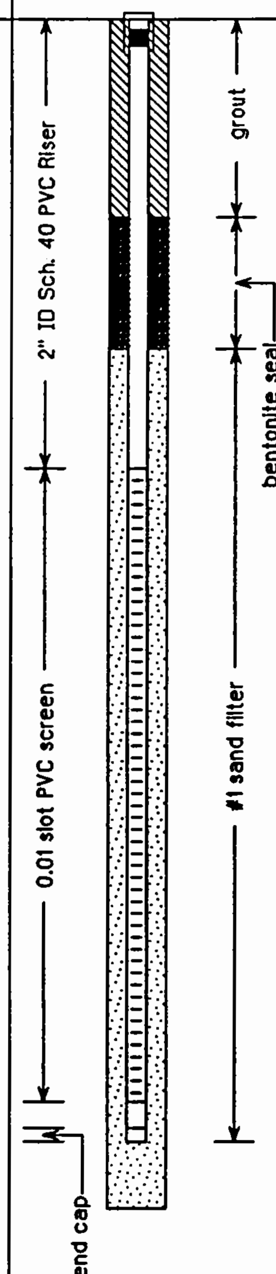
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS15A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319233.04 E, 373055.28 N*
Location: *Charleston, SC*	Surface Elevation: *12.0 feet msl*
Started at *0900 on 1-21-97*	TOC Elevation: *12.01 feet msl*
Completed at *1105 on 1-21-97*	Depth to Groundwater: *7.52 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.49 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *17.0 feet bgs*
Geologist: *D. Felter*	Well Screen: *6.8 to 16.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0							ML	Surface conditions: Asphalt Cuttings 0-5' bgs: Silt: brown; clayey.	
5			1	25			SM	Sand: brown; fine; silty; moist.	7 / 6.5
10			ST-1	100			CL	Shelby tube: Top and bottom: Clay; blue-gray; sandy; saturated; fuel odor.	2 / 0
15			2	100			OL	Clay: gray; silty; organic; soft; saturated.	-3 / -5
20									

WELL DIAGRAM



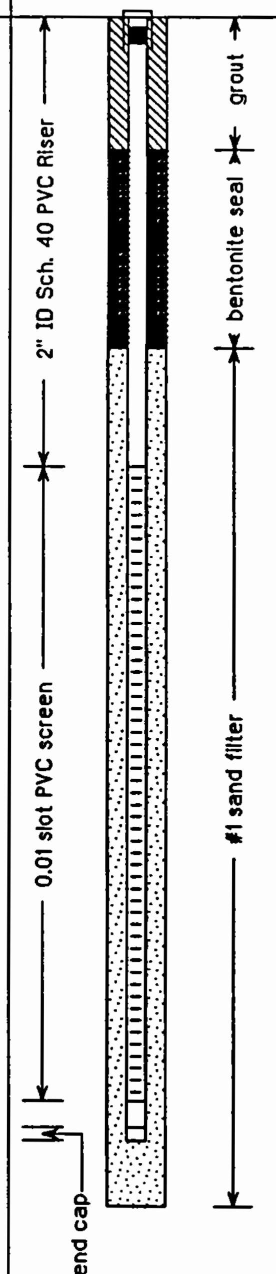
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS15B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319281.19 E, 373119.24 N*
Location: *Charleston, SC*	Surface Elevation: *10.2 feet msl*
Started at *1450 on 1-21-97*	TOC Elevation: *10.10 feet msl*
Completed at *1600 on 1-21-97*	Depth to Groundwater: *5.33 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.77 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *17.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *6.8 to 16.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt	
								Cuttings logged below. Please refer to Boring Log NBCGFDS15A for detailed lithologic descriptions.	7.2
5							SC	Cuttings 3-8' bgs: Sand: tan; clayey.	2.2
							SC / OL	Cuttings 8-10' bgs: Clay: gray; sandy; gradational change to clayey sand throughout interval; saturated at 10' bgs.	-2
10							CL / OL	Cuttings 10-13' bgs: Clay: dark gray; soft; medium plasticity; marsh clay.	-2.8
15									
20									

WELL DIAGRAM



EnSafe/Allen & Hoshall

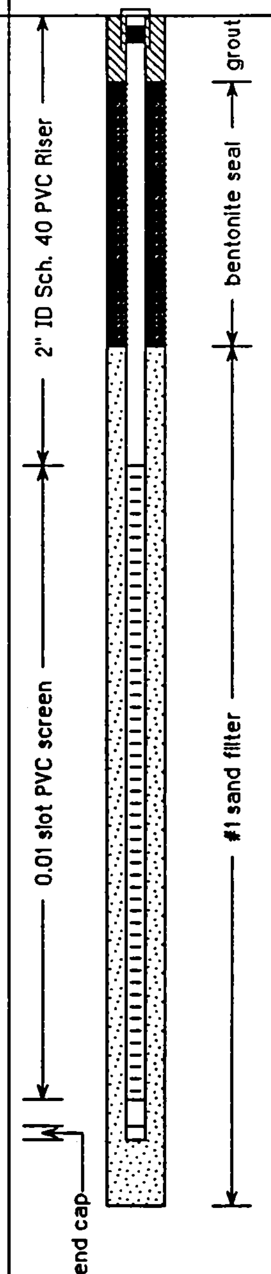
Monitoring Well NBCGFDS15C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319260.89 E, 373021.19 N*
Location: *Charleston, SC*	Surface Elevation: *11.0 feet msl*
Started at *0815 on 1-22-97*	TOC Elevation: *10.90 feet msl*
Completed at *0940 on 1-22-97*	Depth to Groundwater: *6.15 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.75 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *17.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *6.8 to 16.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–2								Surface conditions: Asphalt Cuttings logged below. Please refer to Boring Log NBCGFDS15A for detailed lithologic descriptions.	9
2–6							SM	Cuttings 2-6' bgs: Sand: tan to orange; clayey; soft.	5
6–13							SM/CL	Cuttings 6-13' bgs: Clay: gray; sandy; gradational transition to clayey sand throughout interval; slight petro odor.	2

Depth scale: 5, 10, 15, 20

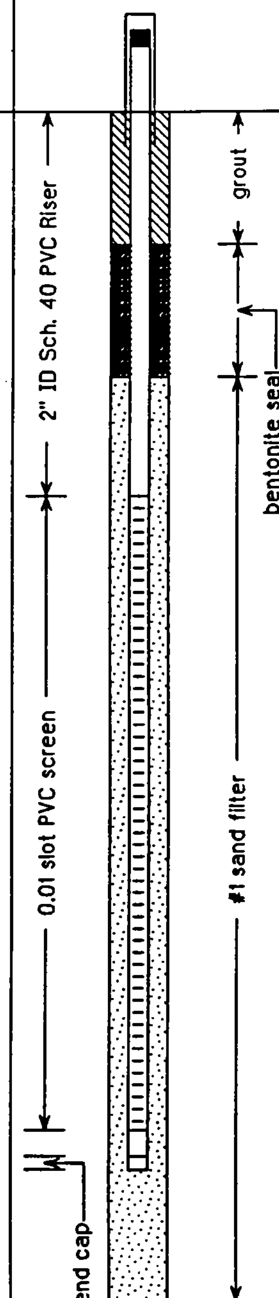
WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCGFDS16A
Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318744.39 E, 373999.82 N*
Location: *Charleston, SC*	Surface Elevation: *8.0 feet msl*
Started at *1350 on 1-22-97*	TOC Elevation: *10.50 feet msl*
Completed at *0800 on 1-23-97*	Depth to Groundwater: *6.27 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.23 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *16.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *5.8 to 15.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass	
							CL	Clay: brown; silty; some fine to medium sand; stiff; slightly moist.	4 / 3.8
5							OL	Clay: gray w/ brown mottling; silty; some sand; soft; organic; medium plasticity.	3
			1	50	0				
							SP	Sand: lt. green-gray; fine to medium; micaceous; w/ orange clayey mottling; interbedded with thin, soft clay lenses; wet.	0 / -1.2
10			2	60	0		CL	Shelby tube: Top: Clay: dark brown; silty; sandy; soft; low plasticity.	-2 / -3.8
			ST-1	90					
							SC	Sand: lt. green-gray; fine to medium; micaceous; clayey; soft; wet.	-6 / -6.4
15							CH / CL	Clay: green-gray; medium plasticity; moderately stiff; w/ mottled brown to orange, thin sand laminae and lenses; moist.	-7.7
			3	83	0				
20									

WELL DIAGRAM



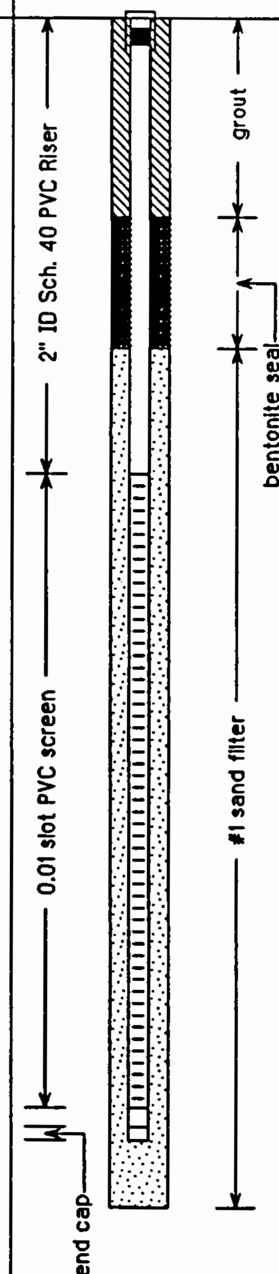
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS16B

Project: Fuel Distribution System - Naval Base Charleston	Coordinates: 2318700.08 E, 374180.76 N
Location: Charleston, SC	Surface Elevation: 8.4 feet msl
Started at 1040 on 1-23-97	TOC Elevation: 8.19 feet msl
Completed at 1135 on 1-23-97	Depth to Groundwater: 2.99 feet TOC Measured: 3/6/97
Drilling Method: 4.25" ID (8.0" OD) HSA with split spoon	Groundwater Elevation: 5.20 feet msl
Drilling Company: GeoTek Drilling (SC Cert. #794)	Total Well Depth: 17 feet bgs
Geologist: D. Felter	Well Screen: 6.9 to 16.5 feet bgs

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt (Road) to 2.5' bgs. Cuttings logged below. Please refer to Boring Log NBCGFDS16A for detailed lithologic descriptions.	
							CL/OL	Cuttings 2.5-5' bgs: Clay: brown; silty; grading to black marsh clay.	5.9
5							OL	Cuttings 5-18' bgs: Clay: dark gray; marsh clay.	3.4
10									
15									
									-9.6
20									

WELL DIAGRAM



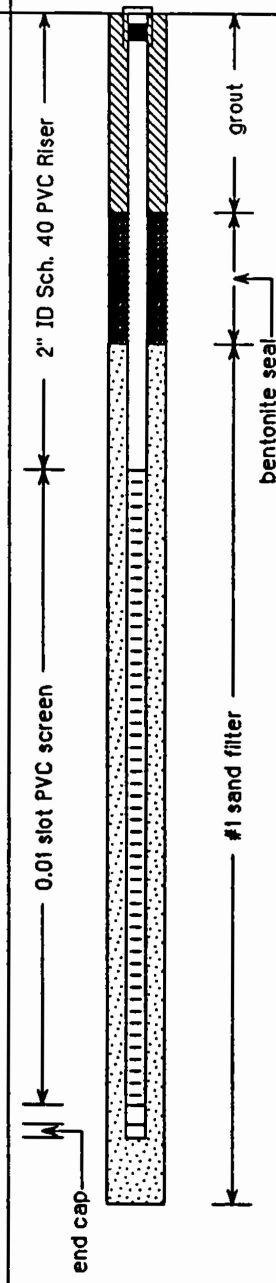
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS16C

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318744.03 E, 374125.72 N*
Location: *Charleston, SC*	Surface Elevation: *9.2 feet msl*
Started at *0920 on 1-23-97*	TOC Elevation: *9.01 feet msl*
Completed at *1018 on 1-23-97*	Depth to Groundwater: *4.94 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.07 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *17 feet bgs*
Geologist: *D. Felter*	Well Screen: *6.9 to 16.5 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt (Road) to 2' bgs. Cuttings logged below. Please refer to Boring Log NBCGFDS16A for detailed lithologic descriptions.	7.2
							ML / CL	Cuttings 2-5' bgs: Silt: dark brown; grading to very silty clay.	
5									4.2
							OL	Cuttings from 5-18' bgs: Clay: dark gray; soft; wet; marsh clay.	
10									
15									
									-8.8
20									

WELL DIAGRAM



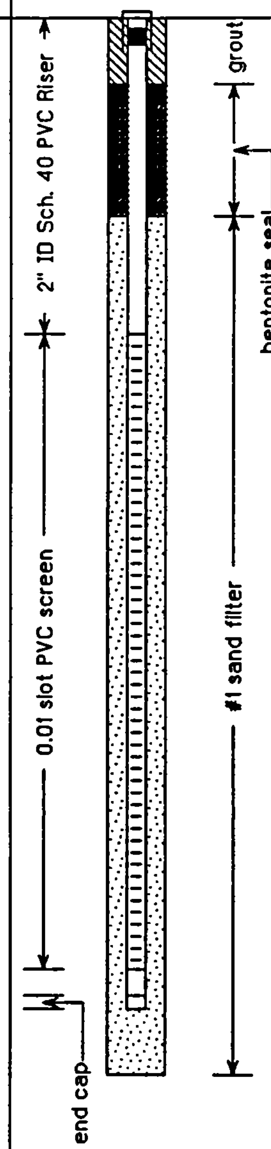
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS17A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319504.28 E, 374258.26 N*
Location: *Charleston, SC*	Surface Elevation: *9.6 feet msl*
Started at *0835 on 1-22-97*	TOC Elevation: *9.32 feet msl*
Completed at *1030 on 1-22-97*	Depth to Groundwater: *4.97 feet TOC* Measured: *3/7/96*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.35 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15.0 feet bgs*
Geologist: *D. Felter*	Well Screen: *4.8 to 14.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0								Surface conditions: Concrete	
							OL	Cuttings 0.5–4' bgs: Clay: dark gray; organic; marsh clay.	5.6
5			1	25			SM	Sand: gray to tan; fine; silty; saturated.	5.1
10			ST-1	100			CL	Shelby tube: Top and bottom: Clay: brown; sandy.	.4 / 2.4
									4.4
15			2	100			OL	Clay: gray-blue; soft; organic; saturated.	5.4
							CL	Clay: brown and gray; little sand; very stiff.	6.4
20									

WELL DIAGRAM



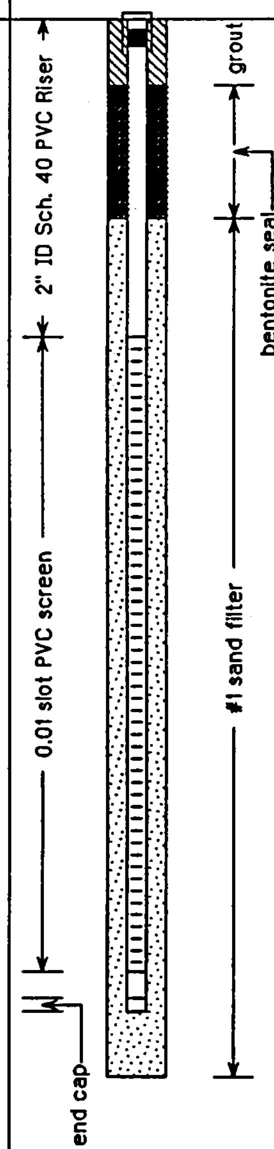
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS17B

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2319571.01 E, 374187.94 N*
Location: *Charleston, SC*	Surface Elevation: *9.2 feet msl*
Started at *1050 on 1-22-97*	TOC Elevation: *9.10 feet msl*
Completed at *1200 on 1-22-97*	Depth to Groundwater: *4.81 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *4.29 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *15.0 feet bgs*
Geologist: *D. Felter*	Well Screen: *4.8 to 14.4 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0–5							CL	Surface conditions: Concrete Cuttings logged below. Please refer to Boring Log NBCGFDS17A for detailed lithologic descriptions. Cuttings 0-5' bgs: Clay: brown; silty.	
5–10							CL/OL	Cuttings 5-10' bgs: Clay: gray; silty; sandy; soft; wet.	4.2
10–14							OL	Cuttings 10-14' bgs: Clay: dark gray; soft; organic; marsh clay.	-.8
14–16							CL	Cuttings 14-16' bgs: Clay: tan; sandy.	-4.8
16									-6.8
20									

WELL DIAGRAM



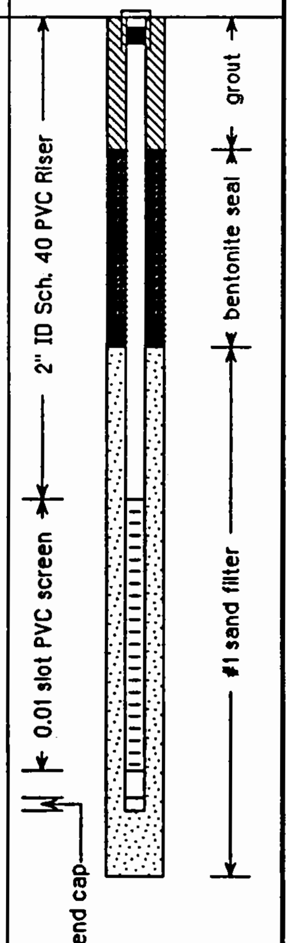
EnSafe/Allen & Hoshall

Monitoring Well NBCGFDS18A

Project: *Fuel Distribution System – Naval Base Charleston*	Coordinates: *2318470.70 E, 376004.24 N*
Location: *Charleston, SC*	Surface Elevation: *8.6 feet msl*
Started at *0930 on 1-23-97*	TOC Elevation: *8.38 feet msl*
Completed at *1155 on 1-23-97*	Depth to Groundwater: *6.29 feet TOC* Measured: *3/6/97*
Drilling Method: *4.25" ID (8.0" OD) HSA with split spoon*	Groundwater Elevation: *2.09 feet msl*
Drilling Company: *GeoTek Drilling (SC Cert. #794)*	Total Well Depth: *12.0 feet bgs*
Geologist: *S. Parker*	Well Screen: *7.3 to 11.6 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Asphalt	
5									
							SM	Sand: mottle gray and brown; silty; some gravel; loose; moist.	2.6
							SC / SP	Sand: gray; medium to coarse; clayey; shelly; loose; wet.	1.9
			1	100	36		OL	Clay: gray; interlaminated w/ very fine to fine sand; organic; medium plasticity.	1.1 / .6
10							OL	Clay: gray; interlaminated w/ silt and very fine sand; organic; low to medium; plasticity; peat interval from 11.3-11.6 ft bgs.	-1.4
							PT		-2.7 / -3
			2	100	59		OL		-3.4
15									
20									

WELL DIAGRAM



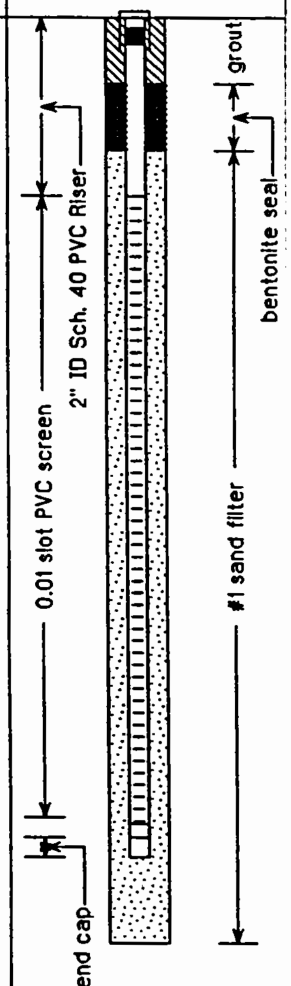
EnSafe/Allen & Hoshall

Monitoring Well NBCF619003

Project: *ZONE F – Naval Base Charleston*	Coordinates: *2319994.81 E, 372789.81 N*
Location: *Charleston, SC*	Surface Elevation: *6.4 feet msl*
Started at *12:30 on 08-29-96*	TOC Elevation: *6.36 feet msl*
Completed at *13:45 on 08-29-96*	Depth to Groundwater: *3.01 feet TOC* Measured: *12/18/96*
Drilling Method: *4.25" ID (7.5" OD) HSA with split spoon sampler*	Groundwater Elevation: *3.35 feet msl*
Drilling Company: *Alliance Environmental (SC cert. #889)*	Total Well Depth: *12.7 feet bgs*
Geologist: *D. Doyle*	Well Screen: *2.7 to 12.1 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: 0.0 – 0.2 asphalt; 0.2 – 0.9 gravel; 0.9 to 1.1 asphalt.	
5							SM	Sand: dark and light brown laminated; fine; some silt; dense; wet.	2.4 / 1.7
			1	35	5700		OL/ML	Silt and clay: dark gray and black; high organic; soft; saturated.	-.4 / -.6
			2	50	280				
10							OL/ML	Silt and Clay: dark gray and black; high organic; soft; saturated.	-3.6
			3	100	1785				-5.6
15									
20									

WELL DIAGRAM



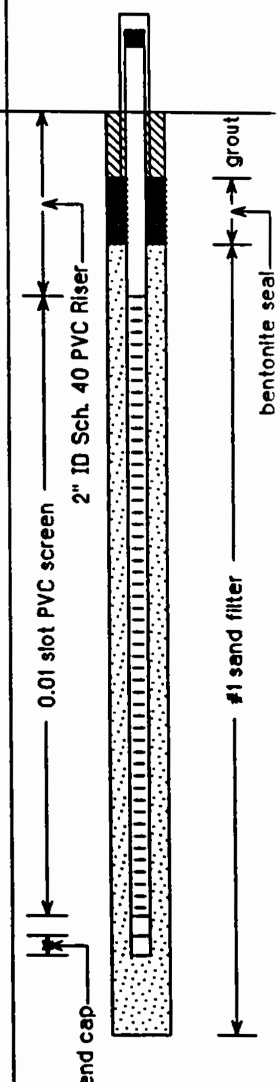
EnSafe/Allen & Hoshall

Monitoring Well NBCGGDG002

Project: ZONE G - Naval Base Charleston	Coordinates: 2318989.64 E, 372797.26 N
Location: Charleston, SC	Surface Elevation: 8.5 feet msl
Started at 10:15 on 08-28-96	TOC Elevation: 10.96 feet msl
Completed at 11:45 on 08-28-96	Depth to Groundwater: 4.77 feet TOC Measured: 12/18/96
Drilling Method: 4.25" ID (7.5" OD) HSA with split spoon sampler	Groundwater Elevation: 6.19 feet msl
Drilling Company: Alliance Environmental (SC cert. #889)	Total Well Depth: 12.8 feet bgs
Geologist: D. Doyle	Well Screen: 2.8 to 12.2 feet bgs

DEPTH IN FEET	SAMPLE NO.	% RECOVERY	PID (ppm)	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
					Surface conditions: Grass	
				CL	Clay: brown; silty; trace organic content; soft; moist.	5.5
				OL	Clay: black; silty; high organic content; soft; moist.	4.9
5	1	20	0			
					Shelby tube (6-8'): Top: Clay: black and brown; silty; high organic content.	
	2	30				
				ML	Silt: brown; sandy (fine to coarse); soft; saturated.	0
10	3	100	540	CL	Clay: gray; silty; trace fine to coarse sand; soft; saturated.	-1.5 / -2
				ML SM	Silt: brown; sandy (fine to coarse sand); loose; saturated.	-3.5
	4	75	0	CL	Clay: gray; sandy (fine to coarse); silty; soft; saturated.	-5 / -5.5
15						
20						

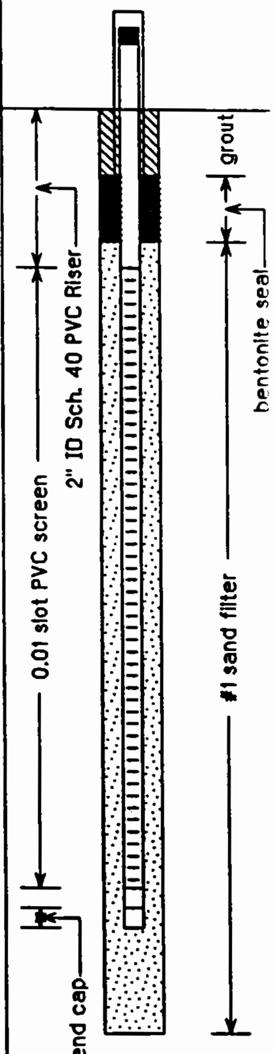
WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCG638001
Project: ZONE G - Naval Base Charleston	Coordinates: 2321520.61 E, 372285.01 N
Location: Charleston, SC	Surface Elevation: 7.4 feet msl
Started at 09:00 on 09-11-96	TOC Elevation: 9.87 feet msl
Completed at 10:30 on 09-11-96	Depth to Groundwater: 7.78 feet TOC Measured: 12/18/96
Drilling Method: 4.25" ID (7.5" OD) HSA with split spoon sampler	Groundwater Elevation: 2.12 feet msl
Drilling Company: Alliance Environmental (SC cert. #889)	Total Well Depth: 12.4 feet bgs
Geologist: D. Doyle	Well Screen: 2.4 to 11.8 feet bgs

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: Grass	
5							OL	Clay: black; silty; high organic content; soft; saturated.	3.4
			1	100	0				1.4
								Shelby tube (6-8'): Bottom: Clay: gray-brown; silty; soft; saturated.	
			2	100			SM	Sand: brown; coarse; silty; loose; saturated.	-.6
									-1.6
10			3	50	220		ML	Silt: yellow-brown; some medium to coarse sand; soft; saturated.	-2.6
									-3.6
			4	50	50				
15									
20									

WELL DIAGRAM



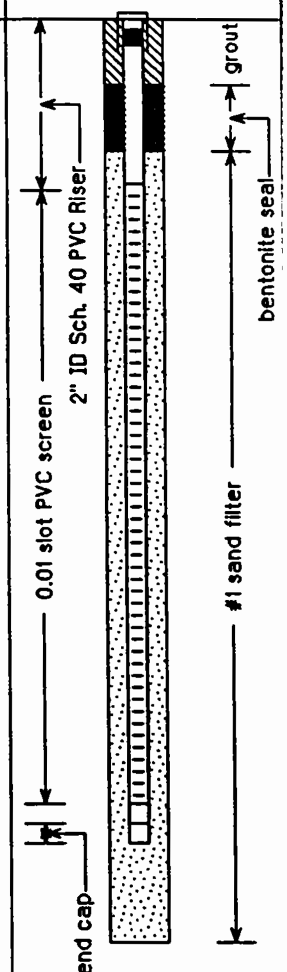
EnSafe/Allen & Hoshall

Monitoring Well NBCG011001

Project: *ZONE G – Naval Base Charleston*	Coordinates: *2319716.3 E, 371889.2 N*
Location: *Charleston, SC*	Surface Elevation: *10.4 feet msl*
Started at *14:00 on 09-09-96*	TOC Elevation: *10.14 feet msl*
Completed at *15:30 on 09-09-96*	Depth to Groundwater: *6.66 feet TOC* Measured: *12/18/96*
Drilling Method: *4.25" ID (7.5" OD) HSA with split spoon sampler*	Groundwater Elevation: *3.48 feet msl*
Drilling Company: *Alliance Environmental (SC cert. #889)*	Total Well Depth: *12.5 feet bgs*
Geologist: *D. Doyle*	Well Screen: *2.5 to 11.9 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface condations: Grass	
5							CL SC	Interbedded sand and clay: brown and gray mottled; fine to medium; stiff; moist.	6.4 / 4.9
			1	75	0		CL SC	Interbedded sand and clay: as above.	4.4 / 2.9
			2	75	0			Shelby tube (8-10' bgs): bottom: Sand: gray; medium; some silt; dense; saturated.	
10			3	100			SM	Sand: gray; medium; silty; loose; saturated.	.4
							SM	Sand: red-brown; medium; silty; loose; saturated.	-1.1
			4	75	0				
15									
20									

WELL DIAGRAM



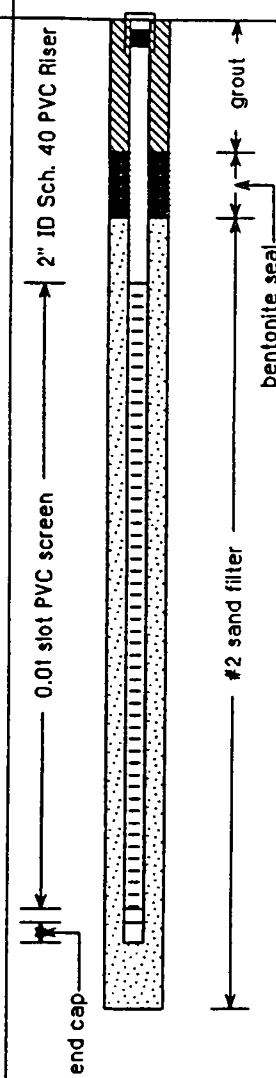
EnSafe/Allen & Hoshall

Monitoring Well NBCF620003

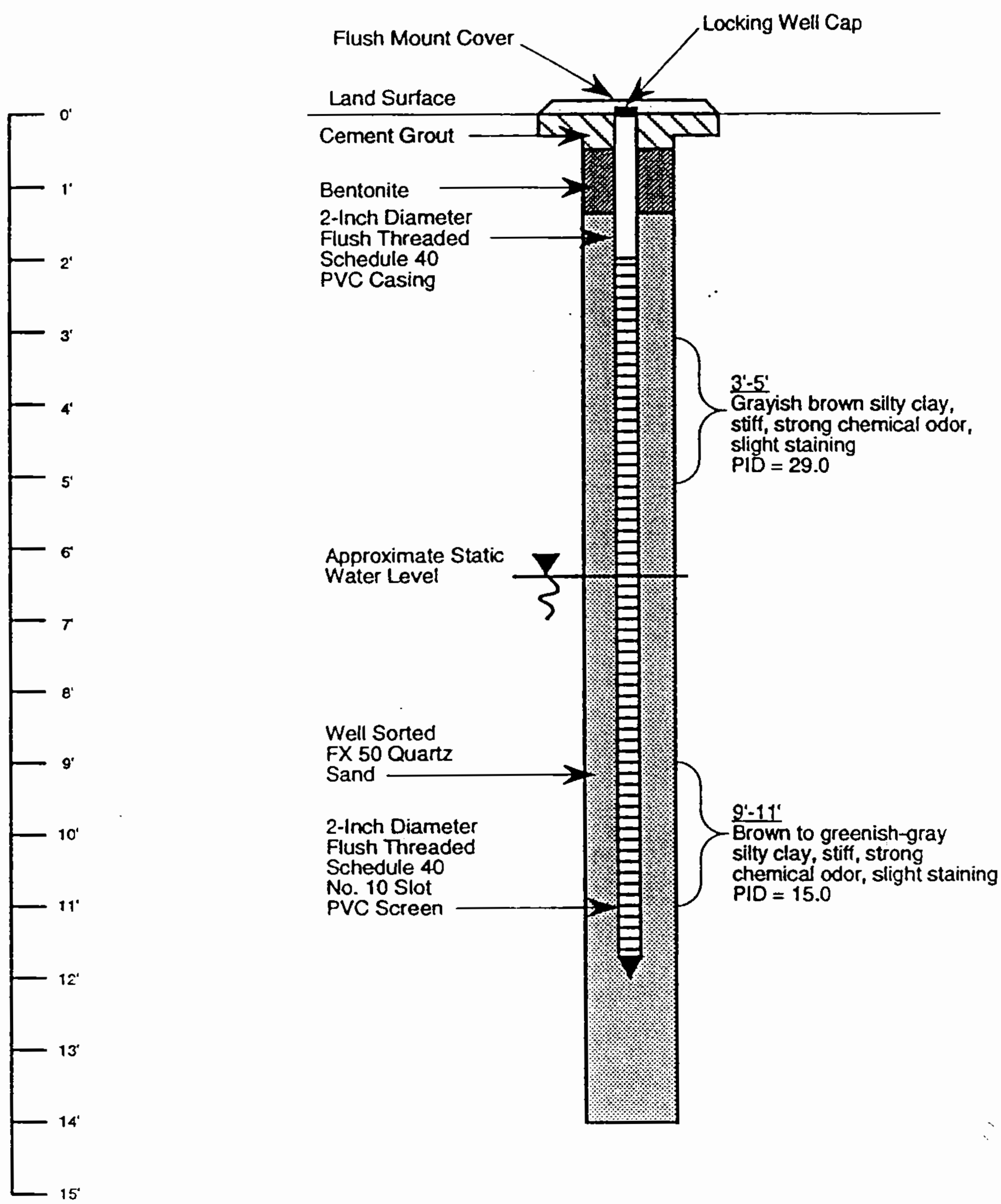
Project: *ZONE F – Naval Base Charleston*	Coordinates: *2320391.32 E, 373075.67 N*
Location: *Charleston, SC*	Surface Elevation: *10.4 feet msl*
Started at *0830 on 4-17-97*	TOC Elevation: *10.49 feet msl*
Completed at *0920 on 4-17-97*	Depth to Groundwater: *6.55 feet TOC* Measured: *4-29-97*
Drilling Method: *4.25" ID (7.5" OD) HSA with split spoon sampler*	Groundwater Elevation: *3.94 feet msl*
Drilling Company: *Miller Drilling (SC cert. # 1236)*	Total Well Depth: *14.0 feet bgs*
Geologist: *SHW*	Well Screen: *4.0 to 13.5 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
0								Surface conditions: gravel and grass.	
							FILL	Fill: loose, medium grain, brown sand with gravel.	7.4 / 6.9
5			1	25	0				
10			2	0			CL / CH	Clay: green; sandy; fat; tight; stiff; damp.	.4
							SC	Sand: medium to coarse; loose; clayey; wet.	-.6
			3	70	0				-1.6
							SC	Sand: green; as above w/ low plasticity clay.	-2.6
							CH	Clay: red-green mottled; silty; fat; tight; damp.	-3.6
15			4	100	0				-4.6
20									

WELL DIAGRAM



Date Installed: 6/14/96
Method: Hollow Stem Auger Drill Rig
Latitude: 32°51'27"
Longitude: 79°57'28"
SC Certified Well Driller: Mark Welsh, #1113



NOTE: PID Measured With HNu Photoionization Detector, Model# P1-101
PID Concentration Reported in Parts Per Million (ppm)

GENERAL ENGINEERING LABORATORIES, INC.
environmental consulting and analytical services
P.O. BOX 30712
CHARLESTON, SC 29417
(803) 556-8171

PROJECT: cpwc00296

EVALUATION OF BASELINE ENVIRONMENTAL CONDITIONS PROPOSED CPW LEASE AREAS NAVAL BASE CHARLESTON CHARLESTON, SOUTH CAROLINA

WELL CONSTRUCTION LOG

MW-14

DATE: June 19, 1996

DRAWN BY: KEC

APPRV. BY: TDJ

EnSafe/Allen & Hoshall

Monitoring Well NBCEGDE012

Project: *ZONE E – Naval Base Charleston*	Coordinates: *2318519.82 E, 375916.46 N*
Location: *Charleston, SC*	Surface Elevation: *8.5 feet msl*
Started at *1345 on 9-29-95*	TOC Elevation: *8.41 feet msl*
Completed at *1620 on 9-29-95*	Depth to Groundwater: *7.98 feet TOC* Measured: *3/13/96*
Drilling Method: *4.25" ID (7.5" OD) HSA with split spoon*	Groundwater Elevation: *0.43 feet msl*
Drilling Company: *Atlantic Drilling (SC cert #1210)*	Total Well Depth: *15 feet bgs*
Geologist: *J. Williams*	Well Screen: *5 to 14 feet bgs*

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: asphalt	
5			1	100	0		SP	Sand: orange-red, oxidized, with some coarse gravel, grading to well-sorted gray sand.	4 / 2
10			2	100	0		SP	Sand: white with brown oxidized stains throughout, saturated from 9.5-10.5'.	1 / 3
15			3	100	0		SP	Sand: light tan, saturated grading to dark gray in color.	6 / 8
20									

WELL DIAGRAM