GEOTECHNICAL STUDY
WOODLANDS WASTEWATER TREATMENT PLANT NO. 2
TCB JOB NO. 13-27000-105
WOODLANDS, TEXAS

Prepared For

TURNER COLLIE & BRADEN, INC.
HOUSTON, TEXAS

Prepared By

MCBRIDE-RATCLIFF AND ASSOCIATES, INC.
HOUSTON, TEXAS

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McBride-Ratcliff and Associates, Inc.
Raytheon Engineers & Constructors

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Turner Collie & Braden, Inc.
P.O. Box 130089
Houston, Texas 77219

ATTENTION: Mr. Michael G. Baugher, P.E.

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Introductory Summary

Presented here are the findings of our geotechnical study for the Woodlands Wastewater Treatment Plant No. 2 located southeast of Cochran's Crossing in Woodlands, Texas. You authorized our work with the executed *Subconsultant Agreement* and Purchase Order No. 4504. We performed our study in general accordance with our proposal, MRA Proposal No. 94-P731, dated November 3, 1993, and changes to the field program which you outlined prior to notification to proceed.

The principal finding of our study is that the stratigraphy encountered within the project borings located in the Phase One Development area consists primarily of clayey sands, silty fine sands, and sandy silts to the 5-ft to 20-ft depths explored. In Boring CB-17, located at the lift station site, alternating strata of cohesionless to semi-cohesive soils and cohesive soils were encountered to the 60-ft depth explored. Except for Boring CB-21, the soils encountered to 2 ft to 5-ft depths at each boring location were interpreted to be fill soils. In Boring CB-21, which was located in a higher area of the site, the fill thickness was interpreted to be about 20 ft.

The ground surface elevation of the Phase Two Development area appears to be about 8 ft to 10 ft higher than the Phase One area. On the basis of the soil conditions observed in Borings CB-27 through CB-31, the soils within the upper 8-ft to 17-ft depth were interpreted to be fill soils and were underlain by cohesionless soils to the 30-ft depth explored. The fill soils consist primarily of clayey sands, silty fine sands, and sandy silts; however, in Boring CB-30 about 11 ft of the 17-ft fill thickness was visually classified as ash. The ash was damp during drilling and collapsed during sampling. The fill soils contained wood fragments, nails, and other debris.

The grades of the pavement were not known at the time of our study. The potential exists that both sandy clay and silty fine sands to clayey sands may be encountered at the pavement subgrade. Because of the mixed soil conditions, we recommend that a hydrated lime-fly ash stabilizer be considered to stabilize the pavement subgrade soils to 6-in. depth. The use of a hydrated lime-fly ash stabilizer will eliminate the need to identify and differently treat the more sandy areas from more clayey areas. Lime-fly ash stabilization should be in general accordance with the TxDOT Specifications, Item 265, and should be compacted to at least 95% of the maximum dry density within three percentage points of the optimum moisture content (ASTM D 698). For planning purposes, 4% hydrated lime and 8% fly ash, by dry weight, may be used for the subgrade soils. Actual stabilizer requirements should be verified after grading operations have been completed. Rigid pavement thicknesses for areas with passenger car and light pick-up truck traffic could be 5 in. For heavier trucks, such as small delivery trucks and driveway areas, 6-in. thick pavement should be considered. A 7-in. thick pavement should be used for heavy trucks such as 18-wheelers and dumpster unloading type vehicles.

The lift station depth may approach 50 ft. The stratigraphic conditions observed in Boring CB-17, located at the proposed lift station site, consist of alternating strata of cohesive and cohesionless soils to the 60-ft depth explored. Sandy clay soils were encountered from ground surface to about 15-ft depth and were underlain to about 20-ft depth by silty fine sands. These sands were underlain by sandy clays to about 28-ft depth, fine sands to about 38-ft depth, and sandy clays and clays to about 56-ft depth. A deeper fine sand stratum was encountered below 56-ft depth to the 60-ft boring depth. Excavations for the lift station bearing at about 50-ft depth are expected to penetrate both cohesive and waterbearing cohesionless soils and terminate within cohesive soils. We recommend that the lift station base not extend below 54-ft depth to assure bearing within clay soils. The recommended design gross bearing pressure for the lift station base located at approximately 50-ft depth would be 3500 psf. This bearing pressure assumes that the lift station base is bearing in competent, sandy clays to clays.

Below-grade units will be constructed throughout the Phase One area with unit bases located at 4-ft to 12-ft depths. Excavations for the below-grade units are expected to terminate in both cohesionless and cohesive soils. The thickener, constructed in the vicinity of Boring CB-16, is expected to penetrate the surficial clayey sand fill and terminate within the silty fine sands. The aeration/digester basin excavations are expected to terminate within clayey sand fill soils. The clarifier and return sludge pump station excavations are expected to terminate within clayey sands and silty fine sands. Free water was not encountered within the depths to be excavated for the below-grade structures; however, the borings contained water when water-level measurements were made 24 to 48 hours after completion of drilling. During periods of inclement weather, water may become trapped within the upper surface soils; such water can likely be handled with sumps and pumps. While we do not expect excavations within the upper 12-ft depth to encounter waterbearing soils, the Contractor should understand that these soils may be waterbearing during construction. Slab foundations constructed on undisturbed, clayey sands to silty fine sands may be designed using an allowable gross bearing pressure of 3000 psf. If footings are used, an allowable gross bearing pressure of 3500 psf could be used.

Principal structural loads for the at-grade structures within the Phase One Development areas may be supported on either drilled pier-grade beam foundation systems or slab-on-grade foundation systems. If a drilled pier system is used, drilled straight-sided shafts may bear 8 ft below the grade existing at the time of this study. The 8-ft bearing depth does not account for any fill which may be placed to achieve the desired floor slab elevations. The footing shaft should be extended to account for the fill thickness at any given footing location. Footings may be sized for an allowable total gravity load net bearing pressure (live load and dead load) of 4000 psf, with a maximum allowable dead load pressure of 2700 psf. The recommended pressures may be increased by 33% for transient loading conditions, such as wind. Our recommendations include a factor of safety of 2 for total load, and a factor of safety of 3 for dead load.

Rigid slab design standards are provided in the *Criteria for Selection and Design of Residential Slab-on-Ground,* PB-261-556, developed by the Building Research Advisory Board (BRAB) for the Federal Houston Administration. A soil support index of 0.95 could be used in the design. Recommended PTI parameters are based on the predominant soil type, estimated percentage of clay mineral, and type of clay mineral composing the soil. The clay content was taken as 30%, the minimum clay content for which the procedure is applicable. Considering an edge moisture variation distance of 4.0 ft for center lift and 5.0 ft for edge lift, differential soil movements of 0.28 in. for center lift and 0.23 in. for edge lift could be used in the design.

Project Description

Woodlands Wastewater Treatment Plant No. 2 will be located off Research Forest Drive, southeast of Cochran's Crossing in Woodlands, Texas (Key Map 217T). Fill soils have been placed at the site; however, the lateral and vertical extent of the fill and the fill quality are not known. A lift station and ground storage tank are currently located at the site. MRA previously performed a geotechnical study at the site (MRA Project No. 82-0522, dated January 5, 1983). The site layout is included on Figure 1.

The wastewater treatment plant will include a lift station, bar screen and grit chamber, aeration basins with flow splitting structure, final clarifier, low head filters and chlorine contact basins, chlorine and dechlorination buildings, blower station, return sludge pump station, digester basin, thickener, belt press building, operations building, stand-by generator building, Parshall flume, and concrete pavement. The lift station may be as deep as 50 ft. The bar screen and grit chamber will be an at-grade structure with above-grade units. The aeration/digester basins will be about 5-ft deep. The clarifier will be about 12-ft deep. The thickener will be located 5 ft below grade. The chlorine and dechlorination buildings, Parshall flume, belt press building, operations building, and stand-by generator will be at-grade structures. The chlorine basin and low head filters will be based at 8-ft depth, and the return sludge pump station will be based at 12-ft depth.

Scope of Study

The objectives of this study were to explore soil and groundwater conditions and to develop foundation design recommendations and construction guidelines for individual treatment units and to provide subgrade preparation recommendations for the at-grade paving areas. To accomplish our objectives, our study included a field exploration, laboratory testing, and evaluation of the field and laboratory data to develop our design recommendations. Details of each phase, our findings, and our recommendations are addressed in subsequent sections of this report.

Field Exploration

The field exploration consisted of drilling 16 soil borings, Borings CB-17 through CB-31, to 5-ft to 60-ft depths. The approximate locations of the borings are shown on Figure 1. The boring locations were staked in the field via survey by your subcontractor prior to mobilization of drilling equipment. The borings were drilled on November 3 and 4, 1994, using buggy-mounted drilling equipment. Our field operations were in general accordance with ASTM D 1452. Soils typically were sampled at continual 2-ft intervals to 10-ft depth and at a 5-ft interval thereafter.

Soil Sampling. Cohesive soils typically were obtained by hydraulically pushing a 3-in. diameter, thin-walled tube a distance of about 24 in. Our field sampling procedure was conducted in general accordance with the *Standard Practice for Thin-Walled Tube Sampling of Soils* (ASTM D 1587). Our field technician extruded the soil samples in the field, visually classified the recovered soils, and obtained a penetration resistance measurement of the recovered soils using a calibrated pocket penetrometer. Representative portions of each recovered soil sample were placed into secure containers and transported to our laboratory.

Cohesionless and semi-cohesive soils were sampled by driving a 2-in. diameter, split-barrel sampler. The sampler was driven about 18 in. by blows from a 140-lb hammer falling 30 in. Our sampling procedure was in general accordance with the *Standard Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D 1586). Our field technician recorded the number of blows required to drive the sampler through each 6-in. interval. These blow counts are shown on the boring logs. The sum of blows required to penetrate the final 12 in. is the Standard Penetration Test (SPT) "N" value. Our technician visually classified the recovered soil in the split-barrel sampler and placed representative portions in glass jars with screw top caps.

Piezometer Installation. One piezometer was installed within Boring CB-17, located at the proposed lift station site, to evaluate long-term water-level conditions. The approximate piezometer location is shown on Figure 1.

The piezometer was constructed with 1.25-in. diameter PVC riser and a 10-ft slotted PVC screen. The screen annulus was backfilled with a uniform fine sand. A bentonite seal was placed above the filter sand to ground surface to reduce the piezometric influences from overlying soil strata. The top of the piezometer extended about 3 ft above ground surface and was vented to permit equilibrium with atmospheric pressures. Details of the piezometer construction are recorded on the piezometer installation report included in Attachment B.

After installation, the piezometer was developed to remove excess drilling fluids and sediments. The piezometer was developed using bailer techniques until the discharge water was visually clear of sediments. The dates of piezometer completion and development are shown on the piezometer log. The recorded water-level readings are shown on the individual piezometer log.

Water-Level Measurements. The soil borings were dry augered until free water was encountered or to the total depth of boring to evaluate the presence of perched or free-water conditions. The observed depth to water in the open boreholes during drilling and the observed depth to water about 24 to 48 hours after completion of drilling are recorded on the boring logs. Long-term water-level measurements were made after the installation and development of the piezometer. The static water-level measurements are referenced from ground surface and are recorded on the piezometer report included in Attachment B.

Laboratory Testing

We performed soil mechanics laboratory tests on selected samples to evaluate the physical and engineering properties of the recovered samples. The type, ASTM designation, and number of tests which we performed are tabulated as follows:

Type of Test	Number of Tests
Natural Water Content (ASTM D 2216)	69
Atterberg Limits (ASTM D 4318)	21
Unconfined Compression (ASTM D 2166)	4
Unconsolidated Undrained Triaxial Compression (ASTM D 2850)	1
Dry Unit Weight	7
Percent Finer than No. 200 Sieve (ASTM D 1140)	18

Boring and Piezometer Logs

Our interpretations of general soil and water-level conditions at the boring locations are included on the boring and piezometer logs. Our interpretation is based on both the visual descriptions and field penetration characteristics of the recovered soils and the results of laboratory testing. The boring logs and a key to the terms and symbols used on the logs are presented in Attachment A. The piezometer log is located within Attachment B.

Subsurface Conditions

The borings indicate subsurface conditions only at the specific locations and time, and only to the depths penetrated. The borings do not necessarily reflect strata variations that may exist between boring locations. In addition to the 16 borings drilled during this study, the stratigraphy at the site was evaluated using the stratigraphic conditions observed in the 15 borings drilled previously at the site (MRA Project No. 82-0522, dated January 5, 1983). The validity of the recommendations is based in part on assumptions about the stratigraphy made by the Geotechnical Engineer. Such assumptions may be confirmed only during earthwork construction. If subsurface conditions different from those described are noted during construction, recommendations in this report must be reevaluated.

Soil Stratigraphy - Phase One Development. The soil stratigraphy encountered within the project borings located in the Phase One Development area consist primarily of clayey sands, silty fine sands, and sandy silts to the 5-ft to 20-ft depths explored. In Boring CB-17, located at the lift station site, alternating strata of cohesionless to semi-cohesive soils and cohesive soils were encountered to the 60-ft depth explored. Except for Boring CB-21, the soils encountered to 2-ft to 5-ft depths (elevations 142 ft to 139 ft) at each boring location were interpreted to be fill soils. In Boring CB-21, which was located in a higher area of the site, the fill thickness was interpreted to be about 20 ft (elevations 156 ft to 136 ft). The classification of soils as fill is based on considerable judgment and the presence of substructure such as roots, organics, debris, or materials within the soil matrix. The actual fill depth, if any, may vary from that interpreted at a given borehole location. Debris, including plastic and fiberglass was encountered in Boring CB-24; this boring was terminated at 4.5-ft depth as a result of refusal. Details of the stratigraphic conditions at each boring location are included on the boring log. A profile of the observed stratigraphy is included on Figure 2.

Soil Stratigraphy - Phase Two Development. The ground surface elevation of the Phase Two Development area appears to be about 8 ft to 10 ft higher than the Phase One area. The elevation data was obtained from the topographic information included on the plan of borings which you supplied. On the basis of the soil conditions observed in Borings CB-27 through CB-31, the soils within the upper 8-ft to 17-ft depth (elevations 138 ft to 132 ft) were interpreted to be fill soils and were underlain by cohesionless soils to the 30-ft depth explored. The fill soils consist primarily of clayey sands, silty fine sands, and sandy silts; however, in Boring CB-30 about 11 ft of the 17-ft fill thickness (elevations 147 ft to 136 ft) was visually classified as ash. The ash was damp during drilling and collapsed during sampling. The fill soils contained wood fragments, nails, and other debris. Details of the stratigraphic conditions at each boring location are included on the boring log. A profile of the observed stratigraphy is included on Figure 2.

Soil Properties. Plasticity indices of the fill soils ranged from 3 to 23, with most less than 10. The fill soils are not expected to exhibit shrink/swell related movements with moisture content variations. However, these soils are sensitive to moisture and will lose strength when saturated. Chemical stabilization is often required to dry the soils during periods of inclement weather. SPT "N" values within the fill and natural soils ranged from 7 blows per ft to 72 blows per ft, with most between 12 and 27 blows per ft. The higher blow counts may indicate the presence of cemented sands or gravel substructure. Fines contents of 4% were measured for the sand fill recovered surficially in Boring CB-25 and 24% to 44% within the more silty fine sand fill encountered in the other borings. A fines content of 56% was measured in the sandy silt fill soils recovered between 4-ft and 6-ft depth in Boring CB-31.

The fill soils encountered surficially in Boring CB-29, were classified as sandy clay soils. An undrained shear strength of 4420 psf was determined for these soils. The undrained shear strength was determined through unconfined compressive strength testing.

In Boring CB-17, an undrained shear strength of 1010 psf, determined through unconsolidated undrained triaxial compression tests, was measured for the cohesive soils recovered between 43-ft and 45-ft depth. This strength corresponds to stiff consistency soils.

A fines content of 10% was determined for the deeper sand soils recovered between 58-ft and 60-ft depth in Boring CB-17. A SPT "N" value of 17 blows per ft was measured within these soils.

Groundwater Conditions. Free water was not encountered during drilling in the Phase One Development area. Water was measured within the open boreholes at 0.6-ft to 19.8-ft depths about 24 to 48 hours after completion of drilling. The shallow water levels are believed to represent water infiltration into the open borehole from the surface. The silty fine sands, clayey sands, and sandy silts are sensitive to moisture and can develop perched water levels as a result of inclement weather.

The project piezometer indicates a 14.5-ft deep water level. This level is located within the natural sand soils and suggests that these soils do not exhibit excess piezometric head. However, the piezometer installation did not isolate the waterbearing layers since the bentonite seal was not located just above the deepest waterbearing zone. We believe the 14.5-ft depth is indicative of the water level within the upper sand layer.

In the Phase Two area, wet sands and caving borehole conditions were encountered in three of the five borings drilled. In Borings CB-27, CB-30, and CB-31, wet, caving soils were encountered at depths of 11.5 ft to 18 ft. Water was observed within the open boreholes at depths ranging from 7.9 ft to 16.9 ft when measured about 24 to 48 hours after completion of drilling.

Site Preparation

Site preparation activities should include stripping, proofrolling, grade adjustments, site drainage, and pavement subgrade preparation. Each of these topics is addressed in the following paragraphs.

Site Stripping. We recommend that areas within building and pavement construction lines should be stripped of roots, debris, and other deleterious matter to a depth of at least 4 in. Unless the stripped soils are cleaned of deleterious material, including roots, we do not recommend that the strippings be used as building or pavement fill.

Proofrolling. After stripping and cuts to the subgrade are completed and before placement of fill for grade adjustments, the exposed subgrade should be proofrolled to detect soft, weak, wet, or poorly compacted areas. Proofrolling will be particularly important because of the presence of fill soils at the site. Proofrolling of the subgrade should be performed with a heavy rubber-tired vehicle, such as a pneumatic-tired roller or a loaded dump truck. All soft, weak, wet, poorly compacted, or pumping areas of the subgrade should be removed and replaced with material of similar classification and density as the adjacent, competent in situ soils. Proofrolling is generally effective to an approximate depth of 12 to 18 in. Deeper, weak strata could be expected to go undetected. Because of the importance of constructing the treatment units and pavement on a competent subgrade, we recommend that the Geotechnical Engineer or his representative monitor the stripping and proofrolling operations.

Grade Adjustments. Fill for grade adjustments and/or trench backfill should be select fill or soils similar to the sandy soils encountered at the site. Select fill should be homogeneous, cohesive soils free of roots, organic matter, and deleterious material. The plasticity index (PI) of select fill should be between 7 and 20, and the liquid limit should be between 15 and 45. Higher PI soils should not be blended with sands to create select fill.

Regardless of fill type, fill should be placed on properly stripped and proofrolled surfaces in maximum 8-in. thick loose lifts. Each lift should be compacted to at least 95% of the standard Proctor maximum dry density (ASTM D 698). The moisture content for select fill during placement and compaction should be within two percentage points dry to four percentage points wet of the optimum moisture content. The moisture content for more sandy fill during placement and compaction should be within two percentage points of the optimum moisture content. The Contractor should be aware that compaction and moisture control of the sandy soils can be difficult. Water should be added judiciously to sandy soils since these soils can pump at moisture contents just above the optimum moisture content. Any fill placement thicker than one 8-in. loose measure lift should be tested and documented by the Geotechnical Engineer.

Site Drainage. The ground surface should be graded at all times to provide positive surface drainage away from construction areas. Water must not be allowed to pond on the surface during construction. Drainage should be maintained throughout the life of the structure to prevent water from collecting adjacent to the unit slabs. Landscaping and irrigation systems should be planned with the understanding that landscaping absorbs moisture from expansive soils making them prone to shrinkage, and irrigation provides moisture making expansive soils prone to swelling. Irrigation also provides a moisture source for the on-site sands which are sensitive to moisture; when these soils become saturated they lose strength. Construction should not proceed if the sandy site soils are saturated. The balance between landscaping and irrigation is delicate and changes as landscaping matures.

Pavement Subgrade Stabilization. The topstratum soils within the proposed paved areas consist of silty fine sands, clayey sands, and some sandy clays. The surficial sands do not exhibit shrink/swell characteristics; however, these soils are moisture sensitive. When the soils become saturated, they lose strength and are unable to support construction equipment. The surficial sandy clays are inferred to have a low shrink/swell potential with variations in moisture. Variations in moisture content in soils below pavement structures typically occur because water infiltrates through joints and cracks within the pavement. Stabilizing the soils immediately below the pavement is an effective means of cutting off the moisture flow.

The decision to stabilize the subgrade should be based upon not only the soil conditions at the site and the anticipated traffic conditions but also upon the life-cycle costs of the pavement system which includes both the subgrade and concrete paving. Our experience suggests that stabilization of the paving subgrade *reduces* life-cycle costs despite the initially higher investment.

Stabilization plays three important roles in the performance of a pavement system. In areas where sandy subgrade is present, infiltration of water through unsealed joints results in wet conditions along the joints. If the sandy soils are not stabilized, the water accumulates within the sandy soils. The soils become saturated and lose strength. As traffic passes across the joint, the wet sands and water are hydraulically pumped upwards through the joints to the surface. A void results beneath the pavement leaving the pavement partially unsupported. As the condition continues, the area of strength loss and loss of pavement support grows until the pavement cracks under load. Cracks then serve as new sources for water migration into the subgrade and the process spreads. Only a pavement that is completely sealed against water infiltration throughout its life will avoid this condition. Unfortunately, most joint sealing is not 100% effective.

With a more clayey subgrade, water penetration through the unsealed joints again results in wet conditions along the joints and swelling of the expansive clays in the supporting soils. Swelling results in cracking of the pavement and, again, additional sources for water migration into the subgrade. Thus, the swelling and cracking spread. Stabilization of clayey soils reduces the tendency of those soils to swell and creates a moisture barrier between the pavement and the underlying expansive clays.

In addition to creating a moisture barrier, the third benefit of stabilization is that the modulus of subgrade reaction (strength) of the in situ soils is increased by factors ranging from 4 to 8. With the increased modulus, the performance of the system is improved either through longer life or increased allowable capacity. For a given allowable capacity, stabilized subgrade soils allow the use of thinner pavement sections because of the increase in subgrade strength. The thickness of the pavement on stabilized subgrade is reduced by 5% to 15% compared to thickness on unstabilized subgrade.

The grades of the pavement were not known at the time of our study. The potential exists that both sandy clay and silty fine sands to clayey sands may be encountered at the pavement subgrade. Because of the mixed soil conditions, we recommend that a hydrated lime-fly ash stabilizer be considered to stabilize the pavement subgrade soils to 6-in. depth. The use of a hydrated lime-fly ash stabilizer will eliminate the need to identify and differently treat the more sandy areas from more clayey areas.

Lime-fly ash stabilization should be in general accordance with the TxDOT Specifications, Item 265, and should be compacted to at least 95% of the maximum dry density within three percentage points of the optimum moisture content (ASTM D 698). For planning purposes, 4% hydrated lime and 8% fly ash, by dry weight, may be used for the subgrade soils. Actual stabilizer requirements should be verified after grading operations have been completed.

Remediation of Previously Worked Areas. The Contractor should be aware that satisfactory proofrolling, in-place density tests, or stabilization during the early stages of construction does not imply ultimate acceptance of the work. If the worked areas are used as haul roads, inclement weather occurs, or the areas are permitted to remain open prior to paving, additional proofrolling, in-place density testing, and/or stabilization may be required. Additionally, it is the Contractor's responsibility to maintain the moisture of the subgrade soils within the unit footprints and paved areas until the concrete is placed. The Contractor should be aware that moisture should be introduced into the clayey sands to very sandy clays in a judicious manner. The introduction of water, either intentionally or through inclement weather, may result in pumping areas which had not previously pumped. Such areas will require remediation before construction proceeds.

Pavement Design Thickness

Usage classifications for pavement selection on properly compacted and prepared subgrade soils are as follows:

Vehicle Classification and Traffic Loadings		
Classification	Gross Vehicle Load (lb)	Description
Light	6,000	Cars, Light Trucks & Parking Lots
Medium	10,000	Medium Trucks & Driveways
Heavy	20,000	Heavy Trucks & Roadways

Rigid pavement thicknesses for the various usage classifications are 5 in., 6 in., and 7 in., respectively.

It is essential to maintain the pavement to prevent infiltration of water into the subgrade soils. Allowing water in the subgrade may result in pavement failure and high maintenance costs. Construction joints should be placed such that runoff is not directed parallel to their length; parallel runoff permits water to penetrate the joint and enter the subgrade. Block outs for storm sewer drains should be a minimum of 10 ft x 10 ft or preferably should be constructed as an integral part of the pavement system without construction joints. A plan of construction joints should be prepared and reviewed prior to pavement construction. Periodic maintenance should be performed on the pavement sections to seal any surface cracks and to prevent infiltration of water into the subgrade. Maintenance of cracks will be more frequent and costly if stabilization is not performed.

Lift Station Design and Construction Requirements

The lift station depth may approach 50 ft. The stratigraphic conditions observed in Boring CB-17, located at the proposed lift station site, consist of alternating strata of cohesive and cohesionless soils to the 60-ft depth explored. Sandy clay soils were encountered from ground surface to about 15-ft depth and were underlain to about 20-ft depth by silty fine sands. These sands were underlain by sandy clays to about 28-ft depth, fine sands to about 38-ft depth, and sandy clays and clays to about 56-ft depth. A deeper fine sand stratum was encountered below 56-ft depth to the 60-ft boring depth. Excavations for the lift station bearing at about 50 ft are expected to penetrate both cohesive and waterbearing cohesionless soils and terminate within cohesive soils. We recommend that the lift station base not extend below 54-ft depth to assure bearing within clay soils. Because of the presence of several sand layers, expected to be waterbearing, dewatering will be required to complete the lift station construction. The following sections address sidewall stability, lateral earth pressures, uplift, ground heave, bearing capacity, and dewatering considerations.

Sidewall/Bottom Stability. Caisson excavations for the lift station are expected to penetrate both cohesive and waterbearing cohesionless soils and terminate within cohesive soils. We recommend that the lift station base not extend below 54-ft depth to assure bearing within clay soils. Caisson installations often experience some sloughing and loss of ground near ground surface. Conventional earthwork techniques are required to correct such areas.

Lateral Earth Pressure. Lateral earth pressure is based on the existing natural soil conditions encountered during excavation. During installation, when the structure shell is at design depth but the base is not constructed, equivalent fluid density values above the groundwater depth may be used. This recommendation assumes that transmissive zones are dewatered or that active drainage is occurring along the interface of the moving walls and soil.

The lateral earth pressures can be calculated by multiplying the equivalent fluid density for the natural soil type by the depth below the ground surface. All wall pressures below the design water level must include the effect of groundwater. We recommend using a design water level of about 10 ft for the lift station to provide for some variation in the areal groundwater level. A more conservative design approach would be to place the areal groundwater level at ground surface. The equivalent fluid densities for various soil types are presented in the following table.

EQUIVALENT FLUID DENSITIES (pcf)			
Material Type	Compactive Effort (% of ASTM D 698)	Above Water Table	Below Water Table*
Bank Sand (Fines Content < 25%)	88 to 92 93 to 98	55 75	88 96
Select Cohesive ($7 \leq PI \leq 20$)	88 to 92 93 to 98	65 85	95 103
Non-select Cohesive ($PI > 20$)	88 to 92 93 to 98	75 100	105 113
* These values include a groundwater pressure component.			

Lateral pressures due to surcharge loading, if present, should be added to the above recommended pressures. A uniformly distributed lateral pressure equal to 0.4 to 0.5 times the surcharge is recommended for design. The upperbound compactive effort should be used if surcharge loads are present.

Uplift. Uplift resistance against the hydrostatic pressures for units placed below the groundwater level may be developed using the following approaches:

- Increasing the dead load of the unit,
- Using tension piers or piles as anchors, or
- Using adhesion between the soil and structure wall or frictional resistance of the soil.

Concrete mass provides dead load to counterbalance uplift pressures. This approach provides a conceptually simple design solution for units that extend to moderate depths below the static-water level. The use of tension piers as anchors is appropriate for deep units that are constructed using caisson techniques. Anchors acting in tension may consist of drilled straight shafts installed from existing ground surface. Drilled shafts would be concreted up to final design grade, with steel in place, and tied into the unit slab during construction. Construction of drilled shafts below the groundwater depth will require the use of drilling slurry or casing to maintain sidewall stability through silt and sand layers. The piers are connected to the unit foundation and act as anchors in tension using skin friction to resist uplift pressures.

The depths required for anchor piers are estimated from axial tensile capacity curves developed for the soil conditions encountered in the borings. These curves would be developed using methods discussed in *Drilled Shaft: Construction Procedures and Design Methods*, U.S. Department of Transportation, 1988, by L.C. Reese and M.W. O'Neil and using our area experience. Additional borings will be required to obtain deeper subsurface information to develop design axial uplift capacity curves.

Adhesion or frictional resistance is not commonly included as a factor in uplift resistance for caisson installations because of (1) the potential for developing voids along the soil-wall interface during caisson excavation, (2) misalignment of the structure as it moves downward, and (3) loss of ground or sloughing that may occur during excavation. We expect a long-term frictional resistance along the sides of the caisson of about 300 psf, provided the caisson is grouted in place.

Ground Heave at Excavation Bottom. We do not believe that heave is a major design consideration. If heave occurs, short-term effects would be less than 1 in.

Bearing Capacity. The bottom of the excavation must be maintained in a dry and stable condition if reasonable bearing capacities are to be realized. The recommended design gross bearing pressure for the lift station base located at approximately 50-ft depth would be 3500 psf. This bearing pressure assumes that the lift station base is bearing in competent sandy clays to clays. Disturbance of the bearing surface during construction must be kept to a minimum.

Dewatering Considerations. Dewatering options for the waterbearing sands encountered between about 15-ft and 20-ft depth and 28-ft and 38-ft depth include closely-spaced well points or eductors. Vacuum wellpoint dewatering generally is applicable for dewatering sands and silts within the upper 15 ft of an excavation. Excavations deeper than 15 ft can be dewatered by installing the wellpoint system on a bench inside the excavation. The eductor system is similar to wellpoints in that it consists of common manifolds connected to individual wellpoint units installed from ground surface, but requires an additional water supply line. The spacing of the points can be reduced as needed to minimize residual piezometric head between the units. Eductor systems are generally more effective than vacuum type wellpoint systems in dewatering excavations greater than 15-ft depth. We recommend that the dewatering system be activated and remain active throughout the below-grade excavation. We recommend that the silty fine sands encountered below 56-ft depth be relieved of excess pressure to at least 56-ft depth to assure a stable excavation base.

Below-Grade Unit Design and Construction Considerations

Below-grade units will be constructed throughout the Phase One area with unit bases located at 4-ft to 12-ft depths. Excavations for the below-grade units are expected to terminate in both cohesionless and cohesive soils. The thickener, constructed in the vicinity of Boring CB-16, is expected to penetrate the surficial clayey sand fill and terminate within the silty fine sands. The aeration/digester basin excavations are expected to terminate within clayey sand fill soils. We recommend that the excavation for the aeration basin extend to the natural clayey sand at about 6-ft depth. If the unit cannot be founded at 6-ft depth, cement-stabilized sand or select fill should be placed to the desired bearing surface. The clarifier and return sludge pump station excavations are expected to terminate within clayey sands and silty fine sands. Free water was not encountered within the depths to be excavated for the below grade structures; however, the borings contained water when water-level measurements were made 24 to 48 hours after completion of drilling. During periods of inclement weather, water may become trapped within the upper surface soils; such water can likely be handled with sumps and pumps. While we do not expect excavations within the upper 12-ft depth to encounter waterbearing soils, the Contractor should understand that these soils may be waterbearing during construction.

Bearing capacity, bottom stability, lateral earth pressure, and uplift are elements considered in below-grade structure design. Construction methods and groundwater control are the Contractor's responsibility. We provide an overview of the available construction methods and groundwater control for informational purposes. Design and construction considerations are addressed in the following paragraphs.

Bearing Capacity. On the basis of the soils encountered, excavations within the upper 4 to 12-ft depth are expected to terminate primarily within dry clayey sands to silty fine sands and sandy clays. Slab foundations constructed on undisturbed, clayey sands to silty fine sands and sandy clays may be designed using an allowable gross bearing pressure of 3000 psf. If footings are used, an allowable gross bearing pressure of 3500 psf could be used.

Bottom Stability. Free water was not encountered in the boreholes in the Phase One development area. However, water was observed at 0.6-ft to 12.8-ft depths in the open boreholes when measured about 24 to 48 hours after completion of drilling. The near surface water levels appear to reflect the infiltration of surface water into the open boreholes or may reflect a perched water condition. Bottom stability is not expected to be a concern for the below-grade structures extending to 4-ft to 12-ft depths. However, we recommend that the water levels be verified just before construction.

Uplift. Since free water was not encountered during drilling for the below-grade units located within the Phase One Development area, we do not believe that uplift will be a design issue.

Lateral Earth Pressures. For open-cut or retained techniques, the walls of the treatment units will be subject to lateral earth pressure developed from placed backfill. The magnitude of the lateral earth pressures is primarily dependent on the type of backfill, relative density of the backfill, construction method, and wall rigidity.

Cohesionless soils, such as sands with little or no fines, are preferred as backfill materials. Granular backfill should have less than 25% of material smaller than a No. 200 sieve size. Clay soils are typically less desirable materials because they are difficult to keep drained, produce larger earth pressures than granular soils, and can develop high swell pressures from expansion. If cohesive soils are used, we suggest homogeneous select fill soils having a PI ranging from 7 to 20 be used. Cohesive soils with PI's greater than 20 are not as desirable and may result in higher wall pressures because of swell potential.

Granular backfill should be placed in maximum 12-in. lifts and compacted by vibratory or pneumatic equipment to 88% to 92% of the standard Proctor maximum dry density as determined by ASTM D 698. We suggest that a 3 ft cohesive cap be compacted on top of the granular backfill to reduce surface runoff infiltration.

Cohesive fill should be placed in maximum 8-in. lifts and compacted by sheepsfoot or tamping foot equipment to 88% to 92% relative compaction as determined by ASTM D 698. Select cohesive fill should be placed at a water content within two percentage points dry to four percentage points wet of the optimum moisture content. If used, high plasticity cohesive soils should be moisture-adjusted to the optimum moisture content or within four percentage points wet of the optimum moisture content to reduce swell potential. We recommend that the site be graded to prevent ponding of water adjacent to below grade structures and to prevent buildup of water pressures resulting from potential infiltration.

To reduce lateral earth pressures, over-compaction of the backfill materials should be avoided. A higher compactive effort to achieve 93% to 98% of ASTM D 698 would be required in cases where backfill will support a surcharge.

The lateral earth pressures can be calculated by multiplying the equivalent fluid density for the backfill type by the depth below the ground surface. The equivalent fluid densities for various backfill materials and compactive efforts were outlined in the *Lift Station Design and Construction Requirements* section of this report.

Any surcharge loads on areas adjacent to subsurface walls should also be considered. Local surcharge loads adjacent to the wall, if present, should be incorporated into the pressure diagrams. A surcharge load, q, will typically result in a lateral load equal to 0.4q to 0.5q. As a factor of safety for lateral design, the surcharge loads should be multiplied by a factor of 1.5.

Construction Methods. Two construction methods can be considered to install the below-grade treatment units. These methods include open-cut installation and retained excavations. The open-cut option is the most basic installation technique for below-grade facilities. The approach provides the best access for construction and has the least effect on the design of the structure. However, the demands on space and earthwork are upperbound, and dewatering of transmissive strata, if present, must be sufficient to avoid slope instabilities and maintain a stable bearing surface. Temporary sideslopes of 1(V):1(H) to 1(V):3(H) can be used in the cohesionless soils encountered. If more clayey soils are encountered, temporary sideslopes of 1(V):1(H) may be used.

Retained excavations generally require less ground surface area than the open-cut approach as well as less groundwater control support for transmissive zones penetrated by the excavation and retention system. A retained excavation detail can begin from ground surface or from an initial open-cut down to a level above the measured static-water elevation. The retention system can consist of driven sheetpile, soldier pile/lagging, or drilled shafts. Design parameters for temporary trench walls are included in Figure 3.

Groundwater Control. We believe that shallow excavations within the Phase One Development area to depths of 4 ft to 12 may be completed in dry soils since the soils within the Phase One area borings were dry during drilling and before demobilization at the end of the day. The Contractor should be prepared for sloughing of the soils in the deeper excavations. We do not recommend that below-grade excavations be allowed to remain open for more than about 2 hours. If excavations must remain open, a seal slab should be placed in the excavation base.

Trenching and Shoring. The current Occupational Safety and Health Administration (OSHA) standards (in 29 CFR, part 1926, Subpart P) include provisions for the design of sloping and benched trench excavations in single or multiple-layer soil stratigraphies less than 20-ft deep, in lieu of bracing and shoring. The regulations specify maximum slope declivities contingent on soil type: Type A, Type B, or Type C. The encountered cohesionless fill soils and natural soils are classified as Type C. The trench shield (box), if used, should be designed by the Contractor to withstand lateral loads imposed by specific site soil conditions.

The soil stratigraphy and groundwater conditions encountered during excavations may vary from those observed in the project borings or characterized herein. The Contractor should collect additional subsurface information as he deems necessary to determine if the conditions reported are representative on a station-by-station basis. All excavations and retaining structures should be monitored on a continuous basis by experienced personnel who can make evaluations as to the appropriateness of the retention system used.

At-Grade Structures

Principal structural loads for the at-grade structures within the Phase One Development areas may be supported on either drilled pier-grade beam foundation systems or slab-on-grade foundation systems. Design parameters for each of the foundation types are presented in the following paragraphs.

__Drilled Pier - Grade Beam System__. Principal loads for the proposed at-grade structures may be supported on drilled straight-sided, cast-in-place concrete footings bearing 8 ft below the grade existing at the time of this study. The 8-ft bearing depth does not account for any fill which may be placed to achieve the desired floor slab elevations. The footing shaft should be extended to account for the fill thickness at any given footing location. Footings may be sized for an allowable total gravity load net bearing pressure (live load and dead load) of 4000 psf, with a maximum allowable dead load pressure of 2700 psf. The recommended pressures may be increased by 33% for transient loading conditions, such as wind. Our recommendations include a factor of safety of 2 for total load, and a factor of safety of 3 for dead load.

Concrete should be placed in footings following drilling and observation of the cleaned footing. Excavated footings should not be allowed to remain open for more than 2 hours before placing concrete. Seepage of water from the sandy substructure may enter the footing excavation; however, the water likely can be handled by sumps and pumps. Water in excess of 1 in. should be removed from the excavations before concrete is placed. The Geotechnical Engineer or experienced Soils Technician should be present during footing installation to verify the condition of the bearing surface and the bearing depth.

Total post construction settlements of less than 0.5 in. are anticipated for drilled footings installed using proper construction techniques. Differential movements between adjacent column units are not expected to exceed 75% of the expected total settlement. The performance of the foundation units will be more sensitive to construction quality than soil-structure interaction.

Given the presence of the clayey sand to silty fine sand surface soils, the floor slab may be constructed at-grade. Floor slab subgrade preparations should meet the guidelines outlined in the *Site Preparation* section of this study. Grade beams should be placed beneath all exterior and interior load-bearing walls. Grade beams should be designed to support the imposed loads.

__Slab-on-Grade Foundations__. Rigid slab design standards are provided in the *Criteria for Selection and Design of Residential Slab-on-Ground,* PB-261-556, developed by the Building Research Advisory Board (BRAB) for the Federal Houston Administration. Recommended BRAB design parameters are based on the plasticity indices of the soil samples recovered from the project borings. The BRAB slab design parameters are as follows:

Design Plasticity Index (PI)	23
Climatic Rating (C_w)	25
Soil Support Index (C)	0.95
Unconfined Compressive Strength (q_u)	1.0 tsf

As an alternative to a rigid slab-on-grade, a post-tensioned foundation system could be used. Recommended PTI parameters are based on the predominant soil type, estimated percentage of clay mineral, and type of clay mineral composing the soil. The clay content was taken as 30%, the minimum clay content for which the procedure is applicable. Using the *Design and Construction of Post-Tensioned Slabs-on-Ground*, by the Post-Tensioning Institute (PTI), our judgment in selecting design parameters, and the grain size data for the near-surface sandy clays, post-tensioned slab design parameters are:

Predominant Soil Type	Clayey Sand (SC)/Sandy Clay (CL)
Clay Mineral (assumed)	Montmorillonite (30%)
Thornthwaite Moisture Index (I_m)	+18
Depth to Constant Soil Suction (assumed)	7 ft
Constant Soil Suction	3.3 pF
Moisture Velocity (assumed)	0.7 in./month
Allowable Bearing Pressure	2000 psf
Edge Moisture Variation Distance (e_m)	
Center Lift	4.0 ft
Edge Lift	5.0 ft
Differential Soil Movement (y_m)	
Center Lift	0.28 in.
Edge Lift	0.23 in.

The PTI parameters are based on our interpretation of the on-site soils and empirical data published in the PTI design manual. These estimates are considered approximate and may be supplemented with laboratory swell tests for more accurate determinations. Currently, there are no reliable techniques for making independent estimates of the PTI design parameters.

The PTI differential soil movement estimates do not account for site preparation and vegetative influences, such as drainage, prior trees, and landscaping, which can greatly influence foundation performance. The actual performance of slab-on-grade foundations will largely depend on actual soil moisture conditions, construction techniques, site preparation, and landscaping. Slab-on-grade foundations should not be constructed on saturated sands and silts.

Phase Two Development Considerations

The Phase Two Development area consists of an 8-ft to 18-ft thick, undocumented fill body. The fill soils consist of silty fine sands, clayey sands, sandy silts, and some sandy clay and silty clay soils. In Boring CB-30, about 11 ft of the interpreted 17-ft thick fill body was visually described as black ash. Debris consisting of nails, wood fragments, and gravel pieces were encountered within the fill body. The "ash" soils are not considered suitable for support of future treatment units. Before construction proceeds in the Phase Two Development area, additional exploration including test pits and soil borings should be performed to evaluate soil conditions at the individual treatment units. Although four of the five soil borings indicate silty fine sand, clayey sand, and some clay-type fill soils, the stratifications in the five borings are not consistent. It appears that deleterious fill is present at the site and the five borings are insufficient to identify the lateral and vertical limits of the fill. The lateral limits of the fill may best be determined through test pit excavations. However, given the depth of the fill, additional borings will be required to delineate fill depth.

Design Review

Review of the design and construction plans as well as the specifications should be performed by MRA before release. The review is aimed at determining if the geotechnical design recommendations and construction criteria presented in this report have been properly interpreted. Design review is not within the scope of work authorized in this study. Should you elect to retain MRA to perform a design review, additional fees would be applicable.

Limitations

This report has been prepared for the exclusive use of Turner Collie & Braden, Inc., for specific application to the construction of Wastewater Treatment Plant No. 2 within Woodlands, Texas. Our report has been prepared in accordance with generally accepted geotechnical engineering practice common to the local area. No other warranty, express or implied, is made.

The analyses and recommendations contained in this report are based on the data obtained from the referenced subsurface exploration. The borings indicated subsurface conditions only at the specific locations and time, and only to the depths penetrated. The borings do not necessarily reflect strata variations that may exist between boring locations. The validity of the recommendations is based in part on assumptions about the stratigraphy made by the Geotechnical Engineer. Such assumptions may be confirmed only during earthwork and foundation construction. If subsurface conditions different from those described are noted during construction, recommendations in this report must be reevaluated.

If any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report are modified or verified in writing by MRA. MRA is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or reuse of the subsurface data or engineering analyses without the express written authorization of MRA.

Closing Remarks

We appreciate the opportunity to serve you on this project. Should you wish, we can provide construction materials quality control during construction to ensure that the recommendations outlined in our report are implemented in the field. If we may be of further assistance to you or if you have any questions about our recommendations, please call.

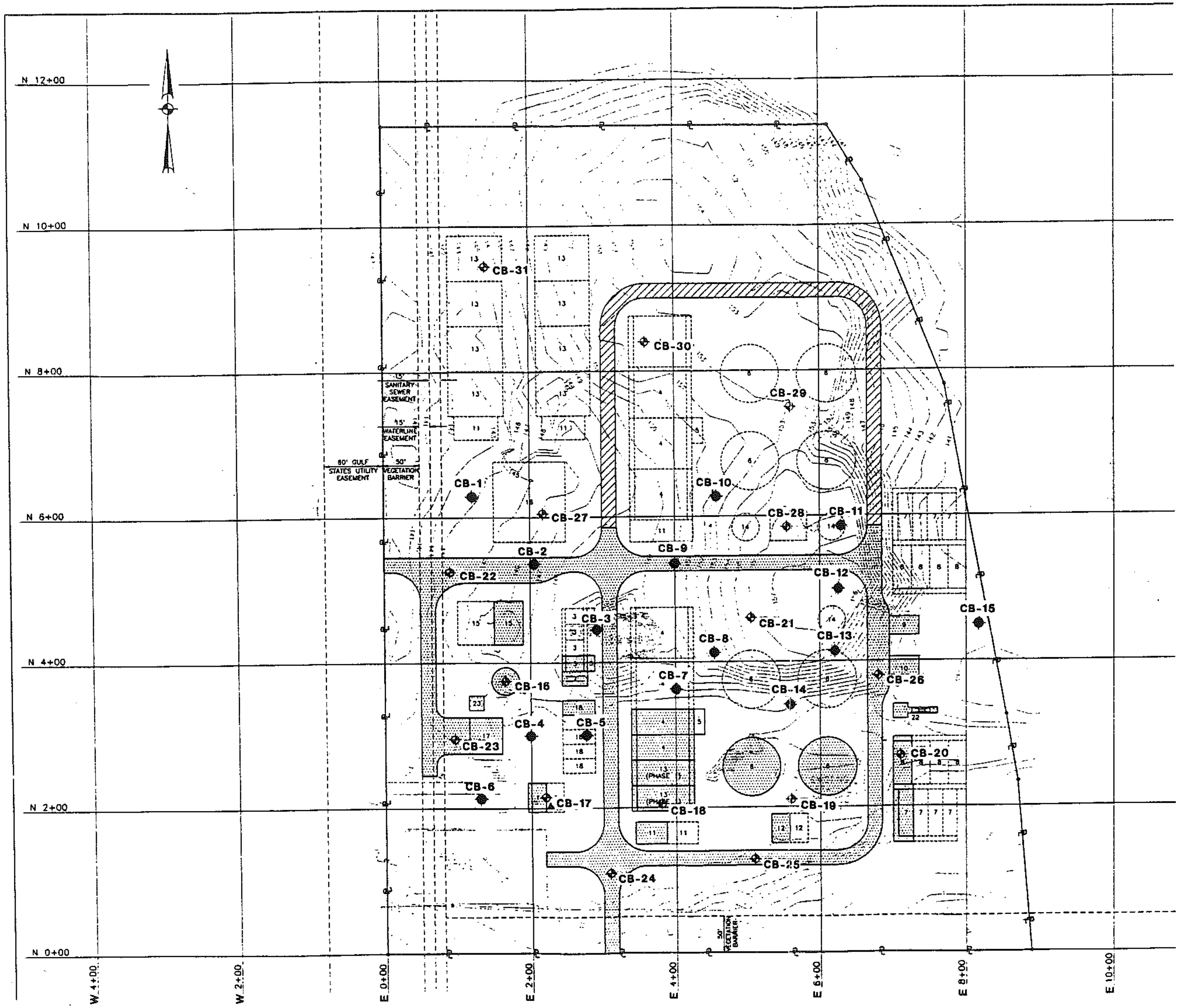
Sincerely,
McBRIDE-RATCLIFF AND ASSOCIATES, INC.

Marie Johnson Starich, P.E.

STATE OF TEXAS
MARIE JOHNSON STARICH
62037
REGISTERED PROFESSIONAL ENGINEER

Reviewed by: ____________________

MJS:1994\reports-4\94-0312.wtp

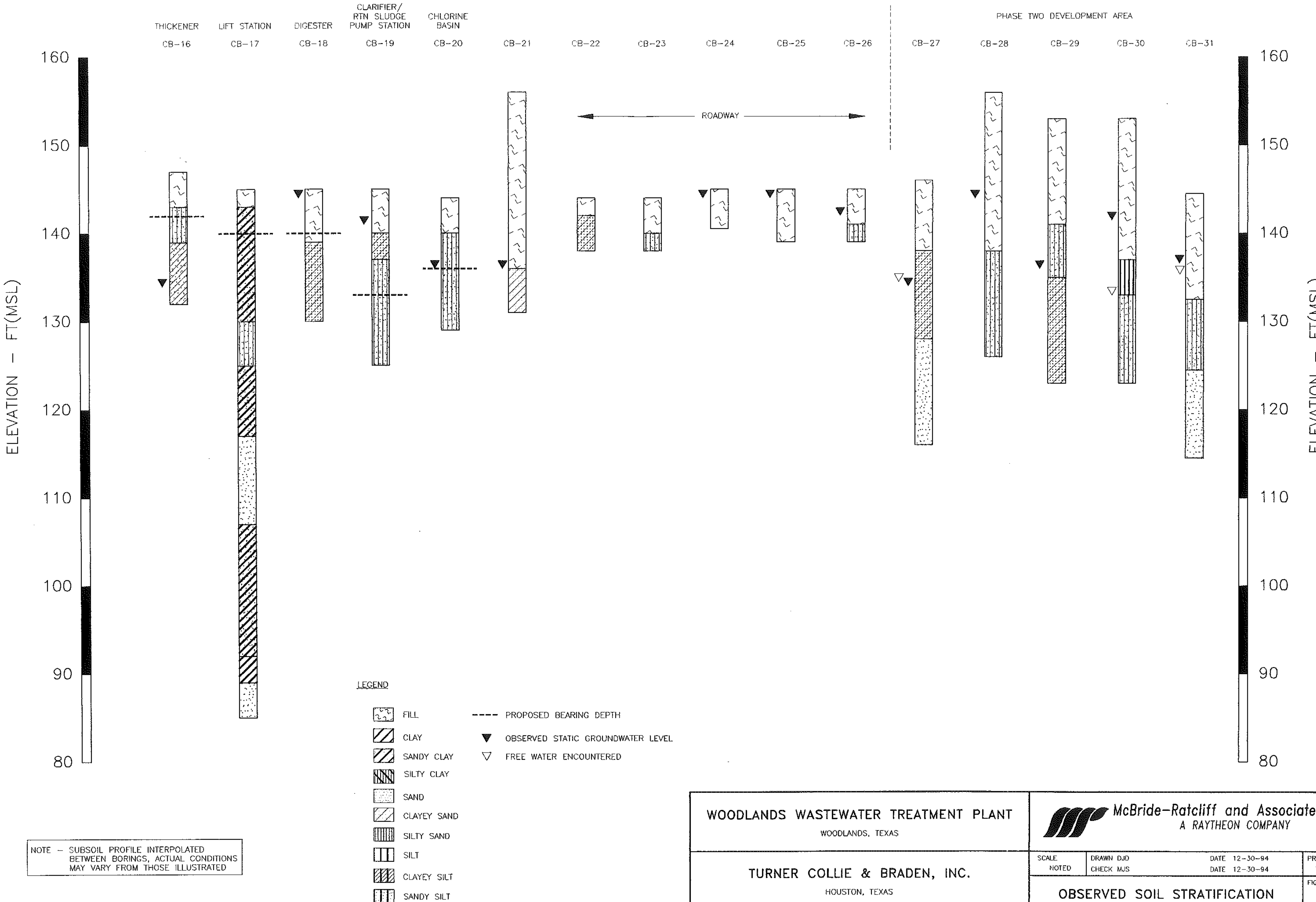


LEGEND:

- ⌖ Approximate Boring Location
- ● Previous Boring Location (MRA Project No. 82-0522)
- ▲ Approximate Piezometer Location

SCALE-FT
0 160 320

WOODLANDS WASTEWATER TREATMENT PLANT **WOODLANDS, TEXAS**	McBride–Ratcliff and Associates, Inc. A RAYTHEON COMPANY		
TURNER COLLIE & BRADEN, INC. **HOUSTON, TEXAS**	SCALE: NOTED	DRAWN SMH DATE 12-30-94 CHECK MJS DATE 12-30-94	PROJECT NO. 94-0312
	PLAN OF BORINGS		FIGURE 1



NOTE – SUBSOIL PROFILE INTERPOLATED BETWEEN BORINGS, ACTUAL CONDITIONS MAY VARY FROM THOSE ILLUSTRATED

WOODLANDS WASTEWATER TREATMENT PLANT WOODLANDS, TEXAS	McBride-Ratcliff and Associates, Inc. A RAYTHEON COMPANY		
TURNER COLLIE & BRADEN, INC. HOUSTON, TEXAS	SCALE NOTED	DRAWN DJD DATE 12-30-94 CHECK MJS DATE 12-30-94	PROJECT NO. 94-0312
	OBSERVED SOIL STRATIFICATION		FIGURE 2

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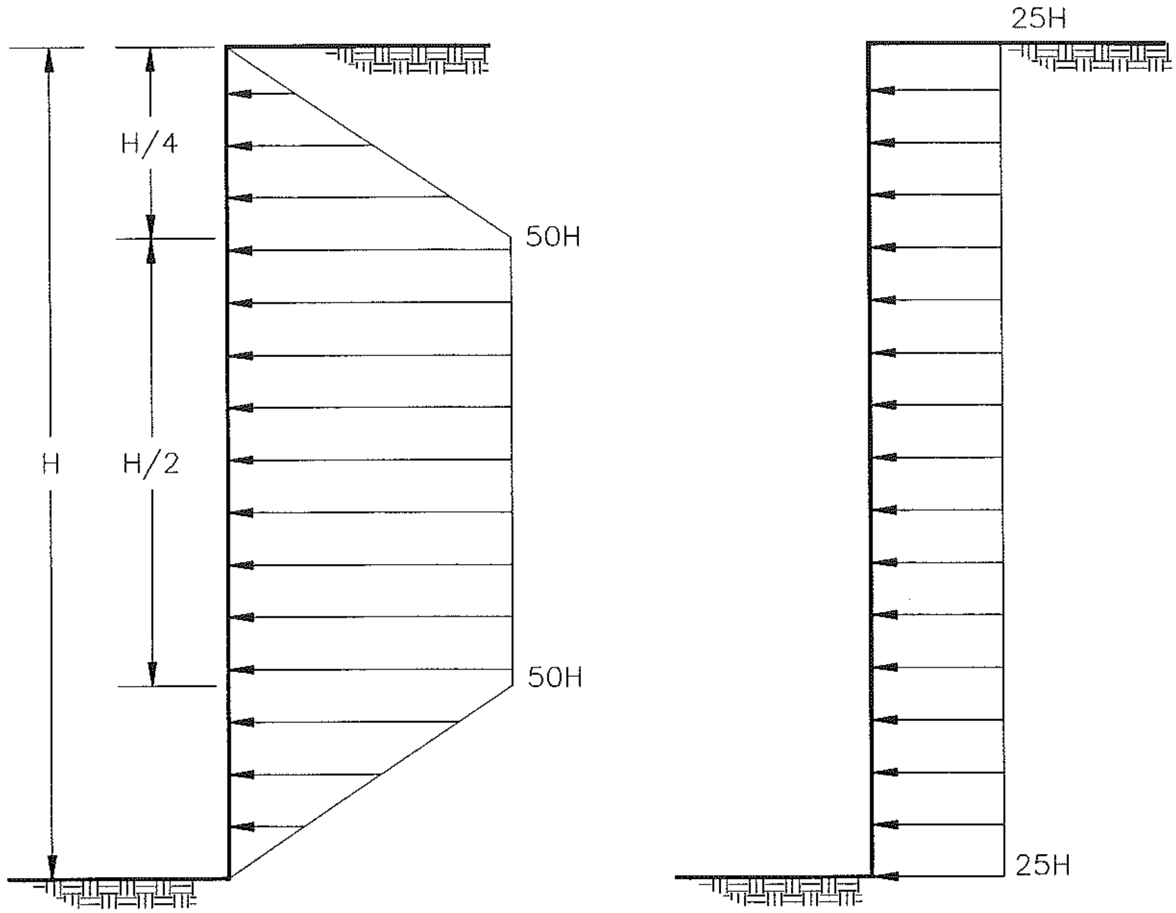


COHESIVE SOILS

COHESIONLESS SOILS

LATERAL PRESSURE DIAGRAMS
(BRACED TEMPORARY TRENCH WALL)

94-0312\0003 13:56 01/05/95

WOODLANDS WASTEWATER TREATMENT PLANT WOODLANDS, TEXAS	McBride-Ratcliff and Associates, Inc. A RAYTHEON COMPANY			
	SCALE N.T.S.	DRAWN DJD CHECK MJS	DATE 1-5-95 DATE 1-5-95	PROJECT NO. 94-0312
TURNER COLLIE & BRADEN, INC. HOUSTON, TEXAS	LATERAL EARTH PRESSURE DIAGRAMS			FIGURE 3

Attachment A

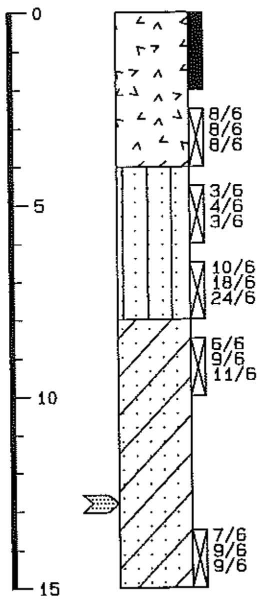
SOIL BORING LOGS

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-16
File No.: 94-0312
Date : 11-3-94
Elevation : - ft.

Dry Augered 0 to 15 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 12.8 ft. after 24 hrs.



ELEV / DEPTH	SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
		Brown CLAYEY SAND "FILL"	5						
		-medium dense below 2.5'	11				23	10	
		Loose gray & tan SILTY FINE SAND (SM)							
		-dense below 6.5'							38
		Medium dense gray & tan CLAYEY SAND (SC)							
			13						

Bottom @ 15'
Borehole collapsed at 13.3-ft depth before 24-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

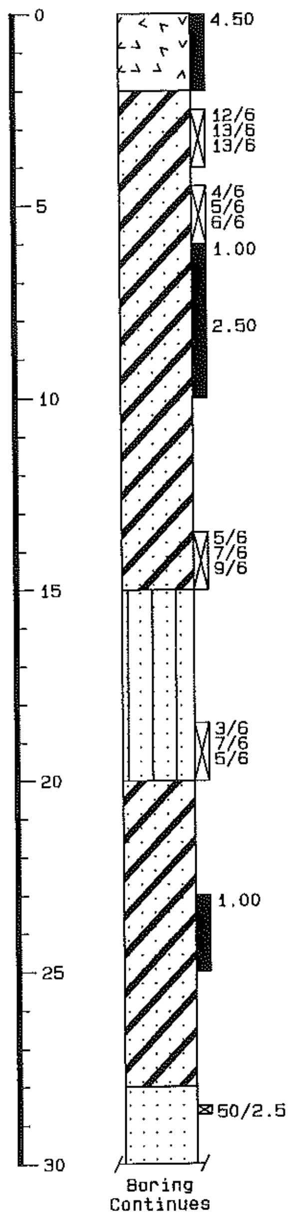
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-17
File No.: 94-0312
Date : 11-4-94
Elevation : – ft.

Dry Augered 0 to 16 ft. Water at ft; Caving at ft.
Wash Bored 16 to 60 ft. Water at ** ft. after

ELEV / DEPTH — SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Very stiff-hard tan & gray SANDY CLAY "FILL"	9				29	16	
Very stiff brown & tan SANDY CLAY (CL) w/sand pockets -stiff below 4.5'	9						
	13	125					
	14						
	15				25	12	
Medium dense gray & tan SILTY FINE SAND (SM) -damp, caving @ 16'							
Firm gray & tan SANDY CLAY (CL) very sandy							
	13						
Very dense tan FINE SAND (SP) w/gravel pieces							

Bottom @ 60'
Piezometer installed in this boring.

McBride-Ratcliff and Associates, Inc.

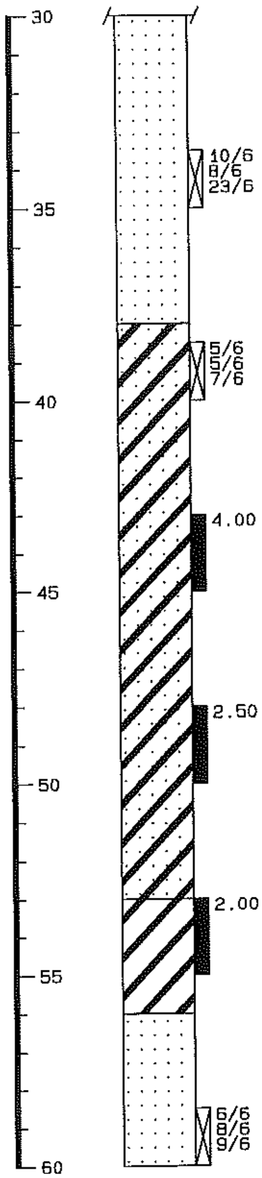
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas

Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-17
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 16 ft. Water at ft; Caving at ft.
Wash Bored 16 to 60 ft. Water at ** ft. after

ELEV / DEPTH; SOIL SYMBOLS, SAMPLER SYMBOLS, SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
	Very dense tan FINE SAND (SP) w/gravel pieces							
	-dense below 33'							10
	Stiff gray & tan SANDY CLAY (CL) w/sand pockets	24						
		18	111	1.01 (22)	5			
	Stiff tan & gray CLAY (CH)	41						
	Medium dense tan & gray FINE SAND (SP-SM)							
								10

Bottom @ 60'
Piezometer installed in this boring.

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas

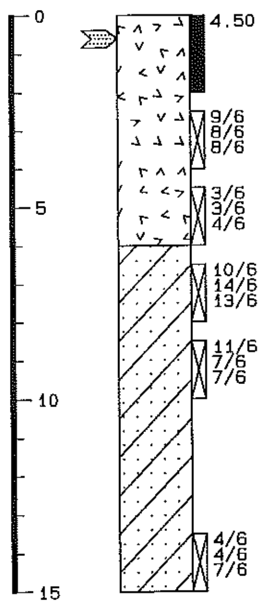
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-18
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 15 ft. Water at ft; Caving at ft.

Wash Bored to ft. Water at 0.6 ft. after 48 hrs.

ELEV / DEPTH | SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Brown & gray CLAYEY SAND "FILL"	9						
-medium dense w/wood chips below 2.5'	8						
-loose below 4.5'	11				19	6	
Medium dense brown & gray CLAYEY SAND (SC)	11						
	10				15	3	

Bottom @ 15'

Borehole collapsed at 3.8-ft depth before 48-hr water-level reading.

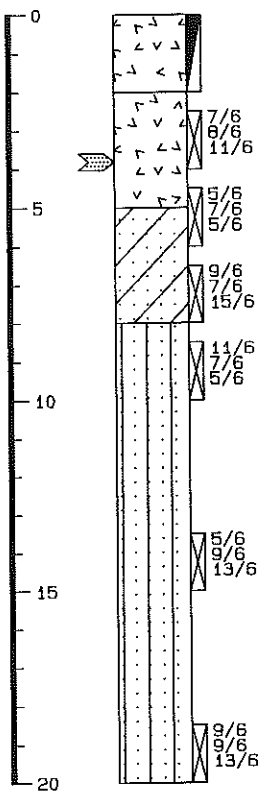
McBride-Ratcliff and Associates, Inc.

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-19
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 20 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 3.8 ft. after 48 hrs.



ELEV / DEPTH	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0	Brown CLAYEY SAND "FILL"	7						
	Medium dense tan & gray CLAYEY SAND "FILL"	11				17	4	
5	Medium dense tan & gray CLAYEY SAND (SC)	11						
	Medium dense gray & tan SILTY FINE SAND (SM)							
	-damp below 13'							43
20								43

Bottom @ 20'
Borehole collapsed at 8.2-ft depth before 48-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

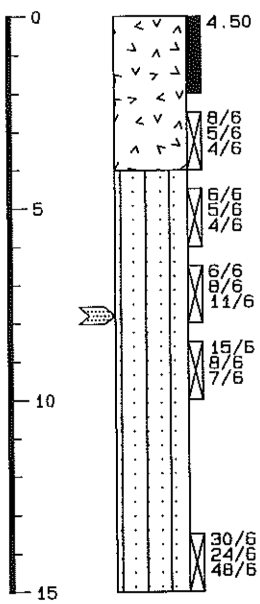
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-20
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 15 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 7.8 ft. after 48 hrs.

ELEV / DEPTH — SOIL SYMBOLS, SAMPLER SYMBOLS, SAMPLE NO.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Hard tan & gray SANDY CLAY "FILL"	13	123	4.42	5			
-stiff below 2'	8				23	11	
Loose brown & gray SILTY FINE SAND (SM)	7						
-medium dense below 6'	6						
							33
-very dense below 13'							

Bottom @ 15'
Borehole collapsed at 8.2-ft depth before 48-hr water-level reading.

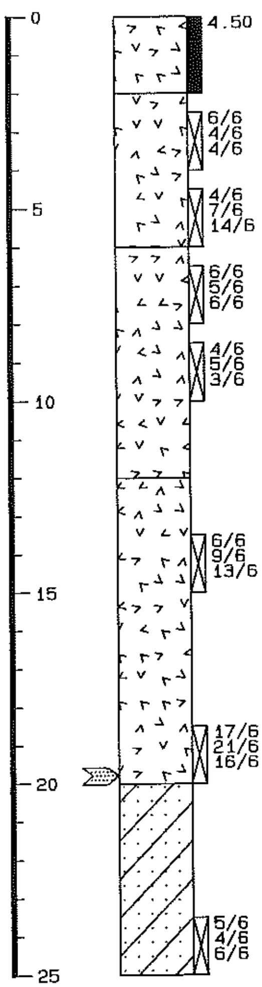
McBride-Ratcliff and Associates, Inc.

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-21
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 25 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 19.8 ft. after 48 hrs.



ELEV / DEPTH	SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0	4.50	Very stiff-hard tan & gray SANDY CLAY "FILL"	9						
	6/6 4/6 4/6	Loose tan & gray SILTY FINE SAND "FILL" w/clay pockets & organics	8						24
5	4/6 7/6 14/6	-medium dense below 4'	11						
	6/6 5/6 6/6	Stiff tan & gray SANDY CLAY "FILL" w/calcareous nodules	12						
10	4/6 5/6 3/6								
15	6/6 9/6 13/6	Medium dense tan & gray CLAYEY SAND "FILL" w/organics	11				15	3	
20	17/6 21/6 16/6	-dense w/decayed wood fragments below 18'	11				15	2	
		Loose gray & tan CLAYEY SAND (SC)							
25	5/6 4/6 6/6								

Bottom @ 25'
Borehole collapsed at 20.3-ft depth before 48-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

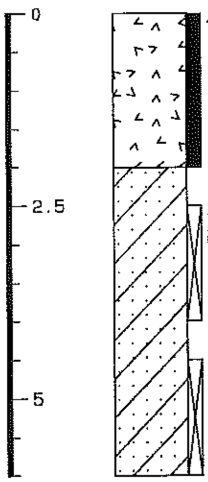
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-22
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 6 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at ft. after

ELEV / DEPTH	SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0	4.50	Very stiff-hard red & gray SANDY CLAY "FILL"	13				38	23	
2.5	4/6 3/6 5/6	Loose brown & gray CLAYEY SAND (SC)							
5	7/6 9/6 7/6	-medium dense below 4.5'							



Bottom @ 6'

McBride-Ratcliff and Associates, Inc.

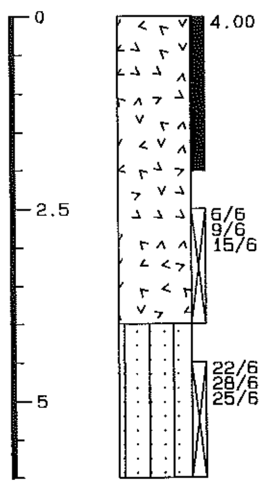
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-23
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 6 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at Dry ft. after 48 hrs.

ELEV DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0	4.00	Very stiff tan & gray SANDY CLAY "FILL" w/organics	6						
2.5	6/6 9/6 15/6		10				30	16	
		Very dense gray & tan SILTY FINE SAND (SM)							
5	22/6 28/6 25/6		8						



Bottom @ 6'
Borehole collapsed at 4.9-ft depth before 48-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

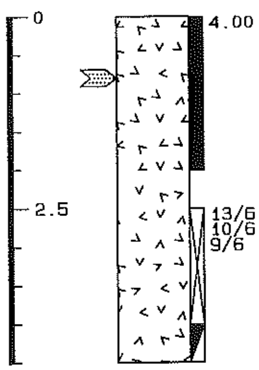
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-24
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 4.5 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 0.8 ft. after 48 hrs.

ELEV / DEPTH	SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0	4.00	Tan & gray CLAYEY SAND "FILL"	8						
2.5	13/6 10/6 9/6	-medium dense below 2.5'	10				18	4	
		-plastic, fiberglass @ 4' -refusal @ 4.5'							



Bottom @ 4.5'
Borehole collapsed at 2.2-ft depth before 48-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

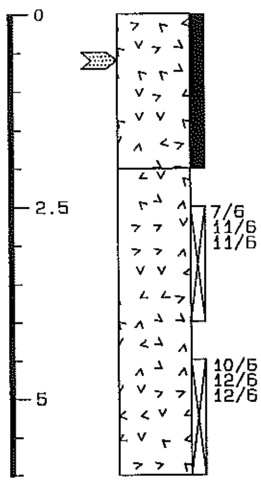
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas

Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-25
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 6 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 0.6 ft. after 48 hrs.



ELEV / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0		Gray & tan FINE SAND "FILL" w/organics	10						4
2.5		Medium dense tan & gray CLAYEY SAND "FILL"	8						
5		-w/shell & organics below 4.5'	8						

Bottom @ 6'
Borehole collapsed at 2.5-ft depth before 48-hr water-level reading.

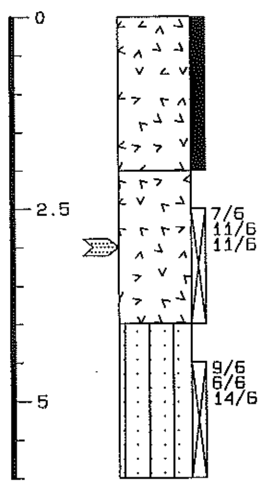
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-26
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 6 ft. Water at ft; Caving at ft.
Wash Bored to ft. Water at 3.0 ft. after 48 hrs.

ELEV / DEPTH | SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Gray & tan SILTY FINE SAND "FILL"	14						26
Medium dense tan & gray CLAYEY SAND "FILL"	11				21	10	
Medium dense tan & gray SILTY FINE SAND (SM)	7						

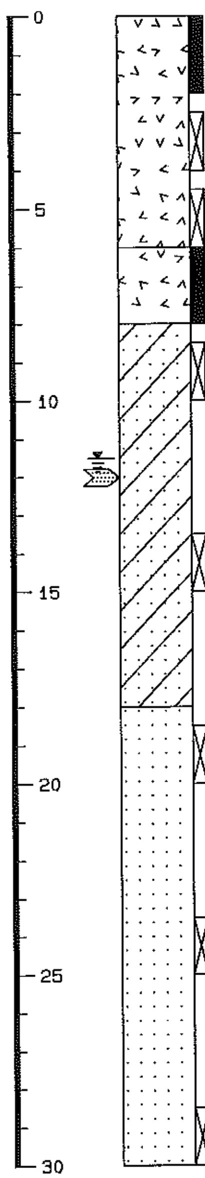
Bottom @ 6'
Borehole collapsed at 3.2-ft depth before 48-hr water-level reading.

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-27
File No.: 94-0312
Date : 11-3-94
Elevation : - ft.

Dry Augered 0 to 11.5 ft. Water at 11.5 ft; Caving at ft.
Wash Bored 11.5 to 30 ft. Water at 12.0 ft. after 24 hrs.



ELEV / DEPTH	SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.	Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
0		Tan & gray CLAYEY SAND "FILL"	11						
	21/6 22/6 19/6	-dense below 2.5'	8				17	5	
	10/6 5/6 3/6	-loose below 4.5'	12						
	1.00	Firm tan & gray SANDY CLAY "FILL"	12	112	0.65	6			
	9/6 7/6 6/6	Medium dense gray & tan CLAYEY SAND (SC)	12				15	2	
		-caving @ 11.5'							
	7/6 11/6 15/6		15						
	9/6 12/6 21/6	Dense gray & tan FINE SAND (SP-SM) w/gravel & fragments							
	12/6 24/6 38/6	-very dense below 23'							7
30	12/6 18/6 41/6								

Bottom @ 30'
Borehole collapsed at 22.8-ft depth before 24-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

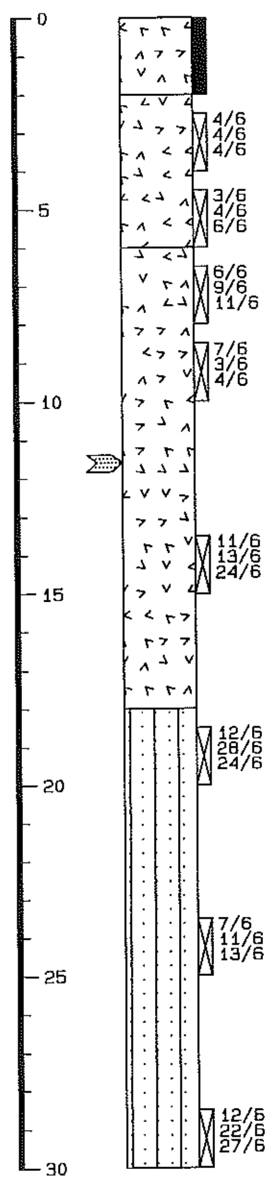
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-28
File No.: 94-0312
Date : 11-3-94
Elevation : - ft.

Dry Augered 0 to 16.5 ft. Water at ft; Caving at ft.
Wash Bored 16.5 to 30 ft. Water at 11.6 ft. after 24 hrs.

ELEV / DEPTH — SOIL SYMBOLS, SAMPLER SYMBOLS, SAMPLE NO.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Gray & tan SILTY FINE SAND "FILL" w/roots	10						
Loose gray & tan CLAYEY SAND "FILL" w/clay pockets	10				19	5	
	13						
Medium dense tan & gray SILTY FINE SAND "FILL" w/organics							44
-loose below 8.5'	10						
-dense below 13.5'	10						
-caving @ 16.5'							
Very dense tan & gray SILTY FINE SAND (SM)							27
-medium dense w/gravel fragments below 23'							
-dense below 28'							

Bottom @ 30'
Borehole collapsed at 18.0-ft depth before 24-hr water-level reading.

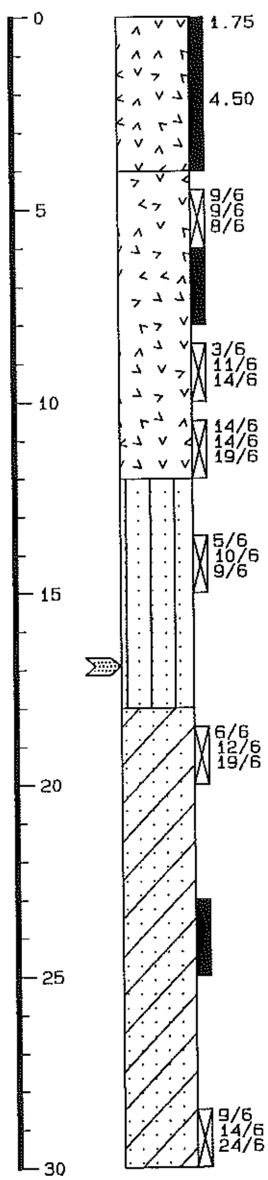
McBride-Ratcliff and Associates, Inc.

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-29
File No.: 94-0312
Date : 11-3-94
Elevation : - ft.

Dry Augered 0 to 16 ft. Water at ft; Caving at ft.
Wash Bored 16 to 30 ft. Water at 16.9 ft. after 24 hrs.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Gray & tan CLAYEY SAND "FILL" w/wood fragments & roots	15				18	6	
	16						
Medium dense gray & tan SILTY FINE SAND "FILL" w/clay pockets							26
	12						
	11						
-dense below 10.5'	11						
Medium dense gray & tan SILTY FINE SAND (SM)							24
-caving @ 16'							
Dense gray & tan CLAYEY SAND (SC) w/gravel fragments							
	18				19	6	

Bottom @ 30'
Borehole collapsed at 22.7-ft depth before 24-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

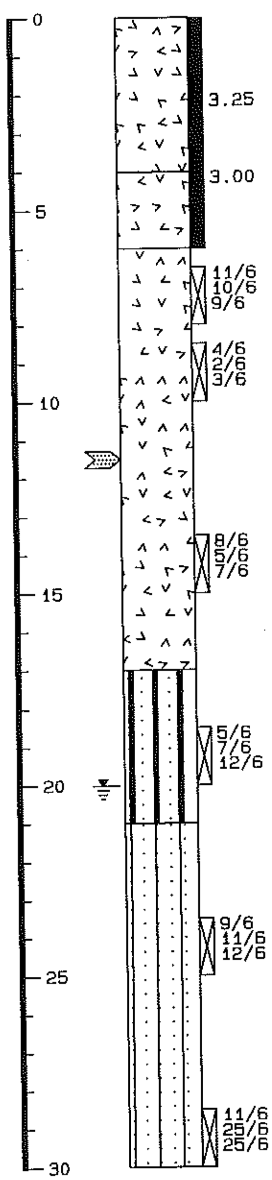
LOG OF BORING

Project : Woodlands Wastewater Treatment Plant
No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc.
Houston, Texas

Boring No.: CB-30
File No.: 94-0312
Date : 11-4-94
Elevation : - ft.

Dry Augered 0 to 12 ft. Water at 20.0 ft; Caving at ft.
Wash Bored 12 to 20 ft. Water at 11.5 ft. after 48 hrs.

ELEV / DEPTH — SOIL SYMBOLS / SAMPLER SYMBOLS / SAMPLE NO.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Gray & tan CLAYEY SAND "FILL" w/organics	17						
	12				20	6	
Very stiff gray & tan SANDY CLAY "FILL" w/organics	14	113			23	11	
Firm black "FILL" wet ash w/wood fragments, nails, & debris	13						
	15						
-caving @ 12'							
	21						
Medium dense gray & tan SANDY SILT (ML)							53
Medium dense gray & tan SILTY FINE SAND (SM)							
-dense w/gravel fragments below 28.5'							

Bottom @ 30'
Borehole collapsed at 15.7-ft depth before 48-hr water-level reading.

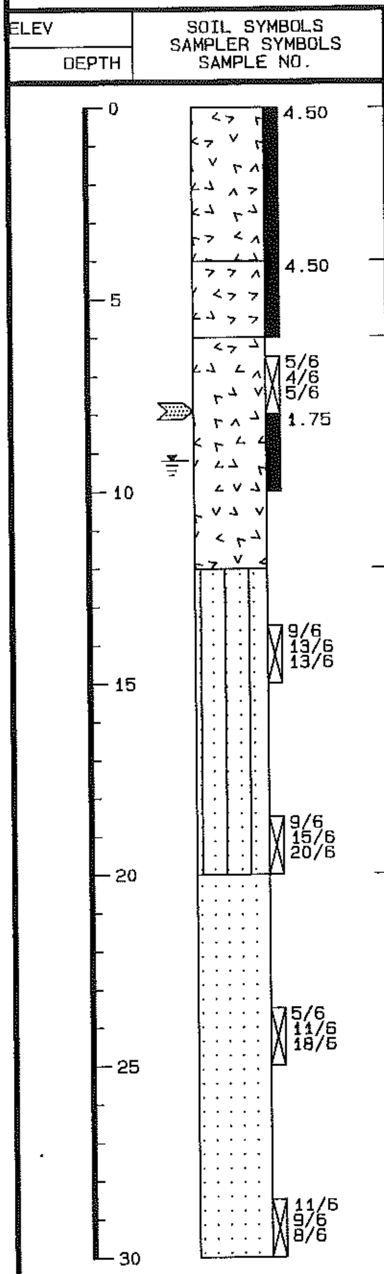
McBride-Ratcliff and Associates, Inc.

LOG OF BORING

Project : Woodlands Wastewater Treatment Plant No. 2, Woodlands, Texas
Client : Turner Collie & Braden, Inc. Houston, Texas

Boring No.: CB-31
File No.: 94-0312
Date : 11-3-94
Elevation : - ft.

Dry Augered 0 to 7.5 ft. Water at 9.2 ft; Caving at ft.
Wash Bored 7.5 to 30 ft. Water at 7.9 ft. after 24 hrs.



Description	Wc (%)	Dens. (pcf)	QU or UU (tsf)	Str (%)	LL	PI	#200 (%)
Gray & tan CLAYEY SAND "FILL"	9				20	6	
-w/wood fragments & organics below 2'							
Gray & tan SANDY SILT "FILL"	15	112	0.93	3			56
Loose gray & tan CLAYEY SAND "FILL" w/organics	16						
	16	119	1.02	6			
Medium dense gray & tan SILTY FINE SAND (SM) -dense, wet, caved to 9.2'							46
Medium dense tan & gray FINE SAND (SP-SM)							6

Bottom @ 30'
Borehole collapsed at 14.2-ft depth before 24-hr water-level reading.

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-1
FILE NO. 82-522
DATE 12-21-82

DRY AUGERED 0 TO 15 FEET
WASH BORED 15 TO 20 FEET

FREE WATER ENCOUNTERED YES NO

AT 14.0 FT. DEPTH.

WATER AT 3.0 FT. AFTER 3 hours

DEPTH (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
	1.50								Firm gray CLAYEY SAND (SC) w/ferrous nodules @ 2'
	2.00								dense, gray & tan @ 4'
5	2.50	13	118	1.87	3				w/sand pockets below 6'
	3.00								
10									
									gray @ 13'
		16							
15									Very dense gray SILTY SAND (SM)
	50/5½"								w/gravel @ 18½'
20									Bottom hole @ 20'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-2
FILE NO. 82-522
DATE 12-21-82

DRY AUGERED 0 TO 6 FEET
WASH BORED 6 TO 20 FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT ** FT. AFTER

DEPTH (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
	1.50	15	112	1.02	5				Firm gray CLAYEY SAND (SC)
	N=9								
5	N=23								dense @ 6½'
	N=31			-200=59.2%					
	N=9								firm w/18" sandy clay layer @ 8½'
10									Dense gray SILTY SAND (SM)
									w/small gravel below 13½'
	N=34								
15									
	N=42								
20									Bottom hole @ 20'
									** Surface water flowing into borehole

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-3
FILE NO. 82-522
DATE 12-20-82

DRY AUGERED 0 TO 10 FEET
WASH BORED 10 TO 20 FEET

FREE WATER ENCOUNTERED YES NO (YES underlined)

AT 8.0 FT. DEPTH.

WATER AT ** FT. AFTER

DEPTH (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
	N=5								Loose gray SILTY SAND (SM)
5	3.50	16	114	1.95	7	26	14	12	Stiff gray & tan VERY SANDY CLAY (CL) w/sand pockets & ferrous nodules
	3.00								
	1.50	15	121	0.51 (5)	5				Firm tan & light gray CLAYEY SAND (SC) w/sand pockets
10									
	N=28			-200=21.6%					Firm tan & light gray SILTY SAND (SM)
15									dense, w/gravel @ 16½'
	N=61								very dense @ 18½'
20									Bottom hole @ 20'

** Borehole collapsed @ 7'-8"

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-4
FILE NO. 82-522
DATE 12-20-82

DRY AUGERED 0 TO 15 FEET
WASH BORED 15 TO 40 FEET

FREE WATER ENCOUNTERED YES NO

AT 12.0 FT. DEPTH.

WATER AT 3.4 FT. AFTER 4 hours

Depth (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
		13		-200=49.7%					Firm gray VERY SILTY SAND (SM) w/roots
	N=10								Firm gray CLAYEY SAND (SC) w/ferrous nodules w/sand layers & clay pockets @ 4' dense tan & gray @ 6'
5	3.00	16	116	0.78 (3)	5				
	3.50								
	3.50	15	115	1.62 (5)	3				
10									
	N=6								Firm gray SILTY SAND (SM) w/very sandy clay layers @ 13½'
15									
	50/6"								very dense w/gravel @ 18½'
20									
	50/6"								
25									
	N=7								Stiff tan GRAVELLY CLAY
30									Stiff red CLAY (CH)
	2.50	39	81	1.41	3				
35									
	3.00	18	110						Very stiff gray & tan SANDY CLAY (CL)
40									Bottom hole @ 40'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-5
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED TO FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT FT. AFTER

DEPTH (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
									Firm gray SILTY SAND (SM)
	1.50	13	116			16	14	2	Firm gray CLAYEY SAND (SC) w/sand pockets gray & tan @ 4'
5	N=18								
	N=18								
	2.50	14	119	1.45	9				Stiff tan & light gray SANDY CLAY (CL) w/sand pockets
10									
	N=14								Firm tan & light gray CLAYEY SAND (SC)
15									Bottom hole @ 15'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-6
FILE NO. 82-522
DATE 12-21-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT 8.5 FT. AFTER 4 hours

Depth (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid (LL)	Plastic (PL)	Plasticity Index (PI)	DESCRIPTION OF STRATUM
0–4	N=8								Loose gray SILTY SAND (SM) tan @ 2'
4–11	N=15								Stiff tan & light gray SANDY CLAY (CL) w/sand & clay pockets very stiff @ 6'
	4.5+	19	109	3.56	8				
	4.5+								
11–15	N=91	12							Very dense gray CLAYEY SAND (SC)
15									Bottom hole @ 15'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-7
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT ** FT. AFTER

DEPTH (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
	N=5								Loose gray CLAYEY SAND (SC)
	N=13	14				14	12	2	firm @ 2½'
5	N=11								tan & light gray @ 4½'
	N=13								
		13							Firm gray SILTY SAND (SM)
10									
	N=5								Medium gray VERY SANDY CLAY (CL)
15									Bottom hole @ 15'

** Water @ 2' in borehole after 3 hours. (possible surface water)

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-8
FILE NO. 82-522
DATE 12-20-82

DRY AUGERED 0 TO 12 FEET
WASH BORED 12 TO 25 FEET

FREE WATER ENCOUNTERED YES NO

AT 11.0 FT. DEPTH.

WATER AT FT. AFTER

FIELD DATA		LABORATORY DATA								
DEPTH (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain, %	ATTERBERG LIMITS Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
	1.50	15	113	0.70	3				Firm gray CLAYEY SAND (SC)
	N=8								w/ferrous nodules @ 4'
5	N=18	15				19	14	5	
	N=19								
	N=9								w/sandy clay layers below 8½'
10									
	N=5	21				34	17	17	
15									
20	50/6½"			-200=29.2%					Very dense gray SILTY SAND (SM) w/small gravel
	N=57								
25									Bottom hole @ 25'

PENETRATION RESISTANCE

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-9
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT 7.3 FT. AFTER 2 hours

SOIL SYMBOL	DEPTH (feet)	SAMPLES	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
				15							Loose gray SILTY SAND (SM)
			N=6								Firm gray CLAYEY SAND (SC) w/sand layers & pockets
	5		N=18								
			N=13	15				13	12	1	
			N=18								
	10										
											Firm gray SILTY SAND (SM) w/clay layers
			N=19								
	15										Bottom hole @ 15'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-10
FILE NO. 82-522
DATE 12-20-82

DRY AUGERED 0 TO 11 FEET
WASH BORED 11 TO 25 FEET

FREE WATER ENCOUNTERED YES NO

AT 11.0 FT. DEPTH.

WATER AT 2.5 FT. AFTER 3 hours

SOIL SYMBOL	DEPTH (feet)	SAMPLES	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
											Loose gray SILTY SAND (SM)
		X	N=10	14							firm @ 2½'
	5	X	N=13	15				18	14	4	Firm gray CLAYEY SAND (SC) w/ferrous nodules
		X	N=12								
		X	N=13								
	10										
											Dense gray fine SAND (SP) w/gravel
		X	N=33			-200=8.9%					
	15										
		X	N=34								
	20										
		X	N=34								
	25										Bottom hole @ 25'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-11
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT ** FT. AFTER

FIELD DATA: DEPTH (feet)	FIELD DATA: Penetration Resistance (N) or TSF	LAB: Moisture Content %	LAB: Dry Density, PCF	LAB: Compressive Strength TSF	LAB: Failure Strain %	ATTERBERG LIMITS: Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
		11							Firm tan SILTY SAND (SM)
	N=12								
5	N=16			-200=34.7%					tan & light gray, very silty @ 4½'
	N=80								Very dense tan & light gray CLAYEY SAND(SC)
10	N=36	15							w/clay layers below 10'
									Very dense fine SAND (SP)
15	50/6½"								

Bottom hole @ 15'

** Borehole collapsed @ 3.5'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-12
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED 0 TO 20 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO
AT FT. DEPTH.
WATER AT 8.0 FT. AFTER 2 hours

FIELD DATA			LABORATORY DATA				ATTERBERG LIMITS			
DEPTH (feet)	SAMPLES	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
0–4	X	N=23			-200=35.9%					Firm tan & gray SILTY SAND (SM) tan & light gray, very silty @ 2½'
5	X	N=7								Firm tan & gray CLAYEY SAND (SC) w/sandy clay layers @ 6½'
	X	N=22								
10	X	N=17	14				26	21	5	
15	X	N=60								Very dense gray SILTY SAND (SM)
20	X	N=43								dense @ 18½'
										Bottom hole @ 20'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-13
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT ** FT. AFTER

SOIL SYMBOL	DEPTH (feet)	SAMPLES	FIELD DATA: Penetration Resistance (N) or TSF	LABORATORY DATA: Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain - %	ATTERBERG LIMITS: Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
				13							Firm tan SILTY SAND (SM)
			N=14								Firm tan & light gray CLAYEY SAND (SC)
	5		4.5+	13	118	1.11	5				Stiff tan & gray SANDY CLAY (CL) w/sand pockets & layers, ferrous nodules
			1.50	14	119	1.04 (4)	6				
	10		N=37	12							Dense tan & gray CLAYEY SAND (SC)
											Stiff tan & gray VERY SANDY CLAY (CL)
	15		N=82			-200=15.0%					Very dense gray SILTY SAND (SM)

Bottom hole @ 15'

** Borehole collapsed @ 12.5'

* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-14
FILE NO. 82-522
DATE 12-17-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT 7.5 FT. AFTER 1 hour

SOIL SYMBOL	DEPTH (feet)	SAMPLES	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain, %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
											Firm tan SILTY SAND (SM)
			N=13								Firm gray CLAYEY SAND (SC)
	5		N=19								
			N=21	12							Firm tan SILTY SAND (SM)
			N=16								
	10										
			N=28								light gray @ 13½'
	15										Bottom hole @ 15'

• SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

LOG OF BORING

PROJECT: Waste Water Plant No.2
The Woodlands, Texas

CLIENT: The Woodlands Development Corp.
The Woodlands, Texas

BORING NO. CB-15
FILE NO. 82-522
DATE 12-21-82

DRY AUGERED 0 TO 15 FEET
WASH BORED TO FEET

FREE WATER ENCOUNTERED YES NO

AT FT. DEPTH.

WATER AT ** FT. AFTER

Depth (feet)	Penetration Resistance (N) or TSF	Moisture Content %	Dry Density, PCF	Compressive Strength TSF	Failure Strain, %	Liquid LL	Plastic PL	Plasticity Index PI	DESCRIPTION OF STRATUM
0									Firm gray CLAYEY SAND (SC)
2									w/ferrous nodules @ 2'
3	N=11	12							
4									tan & light gray w/clay layers & sand pockets @ 4'
5	3.50	15	117	1.33	3				
9	N=21	13							
13½									w/clay pockets @ 13½'
14	N=9								
15									Bottom hole @ 15'

** Boring drilled in standing water

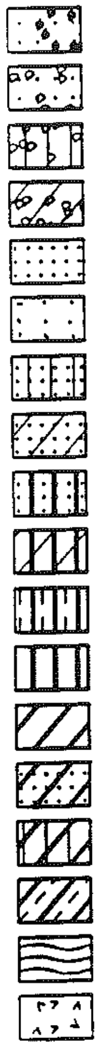
* SLICKENSIDED FAILURE
( ) CONFINING PRESSURE, PSI
G.S. GRAIN SIZE

PENETRATION RESISTANCE
(N) - STANDARD PENETRATION RESISTANCE (SPT)
TSF - POCKET PENETROMETER OR TORVANE ESTIMATED UNCONFINED COMPRESSIVE STRENGTH, TONS PER SQ. FOOT

McBride-Ratcliff and Associates, Inc.

SYMBOLS AND TERMS USED ON BORING LOGS

Unified Soil Classification System Symbols



Symbol	Description
GW	Well-graded Gravel
GP	Poorly-graded Gravel
GM	Silty Gravel
GC	Clayey Gravel
SW	Well-graded Sand
SP	Poorly-graded Sand
SM	Silty Sand
SC	Clayey Sand
ML	Sandy Silt
ML	Clayey Silt
OL	Organic Silt
MH	Inorganic Silt
CH	Clay
CL	Sandy Clay
CL	Silty Clay
OH	Organic Clay
PT	Peat
FILL	Fill

Sampler Symbols

Meaning
Depth of thin-walled tube sample
Depth of Standard Penetration Test (SPT)
Depth of auger sample
Depth of sampling attempt with no recovery

Field Test Data	Meaning
2.50	Pocket penetrometer reading in tons per square foot
8/6	Blow count per 6-in. interval of the Standard Penetration Test
(free-water symbol)	Observed free-water level during drilling
(static-water symbol)	Observed static-water level

Laboratory Test Data	Meaning
W_c (%)	Moisture content in percent
Dens (psf)	Dry unit weight in pounds per square foot
Q_u (tsf)	Unconfined compressive strength in tons per square foot
UU (tsf)	Compressive strength under confining pressure in tons per square foot
Str (%)	Strain at failure in percent
LL	Liquid limit in percent
PI	Plasticity index
#200 (%)	Percent passing the no. 200 mesh sieve
( )	Confining pressure in pounds per square inch
*	Slickensided failure
**	Did not fail

RELATIVE DENSITY OF COHESIONLESS & SEMI-COHESIVE SOILS

The following descriptive terms for relative density apply to cohesionless soils such as gravels, silty fine sands, and fine sands as well as semi-cohesive soils such as sandy silts, clayey silts, and clayey sands.

Relative Density	Typical SPT "N" Value Range**
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	Over 50

** "N" is the number of blows from a 140-lb weight having a free fall of 30 in. required to penetrate the final 12 in. of an 18-in. sample interval. The density designations correspond to a SPT "N" value range based on an effective overburden pressure of 1 tsf. Density descriptors may be modified because of variations in the effective overburden pressure.

CONSISTENCY OF COHESIVE SOILS

The following descriptive terms for consistency apply to cohesive soils such as clays, sandy clays, and silty clays.

Typical Unconfined Compressive Strength (tsf)	Consistency	Typical SPT "N" Value Range
$q_u < 0.25$	Very Soft	≤2
$0.25 \leq q_u < 0.50$	Soft	3-4
$0.50 \leq q_u < 1.00$	Firm	5-8
$1.00 \leq q_u < 2.00$	Stiff	9-15
$2.00 \leq q_u < 4.00$	Very Stiff	16-30
$q_u \geq 4.00$	Very Stiff-Hard	≥31*

* An "N" value of 31 or greater corresponds to a hard consistency. The correlation of consistency with a typical SPT "N" value range is approximate.

Attachment B

PIEZOMETER LOG

PIEZOMETER INSTALLATION REPORT

PROJECT: Woodlands Wastewater Treatment Plant No. 2 — **WELL NO:** P-1

CLIENT: Turner Collie & Braden, INC. — **PROJECT NO:** 94-0312

LOCATION: Boring CB-17

PIEZOMETER COMPLETION

DATE: 11-4-94

DRY AUGURED 0 **TO** 15 **FT**

WASH BORED 15 **TO** 60 **FT**

DRILLING FLUID: Water

PIEZOMETER DEVELOPMENT

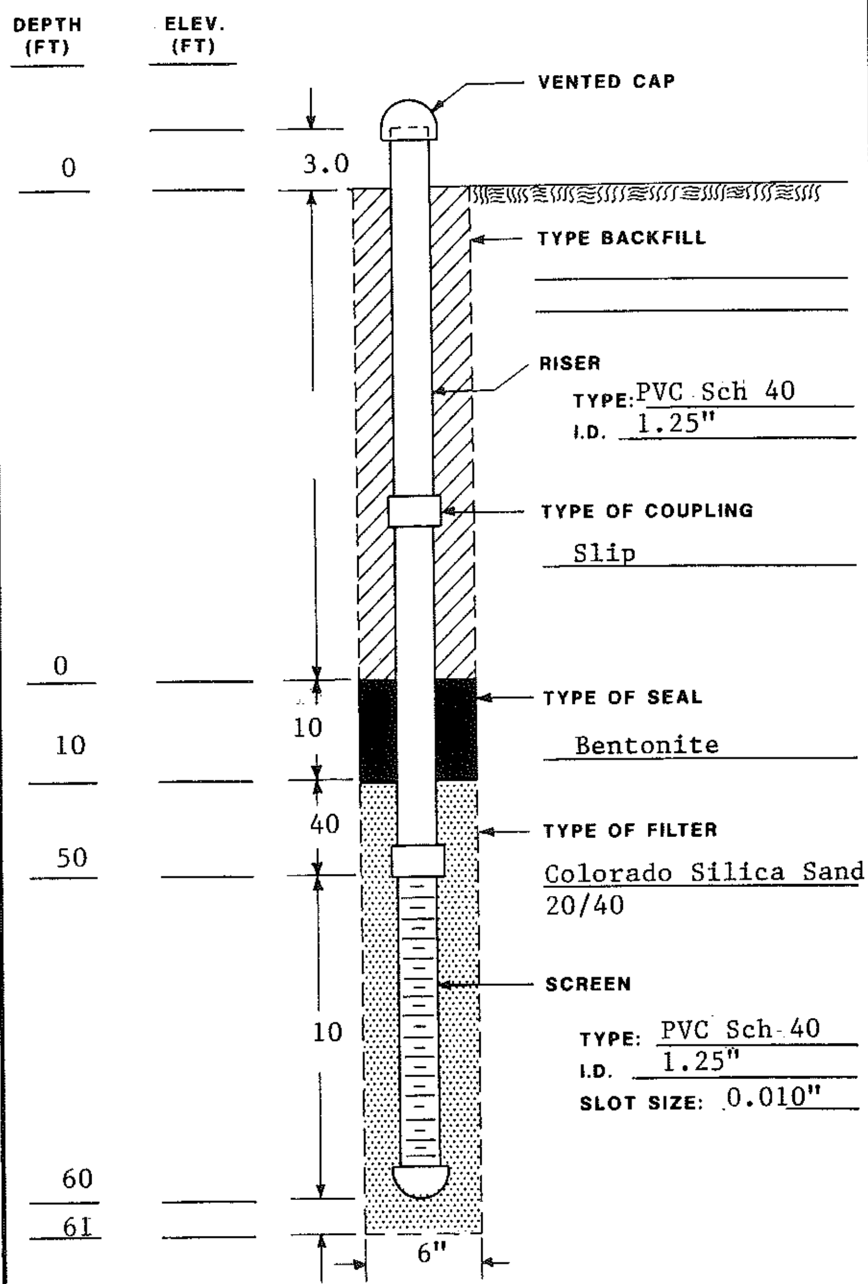
DATE: 11-7-94

METHOD: Bailer

WATER LEVEL READINGS

FREE WATER AT ______ **FT**

DATE	DEPTH*	ELEVATION
11-7-94	14.6	
11-10-94	14.5	
11-12-94	14.4	



REMARKS: *Measured From Ground Surface