# GEOTECHNICAL STUDY
# BUFFALO SPEEDWAY EXTENSION
# FROM WEST AIRPORT BOULEVARD TO WILLOWBEND BOULEVARD
# PAVEMENT, UTILITIES, BRIDGE OVERPASS AND
# OFF-SITE DRAINAGE DITCHES
# GFS NO.: N-000784-0001-3 (FILE NO. SB9240)
# HOUSTON, TEXAS

Prepared for

**CLR, Inc.**
**Waller, Texas**

**February 2012**

Prepared by

**TOLUNAY-WONG ENGINEERS, INC.**
**10710 South Sam Houston Parkway West, Suite 100**
**Houston, Texas 77031**
**713/722-7064**

**Project No. 11.13.180**

February 6, 2012
TWEI Project No. 11.13.180

CLR, Inc.
19530 FM 362
Waller, Texas 77484

Attn: Mr. John P. Peyton, P.E., R.P.L.S.

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**HOUSTON, TEXAS**

Dear Mr. Peyton:

We are pleased to submit our report covering the geotechnical study for the above referenced project. Should you have any questions or comments concerning the information contained herein, please contact us.

We appreciate the opportunity to serve you during this phase of the project, and look forward to continue our services during the construction phase and on future projects.

2/6/2011
STATE OF TEXAS
MOHAMMED S. ISLAM
99415
LICENSED
PROFESSIONAL ENGINEER
M. Islam

Sincerely,
**Tolunay-Wong Engineers, Inc.**
TBPE Firm Registration Number: F-124

M. Islam
Mohammed S. Islam, P. E.

Zeki A. Tolunay, P.E.

Copies Submitted: (2) Mr. John P. Peyton, P.E., R.P.L.S. of CLR, Inc.
(1) Mr. John A. Guajardo, P.E., R.P.L.S. of JAG Engineering, Inc.

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# SUMMARY

The project consists of the construction of Buffalo Speedway Extension from West Airport Boulevard to Willowbend Boulevard in Houston, Harris County, Texas. The principal findings and conclusions of this geotechnical study are summarized as follows.

The subsurface soil stratigraphy along the pavement alignment, based on borings B-1 and B-11 through B-28, generally consists of firm to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and to a lesser extent semi-cohesive sandy silty clays (CL-ML), silty clays with sand (CL-ML) to the 15-ft explored depths in borings B-1, B-11 through B-15, B-17 through B-23, B-25 through B-28, and to 10-ft depth in boring B-24, followed by cohesionless silty sands to the 15.5-ft boring termination depth. In boring B-16, intermixed layers of cohesionless/semi-cohesive silty sands (SM) and clayey sands (SC) were encountered to the 15.5-ft explored depth. A 2-ft thick surficial cohesive fill soils were encountered during our field exploration in borings B-11 through B-13 and B-28.

The subsurface soil stratigraphy at the bridge overpass area, based on borings B-2 through B-10, generally consists of firm to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH) to the 30-ft to 110-ft explored depths in borings B-2, B-5, B-10, and to 27-ft to 63-ft depths in borings B-3, B-4, B-6 through B-9, underlain by very dense, cohesionless/semi-cohesionless to semi-cohesive silty sands (SM), silts with sand (ML), clayey sands (SC), and stiff to very stiff consistency, silty clays (CL-ML) to 33-ft to 66-ft depth, followed by firm to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and to a lesser extent semi-cohesionless/semi-cohesive silts with sand (ML) and silty clays (CL-ML) to the 80-ft to 100-ft boring termination depths. A surficial 2-ft to 8-ft thick cohesionless to cohesive fill was encountered during our field exploration in borings B-4, B-5, and B-8 through B-10.

The subsurface soil stratigraphy at the off-site drainage ditches, based on borings A-1, BB-1, BB-2, C-1 through C-3 and D-1 through D-3, generally consists of soft to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and to a lesser extent semi-cohesive sandy silty clays (CL-ML) to the 20-ft explored depth in borings A-1, BB-1, BB-2, C-2, C-3, D-1 through B-3, and to 12-ft depth in boring C-1, underlain by cohesionless silty sands (SM) to the 20-ft boring termination depth.

Based on the groundwater level measurements, it appears that the groundwater level was at about 8.4-ft to 22.3-ft below existing grade at the time of the field exploration.

The layered soils encountered along the project alignment may be classified as “Type C” based on OSHA. Bedding and backfill for the proposed utility lines should be constructed using City of Houston Specifications or equivalent.

Based on the project borings, excavations for utilities are anticipated to encounter primarily lean clays, sandy lean clays, lean clays with sand, fat clays with sand, fat clays, and to a lesser extent sandy silty clays, silty clays with sand to 10-ft to 15-ft depth, followed by silty sands/clayey sands locally. Perched water seepage or surface runoff into excavations within cohesive/semi-cohesive soils can probably be handled by pumping from sumps. Mechanical dewatering may be necessary if sands/silts become waterbearing during excavation.

After stripping, the pavement subgrade soils should be proofrolled and stabilized to a depth of 8-inches with lime. For planning purposes, a lime content of 8% (dry weight basis) may be considered for the subgrade stabilization. Actual stabilization requirements should be determined in the laboratory by trial. Lime stabilization should be performed in accordance with City of Houston Specifications, Section 02336, *Lime Stabilized Subgrade*. The stabilized soil should be compacted to at least 95% of the standard Proctor maximum dry density within two percentage points of the optimum moisture content (ASTM D 698).

Fill for pavement grading purposes should preferably be earth fill. Earth fill should have plasticity index similar to the on-site cohesive soils and be free of organic matter and excessive silt. Fill for grade adjustments should be placed in lifts not exceeding 8-in. loose measure. Fill below pavement areas should be compacted to at least 95% of the maximum dry density at a moisture content within two percentage points of the optimum, as determined by the standard Proctor density test (ASTM D 698).

Rigid pavement thickness recommendations are based on the "*AASHTO Guide for Design of Pavement Structures–1993*" prepared by the American Association of State Highway and Transportation Officials. The recommended rigid pavement thickness for this project is 10-inch. Design criteria are presented in the text of this report.

Box culverts are planned to be constructed at Buffalo Speedway at about 7-ft to 12-ft depth. An allowable gross total gravity load bearing pressure of 2,000 psf may be used in design for box culvert foundations placed in competent properly prepared subgrade. Box culvert design and construction recommendations are presented in the report text.

The proposed bridge overpass structure for Buffalo Speedway Extension will be supported on cast-in-place concrete drilled shafts. The allowable axial compression load capacity and allowable uplift load capacity curves for 36 and 42 inch diameter cast-in-place concrete drilled shafts for the bridge are presented on Figures 15 through 22.

We understand that embankments will be constructed at the project site. If fill is required for grade adjustment, it should preferably be earth fill. Earth fill should have plasticity index similar to in-situ cohesive soils and be free of organic matter and excessive silt. Fill for grade adjustments should be placed in lifts not exceeding 8-in. loose measure. Fill below pavement areas should be compacted to at least 95% of the maximum dry density at a moisture content within two percentage points of the optimum, as determined by the standard Proctor density test (ASTM D 698).

Stability analyses were performed to evaluate the global stability of the proposed mechanically stabilized earth (MSE) retaining wall and embankment fill at the north and south sides of Buffalo

Speedway Extension bridge overpass crossing Holmes Road. Results of the stability analyses for short term and long-term conditions are presented on Figures 23 through 26, and in the text of this report.

It is planned to construct a traffic signal pole at the intersection of the proposed Buffalo Speedway and West Airport Boulevard. There is a provision for a possible traffic signal pole at Holmes Road and Buffalo Speedway. The foundation design recommendations for traffic signal poles are presented in the report section.

Slope stability analyses of the proposed four (4) off-site drainage ditches with a design slope of 4 horizontal: 1 vertical (4H:1V) were performed to evaluate the channel stability for the short term (end of construction), rapid drawdown, and long-term conditions. Detailed results of our slope stability analyses are presented on Figures 27 through 42, and in the report.

Based on the limited testing, it appears that the medium-to-high plasticity cohesive soils encountered in the project borings are "non-to-slightly dispersive to dispersive".

Stability analyses were performed to evaluate the riprap/grass lined 4H:1V (inside) and 4.5H:1V (outside) embankment slopes for the outfall structures. Outfall construction guidelines and results of the slope stability analyses for short term, intermediate term (rapid drawdown), and long term conditions are presented on Figures 43 through 54, and in the report text.

# 1. INTRODUCTION

## 1.1 General

CLR, Inc. retained Tolunay-Wong Engineers, Inc. (TWEI) to perform a geotechnical evaluation for the construction of Buffalo Speedway Extension from West Airport Boulevard to Willowbend Boulevard in Houston, Harris County, Texas (Key Map 532 X, 572 B & F). We understand that the geotechnical requirements consist of subsurface evaluation, analysis and recommendations for pavement design, utilities, bridge, embankment and off-site drainage ditches.

The study was performed in general accordance with TWEI Proposal No. P07-G231.rev4, dated August 12, 2011, that was part of the Agreement for Sub-consultant Services, dated September 9, 2011.

## 1.2 Project Information

The project consists of the construction of Buffalo Speedway Extension from West Airport Boulevard to Willowbend Boulevard. The proposed development includes two 24-ft wide concrete roadways and raised median with curbs, sidewalks, street lighting, and necessary underground utilities including storm sewers, water lines, and four off-site drainage ditches extending laterally from the alignment (eastward to the HCFCD ditch). The length of the Buffalo Speedway extension project is approximately 13,000 LF, beginning at West Airport Boulevard, extending north to the northern limits located at Willowbend Boulevard.

A roundabout has been also added to the roadway alignment. Additionally, an extension is planned from the main alignment to the intersection with Holmes Road, approximately 1,200 LF. The four drainage ditches are approximately 1,000 to 2,500 LF. A bridge overpass, spanning Holmes Road/Union Pacific Rail Road is also included in the work scope. The project includes a traffic signal at West Airport Boulevard and provisions for a possible signal at Holmes Road.

We received the project design information from CLR, Inc. via email transmittal on November 30, 2011. We understand that the utility lines will be installed within the upper 6-ft to 12-ft depths. The depths of the proposed off-site drainage ditches will be about 7.5-ft to 9-ft. Where the ditches intersect the existing pipeline alignments, the depths of the ditches may be deeper to accommodate box culverts.

Roadway geometry for the proposed Holmes Road intersection includes right-of-way provisions for a future grade separation spanning Holmes Road and the adjacent Union Pacific railroad tracks. The Major Thoroughfare Plan calls for proposed Right-of-Way to be about 100-feet wide. This project is located within the Sims Bayou watershed.

Information furnished by the client indicates that the proposed bridge structure will be about 1,150-ft long, and will be supported on drilled cast-in-place concrete shafts. The size of the shafts will be about 36-inch and 42-inch in diameter. The maximum height of the retaining wall embankments will be about 18-ft at Sta. 193+50.00 at the north side of Holmes Road, and about 18.5-ft at Sta. 182+00.00 at the south side. The proposed embankments will be about 500-ft long at the north side of Holmes Road, and about 450-ft long at the south side.

Our review of drawings indicate that proposed drainage ditches will be about 7.5-ft to 9-ft deep and will be constructed using 4H:1V slope. Precast reinforced concrete box sewers with sizes of 5'x3' to 6'x4' are planned to be installed at the west side of drainage channel outfall (inflow) locations. Corrugated galvanized metal pipes (CGMP) of 48-in. to 60-in. diameters will be placed at the east side of the drainage ditch outfall (outflow) locations towards the HCFCD channel.

An aerial photograph and alignment drawings for the road right-of-way were provided by Mr. John P. Peyton, P.E., R.P.L.S. of CLR during a meeting on April 14, 2011. We conducted our study based on information provided by CLR, our site reconnaissance, City of Houston Design Manual, Chapter 11 "Geotechnical and Environmental Requirements" dated January 1, 2011. The proposed roadway alignment is shown in Figures 1 through 3. The layouts of proposed MSE retaining walls for Buffalo Speedway Extension bridge overpass are presented in Appendix A. The plan and profiles of proposed four (4) off-site drainage ditches are included in Appendix B.

# 2. SCOPE OF STUDY

The objectives of this study were to explore soil and ground water conditions within the project site to formulate geotechnical design recommendations and construction guidelines for the referenced project. The scope of the geotechnical study included the following work tasks:

- Drilling thirty-seven (37) soil borings to 15-ft to 110-ft depths along the project alignment to evaluate the subsurface conditions.

- Performing laboratory tests on selected soil samples recovered from the project borings to evaluate physical and engineering properties of the subsoil.

- Conducting engineering analyses to develop geotechnical design recommendations and construction guidelines for the proposed roadway pavement, utilities, bridge overpass and off-site drainage ditches.

Environmental assessments, recommendations for areas not covered by the boring layout, and site-specific fault studies were outside the scope of work for this study.

# 3. FIELD EXPLORATION AND LABORATORY TESTING

## 3.1 Test Borings

The fieldwork was performed between September 15 and October 3, 2011. The field exploration consisted of drilling, logging and sampling thirty-seven (37) soil borings to 15-ft to 110-ft depths below existing grade. Drilling and sampling were performed by GeoTech Services, LLP. TWEI representatives coordinated the field activities, logged the boreholes, and obtained water level readings during drilling, at the end of the day of drilling and the next day after drilling completion. Borings B-4, B-10, B-19, BB-2 and D-2 were converted into respective piezometers PZ-B4, PZ-B10, PZ-B19, PZ-BB2 and PZ-D2 after completion of drilling. The approximate boring and piezometer locations are shown on Figures 1 through 3.

In borings BB-2 and D-2, we drilled additional 2-ft of depth to clean out the bottom of the boreholes prior to installation of piezometers. The piezometers were installed under the supervision of Mr. Ronnie Linder of Triangle Resources (License # 2987). The well reports submitted to Texas Department of Licensing and Regulations are presented in Appendix C.

## 3.2 Drilling Methods

The field operations were performed in general accordance with *Standard Practice for Soil Investigation and Sampling by Auger Borings* [American Society for Testing and Materials (ASTM) D 1452]. Soil borings were drilled with a buggy rig, and were dry augered to completion depths, or depths where wall instability or free water was encountered and completed using rotary wash drilling techniques in an attempt to measure the groundwater level. Soil samples were obtained at continual 1-ft to 2-ft intervals to 15-ft to 30-ft depths, and then at 5-ft intervals thereafter to the boring completion depths. The soil borings were backfilled with cement-bentonite grout after the next-day groundwater level readings, with the exception of borings B-4, B-10, B-19, BB-2 and D-2, where piezometers were installed in the open boreholes upon completion of sampling.

## 3.3 Soil Sampling

Cohesive soil and soil interpreted to be cohesive during drilling were sampled by hydraulically pushing a 3-inch diameter, thin-walled tube a distance of about 24 inches. The field sampling procedure was conducted in accordance with the *Standard Practice for Thin-Walled Tube Sampling of Soils* (ASTM D 1587). The field technician extruded the soil samples in the field, visually classified the recovered soils, and obtained penetration resistance measurement of the cohesive soils using a calibrated pocket penetrometer. The pocket penetrometer readings are presented on the boring logs in Appendices D through F. Based on experience with local soils, a factor of 0.67 was applied to penetrometer reading to estimate the consistency of the cohesive overconsolidated soils. Representative portions of the soil samples extruded in the field were wrapped in foil, placed into plastic bags, and transported to the laboratory.

Cohesionless/semi-cohesionless to semi-cohesive soil and soil interpreted to be granular during drilling were recovered by driving a 2-inch-diameter, split barrel sampler. The sampler was driven 18 inches by a 140-pound hammer falling about 30 inches in general accordance with the *Standard Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D 1586). The field technician recorded the number of blows required to drive the sampler through three consecutive 6-inch sampling intervals. The sum of the blows required to penetrate the final 12 inches is the Standard Penetration Test (SPT) "N" value. Each sample obtained from the split barrel was visually classified, placed in an air-tight plastic bag, and transported to our laboratory for testing. The compactness of the cohesionless to semi-cohesive soil and the consistency of the cohesive soil were inferred from $N_{60}$ (i.e., SPT "N" blowcount value corrected for field procedure to an average energy ratio of 60%). The SPT data are presented on the logs of borings in Appendices D through F.

## 3.4 Boring Logs

Our interpretations of general soil and groundwater conditions at the boring locations are included on the boring logs. The interpretations of the soil types throughout the boring depth and the locations of strata change were based on visual classifications during field sampling, and laboratory testing in accordance with *Standard Practice for Classification of Soils For Engineering Purposes* (ASTM D 2487) and *Standard Practice for Description and Identification of Soils* (ASTM D 2488). The boring logs include the type and interval depth for each sample. The project boring logs and key to the terms and symbols used on the logs are presented in Appendices D through F. Soil profiles of the project boring logs are presented on Figures 4 through 7.

## 3.5 Water-Level Measurements

Groundwater level measurements taken during drilling, the next day of sampling, and static groundwater level measured in the piezometers are summarized in the following Table 3-1.

Table 3-1
Groundwater Level Measurements

| Boring/ Piezometer No. | Boring/ Piezometer Depth | Depth of Dry Augering | Depth to Free Water During Drilling | Groundwater Level Readings | | |
|---|---|---|---|---|---|---|
| | | | | Depth to Groundwater | Caved Depth | Time Lapse Between Drilling Completion & Water Level Reading |
| B-1 | 15 ft | 15 ft | Dry | Dry | - | 23 hours |
| B-2 | 30 ft | 30 ft | Dry | 8.4 ft | 26.2 ft | 22.25 hours |

| Boring/ Piezometer No. | Boring/ Piezometer Depth | Depth of Dry Augering | Depth to Free Water During Drilling | Groundwater Level Readings | | |
|---|---|---|---|---|---|---|
| | | | | Depth to Groundwater | Caved Depth | Time Lapse Between Drilling Completion & Water Level Reading |
| B-3 | 80 ft | 28 ft | 28 ft | 22.3 ft | 27.7 ft | 15 minutes |
| B-4/PZ-B4 | 80 ft/80 ft | 30 ft | 28 ft | 14.90 ft (PZ-B4)<br>14.80 ft (PZ-B4)<br>15.30 ft (PZ-B4) | - | 9/23/2011<br>10/21/2011<br>11/28/2011 |
| B-5 | 110 ft | 30 ft | - | - | - | - |
| B-6 | 100 ft | 30 ft | 28 ft | 13.2 ft | 25.8 ft | 15 minutes |
| B-7 | 99.3 ft | 30 ft | 30 ft | 13.4 ft | 26.4 ft | 15 minutes |
| B-8 | 100 ft | 30 ft | 28 ft | 13.2 ft | 26.5 ft | 15 minutes |
| B-9 | 80 ft | 20 ft | 20 ft | 17.6 ft | 18.0 ft | 15 minutes |
| B-10/PZ-B10 | 30 ft/30 ft | 30 ft | 30 ft | 13.70 ft (PZ-B10)<br>Damaged (PZ-B10) | - | 9/23/2011<br>10/21/2011 |
| B-11 | 15 ft | 15 ft | Dry | Dry | - | 25.75 hours |
| B-12 | 15 ft | 15 ft | Dry | Dry | - | 18 hours |
| B-13 | 15 ft | 15 ft | Dry | Dry | - | 17 hours |
| B-14 | 15 ft | 15 ft | Dry | Dry | - | 21 hours |
| B-15 | 15 ft | 15 ft | Dry | Dry | - | 21.5 hours |
| B-16 | 15.5 ft | 15.5 ft | Dry | Dry | 13.0 ft | 22.5 hours |
| B-17 | 15 ft | 15 ft | Dry | Dry | - | 23 hours |
| B-18 | 15 ft | 15 ft | Dry | Dry | - | 24 hours |
| B-19/PZ-B19 | 15 ft/17 ft | 15 ft/17 ft | Dry | Dry (PZ-B19)<br>16.85 ft (PZ-B19)<br>15.70 ft (PZ-B19) | - | 9/23/2011<br>10/21/2011<br>11/28/2011 |
| B-20 | 15 ft | 15 ft | Dry | Dry | 14.4 ft | 30.5 hours |
| B-21 | 15 ft | 15 ft | Dry | Dry | 14.3 ft | 4.25 hours |
| B-22 | 15 ft | 15 ft | Dry | Dry | 14.1 ft | 5.5 hours |

| Boring/ Piezometer No. | Boring/ Piezometer Depth | Depth of Dry Augering | Depth to Free Water During Drilling | Groundwater Level Readings | | |
|---|---|---|---|---|---|---|
| | | | | Depth to Groundwater | Caved Depth | Time Lapse Between Drilling Completion & Water Level Reading |
| B-23 | 15 ft | 15 ft | Dry | Dry | 13.5 ft | 57 hours |
| B-24 | 15.5 ft | 15.5 ft | Dry | Damp | 12.8 ft | 73.5 hours |
| B-25 | 15 ft | 15 ft | Dry | Damp | 13.9 ft | 74 hours |
| B-26 | 15 ft | 15 ft | Dry | Dry | 14.5 ft | 74.5 hours |
| B-27 | 15 ft | 15 ft | Dry | Dry | - | 75.5 hours |
| B-28 | 15 ft | 15 ft | Dry | Dry | - | 76 hours |
| A-1 | 20 ft | 20 ft | Damp @ 18.4 ft | 14.4 ft | 15.0 ft | 8 hours |
| BB-1 | 20 ft | 20 ft | Dry | Dry | 18.3 ft | 24 hours |
| BB-2/PZ-BB2 | 20 ft/22 ft | 20 ft | Dry | Dry (PZ-BB2)<br>20.80 ft (PZ-BB2)<br>19.90 ft (PZ-BB2) | - | 9/23/2011<br>10/21/2011<br>11/28/2011 |
| C-1 | 20 ft | 20 ft | Dry | 14.9 ft | 15.0 ft | 30.5 hours |
| C-2 | 20 ft | 20 ft | Dry | Dry | 19.1 ft | 30.5 hours |
| C-3 | 20 ft | 20 ft | Dry | Dry | 18.9 ft | 31.5 hours |
| D-1 | 20 ft | 20 ft | Dry | Dry | 18.7 ft | 25 hours |
| D-2/PZ-D2 | 20 ft/22 ft | 20 ft | Dry | 11.75 ft(PZ-D2)<br>11.10 ft (PZ-D2)<br>12.10 ft (PZ-D2) | - | 9/23/2011<br>10/21/2011<br>11/28/2011 |
| D-3 | 20 ft | 20 ft | Dry | 10.4 ft | 10.6 ft | 6.5 hours |

Water level measured in an open borehole may not accurately reflect the true (static) groundwater condition since it may be time dependent. A more accurate determination of the static groundwater level is made in open standpipe piezometers. Piezometer installation was included in the work scope of this project. Borings B-4, B-10, B-19, BB-2 and D-2 were converted into respective piezometers PZ-B4, PZ-B10, PZ-B19, PZ-BB2 and PZ-D2 after

completion of drilling. The piezometer reports are presented in Figures 8 through 12. The well reports submitted to Texas Department of Licensing and Regulations are included in Appendix C.

## 3.6 Laboratory Testing

Laboratory tests were performed on selected soil samples to measure physical and engineering properties. Brief descriptions of the tests are presented below.

- ***Laboratory Determination of Water (Moisture) Content of Soil and Rock - ASTM D 2216.*** The water content of a material, expressed as a percentage, is defined as the ratio of the mass of pore or free water in a given mass of material to the mass of the solid material particles. Moisture content can provide an indication of cohesive soil shear strength and compressibility when compared to Atterberg limits.

- ***Liquid Limit, Plastic Limit, and Plasticity Index of Soils - ASTM D 4318.*** These soil properties are used to distinguish different soil types and provide an evaluation of volume change potential when considered in conjunction with natural moisture content. The liquid limit and plastic limit of soils, referred to as the Atterberg limits, distinguish the boundaries of the several consistency states of plastic soils. The plasticity index of the soil is the difference between the liquid limit and the plastic limit.

- ***Amount of Material in Soils Finer Than the No. 200 (75-µm) Sieve - ASTM D 1140.*** This test determines the total amount of material in soils finer than the No. 200 sieve. The test result is presented as the percent of silt and clay sizes by weight in the sample and can provide an indication of the soil permeability.

- ***Particle Size Analysis of Soils - ASTM D 422.*** This method quantitavely determines the distribution of particle sizes larger than 75-µm (retained on the No.200 sieve) by sieving. The distribution of particle sizes smaller than 75-µm can be determined by a sedimentation process, using a hydrometer.

- ***Unconfined Compressive Strength of Cohesive Soil - ASTM D 2166.*** This test determines the unconfined compressive strength of cohesive soil in the undisturbed, remolded or compacted condition, using strain-controlled application of the axial load. The unconfined compressive strength of a cohesive soil sample is twice its undrained shear strength.

- ***Unconsolidated-Undrained Triaxial Compression – ASTM D 2850.*** This compression test consists of placing a relatively undisturbed cylindrical specimen in a pressurized triaxial chamber and then loading it to failure, without allowing drainage, using strain-controlled application of the axial load. The compressive strength of a cohesive soil sample is twice its undrained shear strength.

- ***Multi-stage Consolidated-Undrained Triaxial Compression With Pore Pressure Measurements – Modified ASTM D 4767).*** This compression test consists of first consolidating a cylindrical specimen in a pressurized triaxial chamber and then loading it in three stages before it is sheared quickly without allowing drainage. Pore pressures are measured during the testing to determine the effective stress parameters.

- ***Incremental Consolidation – ASTM D 2435.*** In this test, a portion of the soil sample is carefully trimmed, set in the oedometer cell, loaded incrementally beyond the preconsolidation pressure (Pc) point, and then the load is removed. This test, through the estimation of the overconsolidation ratio (OCR), determines the stress history (i.e., underconsolidated, normally consolidated, or overconsolidated) of the soil sample and its compressibility characteristics.

- ***Density of Soil - ASTM D 2937***. Total unit weight of the soil aggregate is defined as the weight of the aggregate (soil plus water) per unit volume. Knowing the total unit weight and moisture content, dry unit weight can be computed.

- ***Determining Dispersive Characteristics of Clayey Soils by Crumb Test - ASTM D 6572.*** This test method provides a qualitative indication of the natural dispersive characteristics of clayey soils. A cube of remolded soil approximately 15 mm (5/8 in.) on each side is placed on the bottom of a white porcelain dish containing 250 mL of distilled water during the test. Temperature of water is recorded during the test. The visual determinations of dispersion grade are made and recorded at 2 minutes, 1 hour and 6 hours.

- ***Dispersive Characteristics of Clay Soils by Double Hydrometer Test - ASTM D 4221.*** This method quantitatively determines the distribution of particle sizes smaller than 5-µm which is determined by a sedimentation process, without mechanical agitation and to which no dispersive agent is added. The amount of particles smaller than 5-µm determined by this method compared with the total amount of particles smaller than 5-µm determined by a sedimentation process, using a solution of sodium hexametaphosphate, is the measure of dispersive characteristics of the soils.

- ***Identification and Classification of Dispersive Clays by Pinhole Test- ASTM D 4647.*** In the pinhole test method, distilled water flows horizontally initially under a hydraulic head of 50 mm through a 1.0 mm diameter hole punched in the soil specimen. Test results are evaluated from the appearance of the flowing solution emerging from the specimen, the rate of flow, and the final size of the hole through the specimen.

- ***Sulfate Content of Soils – (EPA 300).*** This analytical test determines amount of sulfates in soil which in turn is indicative of corrosive potential of the subgrade soils for bridge and pavement structures.

- ***Laboratory Compaction Characteristics and Moisture Density Relationship of Soils-ASTM D 698.*** These test methods cover laboratory compaction methods used to determine the relationship between molding water content and dry unit weight of soils compacted in a 4 or 6-in. diameter mold with a 5.5 lb rammer dropped from a height of 12-in producing a compactive effort of 12400 ft-lb/ft$^3$.

Results of the laboratory tests are presented in Appendices C through E, respectively. Selected Particle Size Analysis of Soils, Moisture Density Relationship of Subgrade, Consolidated Undrained Triaxial Compression with Pore Pressure Measurements, Consolidation, Pinhole Dispersion, Double Hydrometer and Crumb test results are presented in Appendix G. The results of the chemical laboratory tests are included in Appendix H.

# 4. GENERAL GEOLOGY AND CURSORY FAULT REVIEW

## 4.1 General Geology

An assessment of general geology was conducted by a review of geologic literature concentrating on regional geological maps of the State of Texas.

The Buffalo Speedway Extension, from the Willowbend Boulevard, south to West Airport Boulevard site is situated in the Gulf Coastal Plain Physiographic region of Texas. The Gulf Coastal Plain region contains sediments that have been deposited by fluvial and deltaic processes. The sediments are represented as a series of wedges thickening towards the coast. The sediments of the Harris County area were deposited during the Quaternary and Tertiary Periods of the Cenozoic Era. The Quaternary Period is divided into two geologic epochs, the Holocene and the Pleistocene. The Tertiary Period is divided into five geologic epochs, Pliocene, Miocene, Oligocene, Eocene, and Paleocene.

The Holocene Epoch is the youngest epoch of the Quaternary Period. The Holocene consists of recent sediments deposited in present day alluvial valleys and floodplains of the major drainage systems. These sedimentary units typically contain cohesionless soils (sands, silts, and their intermixtures) intermixed with cohesive soils (clays, sandy clays, and silty clays).

The Pleistocene Epoch includes the sedimentary deposits of the Beaumont, Lissie, and Willis Formations. The Beaumont is the youngest, followed by the Lissie and the Willis Formations. In the past, the Lissie was divided into the Montgomery and the Bentley Formations. In modern nomenclature, the Lissie is considered to be one formation. The sediments that compose each of these geologic formations are similar in depositional composition in that streams of coalescing fluvial and deltaic systems deposited them. The soils, which developed from these systems, include clay, silt, sand, and their intermixtures.

According to the Geologic Atlas of Texas, Houston Sheet, 1982, the site is situated entirely on the outcrop of the Beaumont Formation. The formation is mostly stream channel; point bar, natural levee, back swamp, and to a lesser extent coastal marsh and mud-flat deposits. The geologic units, which formed these deposits, include interdistributary mud, abandoned channel fill mud, and overbank fluvial mud. Surface soils that comprise the Beaumont Formation at the site consist of, dominantly clay, silt, sand and their intermixtures.

## 4.2 Geologic Surface Faulting

The site surface fault evaluation was conducted using various methods of supporting data: geologic literature, geologic and topographic maps, and aerial photographs. Each method of supporting data was assessed individually and then in conjunction with observations from other findings.

### 4.2.1 Geologic Literature

A review of geologic literature and our in-house database indicate that no surface faults have previously been mapped crossing the site. The central portion of the site is in the Pierce Junction Salt Dome area. Radial normal faults can be formed as a result of salt dome migration. In the immediate vicinity of the site, the Reed Fault (an up-the-coast normal fault) is located about 0.75 miles east of the site. The Reed Fault does project to the site, but has not been mapped at the site.

### 4.2.2 Topographic Maps

Topographic maps by the U.S Geologic Survey are very useful in the recognition of subtle surface features which could be manifested by a surface fault or faults. Additional mapping was performed by the Bureau of Economic Geology, which is headquartered at The University of Texas at Austin. The maps reviewed for this project were the USGS 1921 Bellaire, Texas Quadrangle, USGS 1995 Bellaire, Texas Quadrangle, and the 1982 Geologic Atlas of Texas, Houston Sheet.

The surface expression of the Pierce Junction Salt Dome was identified in the central portion of the site in the USGS 1921 Bellaire, Texas Quadrangle. No surface expressions of possible faults were identified within the site alignment on the maps reviewed.

### 4.2.3 Aerial Photographs

Aerial photographs available from Landisor™ from March 21, 1996, March 10, 1998, March 12, 2000, May 19, 2002, and March 9, 2004 were reviewed, which can be indicative of surface fault activity. Additional aerial photographs from Google Earth™ from March 4, 1944, March 5, 1953, March 5, 1978, March 5, 1989, January 23, 1995, March 5, 2002, January 26, 2004, June 28, 2005, January 9, 2008, January 5, 2010, and March 11, 2011 (provided by Texas General Land Office, USGS, SPOT Image, Digital Globe, and USDA) were reviewed to check for photo-linear or geomorphic features, which can be indicative of surface fault activity. A photo-linear expression could represent the surface expression of a surface fault line. A photo-linear expression can be formed as a result of moisture differences from one side of the surface fault to the other. No photo-linear or geomorphic features were identified on site from the aerial photograph.

## 4.3 Conclusion of the Geologic Fault Review

Several lines of evidence have been analyzed to identify features, which represent the manifestation of surface faulting with respect to the area. According to our in-house geologic database no known surface faults have been mapped crossing the site. An analysis of topographic maps did not identify features we interpret as the manifestation of surface faulting in the vicinity of the site. The aerial photograph did not identify any photo-linear or geomorphic features that could represent a surface fault line. Within the very limited scope of this fault review, no surface faults were identified intersecting the site. A more conclusive study would require a Phase I Fault Study.

## 4.4 Limitations of the Geologic Fault Review

The geologic fault assessment performed for this project is based on our professional evaluation of the geologic data gathered and our experience with fault-related features, their characteristics, and general geologic conditions in the area. The geologic evaluations rendered in this report meet the standard of care of our profession. No other warranty or evaluation, expressed or implied, is included or intended.

# 5. SUBSURFACE CONDITIONS

## 5.1 Soil Stratigraphy

This section presents generalized observed soil stratigraphy at the project site as characterized by the project borings.

### 5.1.1 Pavement and Utilities (B-1 and B-11 through B-28)

The subsurface soil stratigraphy along the pavement alignment generally consists of firm to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and to a lesser extent semi-cohesive sandy silty clays (CL-ML), silty clays with sand (CL-ML) to the 15-ft explored depths in borings B-1, B-11 through B-15, B-17 through B-23, B-25 through B-28, and to 10-ft depth in boring B-24, followed by cohesionless silty sands to the 15.5-ft boring termination depth. In boring B-16, intermixed layers of cohesionless/semi-cohesive silty sands (SM) and clayey sands (SC) were encountered to the 15.5-ft explored depth.

The upper 2-ft thick soils in borings B-11 through B-13 and B-28 were inferred to be cohesive sandy lean clay, lean clay with sand and fat clay with sand fill. It should be noted that it is relatively difficult to accurately delineate fill from similar natural soils. Fill classifications are made based upon visual observations and require considerable judgment. The interpreted fill depths may vary somewhat from the actual conditions.

Calcareous/ferrous nodules, sand seams/pockets, silt pockets/partings, gravel, organics, roots and slickensided substructure were observed within the matrix of cohesive soils. Detailed descriptions of the soil boring logs for pavement and utilities are presented in Appendix D.

### 5.1.2 Bridge (B-2 through B-10)

The subsurface soil stratigraphy at bridge overpass area generally consists of firm to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), sandy fat clays (CH) to the 30-ft to 110-ft explored depths in borings B-2, B-5 and B-10, and to 27-ft to 63-ft depths in borings B-3, B-4, B-6 through B-9, underlain by cohesionless/semi-cohesionless to semi-cohesive silty sands (SM), silts with sand (ML), clayey sands (SC) and silty clays (CL-ML) to 33-ft to 66-ft depth, followed by cohesive sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), and to a lesser extent semi-cohesionless/semi-cohesive silts with sand (ML) and silty clays (CL-ML) to the 80-ft to 100-ft boring termination depths.

The upper 2-ft to 8-ft deep soils in borings B-4, B-5 and B-8 through B-10 were inferred to be cohesionless to cohesive silty sand, sandy lean clay, lean clay with sand and fat clay with sand fill. It should be noted that it is relatively difficult to accurately delineate fill from similar natural soils. Fill classifications are made based upon visual observations and require considerable judgment. The interpreted fill depths may vary somewhat from the actual conditions.

Calcareous/ferrous nodules, sand/silt seams and pockets, siltstone, limestone, and slickensided substructure were observed within the matrix of cohesive soils. Detailed descriptions of the soil boring logs for the bridge overpass and the embankment are presented in Appendix E.

### 5.1.3 Off-Site Drainage Ditches (A-1, BB-1, BB-2, C-1 through C-3 and D-1 through D-3)

The subsurface soil stratigraphy along off-site drainage ditches generally consists of soft to hard consistency, low to high plasticity cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and to a lesser extent semi-cohesive sandy silty clays (CL-ML) to the 20-ft explored depth in borings A-1, BB-1, BB-2, C-2, C-3, D-1 through B-3, and to 12-ft depth in boring C-1, underlain by cohesionless silty sands (SM) to the 20-ft boring termination depth.

Calcareous/ferrous nodules, sand seams, organics and slickensided substructure were observed within the matrix of cohesive soils. Detailed descriptions of the soils boring logs for off-site drainage ditches are presented in Appendix F.

## 5.2 Soil Properties

### 5.2.1 Pavement and Utilities (B-1 and B-11 through B-28)

**Lean/Fat Clay (CL/CH)** Liquid limits ranging from 31% to 49%, with corresponding plasticity indices ranging from 15 to 30 were measured on fifteen (15) selected lean clay samples recovered from various depths in borings B-1 and B-11 through B-28. The median values of liquid limit and plasticity index for the tested soil samples are 42% and 23, respectively.

Liquid limits ranging from 51% to 66%, with corresponding plasticity indices ranging from 31 to 45 were measured on ten (10) selected fat clay samples recovered from various depths in the project borings. The median values of liquid limit and plasticity index for the tested soil samples are 59% and 38, respectively.

In situ moisture contents of the samples were nine percentage points dry to four percentage points wet of their corresponding plastic limits. Twenty-three (23) selected cohesive soil samples yielded fines contents ranging from 64% to 99%.

Twelve (12) unconfined compression and ten (10) unconsolidated undrained triaxial compression tests performed on selected cohesive samples recovered from various depths in the project borings measured undrained shear strength of 1,087 psf to 10,730 psf. Six (6) samples failed along slickensided surfaces during testing. Total unit weights of the tested samples and nine (9) additional samples ranged from 110 pcf to 134 pcf. Apparent shear strength of the samples, based on converted pocket penetrometer readings, were about 670 psf to 3,000 psf. SPT "N" values of 16 and 44 blows per foot were measured within the silty clay stratum in boring B-23. The measured and apparent undrained shear strengths and the SPT values of the semi-cohesive/cohesive soils are indicative of firm to hard, but mostly stiff to hard consistencies.

**Sand (SM/SC)** We measured SPT "N" values ranging from 15 to 41 blows per foot within cohesionless/semi-cohesive soils in borings B-16 and B-24. The SPT blow counts indicate loose to dense consistency. Three (3) selected cohesionless/semi-cohesive silty sand, and clayey sand samples yielded fines contents ranging from 14% to 23%.

Liquid limit of 31%, corresponding plasticity index of 15 and fines content of 43% were measured on the clayey sand sample recovered from the 4-ft to 6-ft depth range in boring B-16.

### 5.2.2 Bridge (B-2 through B-10)

**Lean Clay/Fat Clay (CL/CH)** Liquid limits ranging from 28% to 49%, with corresponding plasticity indices ranging from 12 to 32 were measured on twenty-three (23) selected lean clay samples recovered from various depths in borings B-2 through B-10. The median values of liquid limit and plasticity index for the tested soil samples are 42% and 24, respectively.

Liquid limits ranging from 50% to 74%, with corresponding plasticity indices ranging from 30 to 52 were measured on twenty-seven (27) selected fat clay samples recovered from various depths in bridge borings. The median values of liquid limit and plasticity index for the tested soil samples are 61% and 40, respectively.

Liquid limit of 25%, with corresponding plasticity index of 6 were measured on the silty clay sample recovered from 98 ft to 100 ft depth in boring B-6.

In situ moisture contents of the samples were eight percentage points dry to ten percentage points wet of their corresponding plastic limits. Forty-three (43) selected semi-cohesive/cohesive soil samples yielded fines contents ranging from 70% to 100%.

Thirty-six (36) unconfined compression and twenty-seven (27) unconsolidated undrained triaxial compression tests performed on selected cohesive samples recovered from various depths in the project borings measured undrained shear strength ranging from 770 psf to 7,330 psf. Sixteen (16) samples failed along slickensided surfaces during testing. Total unit weights of the tested and twenty-four (24) additional samples ranged from 115 pcf to 141 pcf. Apparent shear strengths of the recovered cohesive samples, based on converted pocket penetrometer readings, were about 670 psf to 3,000 psf. SPT "N" values ranging from 30 to 55 blows per foot were measured within the silty clay and lean/fat clay strata in borings B-3, B-6 and B-8. The measured and apparent undrained shear strengths and the SPT "N" values of the semi-cohesive/cohesive soils are indicative of firm to hard, but mostly stiff to very stiff-hard consistencies.

**Sand/Silt (SM/ML/SC)** We measured SPT "N" values of more than 50 blows per foot within the cohesionless/semi-cohesioinless strata in borings B-3, B-7 and B-8. The SPT blow counts indicate very dense consistency. Three (3) selected cohesionless/semi-cohesioinless silty sand and silt with sand samples yielded fines contents ranging from 16% to 85%.

Liquid limit of 32%, corresponding plasticity index of 16 and fines content of 43% were measured on the clayey sand sample recovered from the 63-ft to 65-ft depth range in boring B-9.

### 5.2.3 Off-Site Drainage Ditches (A-1, BB-1, BB-2, C-1 through C-3 and D-1 through D-3)

**Lean Clay/Fat Clay (CL/CH)** Liquid limits ranging from 29% to 45%, with corresponding plasticity indices ranging from 13 to 25 were measured on four (4) selected lean clay samples recovered from various depths in borings A-1 and C-1.

Liquid limits ranging from 52% to 74%, with corresponding plasticity indices ranging from 30 to 51 were measured on twenty-one (21) selected fat clay samples recovered from various depths in the project borings. The median values of liquid limit and plasticity index for the tested soil samples are 61% and 39, respectively.

In situ moisture contents of the samples were ten percentage points dry to nine percentage points wet of their corresponding plastic limits. Twenty-seven (27) selected cohesive soil samples yielded fines contents ranging from 57% to 99%.

Nine (9) unconfined compression (UC) and nine (9) unconsolidated undrained (UU) triaxial compression tests performed on selected cohesive samples recovered from various depths range in the project borings measured undrained shear strength ranging from 280 psf to 5,870 psf. Eleven (11) samples failed along slickensided surfaces during testing. Total unit weights of the tested and nineteen (19) additional samples ranged from 119 pcf to 136 pcf. Apparent shear strengths of the recovered semi-cohesive/cohesive samples, based on converted pocket penetrometer readings, were about 500 psf to 3,000 psf. SPT "N" value of 20 blows per foot was measured within the fat clay stratum in boring A-1. The measured and apparent undrained shear strengths and the SPT "N" value of the semi-cohesive/cohesive soils are indicative of soft to hard, but mostly stiff to very stiff-hard consistencies.

**Sand (SM)** We measured SPT "N" values ranging from 24 to 46 blows per foot within the cohesionless stratum in boring C-1. The SPT blow counts indicate medium dense to dense consistency. The cohesionless silty sand sample recovered from the 16.5-ft to 18-ft depth range in boring C-1 yielded fines content of 27%.

### 5.2.4 Additional Test Results

Three (3) one-dimensional incremental loading (IL) consolidation tests were performed on the lean and fat clay samples recovered from various depth intervals in borings B-2 and B-9 to investigate the stress history of the cohesive soils at the site. The consolidation test results are included in Appendix G. A specific gravity of soil solids (Gs) of 2.7 was assumed for the cohesive soil samples. Estimates of the Pc, Cc, Cr, and OCR from the consolidation test data are summarized in Table 5-1 below. The Pc was estimated using Casagrande's empirical procedure.

Table 5-1
Summary of Consolidation Test Results

| Boring No. | Sampling Depth, ft | Soil Type | Pc (tsf) | $e_o$ | Cc | Cr | OCR |
|---|---|---|---|---|---|---|---|
| B-2 | 14-16 | Fat Clay (CH) | 3.94 | 0.637 | 0.19 | 0.007 | 5.8 |
| B-9 | 43-45 | Lean Clay w/ Sand (CL) | 10.13 | 0.376 | 0.12 | 0.014 | 5.3 |
| B-9 | 78-80 | Fat Clay (CH) | 14.13 | 0.691 | 0.23 | 0.034 | 5.0 |

Pc= Preconsolidation Pressure (yield stress); $e_o$ = Void Ratio; Cc= Compression ratio; Cr= Recompression Ratio; and OCR= Overconsolidation Ratio.

We performed six (6) consolidated-undrained (CU) triaxial compression tests with pore water pressure measurements on selected cohesive samples recovered from the 8-ft to 16-ft depth range in borings A-1, B-3, BB-2, C-2, C-3 and D-2. The results of the test are summarized in Table 5-2 and are presented in Appendix G.

Table 5-2
Summary of CU Triaxial Compression Test Results

| Boring No./ Sample Interval | Soil Sample Classification | Total Stress Parameters | | Effective Stress Parameters | |
|---|---|---|---|---|---|
| | | c (psf) | ϕ (deg.) | c' (psf) | ϕ' (deg.) |
| A-1/8'-10' | Sandy Lean Clay (CL) | 238 | 28.8 | 192 | 30.7 |
| B-3/14'-16' | Fat Clay (CH) | 234 | 14.0 | 170 | 21.4 |
| BB-2/8'-10' | Fat Clay (CH) | 256 | 19.5 | 240 | 25.6 |
| C-2/10'-12' | Fat Clay (CH) | 266 | 19.2 | 262 | 25.0 |
| C-3/10'-12' | Fat Clay (CH) | 168 | 15.2 | 160 | 17.8 |
| D-2/10'-12' | Fat Clay (CH) | 390 | 13.7 | 374 | 18.3 |

We determined moisture-density relationship of the fat clay sample recovered from a stock pile of fill soil at boring B-5. The test results are summarized in Table 5-3 and presented in Appendix G.

Table 5-3
Moisture-Density Relationship

| Sample ID | USCS Classification | LL | PI | Optimum Moisture (%) | Maximum Dry Density, pcf |
|---|---|---|---|---|---|
| B-5 | Fat Clay with Sand (CH) | 51 | 30 | 19.3 | 104.1 |

We selected eight (8) soil samples recovered from the upper 6-ft depth in borings A-1, BB-1, BB-2, C-2, C-3, D-1 and D-3 for crumb, pinhole dispersion and double hydrometer tests. The results are presented in Tables 5-4 through 5-6, and in Appendix G.

Table 5-4
Summary of Crumb Test Results

| Boring | Sample Depth Interval (ft) | Soil Sample Description | Dispersive Classification |
|---|---|---|---|
| A-1 | 0-2 | Gray SANDY LEAN CLAY (CL) | Grade 1 – Non Dispersive |
| A-1 | 2-4 | Light gray SANDY LEAN CLAY (CL) | Grade 2 – Intermediate |
| BB-1 | 0-2 | Gray & brown FAT CLAY w/ SAND (CH) | Grade 1 – Non Dispersive |
| BB-2 | 2-4 | Gray & brown FAT CLAY w/ SAND (CH) | Grade 3 – Dispersive |
| C-2 | 2-4 | Gray & brown FAT CLAY (CH) | Grade 1 – Non Dispersive |
| C-3 | 0-2 | Dark gray FAT CLAY (CH) | Grade 1 – Non Dispersive |
| D-1 | 2-4 | Gray & tan FAT CLAY w/ SAND (CH) | Grade 1 – Non Dispersive |
| D-3 | 4-6 | Gray & tan FAT CLAY w/ SAND (CH) | Grade 3 – Dispersive |

Table 5-5
Summary of Pinhole Dispersion Test Results

| Boring | Sample Depth Interval (ft) | Soil Sample Description | Dispersive Classification |
|---|---|---|---|
| A-1 | 0-2 | Gray SANDY LEAN CLAY (CL) | **ND3** –Slightly dispersive clay with very slight to slight colloidal erosion under 380 mm (15-in.) head. Flow rate is 1.8 to 3.0 mL/s. |
| A-1 | 2-4 | Light gray SANDY LEAN CLAY (CL) | **ND2** – Non-dispersive clay with very slight to no colloidal erosion under 380 mm (15-in.) or 1020 mm (40-in.) head. Flow rate is more than 3.0 mL/s. |
| BB-1 | 0-2 | Gray & brown FAT CLAY w/ SAND (CH) | **ND1** – Non-dispersive clay with very slight to no colloidal erosion under 380 mm (15-in.) or 1020 mm (40-in.) head. Flow rate is less than 3.0 mL/s. |
| BB-2 | 2-4 | Gray & brown FAT CLAY w/ SAND (CH) | **ND3** –Slightly dispersive clay with very slight to slight colloidal erosion under 380 mm (15-in.) head. Flow rate is 1.8 to 3.0 mL/s. |
| C-2 | 2-4 | Gray & brown FAT CLAY CH) | **ND2** – Non-dispersive clay with very slight to no colloidal erosion under 380 mm (15-in.) or 1020 mm (40-in.) head. Flow rate is more than 3.0 mL/s. |
| C-3 | 0-2 | Dark gray FAT CLAY CH) | **ND1** – Non-dispersive clay with very slight to no colloidal erosion under 380 mm (15-in.) or 1020 mm (40-in.) head. Flow rate is less than 3.0 mL/s. |
| D-1 | 2-4 | Gray & tan FAT CLAY w/ SAND (CH) | **ND2** – Non-dispersive clay with very slight to no colloidal erosion under 380 mm (15-in.) or 1020 mm (40-in.) head. Flow rate is more than 3.0 mL/s. |
| D-3 | 4-6 | Gray & tan FAT CLAY w/ SAND (CH) | **ND3** –Slightly dispersive clay with very slight to slight colloidal erosion under 380 mm (15-in.) head. Flow rate is 1.8 to 3.0 mL/s. |

Table 5-6
Summary of Double Hydrometer Test Results

| Boring | Sample Depth Interval (ft) | Soil Sample Description | % Dispersion |
|---|---|---|---|
| A-1 | 0-2 | Gray SANDY LEAN CLAY (CL) | 0 |
| A-1 | 2-4 | Light gray SANDY LEAN CLAY (CL) | 0 |
| BB-1 | 0-2 | Gray & brown FAT CLAY w/ SAND (CH) | 0 |
| BB-2 | 2-4 | Gray & brown FAT CLAY w/ SAND (CH) | 38.4 |
| C-2 | 2-4 | Gray & brown FAT CLAY (CH) | 7.9 |
| C-3 | 0-2 | Dark gray FAT CLAY (CH) | 0.4 |
| D-1 | 2-4 | Gray & tan FAT CLAY w/ SAND (CH) | 0.2 |
| D-3 | 4-6 | Gray & tan FAT CLAY w/ SAND (CH) | 20.1 |

### 5.2.5 Chemical Test Results

Laboratory chemical testing (ion concentration sulfates) were performed on selected seven (7) cohesive samples recovered from the upper 10-ft depth of borings B-3 through B-9. The results of the tests are summarized in Table 5-7.

Table 5-7
Chemical Test Results

| Boring No. | Sampling Interval (ft) | Soil Type | Ion Concentration Sulfate (ppm) |
|---|---|---|---|
| B-3 | 2 - 4 | Fat Clay with Sand | 262 |
| B-4 | 6 - 8 | Lean Clay with Sand | 227 |
| B-5 | 6 - 7 | Fat Clay with Sand | 42 |
| B-6 | 4 - 6 | Sandy Lean Clay | 112 |
| B-7 | 8 - 10 | Fat Clay | 8.5 |
| B-8 | 4 - 6 | Lean Clay with Sand | ND* |
| B-9 | 2 - 4 | Fat Clay with Sand | ND* |

*ND = Not detected at the reporting limit

The results of the chemical laboratory tests are included in Appendix H.

## 5.3 Groundwater Observations

Based on the groundwater level measurements presented in Table 3-1, it appears that the static groundwater level at mid September to early October, 2011 was at about 8.4-ft to 22.3-ft below existing grade at the time of the field exploration. Fluctuations in groundwater level may occur with changes in seasonal and climatic condition. Depending on when the project is developed, the observed groundwater conditions may not be representative during construction. We recommend that the water level be verified in the available piezometers prior to construction.

## 5.4 Potentially Petroleum Contaminated Area

We did not encounter any unusual staining or hydrocarbon odors in the project borings during drilling.

# 6. FILL SOIL EVALUATION

A stock pile of fill soils was observed at the north of Holmes Road and Union Pacific Rail Road track crossing the proposed Buffalo Speedway near the location of boring B-5. The stock pile height was about 8 ft. The degree of compaction of the on-site fill soils was evaluated by laboratory tests. Our evaluation of soil properties included dry densities, percent compaction, Atterberg limits and moisture contents.

## 6.1 Laboratory Density Test Evaluation

Our laboratory tests indicated that the fill soils mostly consists of cohesive fat clays with sand and lean clays with sand. The laboratory density tests data are summarized in Table 6-1. The detailed laboratory density test results are presented in our soil boring logs in Appendix D.

Table 6-1
Summary of Compaction Test Results

| Boring No. | Sampling Depth, ft | Soil Type | Borings | | Proctor Test | | Compac-tion (%) | Pass = P Fail = F |
|---|---|---|---|---|---|---|---|---|
| | | | W (%) | Dry Density, pcf | W (%) | Optimum Dry Density, pcf | | |
| B-5 | 0 - 1 | Fat Clay w/ Sand "Fill" | 18 | 98 | 19 | 104 | 94 | F |
| | 1 - 2 | Fat Clay w/ Sand "Fill" | 18 | 106 | | | 100 | P |
| | 2 - 3 | Fat Clay w/ Sand "Fill" | 28 | 100 | | | 96 | P |
| | 3 - 4 | Fat Clay w/ Sand "Fill" | 17 | 111 | | | 100 | P |
| | 4 - 5 | Fat Clay w/ Sand "Fill" | 27 | 96 | | | 92 | F |
| | 5 - 6 | Lean Clay w/ Sand "Fill" | 14 | 110 | | | 100 | P |
| | 6 - 7 | Fat Clay w/ Sand "Fill" | 20 | 105 | | | 100 | P |
| | 7 - 8 | Fat Clay w/ Sand "Fill" | 21 | 95 | | | 91 | F |
| | 8 - 10 | Fat Clay w/ Sand (CH) | 22 | 102 | | | 98 | P |

The Proctor test result for the fat clay w/ sand fill soils indicates maximum dry density of 104.1pcf, with optimum moisture content of 19.3%. The results of our tests indicate that the moisture contents of the fill soils are varying. It ranges between 14% and 28%. The dry density of the fat/lean clay fill soils ranged between 95 and 111 pcf, with corresponding percent compaction between 91 and 100. Our laboratory density test evaluations indicate that out of nine (9) dry densities, six (6) are 95% or greater than the optimum. The rate of passing is 67%.

## 6.2 Recommendations For The Existing Fill

Our laboratory tests and visual observations indicate that the existing fill soils at this location are not properly compacted and may not be used as part of the embankments, if they are within the proposed embankment footprint. The fill should be removed and re-compacted prior to construction of the embankment.

# 7. UTILITIES RECOMMENDATIONS

We understand that the proposed utility lines will probably be installed within the upper 6-ft to 12-ft depth. The recommendations presented in this report are based on an assessment of the observed subsurface conditions at widely-spaced borings. Excavation retention and construction dewatering are the responsibility of the contractor. The contractor should collect additional subsurface information as necessary to determine if the conditions reported herein are representative.

## 7.1 Trenching and Shoring

All vertical excavations deeper than 5-ft must be provided with a trench safety system in accordance with the most current Occupational Safety and Health Administration (OSHA) standards (29 CFR, Part 1926, Subpart P). The OSHA standards include provisions for the design of sloping and/or benched trench excavations in single or multiple layer soil stratigraphy less than 20-ft deep, in lieu of bracing and shoring. Sloping or benching for excavations greater than 20-ft deep must be designed by a registered professional engineer. The regulations specify maximum slope declivities contingent on soil type. The layered soils encountered in the project borings may be classified as "Type C".

The Contractor designated "Competent Person" should review our recommendations to determine the appropriate safe slopes on the job site.

Another option is to excavate vertically and shore temporarily with bracing or trench shield (box). These support systems must be designed to withstand the soil pressures corresponding to the soil types as shown on the boring logs or as encountered during construction. In all cases, excavations should, as a minimum, conform to OSHA guidelines. The trench box, if used as temporary retention system, should be designed by the contractor to withstand lateral loads imposed by the specific soil conditions.

Lateral earth pressures will be imposed on pipeline and trench excavation bracing where cut and cover construction techniques are used. The subsurface soils encountered in the project borings generally consists of cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and to a lesser extent semi-cohesive sandy silty clays (CL-ML), silty clays with sand (CL-ML) to the 15-ft explored depths in borings B-1, B-11 through B-15, B-17 through B-23, B-25 through B-28, and to 10-ft depth in boring B-24, followed by cohesionless silty sands to the 15.5-ft boring termination depth. In boring B-16, intermixed layers of cohesionless/semi-cohesive silty sands (SM) and clayey sands (SC) were encountered to the 15.5-ft explored depth.

Pressure diagrams and methodology for developing earth pressures for shoring and open cut excavations are presented in Figures 13 and 14. Figure 13 presents pressure diagrams for layered soils (cohesionless/ cohesive) and Figure 14 for the case of cohesive soils. The forces on walls and bracing can be determined at any point by adding the earth, ground water, and surcharge pressures. These pressures apply to excavation bracing where soils move a very small amount.

If there is not a relatively tight fit between the soil and bracing, significant movement in association with rapid drying and opening of old fractures could result in sudden failure. The pressure diagrams presented in Figures 13 and 14 do not include a safety factor.

For trench box(es) or shields, there must be sufficient space between the excavation face and the shield to allow shield installation and removal, which is usually a space on the order of 3 to 6 inches.

To avoid surcharging the excavation walls, the stockpiling of excavated material immediately adjacent to the excavation wall should be prohibited. We recommend that stockpile materials be placed away from the excavation a minimum distance of 6 ft from the excavation crest. In addition, the stockpile should not be placed higher than 4 ft. Construction equipment working near the trench may also induce excessive surcharge loads. We recommend shoring the trench in areas adjacent to working equipment.

It should be noted that the soil stratigraphy and ground water 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 described in this report are representative on a station-by-station basis. It is also mandatory that all excavations and retaining structures be monitored on a continuous basis by experienced personnel who can make evaluations as to the appropriateness of the retention system used.

## 7.2 Utility Bedding and Backfill Criteria

Bedding and backfill for water lines, sanitary sewers, and storm sewers should be constructed using City of Houston Department of Public Works and Engineering *Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, and Street Paving*, or an equivalent standard. In accordance with these specifications, the backfill requirements should conform to Section 02317 – "Excavation and Backfill for Utilities," and Section 02320 – "Utility Backfill Material."

**Water Lines.** In accordance with the City of Houston *Standard Construction Details*, water line bedding and backfill for open cut trenches outlined on Drawing No. 02317-04, or equivalent, is applicable for water lines bedded within dry cohesive soils.

**Storm and Sanitary Sewers.** Bedding recommendations outlined on Drawing No. 02317-03, are expected to be applicable for storm and sanitary sewer lines bedded within stable soils.

**Backfill Placement.** Backfill placement should be in accordance with the City of Houston Standard Construction Specifications. Trench zone backfill placement and compaction requirements are provided in Section 02317, *Excavation and Backfill for Utilities*, and are summarized in the following table:

Table 7-1
Trench Zone Backfill Placement and Compaction

| Soil Type | Maximum Lift Thickness (Compacted) | Minimum Compacted Density (ASTM D 698) | Compacted Moisture Content (ASTM D 698) |
|---|---|---|---|
| Bank Run Sand | 9 inches | 95% | ±3 points |
| Cement-Stabilized Sand | 12 inches | 95% (1) | Less than optimum (1) |
| Select Fill | 6 inches | 95% | ± 2 points |
| Random Fill (2) | 9 inches (clay)<br>12 inches (sand) | 90% | None |

(1) As determined by ASTM D 558
(2) Random fill is to be used outside pavement areas.

We recommend a minimum 95% relative compaction for random fill. Backfill material specifications for bank run sand, select backfill, and random backfill are provided in the Specification Section 02320, *Utility Backfill Materials*. The City of Houston Standard Construction Specifications preclude the use of silt, organic clay, and peat as utility backfill materials. Cement-stabilized sand material specifications are provided in Section 02321, *Cement Stabilized Sand.*

The City of Houston Standard Construction Specifications require in-place density testing of pipe embedment and trench zone backfill at a minimum frequency of one test per 40 linear feet (embedment) and two tests per 40 linear feet (backfill), with a minimum of three density tests for each shift of work (Section 02317).

## 7.3 Groundwater Control

Construction dewatering and excavation retention are the contractor's responsibilities. We provide excavation planning comments and suggestions for informational purposes. These comments may be used to review the contractor's proposed excavation procedures.

Excavations for utilities are anticipated to encounter primarily cohesive lean clays (CL), sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH), and lesser extent semi-cohesive sandy silty clays (CL-ML), silty clays with sand (CL-ML) to the 15-ft explored depths in borings B-1, B-11 through B-15, B-17 through B-23, B-25 through B-28, and to 10-ft depth in boring B-24, followed by cohesionless silty sands to the 15.5-ft boring termination depth. In boring B-16, intermixed layers of cohesionless/semi-cohesive silty sands (SM) and clayey sands (SC) were encountered to the 15.5-ft explored depth. Based on subsurface information, ground water seepage or surface runoff within the cohesive/semi-cohesive soils can probably be handled by pumping from sumps. Mechanical dewatering may be necessary if sands/silts become waterbearing during excavation. It is recommended that the

ground water level be maintained at least 3-ft below the bottom of the excavation level. Dewatering should be performed in a manner such that the strength of the foundation soils are preserved throughout the construction. Moreover, dewatering should not cause any instability of the open excavation.

The subsurface water condition is subject to change with variation in climatic conditions and is a function of subsurface soil conditions. An accurate determination of the true ground water level may require several months of observations. Ground water level should be verified prior to construction. The contractor is responsible for assessing the need for ground water control at the site and for developing appropriate dewatering procedures. The contractor should pre-plan dewatering efforts. Additional observation wells or piezometers may be installed as part of the dewatering systems before excavation.

The condition of the bearing surface should be carefully monitored during construction to check for possible bottom heave or other instabilities. Undercutting may be employed to achieve competent bearing conditions. In such cases, grade adjustments can be made by placing lean concrete, or backfilling to grade with cement-stabilized sand (one bag of cement per cubic yard of sand). If precast sections are used, we recommend using cement-stabilized sand for the bedding.

# 8. BOX CULVERT RECOMMENDATIONS

It is planned to construct box culverts at Buffalo Speedway near Sta.125+00, 132+22.76, 142+41, and from Sta. 162+60 to 177+54.86. The size of the box culverts will range from 4-ft x 3-ft to 6-ft x 4-ft. The box culverts will be connected to four (4) off-site drainage ditches. We understand that the proposed box culverts will be installed at about 7 ft to 12 ft depths below grade.

Borings B-10, B-14 through B-16, B-22, B-24 and B-25 are located in the vicinity of the proposed box culvert alignments. Soil properties and soil profiles from those borings were utilized in the foundation analyses of the box culverts.

## 8.1 Trenching and Shoring

Detailed trenching and shoring recommendations for installing the underground utilities are presented in Section 6.1 of this report.

Based upon the results from the field and laboratory investigations, it is our opinion that, in general, temporary open-trench excavations with depths of greater than 5-ft and less than 10-ft can be made on slopes of 0.5(H):1(V) to 1(H):1(V). If water seepage is evident, the entire excavation must have slopes flatter than 1.5(H):1(V). Temporary open-trench excavations with depths of greater than 10-ft and less than 20-ft can be made on slopes of 1.5(H): 1(V) to 2(H): 1(V).

Lateral earth pressures will be imposed on underground structures and trench excavation bracings where a trenched excavation is used to place underground structures from the ground surface. The subsurface soils in borings B-10, B-14 through B-16, B-22, B-24 and B-25 consists of firm to hard consistency, cohesive sandy lean clays (CL), lean clays with sand (CL), fat clays (CH), fat clays with sand (CH) to the 15-ft to 30-ft explored depths in borings B-10, B-14, B-15, B-22 and B-25, and to 10-ft depth in boring B-24, followed by dense, cohesionless silty sands to the 15.5-ft boring termination depth. In boring B-16, intermixed layers of loose to medium dense, cohesionless/semi-cohesive silty sands (SM) and clayey sands (SC) were encountered to the 15.5-ft explored depth.

The lateral earth pressures may 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 are outlined in the following table. The equivalent fluid densities outlined for the higher compactive effort should be used for level backfill with surcharge.

Table 8-1
Equivalent Fluid Densities (pcf)

| SOIL TYPE | COMPACTIVE EFFORT | EQUIVALENT FLUID DENSITIES (pcf) | |
|---|---|---|---|
| | | Above the water level | Below the water level* |
| Select cohesive backfill<br>(7 < PI ≤ 20) | 88 to 92<br>93 to 98 | 65<br>85 | 95<br>103 |
| On site cohesive backfill<br>(PI>20) | 88 to 92<br>93 to 98 | 75<br>100 | 105<br>113 |
| Bank Sand<br>(Fines content <25%) | 88 to 92<br>93 to 98 | 55<br>75 | 88<br>96 |
| * These magnitudes include a water component, if applicable. | | | |

The weights of equivalent fluid shown above do not include a safety factor. Surcharge loads adjacent to open-cut excavations should also be considered. Local surcharge loads adjacent to the edge of the excavation walls, 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 the surcharge loads should be multiplied by a factor of 1.5.

## 8.2 Box Culvert Bedding and Backfill Details

Bedding and backfill specifications for box culvert where satisfactory soil condition exists are outlined on the City of Houston, Department of Public Works and Engineering, *Standard Construction Details* Drawing No. 02317-5. Bedding and backfill specifications for box culvert where unsatisfactory soil condition exists are outlined on the City of Houston, Department of Public Works and Engineering, *Standard Construction Details* Drawing No. 02317-7.

The box culvert recommendations presented in this report are based on an assessment of the observed subsurface conditions near borings B-10, B-14 through B-16, B-22, B-24 and B-25. Excavation retention and construction dewatering are the responsibility of the contractor. The contractor should collect additional subsurface information as necessary to determine if the conditions reported herein are representative of the actual soil conditions.

Clayey soils, such as those encountered in the project boring, may be used as backfill in the trench zone. Compaction by water jetting methods should not be permitted.

Trench backfill has a tendency to shrink and settle after installation. The shrinkage and settlement can adversely affect surface construction of sidewalks and roadways over the trench. Increasing compaction levels for all backfill to at least 95% of ASTM D 698 is one response to reduce shrinkage and settlement. Compacting the backfill at a moisture content two to five percentage points greater than the optimum as determined by ASTM D 698 may also help to reduce shrinkage and settlement. The most conservative detail calls for use of compacted cement-stabilized sand for all backfill beneath new construction.

## 8.3 Box Culvert Bearing Capacity

An allowable gross total gravity load bearing pressure of 2,000 psf may be used in design for a box culvert placed in properly prepared subgrade. Vertical soil pressure above the top of the box culvert may be calculated by multiplying backfill thickness, in feet, by 135 pcf. Traffic wheel load of at least 500 psf should also be incorporated into calculations for vertical pressure.

The condition of the bearing surface should be carefully monitored during construction to check for possible bottom heave or other instabilities. Undercutting may be employed to achieve competent bearing conditions. In such cases, grade adjustments can be made by placing lean concrete, or backfilling to grade with cement-stabilized sand (one bag of cement per cubic yard of sand). If precast sections are used, we recommend using cement-stabilized sand for the bedding.

## 8.4 Excavation and Groundwater Control

Detailed excavation and groundwater control recommendations for underground utilities are included in Section 7.3 of this report.

# 9. PAVEMENT SUBGRADE PREPARATION

Pavement subgrade preparation including site stripping, subgrade stabilization, and fill placement will be required. These considerations are addressed in the following paragraphs.

## 9.1 Site Stripping

Vegetation within the areas of the proposed roadway pavement should be stripped. Stripping should extend a minimum of two feet beyond the edge of the proposed pavement. After stripping, the exposed pavement subgrade should be proof-rolled with a heavy rubber-tire vehicle such as a pneumatic-tire roller or a loaded dump truck. If encountered, soft or wet soils should be undercut and replaced with material of similar physical and moisture characteristics. The ground surface should be appropriately graded throughout construction to prevent ponding of rainfall runoff and provide positive drainage. The stripping and proof-rolling should be witnessed by the Geotechnical Engineer or a representative.

The roadway alignment should be graded such that positive surface drainage away from the work areas is established and maintained at all times. Water should not be allowed to pond on the surface during construction. Failure to achieve good drainage could result in significant construction delays during periods of inclement weather.

## 9.2 Fill Placement

Fill required for grading within the proposed paved areas should be earth fill having plasticity indices similar to the in situ cohesive soils. All fill should be free of organic matter, other deleterious material, and excessive silt. Fill placed at the proposed paved areas should be compacted to at least 95% of the maximum dry density and at a moisture content within two percentage points of the optimum moisture content.

Fill required for grading not under proposed paved roadway should be earth fill having plasticity indices similar to the in situ cohesive soils and should be free of organic matter and excessive silt. Fill not placed under proposed roadway pavement should be compacted to at least 90% of the maximum dry density and at a moisture content within five percentage points of the optimum moisture content.

All fill should be placed in lifts not exceeding 8-in. loose measure. The laboratory-measured maximum dry density and optimum moisture content should be determined in accordance with ASTM D 698. We suggest that any fill placement be tested and documented by the Geotechnical Engineer or a representative.

## 9.3 Subgrade Stabilization

The subsurface soils primarily consist of moderate to high plasticity sandy lean clays, lean clays with sand, and fat clays with sand to about 2-ft to 4-ft depths. Roadway subgrade stabilization

should be considered because stabilization will increase the modulus of subgrade reaction and thus, the pavement life.

Based on the results of our field investigation and laboratory testing, we recommend the subgrade soils within the pavement areas to be stabilized with lime. For planning purposes, a lime content of 6% (dry weight basis) may be considered for the subgrade stabilization. Actual stabilization requirements should be determined in the laboratory by trial. Lime stabilization should adhere to City of Houston Standard Specification Section 02336, *Lime Stabilized Subgrade*.

The prepared subgrade should be stabilized to 8-in. depth. The stabilized soils should be compacted to at least 95% of the standard Proctor maximum dry density (ASTM D 698). The compacted moisture content should be within two percentage points of the optimum moisture content.

# 10. PAVEMENT DESIGN RECOMMENDATIONS

The data presented in this report have been used for analysis of pavement design requirements in accordance with the "AASHTO Guide for Design of Pavement Structures – 1993" prepared by the American Association of State Highway and Transportation Officials (AASHTO). The design approach includes certain modifications to the "AASHTO Interim Guide for Design of Pavement Structures, 1981" which was developed as a result of the AASHTO Road Test program and based on road user definition of failure. The primary basis for the AASHTO pavement prediction method is cumulative heavy axle load applications. A mixed traffic stream of different axle loads and configurations is converted into an equivalent number of heavy load applications, termed 18-kip Equivalent Single Axle Loads (18-kip ESAL), using load equivalency factors determined at the AASHTO Road Test. The general methodology in the AASHTO Guide for Design of Pavement Structures, 1993 (AASHTO Design Guide) relates the total number of 18-kip ESAL's to the service life of the pavement structure. The proposed roadway appears to be a principal thoroughfare.

We performed rigid pavement design analysis that included selection of design parameters in accordance with the AASHTO Design Guide. The following parameters were used in our analyses.

## 10.1 Design Parameters

The AASHTO pavement prediction method requires the definition of four categories of parameters. The categories include design variables, performance criteria, material properties for structural design, and structural characteristics. The following paragraphs describe the parameters used in our pavement design analysis. The selected parameters are in accordance with the current AASHTO Design Guide.

**Time Constraints.** Selection of performance analysis period inputs will affect the pavement design from the dimension of time. The performance period refers to the period of time that an initial pavement structure will last before it needs rehabilitation. The analysis period refers to the period of time for which the analysis is to be conducted. We used a 20-year performance period as a design basis for this project.

**Traffic.** The design procedure is based on cumulative expected 18-kip Equivalent Single Axle Load (ESAL) applications during the analysis period. The AASHTO Design Guide presents a procedure for converting a mixed traffic stream of different axle loads and axle configurations into a design traffic number. Each expected axle load is converted into an equivalent number of 18-kip single axle loads and these loads are summed over the performance period. We used 10 million 18-kip ESAL over a 20-year period to design the required pavement section of the proposed project.

**Reliability.** Reliability is defined, as the probability that a pavement section designed using the AASHTO process will perform satisfactorily for the design period, given the assumed traffic and environmental conditions. Application of the reliability concept requires definition of the

functional classification of the facility, selection of reliability level, and selection of a standard deviation that is representative of local conditions.

For this project, we used a reliability of 95%. Based on the performance prediction error that was developed at the original AASHTO Road Test, a standard deviate ($Z_R$) value of -1.645 corresponding to the 95% level of reliability selected was used in the rigid pavement design. An overall standard deviation ($S_o$) of 0.35 for the projection of future 18-kip ESAL traffic was used in the rigid pavement design.

**Environmental Effects.** Loss of riding quality and serviceability can result from temperature and moisture changes affecting the strength, durability, and load carrying capacity of the pavement and roadbed materials, as well as roadbed swelling due to expansive potential of the subgrade soils. Moisture effects can be controlled by providing proper drainage and surficial sealing. Effects of subgrade treatment and drainage on the pavement design are included in such parameters as the loss of support factor and the drainage coefficient, which are discussed, in the following paragraphs.

**Serviceability.** The serviceability of a pavement is defined as its ability to serve the types of traffic that use the facility. The primary measure of serviceability is the Present Serviceability Index (PSI) which ranges from 0 (impossible road) to 5 (perfect road). The basic design philosophy of the AASHTO Guide is the serviceability/performance concept. This concept provides a means of designing a pavement based on a specific total traffic volume and a minimum level of serviceability desired at the end of the performance period (Terminal Serviceability Index, $p_t$). Selection of $p_t$ is based on the lowest index that will be tolerated before rehabilitation, resurfacing, or reconstruction becomes necessary. The AASHTO Design Guide suggests a $p_t$ of 2.5 (used to indicate pavement in fair condition) or higher for design of major highways, and 2.0 (used to indicate pavement in poor condition) for highways with lesser traffic volumes. Original or Initial Serviceability Index ($p_o$) of 4.5 for rigid pavements which was observed at the AASHTO Road Test, was used in our analysis. Once $p_o$ and $p_t$ are established, the following equation is applied to define the total change in the serviceability index:

$$\Delta PSI = p_o - p_t$$

We used a $p_o$ of 4.5 and a $p_t$ of 2.5 for the rigid pavement analysis based on the AASHTO Design Guide.

**Modulus of Subgrade Reaction (k).** The strength of the subgrade for design of rigid pavements is characterized by the modulus of subgrade reaction (k). The value of k depends on the modulus of elasticity of the subgrade soils. Stabilization and compaction of the subgrade soils will typically result in a Composite Modulus of Subgrade Reaction (k) value of about 350 pci.

**Modulus of Rupture**. The modulus of rupture ($M_R$) for the concrete pavement as required by the design procedure is the mean value determined after 28 days using third-point loading (AASHTO T97). Because of the treatment of reliability in the AASHTO Design Guide, it is strongly recommended that the normal construction specification for modulus of rupture (flexural strength) not be used as input, since it represents a value below which only a small

percent of the distribution may lie. If it is desirable to use the construction specification, then some adjustment should be applied, based on the standard deviation of modulus of rupture and the percent of the strength distribution that normally falls below the specification.

City of Houston Drawing No.: 02751-01 requires a 28 day compressive strength of 3500 psi using a minimum of 5 sacks of cement per cubic yard, which is equivalent to a Modulus of Rupture, S'c = 620 psi.

**Loss of Support**. This factor accounts for the potential loss of support for rigid pavements arising from subbase erosion and/or differential vertical soil movement. It is treated in the actual design procedure by diminishing the effective modulus of subgrade reaction values based on the size of the void that may develop beneath the slab. Recommended loss of support factors (LS) in the AASHTO Design Guide range from 1.0 to 3.0 for stabilized soils. We used a L.S. of 1.0 to reduce the (k) value for the Composite Modulus of Subgrade Reaction from 350 pci to 110 pci.

**Drainage.** The expected level of drainage for a rigid pavement is incorporated into the performance equation through the use of a drainage coefficient, $C_d$. The coefficient will depend on the quality of drainage and the percent of time during the year the pavement structure would normally be exposed to moisture levels approaching saturation. Drainage coefficients ranging from 1.25 (excellent drainage, less than 1% exposure) to 0.70 (very poor drainage, greater than 25% exposure) are given in the AASHTO Design Guide. A $C_d$ value of 1.2 was used in our analysis.

**Load Transfer**. The load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to distribute load across discontinuities such as cracks or joints. The recommended values for J in the AASHTO Design Guide, for different conditions developed from experience and mechanistic stress analysis, range from 2.3 to 4.4. The AASTO Design Guide states, "For jointed concrete pavements with dowels and tied shoulders, the value of J should be between 2.5 and 3.1 based on the agency's experience. The lower J-value for tied shoulders assumes traffic is not permitted to run on the shoulder" (Page II-26 of AASHTO Guide for Design of Pavement Structures, 1993).

A load transfer coefficient of 3.1, which assumes a jointed reinforced concrete pavement with some type of load transfer device such as dowel bars at the joints, was used.

## 10.2 Rigid Pavement Thickness

Based on the discussed design parameters and the AASHTO equation presented on Figure 3.7, page II-45 of the 1993 design guide, the recommended pavement thickness with an 8-inch thick lime stabilized subgrade is presented in the table below:

Table 10-1
Computed Rigid Pavement Thickness

| 18-kip ESAL Applications | Rigid Pavement Thickness (in.) (5.5 Sacks of Cement Per Cubic Yard of Concrete) | | | Subgrade |
|---|---|---|---|---|
| | 7-Day Flexural Break Strength by the Third Point Loading Method | 28-day Compressive Strength | Concrete Modulus of Rupture, S'c | |
| | 550 psi | 3500 psi | 620 psi | |
| 10.0 million | 10.0 | | | 8-in. Lime Stabilized |

## 10.3 Rigid Pavement Reinforcement

Concrete pavements should be reinforced in accordance with the City of Houston Department of Public Works and Engineering Drawing No. 02751-01 entitled "Concrete Pavement Details". Reinforcing steel should consist of reinforcing bars running in both directions. The amount of reinforcing steel may be determined from the following equation:

$$A_s = WFL/2f_s$$

Where:

$A_s$ = required steel area per ft of width
W = weight of the slab (psf)
F = coefficient of resistance between slab and subgrade (generally assumed to be 1.8)
$f_s$ = allowable tensile stress in the steel (psi)
L = length of slab (ft)

The above equation also applies to the design of transverse steel reinforcement in continuously reinforced concrete pavements. Longitudinal reinforcing steel requirements in continuously reinforced concrete pavements are presented in the AASHTO Design Guide.

**Design Example**

Assuming that expansion joints are spaced 80-ft longitudinally and 25-ft transversally, allowable tensile stress in the steel $f_s$ = 0.75 x 40,000 psi (Ref. AASHTO Design Guide 1993, Page II-28) = 30,000 psi, and concrete pavement thickness is 10.0-in., longitudinal steel reinforcement is calculated as follows:

$$A_s = \frac{(10\text{-in}/12\text{-in}) \times 150 \text{ pcf} \times 1.8 \times 80\text{-ft}}{2 \times 30{,}000 \text{ psi}} = 0.30 \text{ in}^2/\text{ft}$$

Using #5 deformed steel reinforcing bars (cross-sectional area $=\pi(5/8/2)^2$ = 0.307 $in^2$) the longitudinal steel spacing is equal to [0.307 $in^2$/(0.30 $in^2$/ft) x 12 in/ft] = 12.3 in.

Transverse steel reinforcement for non-continuously or continuously reinforced concrete pavements:

$$A_s = \frac{(10\text{-in}/12\text{-in}) \times 150 \text{ pcf} \times 1.8 \times 25\text{-ft}}{2 \times 30{,}000 \text{ psi}} = 0.094 \text{ in}^2/\text{ft}$$

Using # 5 deformed steel reinforcing bars the transverse steel spacing is equal to:

$[0.307 \text{ in}^2/(0.094 \text{ in}^2/\text{ft}) \times 12 \text{ in/ft}] = 39.2\text{-in.}$

Based on the above assumptions for expansion joint spacing, steel allowable tensile stress, and pavement thickness, the rigid pavement may be reinforced with #5 deformed steel reinforcing bars spaced at a **maximum** of 12 in. center to center longitudinally, and a **maximum** spacing of 36 in. center to center transversely. If it is desired to use shorter spacing transversely, a 24-inch center-to-center spacing may be used.

The steel reinforcement recommendations provided in this report are based on the assumptions presented above for pavement thickness, joints spacing (longitudinally and transversally), and steel allowable tensile stress. If any of the assumptions used to calculate the steel reinforcement is modified then the steel reinforcement should be modified accordingly.

All longitudinal, transverse and construction joints should be keyed and doweled. As a minimum, dowels should consist of 1¼- inch diameter bars, 18-in. long on 12-in. centers as specified in the City of Houston "Expansion and Construction Joint Details - Drawing No.: 02752-01".

The dummy groove joints are recommended to control cracking in spans in excess of 30-ft in length. According to the City of Houston "Expansion and Construction Joint Details - Drawing No.: 02752-01" ½-inch wide and 3/4-inch deep dummy joints may be sawed in the concrete slab. The City of Houston should be consulted in planning the reinforcing and joint details for the pavement and should govern if found to conflict with the above recommendations.

## 10.4 Pavement Maintenance

It is essential to maintain the pavement to prevent infiltration of water into the subgrade soils. Allowing water into the subgrade will accelerate pavement failure and maintenance requirements. Periodic maintenance must be performed on the pavement sections to seal any surface cracks and prevent infiltration of water.

# 11. BRIDGE FOUNDATION RECOMMENDATIONS

It is planned to construct a bridge overpass structure at the proposed Buffalo Speedway Extension crossing Holmes Road in Houston, Texas. Information furnished by the client indicates that the proposed bridge structure will be about 1,150-ft long and supported on drilled cast-in-place concrete shafts. The shaft diameters will be 36-in. and 42-in. Recommendations regarding drilled shaft design and construction based on borings B-3 through B-9 are given in the following sections.

## 11.1 Deep Foundations

The proposed bridge overpass may be supported on drilled, cast-in-place, straight-sided concrete piers (drilled shaft). Presented in Figures 15, 17, 19 and 21 are recommended allowable axial capacities for 36-in. and 42-in. diameter drilled shafts.

The design capacities are applicable for drilled shafts with minimum three diameters center-to-center spacing. The allowable capacities should be reduced if center-to-center shaft spacing is less than 3 diameters, and TWEI should be consulted to provide the appropriate allowable load reductions.

The design capacities are based on having a complete soil cover around the full length of the drilled shaft. We discounted frictional resistance of the soils to 10-ft below existing ground surface elevation to account for possible disturbance during construction, and possible erosion of the cohesionless soils. Due to presence of a stock pile of fill soils near boring B-5, we conservatively discounted frictional resistance of the soils to 15-ft below existing ground surface elevation at this location.

Load bearing capacity analyses for axial compression loads on drilled shafts were conducted by using the $\alpha$ /$\beta$ coefficient method ($\alpha$ for clay, $\beta$ for sand) to define ultimate shaft friction values and general shear bearing capacity factors to define ultimate end bearing values ("Pile Foundation Analysis and Design" by Poulos and Davis, 1980; "Behavior of Drilled Piers Under Axial Loading", by Reese, Touma and O'Neill, 1976, "User Manual for Coyle" Tucker and Briaud, 1985 and 1990, and "Drilled Shafts: Construction Procedures and Design Methods", by O'Neill and Reese, 1999). Skin friction values in sands were computed using the method "Ref. FHWA-IF-99-0225 Drilled Shafts: Construction Procedures and Design Methods, by O'Neill and Reese, 1999, Pages 281 & B-47". The method uses uncorrected SPT values and the overburden depth to the middle of the layer being evaluated to obtain a dimensionless value, and then multiplying by the effective overburden pressure to obtain the ultimate skin friction in cohesionless soils.

We used the computer program SHAFT Version 6.0 by Ensoft, Inc. to compute the ultimate pile capacities. The recommended input parameters (depth interval below grade, soil type, effective soil unit weight $\gamma$', cohesion c, soil friction $\phi$', and Nq) required for SHAFT were used for each pile capacity analysis. It is our understanding that SHAFT has implemented the methodology for computing the ultimate capacity of drilled shafts as recommended by "Drilled Shafts: Construction Procedures and Design Methods", by O'Neill and Reese, 1999. SHAFT also provides the side load transfer characteristics (also know as t-z curves) and pile tip load versus pile tip movement relations (also known as q-z curves) for different soil layers.

The allowable axial tension load capacities presented in Figures 16, 18, 20 and 22 were determined by a reduction factor of 0.7 times the allowable skin friction ("Drilled Shafts: Construction Procedures and Design Methods", by O'Neill and Reese, 1999 and Closure to "Side Resistance in Piles and Drilled Shafts" by Michael W. O'Neill, ASCE Journal of Geotechnical Engineering, January 2001, Vol. 127, No. 1, 3-16). The buoyant weight of the embedded portion of the shaft may be added to the allowable tension load.

The ultimate pier capacities were reduced by respective factors of safety of 2.0 for skin friction and 3.0 for end bearing in order to generate the allowable axial capacity curves. The weight of the pier was not included in the capacity computations.

Allowable drilled shaft capacities provided in the design charts do not include the group effect. The allowable capacities should be reduced, if the drilled shaft center-to-center spacing is less than 3 diameters and TWEI should be consulted to provide the appropriate allowable load reductions.

The aspect ratio of a drilled shaft, or its length divided by its diameter (L/D), should not exceed about 30 (O'Neill and Reese, 1999, pg 11).

## 11.2 Lateral Load Analyses

It is necessary to design the foundation unit to resist both vertical and lateral loads. The foundations will be subjected to lateral loading from wind forces and other sources. The lateral forces generated from those sources will be taken by mobilization of resistance in the surrounding soils as the unit deflects, and by the structural capacity of the foundation section. We understand that lateral loads for the proposed bridge structure are not of a concern. We will be glad to provide lateral load capacities to aid the design when the foundation depth, type, and size have been selected and if this becomes a design concern.

## 11.3 Axial Group Effects

The overall allowable axial compression load carrying capacity of a group of drilled shafts, in some cases, could be less than the sum of the individual drilled shaft allowable capacities. A reduction in the individual shaft capacity, to allow for group effects, is usually not necessary for shafts having a center-to-center spacing of 3 or more shaft diameters. The reduction in individual capacity depends on several factors including number of shafts in the group, shaft sizes, shaft penetration, shaft spacing, etc. We will be glad to provide axial group effect recommendation to aid the design, when the number of shafts in the group, shaft sizes, shaft penetration, and shaft spacing are selected.

## 11.4 Foundation Settlement

Post-construction vertical movements due to design loads are anticipated to be less than 0.5 in. for drilled shafts installed using proper construction techniques. Movements consist of elastic shortening of the foundation unit and deformation at the foundation tip.

## 11.5 Drilled Shaft Construction Recommendations

Drilled shaft construction and installation should follow TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, June 2004 Edition, Item 416, *Drilled Shaft Foundations*. The ACI 336.1-89 *Standard Specifications for End Bearing Drilled Piers* document can be used in the absence of TxDOT Specifications. The TxDOT Specifications shall always supercede any other specification. Presented below are a few specific recommendations.

1) Drilled shaft excavations should be inspected for verticality and side sloughing. Verticality is specified at one inch in ten feet of the shaft length, and should be checked to the full depth of dry augering prior to introducing drilling mud.

2) Slurry should contain four to eight percent by weight of bentonite additive and should satisfy the slurry specification set forth in TxDOT Standard Specification Item 416.3 or ACI 336.1-89 Section 2.3.5.2.e. Note that the ACI requirements are more stringent than TxDOT Standard Specification Item 416.3. Stricter slurry specifications are required to assure suspension of detritus from drilling operations, and to assure adequate cleaning of the slurry prior to concreting. Cleaning of the slurry is important to prevent deposition of detritus on reinforcement cages and ensure that inclusions of detritus will not be formed within the concrete mass.

3) Before placing concrete, the shaft bottoms should be cleaned out with a drilling bucket in order to remove any sediments which may not be displaced by the concrete. The shaft bottoms should be cleaned with a "clean-out" bucket until rotation on the bottom without crowd (i.e. penetration under force) produces little spoil. Probing after clean-out is essential to verify the condition of the base of the shaft.

4) Concrete should conform to the requirements of TxDOT Standard Specification Item 421, (*Portland Cement Concrete*), or ACI 336.1-89 Section 2.3.5.5.

5) Concrete placement should be accomplished as directed in TxDOT Standard Specification Item 416.3.F. The tremie pipe diameter should be at least eight times as large as the largest concrete aggregate size.

6) A computation of the final concrete volume for each shaft should be made. Shafts taking an unreasonably high or low volume of concrete should be cored to check their integrity.

7) If casing is used it should be extracted slowly and smoothly with a vibratory hammer. The casing should always remain at least one foot below the level of the concrete during placement. Our analyses assume no casing will be left in place. We should be informed if casing would be left in place so we may provide revised shaft capacities.

Shaft excavations should not be made within three (3) shaft diameters (edge to edge) of the shafts which have been concreted within the last 24 hours.

If it is deemed necessary to verify the design charts provided on Figures 15, 17, 19 and 21, then a pile load test may be performed on the selected drilled shaft type prior to the start of

construction. The shaft subjected to the load test should be drilled to the design tip elevation. The pile load test should be performed in accordance with TxDOT Standard Specification Item 404.3.G and ASTM D 1143.

# 12. MSE RETAINING WALL DESIGN AND CONSTRUCTION

We understand that MSE retaining wall embankments will be constructed at Buffalo Speedway crossing Holmes Road in Houston, Texas. Information furnished by the client indicates that the maximum height of the embankments will be about 18-ft at Sta. 193+50.00 at the north side of Holmes Road, and about 18.5-ft at Sta. 182+00.00 at the south side. The proposed embankment will be about 500-ft long at the north side of Holmes Road, and about 450-ft long at the south side. The embankment fill will be supported vertically by mechanically stabilized earth (MSE) retaining walls. The layouts of the proposed retaining walls are presented in Appendix A.

Borings B-2 and B-3 are located in the vicinity of the proposed MSE retaining wall on the north side of the bridge overpass, and borings B-9 and B-10 are located on the south side. Soil properties and soil profiles from these borings were utilized in the foundation and stability analyses of the retaining wall embankment.

## 12.1 MSE Retaining Wall Embankment Foundation Design

Based on the provided project information, the maximum height of the MSE wall is about 18.5-ft at Sta. 182+00.00 on the south side of the bridge. For the 18.5-ft high MSE wall, the minimum required cement stabilized sand backfill width was assumed to be about 13-ft. Soil properties and soil profiles observed in borings B-3 and B-9 were utilized in the foundation engineering and stability analyses of the retaining wall. Soil information from borings B-2 and B-10 were also reviewed during the retaining wall design and stability analyses.

We checked bearing capacity, sliding, and overturning for the proposed retaining walls on the south and north sides of the bridge. The retaining wall design analyses were performed using the computer program *MSEW Verson 3.0 (Ref. Mechanically Stabilized Earth Wall Program by ADAMA Engineering, Inc.)*. The results of the 18-ft and 18.5-ft high MSE wall analyses are presented below, and in respective Appendices I and J.

**<u>18-ft High MSE Retaining Wall Embankment at North of Bridge</u>**

<u>Bearing Capacity:</u>

Allowable Bearing Capacity $q_a$ = 3471 psf

Stress $\sigma_v$ = 3378 psf < 3471 psf

FS $_{\text{bearing capacity}}$ = 2.05 > 2.0 OK (See Page 6 in Appendix I)

<u>Sliding</u>

FS $_{\text{sliding}}$ = 2.10 > 1.5 OK (See Page 6 in Appendix I)

<u>Overturning</u>

FS $_{\text{overturning}}$ = 3.86 > 2.0 OK (See Page 6 in Appendix I)

Based on the analyses provided in Appendix I, the 18-ft high MSE wall has acceptable factors of safety of at least 2.0 against bearing capacity failure and overturning, and an acceptable factor of safety greater than 1.5 against sliding.

**18.5-ft High MSE Retaining Wall Embankment at South of Bridge**

Bearing Capacity:

Allowable Bearing Capacity $q_a$ = 2571 psf

Stress $\sigma_v$ = 3526 psf > 2571 psf

FS $_{\text{bearing capacity}}$ = 1.46 < 2.0 Not OK (See Page 6 in Appendix J)

Sliding

FS $_{\text{sliding}}$ = 1.48 < 1.5 Not OK (See Page 6 in Appendix J)

Overturning

FS $_{\text{overturning}}$ = 3.67 > 2.0 OK (See Page 6 in Appendix J)

Based on the analyses provided in Appendix J, the 18.5-ft high MSE wall has not acceptable factors of safety of at least 2.0 against bearing capacity failure and 1.5 against sliding. The MSE wall has acceptable factor of safety of 2.0 against overturning.

## Soil Improvements

Based on subsurface soil condition at the south of bridge overpass near borings B-9 and B-10, the factor of safety against bearing capacity failure is under 2, and therefore soil improvement will be required under the proposed MSE retaining wall. Soil improvement is not required if the proposed wall height is 10-ft or less.

Soil improvement could be achieved by:

- Overexcavating the upper 4-ft of subgrade within the footprint of the proposed MSE wall base, and for a distance of at least 5 ft beyond the proposed wall perimeter.
- Compacting the exposed soil.
- Backfilling over the compacted soil with cement stabilized sand (CSS) up to the MSE wall base.

Cement stabilized sand should be placed in 8-in. thick loose lifts and compacted to at least 95% of the minimum density determined in accordance with Test Method TEX-114-E.

## 12.2 MSE Retaining Wall Embankment Stability Analyses

Slope stability analyses were performed for the proposed retaining wall embankment sections to evaluate the overall rotational stability. During our stability analyses, we assumed improved soil condition using 4-ft thick cement stabilized sand under the retaining wall base for the section at the south side of the bridge.

The slope stability analyses were performed using the computer program *GSTABL7 version 2.004 (Ref. GSTABL7© with STEDwin© Program by Garry H. Gregory, P.E. and Harald W. Van Aller, P.E.)* and the Modified Bishop slope stability analysis procedures. Soil parameters used in

the stability analyses were based on laboratory test results from soil samples obtained during this investigation. The GSTABL7 computer code searches for the critical slope failure plane and computes the minimum safety factor for a given slope geometry and subsurface soil and groundwater conditions.

Total stress cohesion ($c_T$) and total stress angle of internal friction ($\varnothing_T$) for the clay soils for the short term condition were based upon the UC and UU test results, and TWEI's experience with similar soils. Effective stress cohesion (c') and effective stress angle of internal friction ($\varnothing'$) for the clay soils for the long term condition were based upon CU test results, and TWEI's experience with similar soils. Total/effective stress cohesion and total/effective stress angle of internal friction for the sand layers were based upon the SPT test results.

The cohesion for the long-term condition (using drained parameters) was reduced to accommodate weathering effect on the exposed cohesive soils [i.e., using a correction factor for peak strength recommended by Mesri and Abdel-Ghaffar (1992)].

Slope stability analyses for the proposed retaining wall embankment sections near borings B-3 and B-9 were performed for the following two design conditions:

- Short Term (End of Construction) Condition - The end of construction condition models the initial undrained condition of the soil. Total stress shear strength parameters were used for the analysis. A partially saturated slope was assumed for the short-term condition. For the proposed retaining wall analyses at borings B-3 and B-9, the piezometric levels were placed at El. +35.0 ft and at El. +38.2 ft.

- Long Term Condition – Effective stress shear strength parameters were used for the analysis. A partially saturated retaining wall soils and ground water level were used for the analysis. The water level under the long term condition for the retaining wall was assumed to be at the same elevations under the short-term condition. The long-term case represents steady state piezometric and stress conditions. The long-term models a case in which the slope soils rely on their available drained shear strength for long-term stability.

The computed minimum factors of safety against a slope failure for the retaining wall embankment critical sections selected are shown on Figures 23 through 26 of this report, and are as follows:

Table 12-1
MSE Retaining Wall Embankments Stability Results

| Condition Analyzed | Factor of Safety | |
|---|---|---|
| | **B-3** | **B-9** |
| | **18-ft High MSE Retaining Wall** | **18.5-ft High MSE Retaining Wall** |
| | **w/o Soil Improvement** | **w/ Soil Improvement** |
| Short Term (End of Construction) | 2.31 | 1.78 |
| Long Term | 1.32 | 1.54 |

The typical minimum factor of safety for slope stability which is used for retaining wall embankment design purposes is:

Table 12-2
Recommended Minimum Factor of Safety

| Condition | Factor of Safety |
|---|---|
| Short Term (end of construction) | 1.3 |
| Long Term | |

Global stability analysis results indicate that the 18-ft high retaining wall embankment at the north of bridge overpass will have adequate factors of safety against global rotational failure during the short-term (construction period) and long-term (performance period) conditions. Figures 23 and 24 present the results of the 18-ft high retaining wall global stability analyses.

We also performed stability analyses using 4-ft thick cement stabilized sand under the proposed MSE retaining wall base at the south side of bridge overpass. Our results indicate that 18.5-ft high retaining wall embankment using 4-ft thick cement stabilized sand at the base will have adequate factors of safety against global rotational failure during the short-term (construction period) and long-term (performance period). Our slope stability analyses using 4-ft thick cement stabilized sand at the base are presented in Figures 25 and 26.

## 12.3 MSE Retaining Wall Embankment Settlement Analyses

We estimated the settlement of the proposed retaining walls for three different heights at the south side of the bridge. Settlement analyses were performed using the computer program *FoSSA Version 2.0 (Ref. Foundation Stress & Settlement Analysis Program by ADAMA Engineering, Inc.).* The estimated total and long term settlements for the proposed retaining wall embankments on the south side of the bridge are presented in the following table.

Table 12-3
Estimated Settlement of Retaining Wall Embankments

| Retaining Wall Embankment Height, ft | Settlement, in. | | | |
|---|---|---|---|---|
| | w/o Cement Sand Base | | w/ Cement Sand Base | |
| | Total Settlement | Long Term Settlement* | Total Settlement | Long Term Settlement* |
| 18.5 | 3.25 | 2.65 | 1.40 | 0.92 |
| 14 | 2.62 | 2.14 | 1.10 | 0.71 |
| 10 | 1.89 | 1.53 | - | - |

* Estimated long term settlement which will occur after the retaining wall is fully constructed

The time rates of consolidation of the cohesive strata at the retaining wall embankments of the proposed bridge are estimated as follows:

- about 1/3 years to achieve 30% consolidation;
- about 1/2 years to achieve 50% consolidation;
- about 1.0 years to achieve 70% consolidation;
- about 5.5 years to achieve 90% consolidation.

It is also estimated that about 10% of the consolidation settlement will occur as the retaining wall embankments are being constructed. The time rate consolidation settlement values represent only the estimated long term settlement which will occur after the embankments are fully constructed.

## 12.4 Fill Placement Recommendations

If fill placement is required along the proposed embankment construction section, the subgrade should be stripped of vegetation and other deleterious materials. Tree stumps and large root systems, if encountered, should be grubbed to their full depth. The exposed surface should be proofrolled and any soft spots encountered should be excavated and replaced with suitable fill material. After proofrolling, the exposed surface should be scarified to a depth of at least 4 in. and compacted to the same requirements for the embankment.

The embankment may be constructed with TxDOT Type “C” fill soils. Type “C” fill should be free of organics, deleterious materials, and excessive silt. The fill should be placed in lifts not exceeding 8-in. loose measure and compacted to at least 95% of the maximum dry density determined in accordance with Test Method TEX-114-E. The lifts should be uniform across the entire embankment width. The 2004 Standard Specifications for Construction of Highways, Streets, and Bridges of the TxDOT can be used as a guide for density control specifications.

# 13. TRAFFIC SIGNAL POLE

It is planned to construct a traffic signal pole at the intersection of the proposed Buffalo Speedway and West Airport Boulevard in Houston, Texas. There is a provision for a possible traffic signal pole at the intersection of Holmes Road and Buffalo Speedway. We anticipate that the proposed traffic signal poles will be supported on drilled cast-in-place concrete shafts. Recommendations regarding drilled shaft design and construction are given in the following sections.

## 13.1 General

The foundation system for the project must satisfy two independent engineering criteria with respect to soil conditions. One criterion is that the system be designed with an appropriate factor of safety against bearing capacity failure of the soils underlying the foundations. The second criterion is that movement beneath the foundation system due to compression (consolidation) or expansion (swell) of the underlying soils must be within tolerable limits for the structure.

Boring B-11 is located in the vicinity of the proposed traffic signal pole at the intersection of Buffalo Speedway and Holmes Road, and boring B-28 at the intersection of Buffalo Speedway and West Airport Boulevard. Soil information from nearby deeper borings B-5 and D-1 were also reviewed during the foundation design.

Soil properties and soil profiles from these borings were utilized in the foundation analyses of the structures.

## 13.2 Shallow Foundations for Lightly Loaded Structure

The structural loads of the proposed traffic signal pole may be supported on drilled and underreamed, cast-in-place concrete piers. Borings B-11 and B-28 were drilled at the vicinity of the poles.

### 13.2.1 Drilled, Cast-in-Place, Straight Sided Piers

13.2.1.1 *Allowable Bearing Capacity.* The proposed traffic signal poles may be supported on drilled and underreamed, cast-in-place concrete piers bearing at 15-ft depth below existing grade in competent cohesive soils. To maintain a minimum factor of safety of 3.0 against bearing capacity failure and to limit settlement, we recommend that the design maximum net allowable soil bearing pressure be limited to 3,600 psf. Drilled piers should not be placed closer than preferably three base diameters, center-to-center.

It is frequently advisable in expansive soil environments to provide additional steel reinforcing in the shafts of the underreamed footings. The tension steel should extend the full length of the shaft and the underream. A steel quantity of 0.5% of the gross shaft area is usually sufficient.

The length of the shaft could be greater than 15-ft depending on drilled shaft lateral response analyses, and should to be verified prior to final structural design.

13.2.1.2 *Pier Installation*. The bell/shaft diameter ratio of undereamed footings should not be greater than about three to reduce sloughing and caving potential. Based on observations in the project borings, it should be possible to form stable underreams by designing the piers to bear within competent cohesive soils at about 15-ft below grade. If underreams are planned but cannot be completed because of local anomalies and/or sloughing, the contractor should be required to excavate to a depth specified by the Geotechnical Engineer, and provide a straight-sided pier with the shaft diameter possibly equal to the design bell diameter. We recommended test excavations to evaluate bell stability at the site prior to production piers.

Concrete should be placed in underreamed or straight-sided footings following drilling and inspection. In no instance should an excavation footing be allowed to remain open for more than two hours prior to placement of concrete. Seepage into excavations from perched water is not anticipated. However, if water collects in excess of 1-in. depth at the bottom of the footing excavations, it should be pumped out prior to concrete placement or the concrete should tremied into place.

13.2.1.3 *Foundation Settlement.* Total post-construction settlement of less than 1-in. is anticipated for drilled footings placed using proper construction methods. It should be pointed out that the performance of the foundations would be more sensitive to construction quality than soil-structure interaction. Monitoring of the footing installation by the Geotechnical Engineer or a representative is recommended.

## 13.3 Lateral Load Analyses

It is necessary to design the foundation unit to resist both vertical and lateral loads. The foundations will be subjected to lateral loading from wind forces and other sources. The lateral forces generated from those sources will be taken by mobilization of resistance in the surrounding soils as the unit deflects, and by the structural capacity of the foundation section. We will be glad to provide lateral load capacities to aid the design when the foundation depth, type, and size have been selected and if this becomes a design concern.

# 14. SOIL CORROSION POTENTIAL

Seven (7) selected soil samples recovered from the upper 2-ft to 10-ft depth range in borings B-3 through B-9 were analytically tested to determine sulfate contents. Detailed results of the analytical tests are presented in Appendix H.

The degradation of concrete is caused by chemical agents in the soil or groundwater that react with concrete to either dissolve the cement paste or precipitate larger compounds which cause cracking and flaking. The concentration of water-soluble sulfates in the soils is a good indicator of the potential for chemical attack of concrete. Sulfate concentrations in soil can be used to evaluate the need for protection of concrete based on the general guidelines shown in Table 14-1.

Table 14-1
Sulfate Attack Potential

| Sulfate Ion Concentration, ppm or mg/kg | Aggressiveness(1) |
|---|---|
| >20,000 | Very Severe |
| 2,000 to 20,000 | Severe |
| 1,000 to 2,000 | Moderate |
| < 1,000 | Negligible |

(1)ACI 318-05/ACI 318R-05

On the basis of soil sulfate concentration data shown on Table 5-7 and the general guidelines from Table 10-1, the soils have a "negligible" potential for attacking concrete. Based on the measured soil sulfate concentration, ACI Committee Report 201.2R indicates that special requirements for sulfate resistance are not needed (that is, ASTM C 150 Types I and II are applicable).

Degradation of concrete can also be advanced by the aggregates selected for the concrete mixtures. Alkali-silica reactivity (ASR), a chemical reaction between Portland cement concrete and certain aggregates, can directly cause expansion damage in concrete structures or can expedite other reactions that in turn cause damage, such as rebar corrosion.

Three requirements must be met for ASR expansion to occur: (1) reactive forms of silica or silicate in the aggregate; (2) sufficient alkali (sodium and potassium) primarily from the cement; and (3) sufficiently available moisture in the concrete. If one of the three requirements is not met, expansion due to ASR cannot occur. The concrete aggregate should be checked for ASR.

# 15. OFF-SITE DRAINAGE DITCHES STABILITY ANALYSES

It is planned to construct four (4) off-site drainage ditches for the Buffalo Speedway extension project in Houston, Texas. The proposed drainage ditches are designated as A, B, C and D, and will be extending laterally from the Buffalo Speedway alignment (eastward to the HCFCD ditch). Information furnished by the client indicates that the maximum depth of the drainage channels will be about 7.5-ft to 9-ft. The four drainage ditches are approximately 1,000 to 2,500 LF. We understand that the proposed drainage channel embankments will be stabilized by flattening the slopes to 4(H):1(V). We also reviewed the 100-year water surface elevation (WSE) provided by the client during the stability analyses.

The recommendations provided in this section are based on the results of borings A-1, BB-1, BB-2, C-1 through C-3 and D-1 through D-3, and laboratory test results from soil samples obtained during this investigation.

## 15.1 Slope Stability Analyses

Slope stability analyses were performed for selected sections in the vicinity of borings A-1, BB-1, C-2 and D-3 to evaluate the proposed drainage channel slopes. During our slope stability analyses, we assumed that the slopes will be flattened to 4H:1V. The stability analyses were performed using the computer program *GSTABL7 version 2.005 (Ref. GSTABL7© with STEDwin© Program by Garry H. Gregory, P.E. and Harald W. Van Aller, P.E.)* and the Modified Bishop slope stability analysis procedures. Soil parameters used in the stability analyses were based on experience with local soils and laboratory test results of the soil samples obtained during this investigation. The GSTABL7 computer code searches for the critical slope failure plane and computes the minimum safety factor for a given slope geometry and subsurface soil and ground water conditions.

Total stress cohesion values for clay soils for the short term (end-of-construction) condition were based upon unconfined compression (UC) test results, unconsolidated-undrained (UU) triaxial compression test results, and TWEI's experience with similar soils. Total stress cohesion and angle of internal friction for the clay soils for the rapid drawdown (intermediate) condition were based upon the results of consolidated-undrained (CU) triaxial compression tests with pore pressure measurements, in-house charts, and TWEI's experience with similar soils. Effective stress cohesion and angle of internal friction for clay soils for the long-term and rapid drawdown (intermediate) conditions were based upon the results of the CU triaxial compression tests with pore pressure measurements, in-house charts, and TWEI's experience with similar soils.

The cohesion for the rapid drawdown and long-term conditions (using drained parameters) were reduced to accommodate weathering effect on the exposed cohesive soils [i.e., using a correction factor for peak strength recommended by Mesri and Abdel-Ghaffar (1992)]. Detailed calculations for soil parameters using weathering effects are presented in Appendix K.

The slope stability analyses for the drainage channels with flattened slopes were performed using the soil profiles from borings A-1, BB-1, C-2 and D-3. The analyses were performed for the following three design conditions:

- Short Term (End of Construction). The end of construction condition models the initial undrained condition of the soil. For this analysis, UC and UU shear strength soil parameters were used. The groundwater levels encountered during drilling were used for short term condition. The groundwater levels based on water level measurements during the fieldwork and in the available piezometers were assumed:
    - at El. 40.8 ft for boring A-1 soil profile,
    - at El. 33.2 ft for boring BB-1 soil profile,
    - at El. 38.5 ft for boring C-2 soil profile, and
    - at El. 39.5 ft for boring D-3 soil profile.
- Intermediate Term (Rapid Drawdown) Condition – Total and effective stress shear strength parameters from the CU tests and TWEI's experience with similar soils were used for analyses. The rapid drawdown case models the condition where high flood waters saturate and piezometrically "load" a slope, and then quickly recede, leaving a large unbalanced piezometric head in the slope. The unbalanced head significantly increases shear stresses in the slope. The stresses relax as the unbalanced piezometric head drains out of the slope with time. For our analyses, the high water was assumed near the top-of-bank based on 100-year water surface elevation (WSE), along the slope face, and down to the channel bottom. The high water was assumed at El. 53.5 ft near boring A-1, at El. 52.15 ft near boring BB-1, at El. 51.85 ft near boring C-2, and at El. 50.85 ft near boring D-3.
- Long Term Condition – Effective stress shear strength parameters, a partially saturated channel side-slope, and a saturated bottom were used for analyses. The water levels for the drainage channels were set at the same elevations of the short-term condition. The long-term case represents steady state piezometric and stress conditions. The long-term models a case in which the slope soils rely on their available drained shear strength for long-term stability.

The model for the stability analyses for the 4H:1V slope, including the slope configuration, water level, and soil parameters are shown on Figures 27 through 42.

Soil parameters used in the drainage channel "A" slope stability analyses using the flattened side slope section at boring A-1 are summarized in the following table.

Table 15-1
Soil Parameters at Boring A-1

| Stratum | Depth (ft) | Description | Unit Weight | | ST | | RDD | | LT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\gamma_t$ (pcf) | $\gamma_{sat}$ (pcf) | $c_{uu}$ (psf) | $\phi_{uu}$ (deg) | $c_{cu}$ (psf) | $\phi_{cu}$ (deg) | c' (psf) | $\phi'$ (deg) |
| 1 | 0 - 6 | Sandy Lean Clay (CL) | 123 | 133 | 3000 | 0 | 238 | 28.8 | 192 | 30.7 |
| 2 | 6 - 12 | Sandy Lean Clay (CL) | 125 | 128 | 1300 | 0 | 238 | 28.8 | 192 | 30.7 |
| 3 | 12 - 14 | Fat Clay w/ Sand (CH) | 127 | 127 | 500 | 0 | 256 | 19.5 | 240 | 25.6 |
| 4 | 14 - 16 | Sandy Silty Clay (CL-ML) | 129 | 129 | 280 | 0 | 110 | 29 | 80 | 31 |
| 5 | 16 - 20 | Fat Clay (CH) | 123 | 123 | 2100 | 0 | 256 | 19.5 | 240 | 25.6 |

Soil parameters used in the drainage channel "B" slope stability analyses using the flattened side slope section at boring BB-1 are summarized in the following table.

Table 15-2
Soil Parameters at Boring BB-1

| Stratum | Depth (ft) | Description | Unit Weight | | ST | | RDD | | LT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\gamma_t$ (pcf) | $\gamma_{sat}$ (pcf) | $c_{uu}$ (psf) | $\phi_{uu}$ (deg) | $c_{cu}$ (psf) | $\phi_{cu}$ (deg) | c' (psf) | $\phi'$ (deg) |
| 1 | 0 - 1.5* | Fill: Fat Clay w/ Sand (CH) | 122 | 128 | 1000 | 0 | 256 | 19.5 | 102** | 26 |
| 2 | 1.5 - 7.5 | Fat Clay w/ Sand (CH) | 122 | 128 | 2800 | 0 | 256 | 19.5 | 18** | 26 |
| 3 | 7.5 - 10 | Fat Clay (CH) | 129 | 129 | 1700 | 0 | 256 | 19.5 | 4** | 26 |
| 4 | 10 - 21.5 | Fat Clay (CH) | 123 | 124 | 1500 | 0 | 256 | 19.5 | 240 | 26 |

*Channel embankment at high bank will be raised about 1.5-ft above existing grade.
**Soil properties were adjusted to account for the effect of weathered conditions (due to shrink-swell) in clays.

Soil parameters used in the drainage channel "C" slope stability analyses using the flattened side slope section at boring C-2 are summarized in the following table.

Table 15-3
Soil Parameters at Boring C-2

| Stratum | Depth (ft) | Description | Unit Weight | | ST | | RDD | | LT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\gamma_t$ (pcf) | $\gamma_{sat}$ (pcf) | $c_{uu}$ (psf) | $\phi_{uu}$ (deg) | $c_{cu}$ (psf) | $\phi_{cu}$ (deg) | c' (psf) | $\phi$' (deg) |
| 1 | 0 - 1.5* | Fill: Fat Clay (CH) | 124 | 131 | 1000 | 0 | 266 | 19 | 114** | 25 |
| 2 | 1.5 - 5.5 | Fat Clay (CH) | 124 | 131 | 3000 | 0 | 266 | 19 | 59** | 25 |
| 3 | 5.5 - 9.5 | Fat Clay w/ Sand (CH) | 124 | 131 | 3000 | 0 | 266 | 19 | 32** | 25 |
| 4 | 9.5 - 15.5 | Fat Clay (CH) | 130 | 130 | 2000 | 0 | 266 | 19 | 32** | 25 |
| 5 | 15.5 - 21.5 | Fat Clay (CH) | 123 | 123 | 2000 | 0 | 266 | 19 | 262 | 25 |

*Channel embankment at high bank will be raised about 1.5-ft above existing grade.
**Soil properties were adjusted to account for the effect of weathered conditions (due to shrink-swell) in clays.

Soil parameters used in the channel slope stability analyses using the flattened side slope section at boring D-3 are summarized in the following table.

Table 15-4
Soil Parameters at Boring D-3

| Stratum | Depth (ft) | Description | Unit Weight | | ST | | RDD | | LT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\gamma_t$ (pcf) | $\gamma_{sat}$ (pcf) | $c_{uu}$ (psf) | $\phi_{uu}$ (deg) | $c_{cu}$ (psf) | $\phi_{cu}$ (deg) | c' (psf) | $\phi$' (deg) |
| 1 | 0 - 2.5* | Fill: Fat Clay w/ Sand (CH) | 126 | 132 | 1000 | 0 | 390 | 14 | 173** | 18 |
| 2 | 2.5 - 12.5 | Fat Clay w/ Sand (CH) | 126 | 132 | 4000 | 0 | 390 | 14 | 88** | 18 |
| 3 | 12.5 - 18.5 | Fat Clay (CH) | 125 | 125 | 2200 | 0 | 390 | 14 | 374 | 18 |
| 4 | 18.5 - 22.5 | Lean Clay (CL) | 124 | 126 | 800 | 0 | 238 | 28.8 | 192 | 30.7 |

*Channel embankment at high bank will be raised about 2.5-ft above existing grade.
**Soil properties were adjusted to account for the effect of weathered conditions (due to shrink-swell) in clays.

Where:

ST: Short Term Condition
RDD: Rapid Drawdown Condition
LT: Long Term Condition (Drained Condition)
$\gamma_t$: Moist Unit Weight of Soil
$\gamma_{sat}$: Saturated Unit Weight of Soil
$c_{uu}$: Unconsolidated-Undrained Cohesion
$\phi_{uu}$: Unconsolidated-Undrained Friction Angle
$c_{cu}$: Consolidated-Undrained Cohesion
$\phi_{cu}$: Consolidated-Undrained Friction Angle
c': Consolidated-Drained Cohesion
$\phi$': Consolidated-Drained Friction Angle

A summary of the computed minimum factors of safety using the soil profile from borings A-1, BB-1, C-2 and D-3 are presented in Figures 27 through 42, and in the following Table 15-5.

Table 15-5
Computed Minimum Factors of Safety

| **Condition** | | **Calculated Factor of Safety** | | | |
|---|---|---|---|---|---|
| | | **A-1** | **BB-1** | **C-2** | **D-3** |
| | | **4H:1V Grass Lined Slope** | | | |
| Short Term | | 5.52 | 8.32 | 9.86 | 11.00 |
| Rapid Drawdown | Total Stress | 3.13 | 2.99 | 2.89 | 3.48 |
| | Effective Stress | 3.12 | 1.39 | 1.62 | 1.75 |
| Long Term | | 4.78 | 2.34 | 2.56 | 2.50 |

Table 15-6 summarizes the recommended minimum factors of safety for slope stability analysis.

Table 15-6
Recommended Minimum Factors of Safety

| **Condition** | **Minimum Recommended Factor of Safety** |
|---|---|
| Short Term | 1.3 |
| Rapid Drawdown | 1.25 |
| Long Term | 1.5 |

Results of the stability analyses indicate that off-site drainage channels with side slopes of 4H:1V will have adequate factors of safety against a failure for the short term (end of construction), intermediate term (rapid drawdown), and long-term conditions.

## 15.2 Erosion Control

Some erosional distress and shallow slides should be expected on slopes that are subjected to overbank runoff or are located in the zone of temporary inundation by varying water level or wave action. A grass cover for cohesive slopes is an essential protection for erosion. HCFCD recommends establishing turf grass on all exposed or disturbed soil in a basin (*HCFCD Policy, Criteria and Procedure Manual*, December 2010, Section 6.14.1). A concrete liner or geotextile will provide better protection against erosion and shallow slides. In addition, erosion of the low plasticity cohesive soils may occur due to overbank runoff.

Zones of relatively permeable soils are susceptible to erosion under the action of flowing water, such as overbank flow and sheet flow. These soil zones along the slope, if encountered, may require hard armor such as concrete lining or rip rap if grass cover does not produce a good response. Additional erosion control methods include chemical stabilization, erosion control blankets, bonded fiber matrices, or removal and replacement with high plasticity clays.

Back slope drainage systems are required where the natural ground slopes toward the channel. In addition, concrete lining or riprap may be necessary around pipe inlets and outlets if erosive velocities and turbulence are expected.

The embankment should be protected with vegetation as specified in the HCFCD Policy, Criteria and Procedural Manual, December 2010, Section-10 *"Erosion and Sediment Control (10.3 Turf Establishment)"*.

## 15.3 Soil Dispersion

Side slopes constructed of dispersive soils disaggregate easily and rapidly in water of low salt concentration, and without significant mechanical assistance. Such clays usually have a high proportion of their adsorption capacity saturated with sodium cations. We performed pinhole, double hydrometer and crumb tests on eight (8) selected soil samples collected from the upper 6-ft depth in borings A-1, BB-1, BB-2, C-2, C-3, D-1 and D-3 to determine the potential for dispersivity.

Based on the test results (Tables 5-4 through 5-6), it appears that the tested medium-to-high plasticity cohesive soils are non-to-slightly dispersive to dispersive.

## 15.4 Back Slope Drainage

The main objective of a back slope drainage system is to prevent water from ponding in the back of a channel by providing for the discharge of storm water runoff into the easement. Back-slope interceptor structures should be placed at a maximum spacing of 200-ft center to center. These interceptor structures should be as deep as possible but not less than 2-ft deep in order to provide for adequate flow from the back slope swales to the interceptor structures.

## 15.5 Maintenance

Major maintenance for man-made channel involves removal of vegetation, repair of banks and trash removal. Manual removal of vegetation is very expensive and may require removal at frequent intervals. Channel design may be a more effective means of controlling vegetation.

The need for bank repair is generally dictated by the bank height, bank slope, in-situ soils, wave action, and effectiveness of the perimeter drainage away from the channel. Properly designed perimeter retention systems require little or no maintenance. Mechanically-protected slopes demand a slightly greater maintenance effort. Unprotected slopes require the greatest maintenance effort.

# 16. OUTFALL SLOPE STABILITY ANALYSES

The Buffalo Speedway Extension project includes the construction of outfall structures at the proposed four (4) drainage ditches that will extend from west to east. Information furnished by the client indicates that proposed drainage ditches will be about 7.5-ft to 9-ft deep and will be constructed using 4H:1V slopes. Precast reinforced concrete box sewers with sizes of 5'x3' to 6'x4' are planned to be installed at the west side of the drainage channel outfall locations. The 48-in. to 60-in. diameters corrugated galvanized metal pipes (CGMP) will be constructed at the east side of the drainage ditch outfall locations towards the HCFCD channel. The proposed precast reinforced concrete box sewer outfall structures will have a side slope inclination of 4H:1V. The proposed CGMP outfall structures at HCFCD drainage channel will have side slope inclinations of 4H:1V (inside) and 4.5H:1V to 5H:1V (outside). Slope stability analyses and erosion analyses for the outfall structures are provided in the following paragraphs.

## 16.1 Slope Stability Analyses

Global stability analyses were performed to evaluate the stability of the outfall embankments with riprap and grass lined slope faces. The stability analyses were performed using the computer program code as discussed in previous section 15.2.

Total stress cohesion and total stress angle of internal friction for clay soils for the short term condition were based upon unconfined compression test results and TWEI's experience with similar soils. Total and effective stress cohesion and total and effective stress angle of internal friction for the clay soils for the intermediate term (rapid drawdown) condition were based upon consolidated-undrained triaxial compression with pore pressure measurement test results and TWEI's experience with similar soils. Effective stress cohesion and effective stress angle of internal friction for clay soils for the long-term condition were based upon consolidated-undrained triaxial compression with pore pressure measurement test results and TWEI's experience with similar soils.

The cohesion for the rapid drawdown and long-term condition (using drained parameters) were reduced to accommodate weathering effect on the exposed cohesive soils [i.e., using a correction factor for peak strength recommended by Mesri and Abdel-Ghaffar (1992)].

The outfall embankment slope stability analyses were performed for the soil profiles at borings C-1 and C-3, which consisted of layered and/ cohesive stratigraphy. Slope stability analyses for riprap and grass lined sections were performed for the three design conditions: short term (end of construction), intermediate term (rapid drawdown), and long-term.

Soil parameters used in the outfall embankment slope stability analyses at the west side of the drainage ditch using the critical section at boring C-1 are summarized in the following table.

Table 16-1
Soil Parameters at Boring C-1

| Stratum | Depth (ft) | Description | Unit Weight | | ST | | RDD | | LT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\gamma_t$ (pcf) | $\gamma_{sat}$ (pcf) | $c_{uu}$ (psf) | $\phi_{uu}$ (deg) | $c_{cu}$ (psf) | $\phi_{cu}$ (deg) | c' (psf) | $\phi$' (deg) |
| 1 | - | Riprap | 90 | 95 | 20 | 45 | 20 | 45 | 20 | 45 |
| 2 | 0 – 2* | Fill: Lean Clay w/ Sand (CL) | 125 | 127 | 1000 | 0 | 260 | 18 | 163** | 28 |
| 3 | 2 - 4 | Lean Clay w/ Sand (CL) | 125 | 134 | 1600 | 0 | 260 | 18 | 130** | 28 |
| 4 | 4 - 10 | Lean Clay w/ Sand (CL) | 130 | 134 | 4000 | 0 | 260 | 18 | 64** | 28 |
| 5 | 10 - 12 | Fat Clay w/ Sand (CH) | 125 | 130 | 3000 | 0 | 266 | 19 | 100** | 25 |
| 6 | 12 - 14 | Lean Clay (CL) | 125 | 127 | 500 | 0 | 260 | 18 | 130** | 28 |
| 7 | 14 - 22 | Silty Sand (SM) | 125 | 125 | 0 | 34 | 0 | 34 | 0 | 34 |

*Channel embankment at high bank will be raised about 2-ft above existing grade.
**Soil properties were adjusted to account for the effect of weathered conditions (due to shrink-swell) in clays.

Soil parameters used in the outfall embankment slope stability analyses at the east side of the drainage ditch near HCFCD channel using the critical section at boring C-3 are summarized in the following table.

Table 16-2
Soil Parameters at Boring C-3

| Stratum | Depth (ft) | Description | Unit Weight | | ST | | RDD | | LT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\gamma_t$ (pcf) | $\gamma_{sat}$ (pcf) | $c_{uu}$ (psf) | $\phi_{uu}$ (deg) | $c_{cu}$ (psf) | $\phi_{cu}$ (deg) | c' (psf) | $\phi$' (deg) |
| 1 | 0 - 1.5* | Fill: Fat Clay (CH) | 126 | 127 | 1000 | 0 | 168 | 15 | 72** | 18 |
| 2 | 1.5 - 3.5 | Fat Clay (CH) | 126 | 127 | 1300 | 0 | 168 | 15 | 63** | 18 |
| 3 | 3.5 - 7.5 | Fat Clay w/ Sand (CH) | 124 | 131 | 3000 | 0 | 168 | 15 | 54** | 18 |
| 4 | 7.5 - 10.5 | Fat Clay (CH) | 126 | 127 | 2100 | 0 | 168 | 15 | 45** | 18 |
| 5 | 10.5 - 21.5 | Fat Clay (CH) | 124 | 124 | 2000 | 0 | 168 | 15 | 160 | 18 |

*Channel embankment at high bank will be raised about 1.5-ft above existing grade.
**Soil properties were adjusted to account for the effect of weathered conditions (due to shrink-swell) in clays.

The computed minimum factors of safety for the outfall structure embankments with design slopes of 4H:1V (inside) and 4.5H:1V (outside) are presented on Figures 43 through 54, and are tabulated as follows:

Table 16-3
Computed Factors of Safety of Outfall Embankment

| Condition Analyzed | | Factor of Safety | | |
|---|---|---|---|---|
| | | C-1 | C-3 | |
| | | Inside Slope (4H:1V) | Inside Slope (4H:1V) | Outside Slope (4.5H:1V) |
| Short Term | | 7.60 | 9.80 | 12.56 |
| Rapid Drawdown | Total Stress | 2.73 | 1.96 | 2.08 |
| | Effective Stress | 2.19 | 1.26 | 1.36 |
| Long Term | | 3.24 | 1.91 | 2.24 |

Typical minimum factors of safety against slope failures, which are used for design purposes, are shown in Table 15-6 in Section 15.2.

Results of the slope stability analyses indicate that the outfall embankments with design slopes of 4H:1V (inside) and 4.5H:1V (outside) will have adequate factors of safety against a global failure for the short term (end of construction), rapid drawdown, and long term conditions.

## 16.2 Erosion Control on the Outfall Slope

Some erosional distress should be expected on exposed cohesive slopes that are subjected to overbank runoff or are located in the zone of temporary inundation by ditch/channel levels or wave action. Furnished information indicates that concrete riprap will be used inside the drainage ditch on the slope face of outfall for maintenance purposes. A grass cover for the cohesive slope is planned for the embankment slope face near the HCFCD channel.

# 17. OUTFALL STRUCTURE INSTALLATION

## 17.1 Site preparation

The outfall area should be cleaned of all deleterious material such as wood, rock or tree stumps. The excavation slopes should be flattened to temporary gradients of 1(H):1.5(V) in order to reduce sloughing of the banks during pipe installation and fill placement. After cleaning and clearing, the existing outfall bottom should be proofrolled to detect zones of soft or wet material for removal. If encountered, such soils should be undercut and replaced with material of similar physical and moisture characteristics. Particular care should be given to limiting excessive subgrade drying and desiccation as a means of reducing subsequent subgrade swelling after construction. The ground surface should be appropriately graded downstream throughout construction to prevent ponding of rainfall runoff and provide positive drainage. The clearing and proof-rolling should be witnessed by the Geotechnical Engineer or a representative.

## 17.2 Groundwater Control

Maintaining groundwater and surface water control until backfilling is complete is preferred. Standing or flowing water in the excavation bottom will soften the toes of the sidewalls and slopes. If necessary, water discharge from the drainage canal located upstream should be diverted around the construction area until fill placement is completed.

## 17.3 Bedding and Backfill

### 17.3.1 Corrugated Metal Pipe

Pipe bedding and backfill should be performed in accordance with City of Houston, Department of Public Works and Engineering, *Standard Construction Specifications Section 02642 - Corrugated Metal Pipe.*

The width of the pipe trench should be two times the pipe inside diameter. Prior to installation, the pipe trench subgrade should be prepared as outlined in the "Site Preparation" section. Granular bedding material should be spread evenly on the properly prepared subgrade to a depth of 6-in. and compacted uniformly to a firm, but not hard support. The pipe can be placed on the bedding, then backfilled under the haunches. Typically, the bedding equal to one-third the pipe O.D. should be loosely placed, while the remainder should be compacted to 95% of the maximum dry density per ASTM D 698.

The haunching area of the backfill envelope provides the majority of the resistance against soil and traffic loadings. The backfill material should consist of granular material and compacted to a minimum 90% standard Proctor. The backfill material should be installed uniformly in layers not exceeding 12-in., loose measure, on each side of the pipe. The backfill should be shoveled under the pipe, taking care to fill voids. Backfill construction should continue up to the pipe springline to complete the haunch area.

Initial backfill materials must provide adequate pipe support and extend a minimum of 12-in. above the crown of the pipe. Granular materials may be used. To reduce damage when the

backfill soil is compacted above the pipe, there should be at least 12-in. of cover over the pipe before using hand-held or walk behind compaction equipment, and at least 3-ft of cover before using ride-on equipment.

The initial backfill may then be covered with the on-site cohesive soils. The high plasticity clays should be placed in loose lifts not exceeding 8-in. and compacted to 95% maximum dry density (ASTM D 698) at a moisture content three to five percentage points above optimum moisture.

### 17.3.2 Concrete Box Sewer

Bedding and backfill for box sewer should be performed in accordance with City of Houston, Department of Public Works and Engineering, *Standard Construction Specifications Section 02612 - Precast Reinforced Concrete Box Sewer.*

Place the box sewer on the foundation of firm and stable materials that is accurately shaped to conform to the base. In case of unstable bed, special bedding material should be used as per specification. Compact the backfill to at least 95% of ASTM D 698 at a moisture content two to five percentage points greater than the optimum.

# 18. OUTFALL EMBANKMENT CONSTRUCTION

The Off-site Drainage Ditches Outfall embankments should be constructed in general accordance with Harris County Flood Control District (HCFCD) specifications. The outfall design details are presented in *"Storm Sewer and Riprap Details"* of the HCFCD Policy Criteria & Procedure Manual For Approval and Acceptance of Infrastructure, dated December, 2010. The outfall flow-line elevation should be 1-ft above high water surface elevation. Rip rap should be placed below the outfall to low water elevation. Riprap material requirements are detailed in HCFCD Specification, *Item 02378 – Rip Rap and Granular Fill*. A timber bent may be required to anchor the pipe at its terminus on the high water bank of the ditch. Timber bent construction details are presented in HCFCD Specification, *Item 02646 – Timber Bents.*

# 19. CLOSURE

## 19.1 Limitations

This report has been prepared for the exclusive use of CLR, Inc., and their design team for specific application to the construction of the referenced project at the aforementioned location in Houston, Harris County, 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, at the time borings were drilled, 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 construction. If subsurface conditions different from those described are noted during construction, recommendations in this report must be re-evaluated.

If any changes in the nature, design, or location of the proposed project 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 TWEI. TWEI is not responsible for any claims, damages, or liability associated with interpretation of subsurface data by others or reuse of the subsurface data by others or engineering analyses by others without the expressed written authorization of TWEI.

## 19.2 Design Review

Review of the design and construction plans as well as the specifications should be performed by TWEI 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.

## 19.3 Construction Surveillance

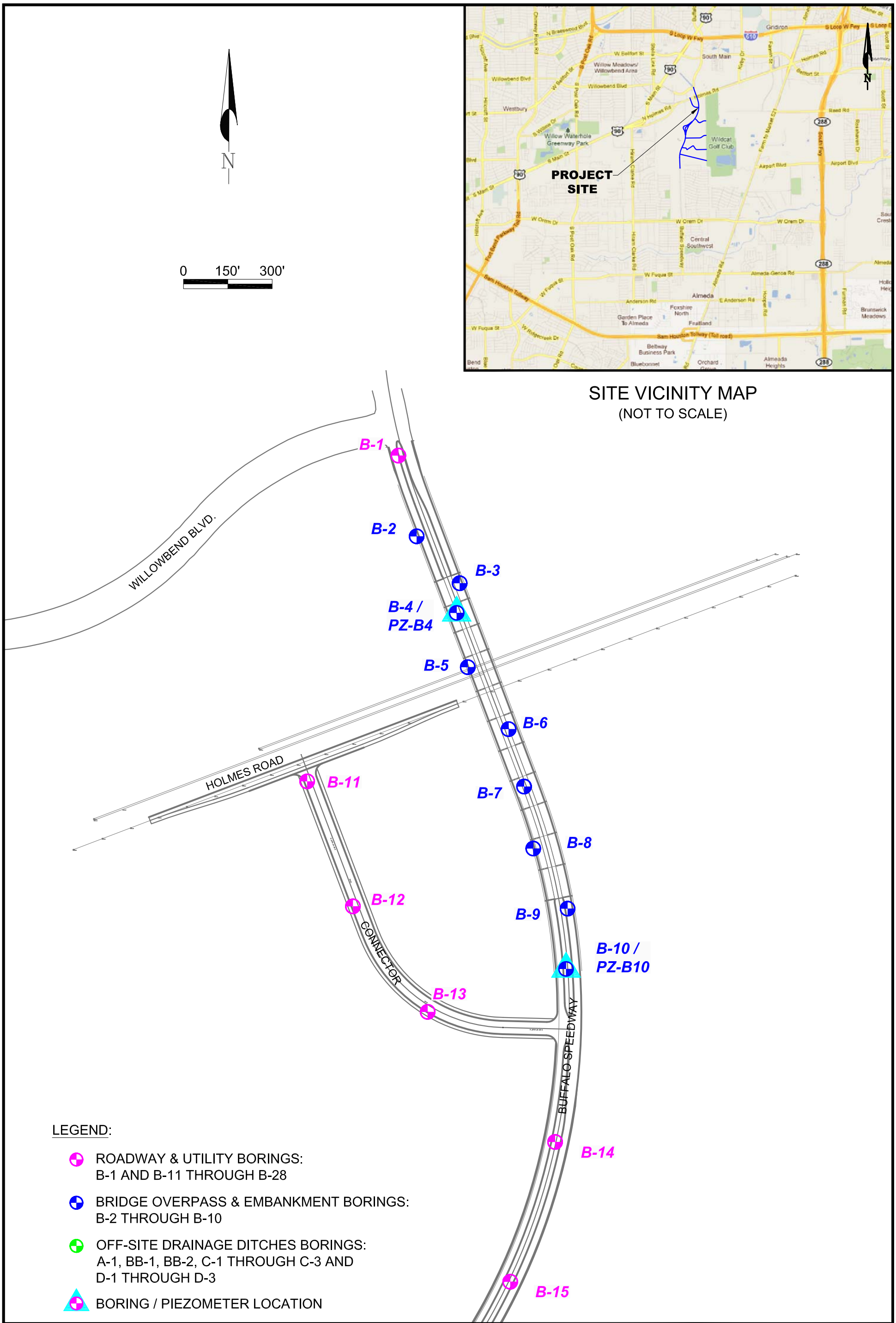
Surveillance of the utility lines, box culverts, bridge, traffic signal pole, MSE retaining wall, off-site drainage ditches, outfall structures, pavement subgrade preparation, and pavement construction is recommended, and has been assumed in preparing our recommendations. This field service is required to check for changed conditions that may result in modifications to our recommendations. The quality of the construction practices will affect foundation performance and should be monitored.

## 19.4 Closing Remarks

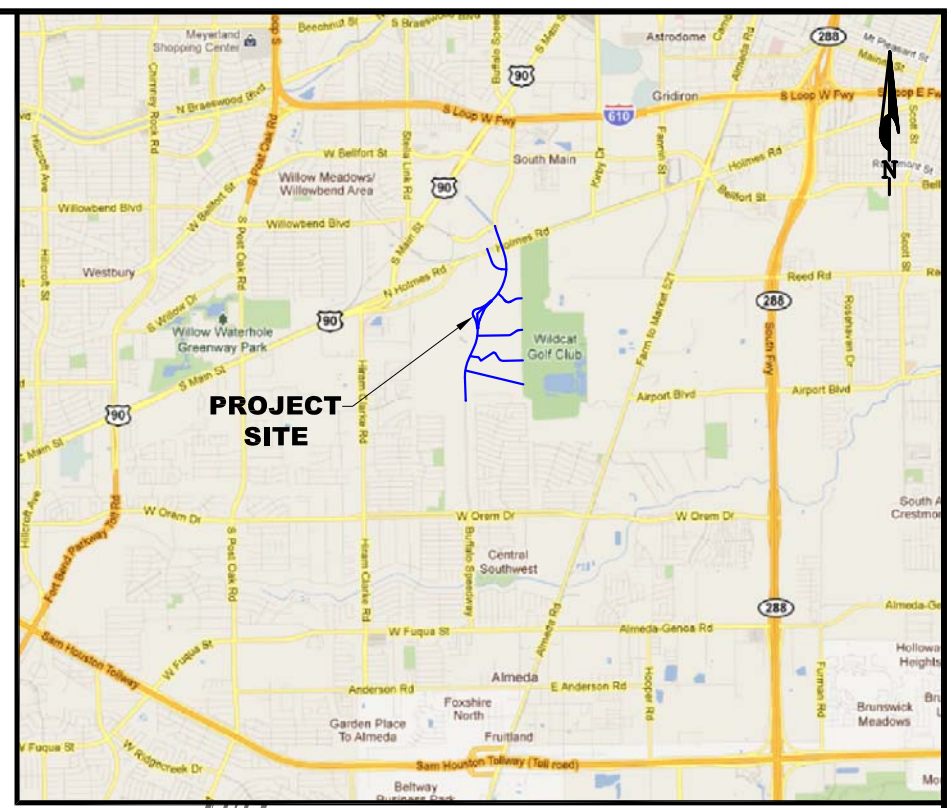
We appreciate the opportunity to be of service during planning of this project and look forward to continuing our services during the construction phase and on future projects.

# FIGURES

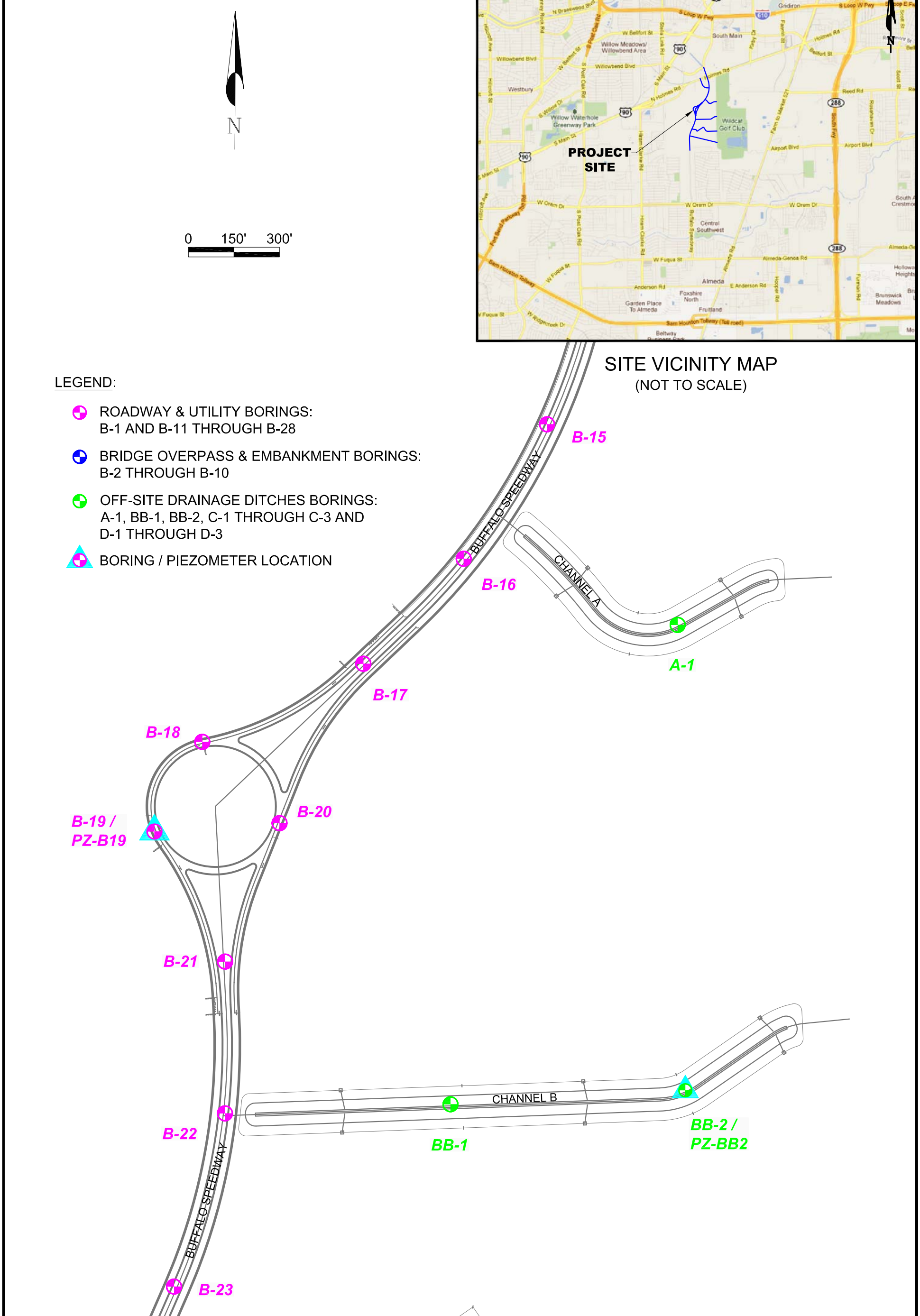
SITE VICINITY MAP
(NOT TO SCALE)



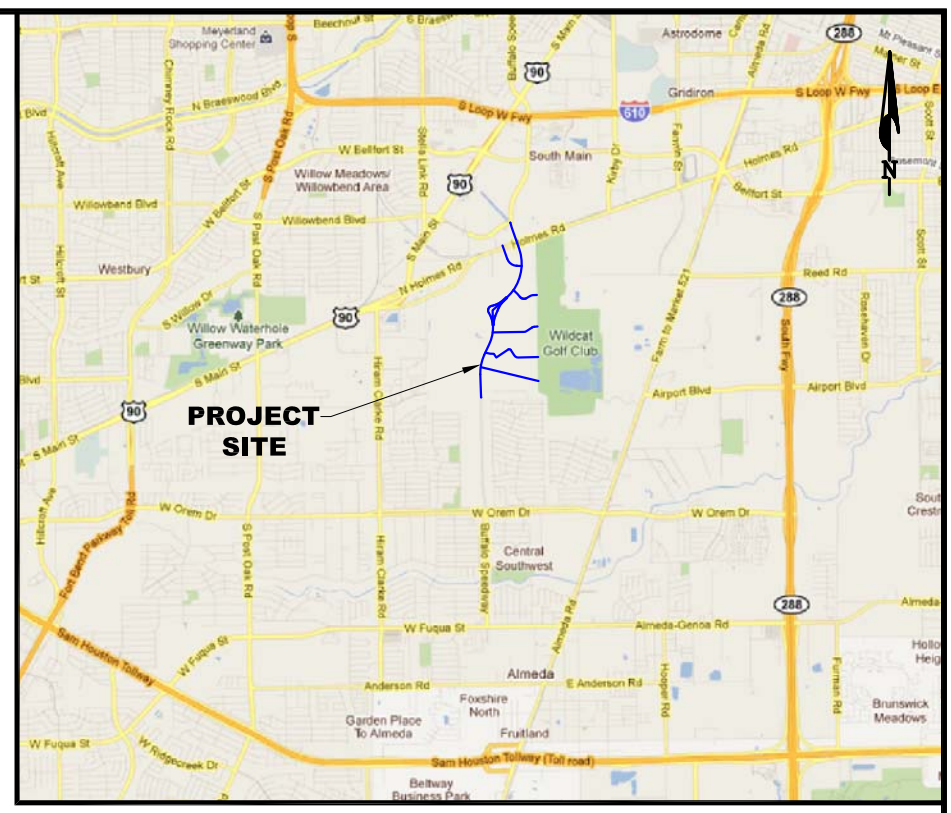

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>PAVEMENT, UTILITIES, BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | PLAN OF BORINGS |
| CLR, INC.<br>WALLER, TEXAS | | PROJECT NO.: 11.13.180 / FIGURE 1 |



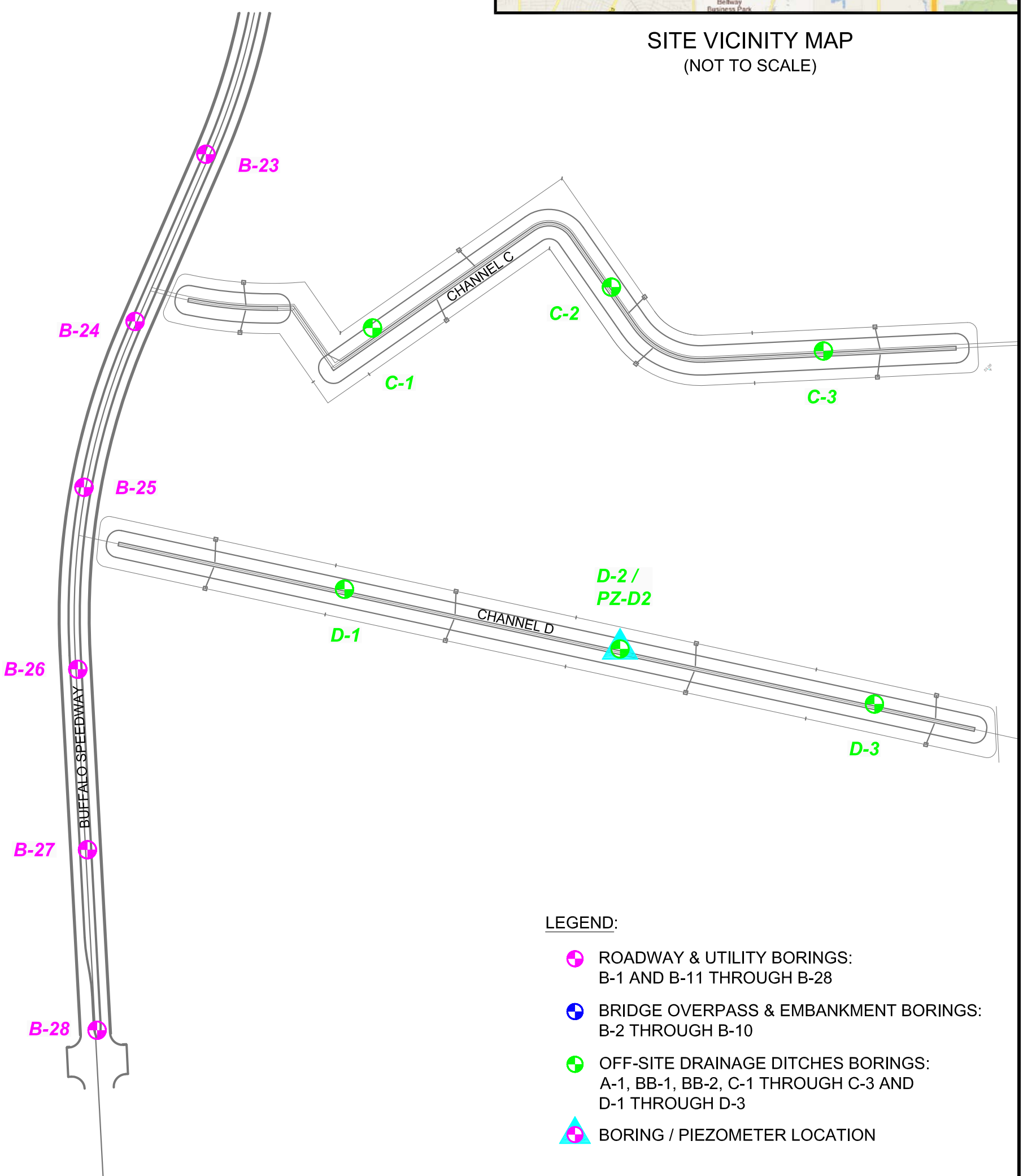

SITE VICINITY MAP
(NOT TO SCALE)




| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>PAVEMENT, UTILITIES, BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | PLAN OF BORINGS |
| CLR, INC.<br>WALLER, TEXAS | | PROJECT NO.: 11.13.180 / FIGURE 2 |




SITE VICINITY MAP
(NOT TO SCALE)

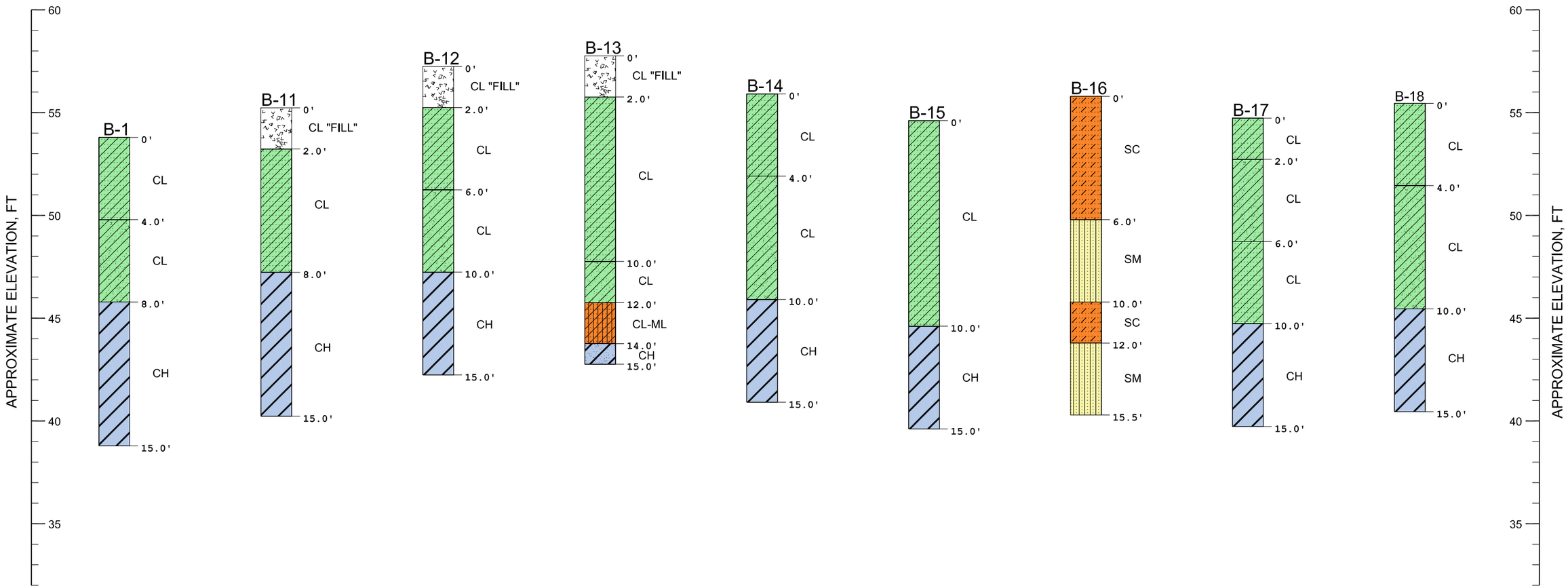



LEGEND:

- ROADWAY & UTILITY BORINGS: B-1 AND B-11 THROUGH B-28
- BRIDGE OVERPASS & EMBANKMENT BORINGS: B-2 THROUGH B-10
- OFF-SITE DRAINAGE DITCHES BORINGS: A-1, BB-1, BB-2, C-1 THROUGH C-3 AND D-1 THROUGH D-3
- BORING / PIEZOMETER LOCATION

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>PAVEMENT, UTILITIES, BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | PLAN OF BORINGS |
| CLR, INC.<br>WALLER, TEXAS | | PROJECT NO.: 11.13.180 / FIGURE 3 |

# BORING LOG PROFILE




**LEGEND**

| | | | |
|---|---|---|---|
| Lean Clay (CL) | Fill | Clayey Sand (SC) | Silty Sand (SM) |
| Sandy Lean Clay (CL) | Fat Clay (CH) | Silty Clay (CL-ML) | Silt w/ Sand (ML) |
| Lean Clay w/ Sand (CL) | Fat Clay w/ Sand (CH) | Sandy Silty Clay (CL-ML) | |

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS & OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

COBOURN LINSEISEN RATCLIFF, INC.
HOUSTON, TEXAS

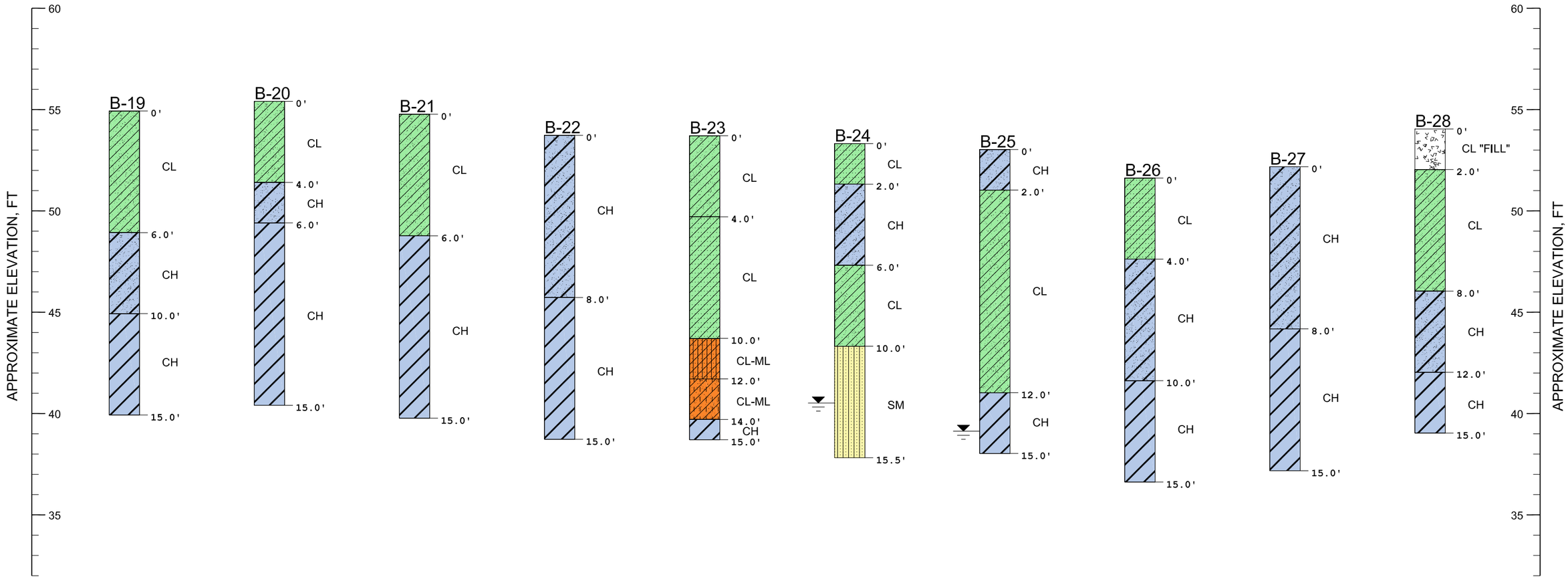
**Tolunay-Wong Engineers, Inc.**
Houston, Texas

SUBSURFACE PROFILE

PROJECT NO.: 11.13.180

FIGURE 4

# BORING LOG PROFILE




**LEGEND**

- Lean Clay (CL)
- Sandy Lean Clay (CL)
- Lean Clay w/ Sand (CL)
- Fill
- Fat Clay (CH)
- Fat Clay w/ Sand (CH)
- Clayey Sand (SC)
- Silty Clay (CL-ML)
- Sandy Silty Clay (CL-ML)
- Silty Sand (SM)
- Silt w/ Sand (ML)

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS & OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

COBOURN LINSEISEN RATCLIFF, INC.
HOUSTON, TEXAS

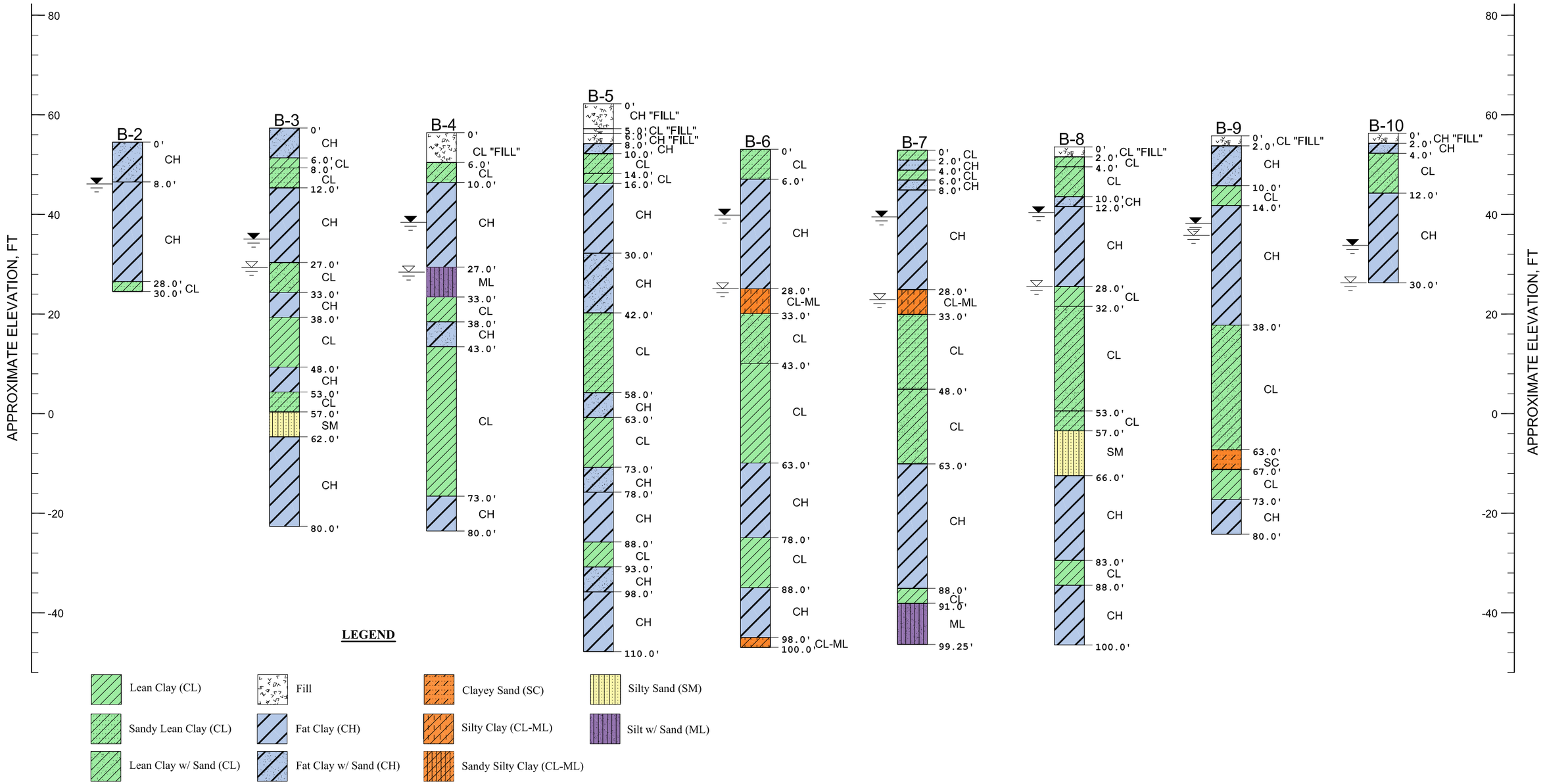
**Tolunay-Wong Engineers, Inc.**
Houston, Texas

SUBSURFACE PROFILE

PROJECT NO.: 11.13.180

FIGURE 5

# BORING LOG PROFILE




BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS & OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

COBOURN LINSEISEN RATCLIFF, INC.
HOUSTON, TEXAS

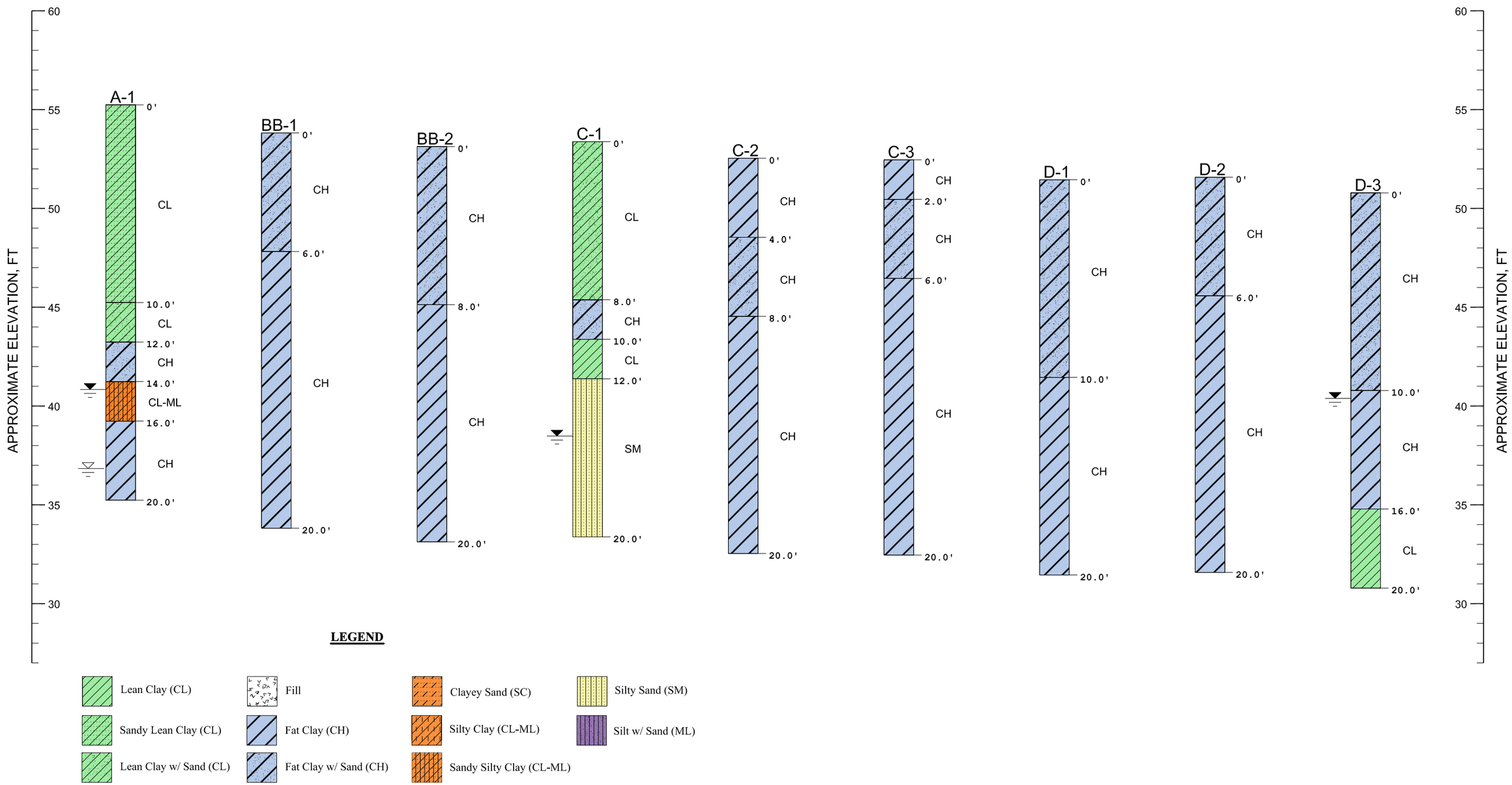
**Tolunay-Wong Engineers, Inc.**
Houston, Texas

SUBSURFACE PROFILE

PROJECT NO.: 11.13.180

FIGURE 6

# BORING LOG PROFILE




| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS & OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | **Tolunay-Wong Engineers, Inc.**<br>Houston, Texas | SUBSURFACE PROFILE |
| COBOURN LINSEISEN RATCLIFF, INC.<br>HOUSTON, TEXAS | | PROJECT NO.: 11.13.180 / FIGURE 7 |

## PIEZOMETER COMPLETION

**Date:** 09/16/11

**Dry Augered:** 0.0 ft to 30.0 ft

**Wash Bored:** 30.0 ft to 80.0 ft

**Drilling Fluid:** None

## PIEZOMETER DEVELOPMENT

**Date:** N/A

**Method:** N/A

## WATER LEVEL READINGS

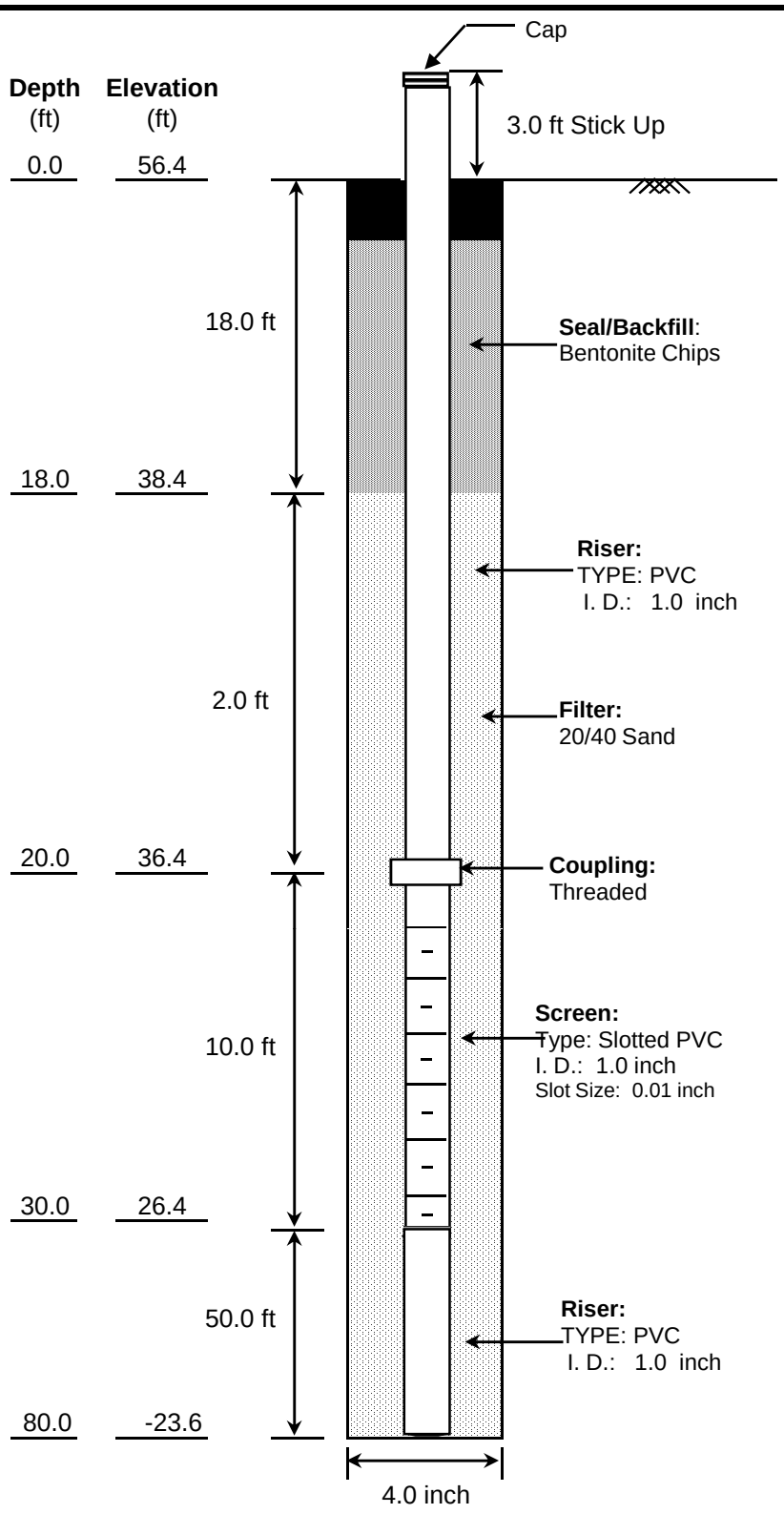
**Free Water at:** 28.0 ft

| Date | Depth, ft* | Elevation, ft |
|---|---|---|
| 09/23/11 | 14.90 | 41.53 |
| 10/21/11 | 14.80 | 41.63 |
| 11/28/11 | 15.30 | 41.13 |

*Depths are measured below existing grade

## REMARKS

1. Boring B-4 was converted into piezometer PZ-B4 upon completion of drilling.




**Project:**
Buffalo Speedway Extension
From W. Airport Blvd to Willowbend Blvd
Houston, Texas

**Tolunay-Wong Engineers, Inc.**
Houston, Texas

**Project Number:**
**11.13.180**

**Client:**
CLR, Inc.
Waller, Texas

**Piezometer Report:**
**PZ-B4**

**Figure 8**

## PIEZOMETER COMPLETION

**Date:** 09/22/11

**Dry Augered:** 0.0 ft to 30.0 ft

**Wash Bored:**

**Drilling Fluid:** None

## PIEZOMETER DEVELOPMENT

**Date:** N/A

**Method:** N/A

## WATER LEVEL READINGS

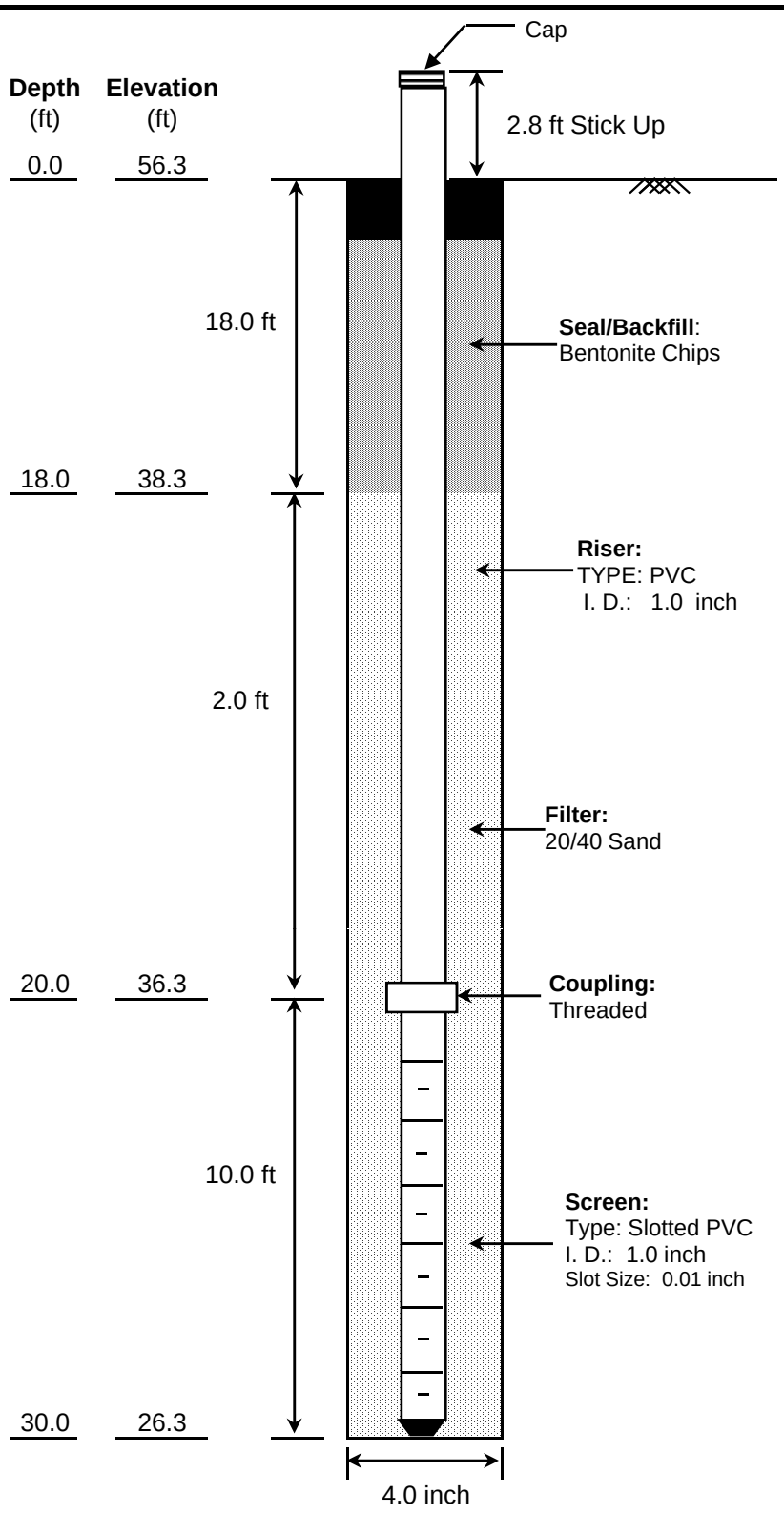
**Free Water at:** 30.0 ft

| Date | Depth, ft* | Elevation, ft |
|---|---|---|
| 09/23/11 | 13.70 | 42.57 |
| 10/21/11 | Damaged | |

*Depths are measured below existing grade

## REMARKS

1. Boring B-10 was converted into piezometer PZ-B10 upon completion of drilling.
2. Borehole was found to be damaged on 10/21/2011.




| | | |
|---|---|---|
| **Project:** Buffalo Speedway Extension From W. Airport Blvd to Willowbend Blvd Houston, Texas | Tolunay-Wong Engineers, Inc. Houston, Texas | **Project Number:** 11.13.180 |
| **Client:** CLR, Inc. Waller, Texas | **Piezometer Report:** PZ-B10 | **Figure 9** |

## PIEZOMETER COMPLETION

**Date:** 09/21/11

**Dry Augered:** 0.0 ft to 17.0 ft

**Wash Bored:**

**Drilling Fluid:** None

## PIEZOMETER DEVELOPMENT

**Date:** N/A

**Method:** N/A

## WATER LEVEL READINGS

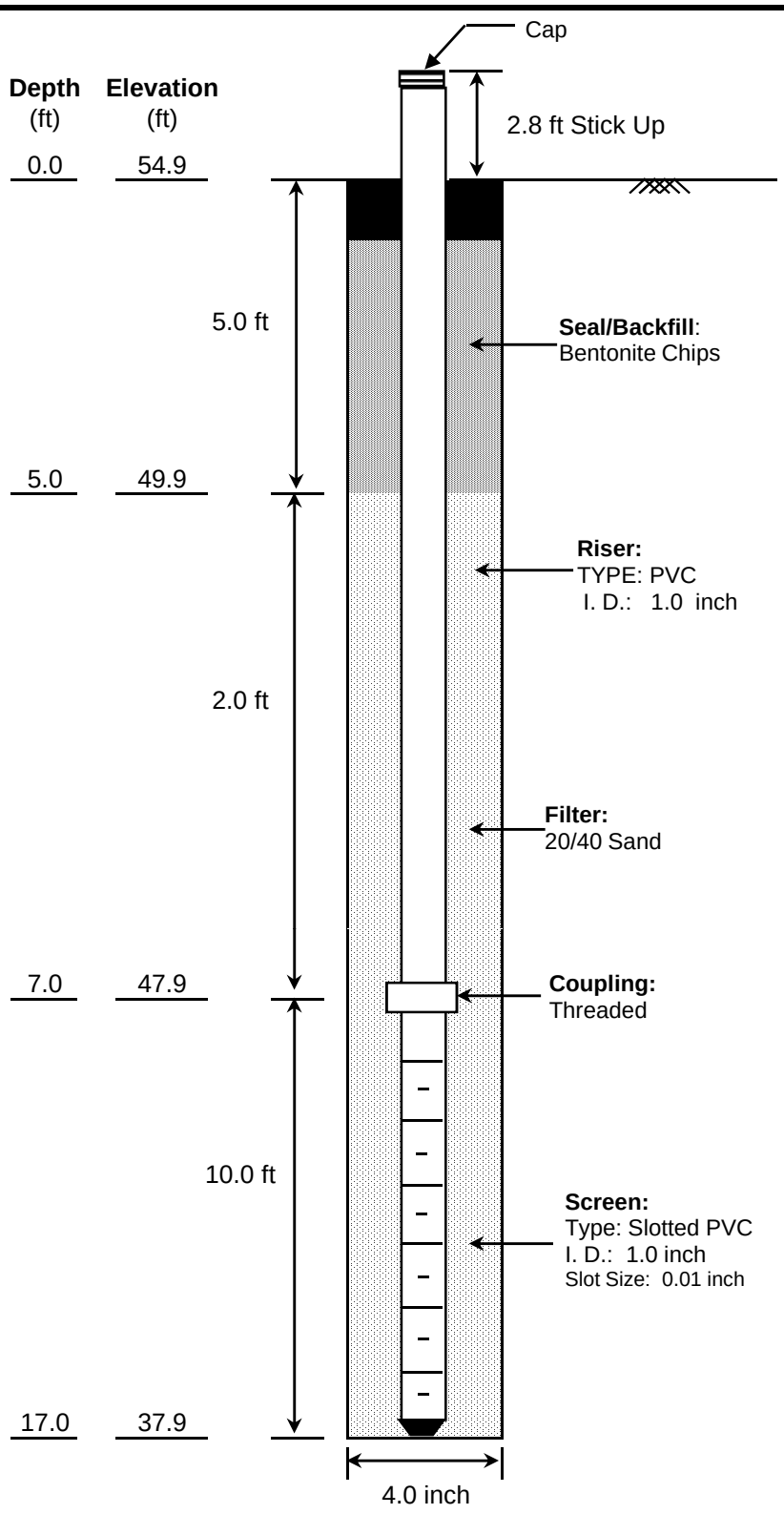
**Free Water at:** 0.0 ft

| Date | Depth, ft* | Elevation, ft |
|---|---|---|
| 09/23/11 | Dry | |
| 10/21/11 | 16.85 | 38.05 |
| 11/28/11 | 15.70 | 39.20 |

*Depths are measured below existing grade

## REMARKS

1. Boring B-19 was converted into piezometer PZ-B19 upon completion of drilling.




**Project:**
Buffalo Speedway Extension
From W. Airport Blvd to Willowbend Blvd
Houston, Texas

**Tolunay-Wong Engineers, Inc.**
Houston, Texas

**Project Number:**
**11.13.180**

**Client:**
CLR, Inc.
Waller, Texas

**Piezometer Report:**
**PZ-B19**

**Figure 10**

## PIEZOMETER COMPLETION

**Date:** 09/20/11

**Dry Augered:** 0.0 ft to 22.0 ft

**Wash Bored:**

**Drilling Fluid:** None

## PIEZOMETER DEVELOPMENT

**Date:** N/A

**Method:** N/A

## WATER LEVEL READINGS

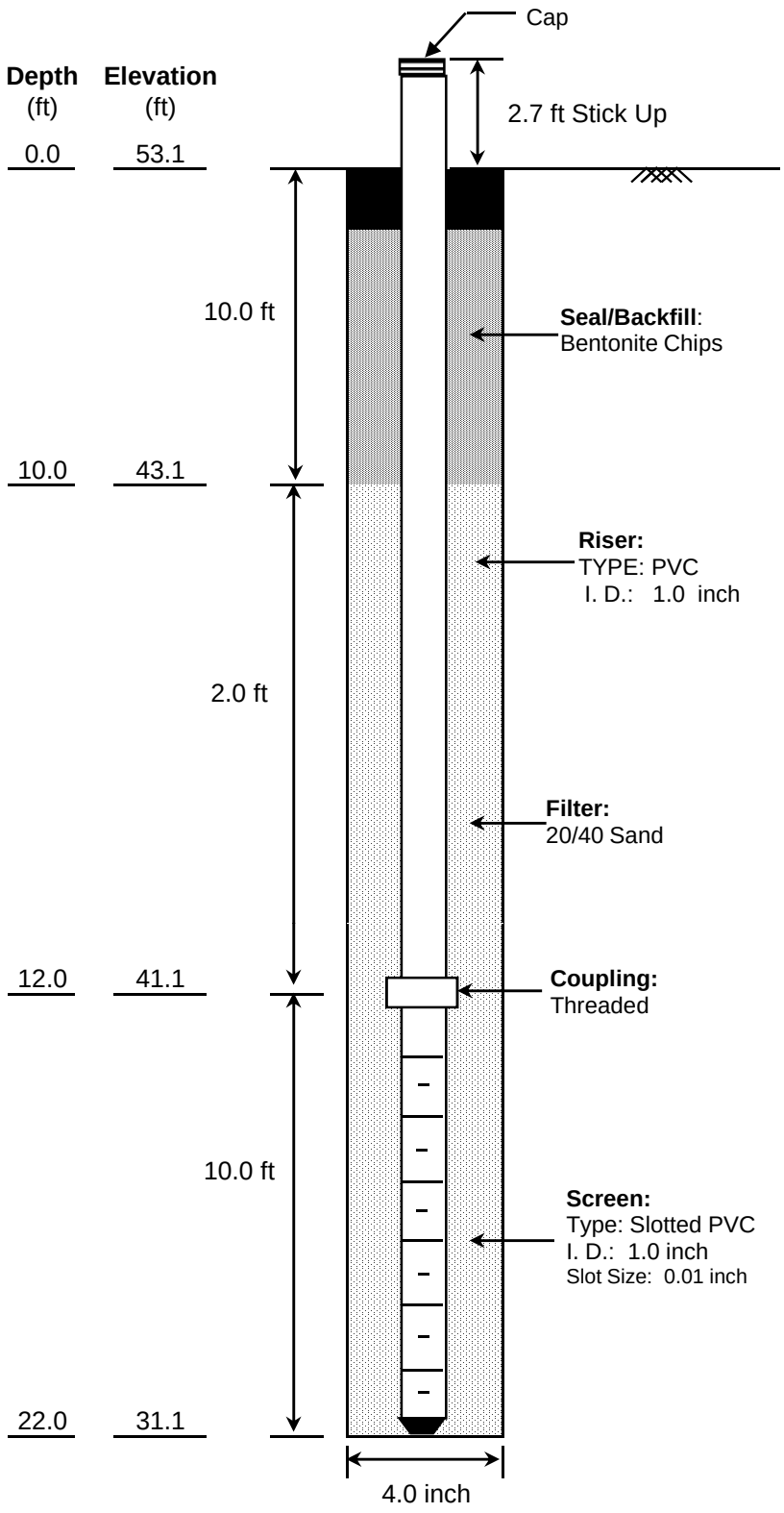
**Free Water at:** Dry

| Date | Depth, ft* | Elevation, ft |
|---|---|---|
| 09/23/11 | Dry | |
| 10/21/11 | 20.80 | 32.33 |
| 11/28/11 | 19.90 | 33.23 |

*Depths are measured below existing grade

## REMARKS

1. Boring BB-2 was converted into piezometer PZ-BB2 upon completion of drilling.




**Project:**
Buffalo Speedway Extension
From W. Airport Blvd to Willowbend Blvd
Houston, Texas

**Tolunay-Wong Engineers, Inc.**
Houston, Texas

**Project Number:**
**11.13.180**

**Client:**
CLR, Inc.
Waller, Texas

**Piezometer Report:**
**PZ-BB2**

**Figure 11**

## PIEZOMETER COMPLETION

**Date:** 09/20/11

**Dry Augered:** 0.0 ft to 22.0 ft

**Wash Bored:**

**Drilling Fluid:** None

## PIEZOMETER DEVELOPMENT

**Date:** N/A

**Method:** N/A

## WATER LEVEL READINGS

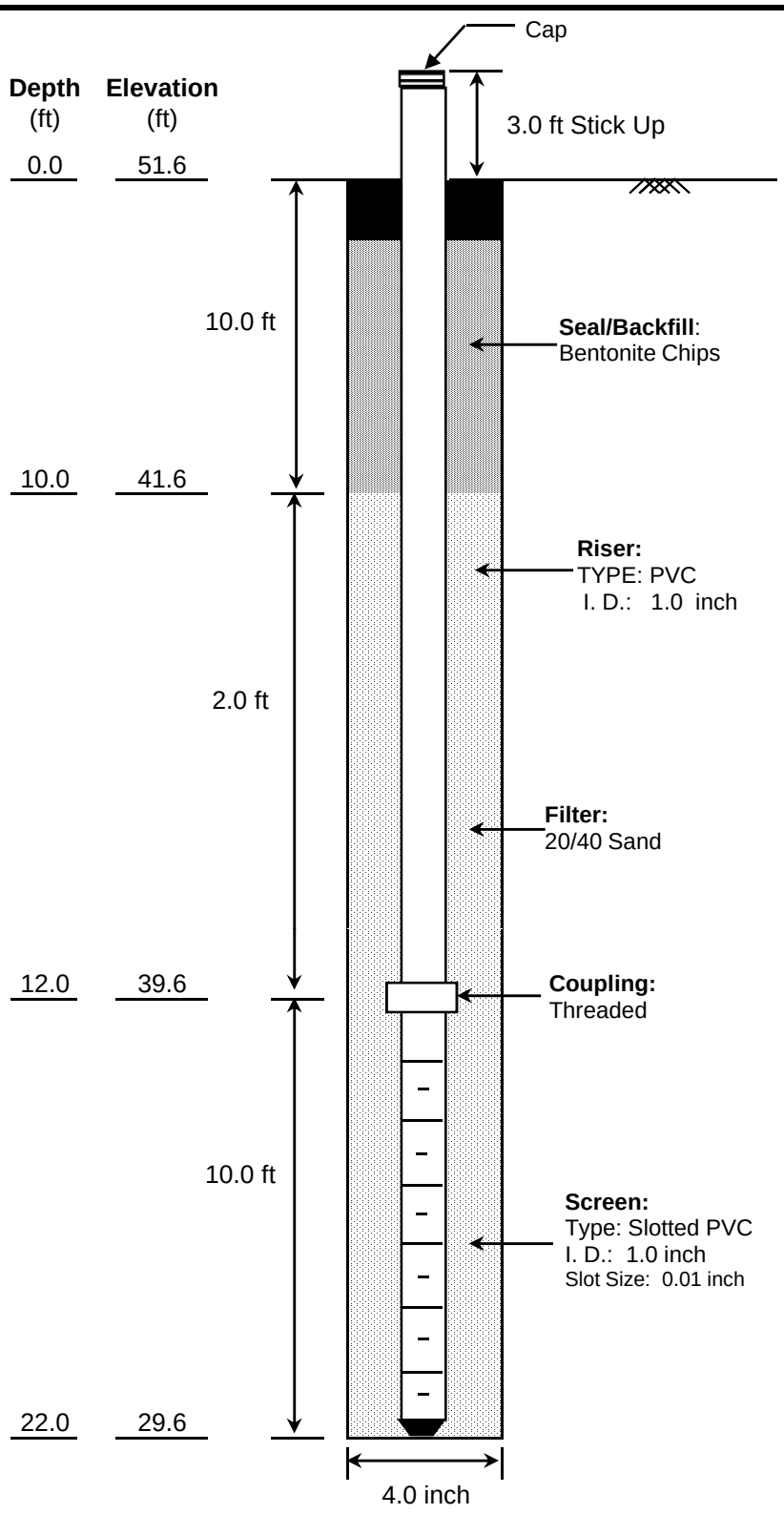
**Free Water at:** Dry

| Date | Depth, ft* | Elevation, ft |
|---|---|---|
| 09/23/11 | 11.75 | 39.83 |
| 10/21/11 | 11.10 | 40.48 |
| 11/28/11 | 12.10 | 39.48 |

*Depths are measured below existing grade

## REMARKS

1. Boring D-2 was converted into piezometer PZ-D2 upon completion of drilling.




**Project:**
Buffalo Speedway Extension
From W. Airport Blvd to Willowbend Blvd
Houston, Texas

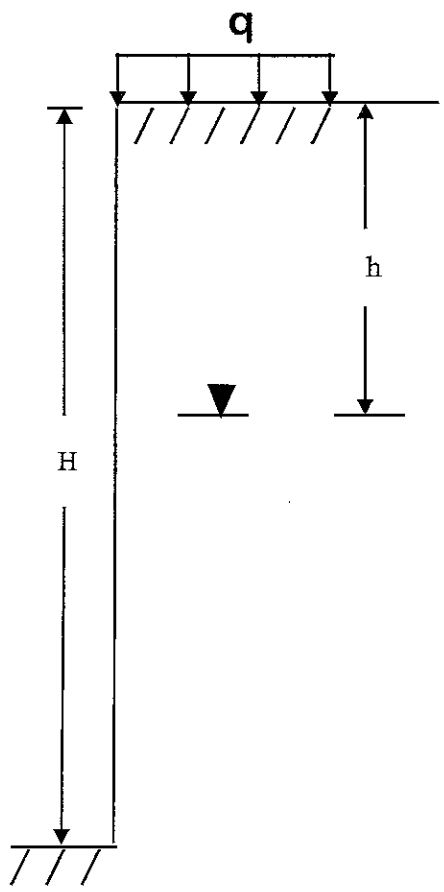
**Tolunay-Wong Engineers, Inc.**
Houston, Texas

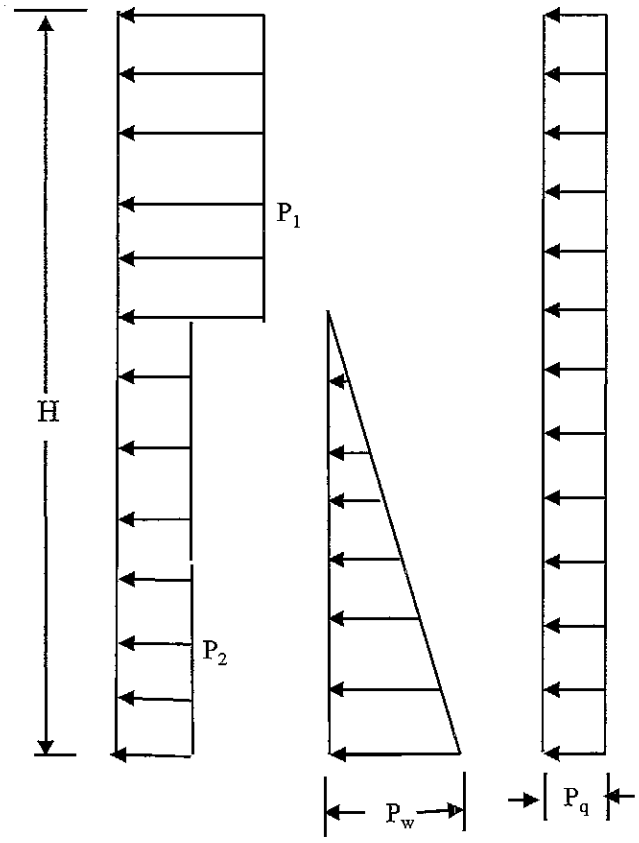
**Project Number:**
**11.13.180**

**Client:**
CLR, Inc.
Waller, Texas

**Piezometer Report:**
**PZ-D2**

**Figure 12**




**BRACED WALL**

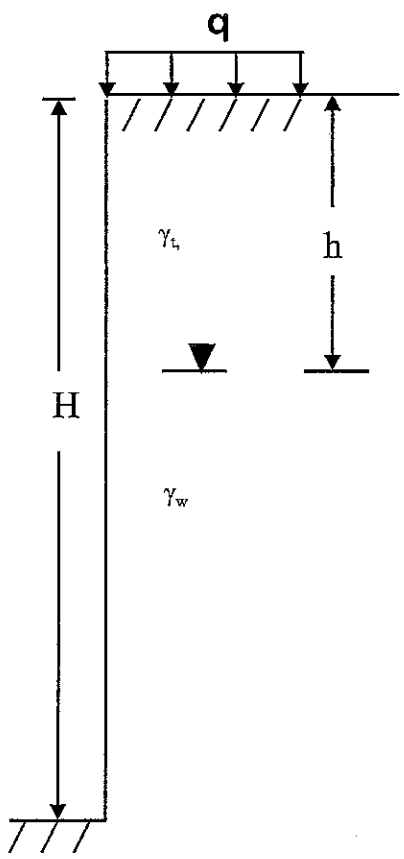
**TYPICAL SOIL PARAMETERS**

$\gamma_t$ = Total Unit Weight
$\gamma_t = 125$ pcf
$\gamma_w = 62.4$ pcf

$P_1 = 0.65\,\gamma_t H$
$P_2 = 0.65\,(\gamma_t - \gamma_w)\,H$
$P_w = \gamma_w\,(H-h)$
$P_q = 0.5q$

If water table below excavation depth , use $P_1$.
If water table at surface, use $P_2$.
Otherwise use $P_1$ & $P_2$ according to water table.

| | | |
|---|---|---|
| Buffalo Speedway Extension<br>From W. Airport Blvd. To Willowbend Blvd., Houston, Texas | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | Project No.: 11.13.180 |
| Client: CLR, Inc.<br>Waller, Texas | Lateral Earth Pressure Diagrams<br>(Cohesionless and Cohesive Intermixed Layers of Soil) | FIGURE 13 |

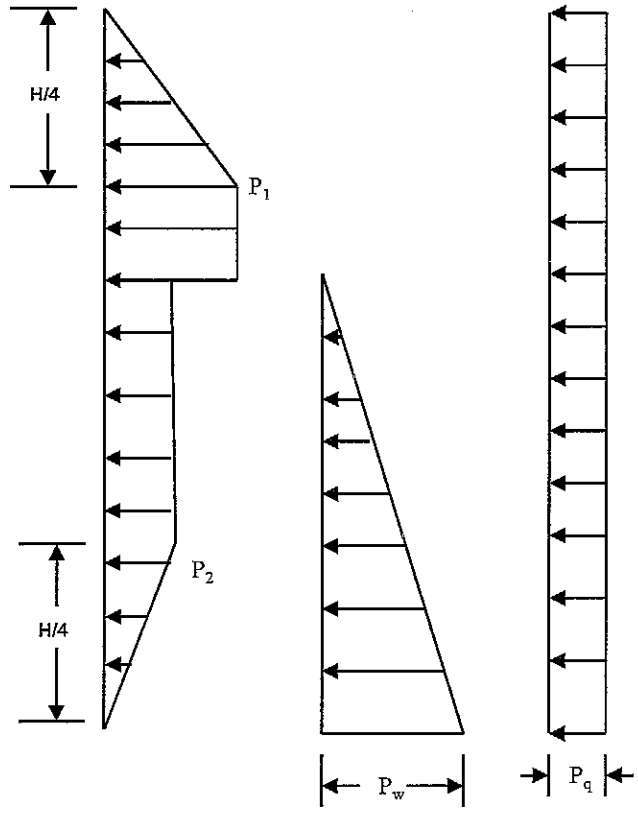



**TYPICAL SOIL PARAMETERS**

$\gamma t$ = TOTAL UNIT WEIGHT

$\gamma_t = 125$ pcf

$\gamma_w = 62.4$ pcf




**BRACED WALL**

$P_1 = 0.4\,\gamma_t H$

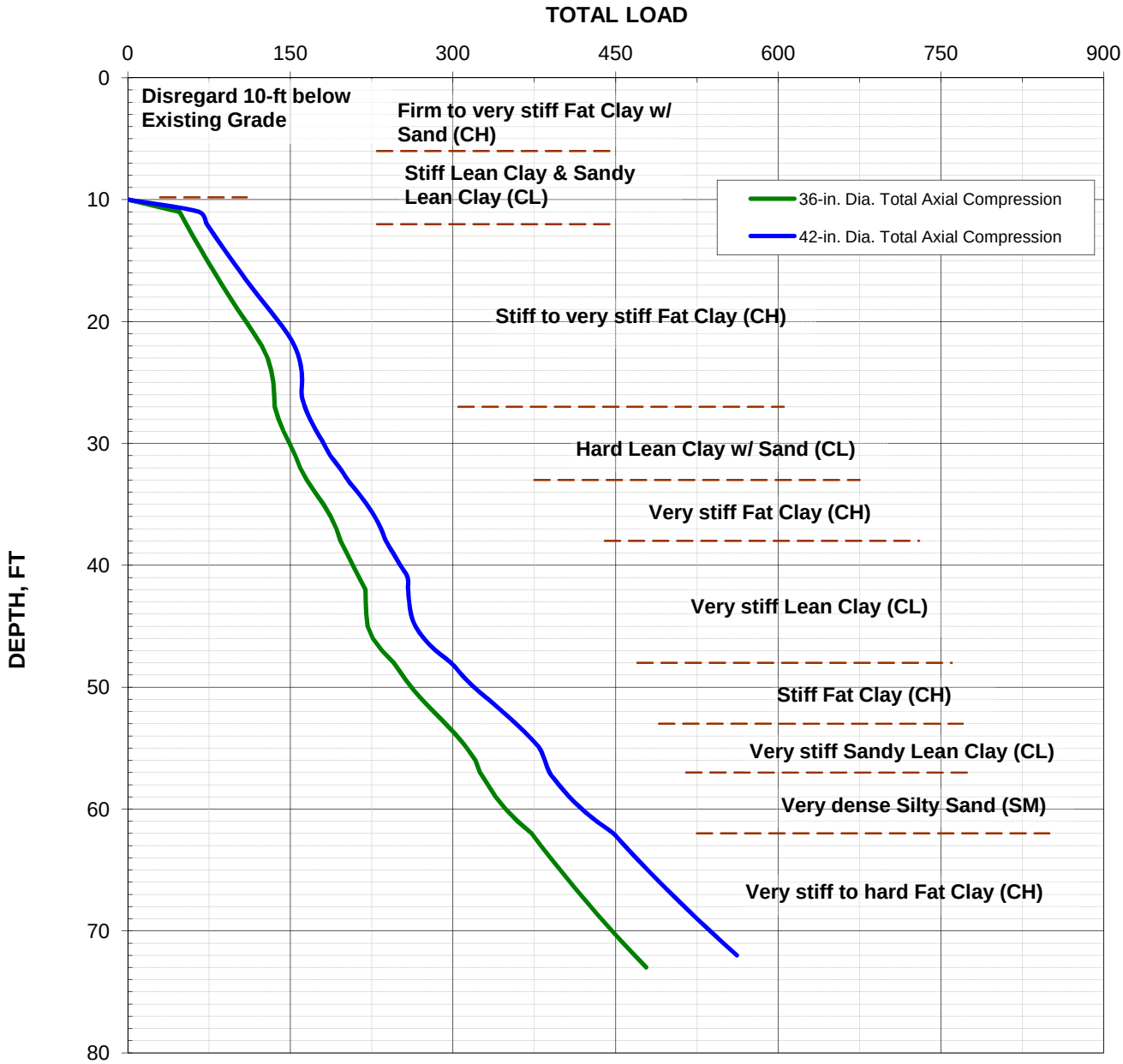
$P_2 = 0.4\,(\gamma_t - \gamma_w)\,H$

$P_w = \gamma_w (H-h)$

$P_q = 0.5q$

If water table below excavation depth use $P_1$.
If water table at surface use $P_2$.
Otherwise use $P_1$ & $P_2$ according to water table.

| | | |
|---|---|---|
| Buffalo Speedway Extension<br>From W. Airport Blvd. to Willowbend Blvd., Houston, Texas | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | Project No.: 11.13.180 |
| Client: CLR, Inc.<br>Waller, Texas | Lateral Earth Pressure Diagrams<br>Cohesive Soil | FIGURE 14 |

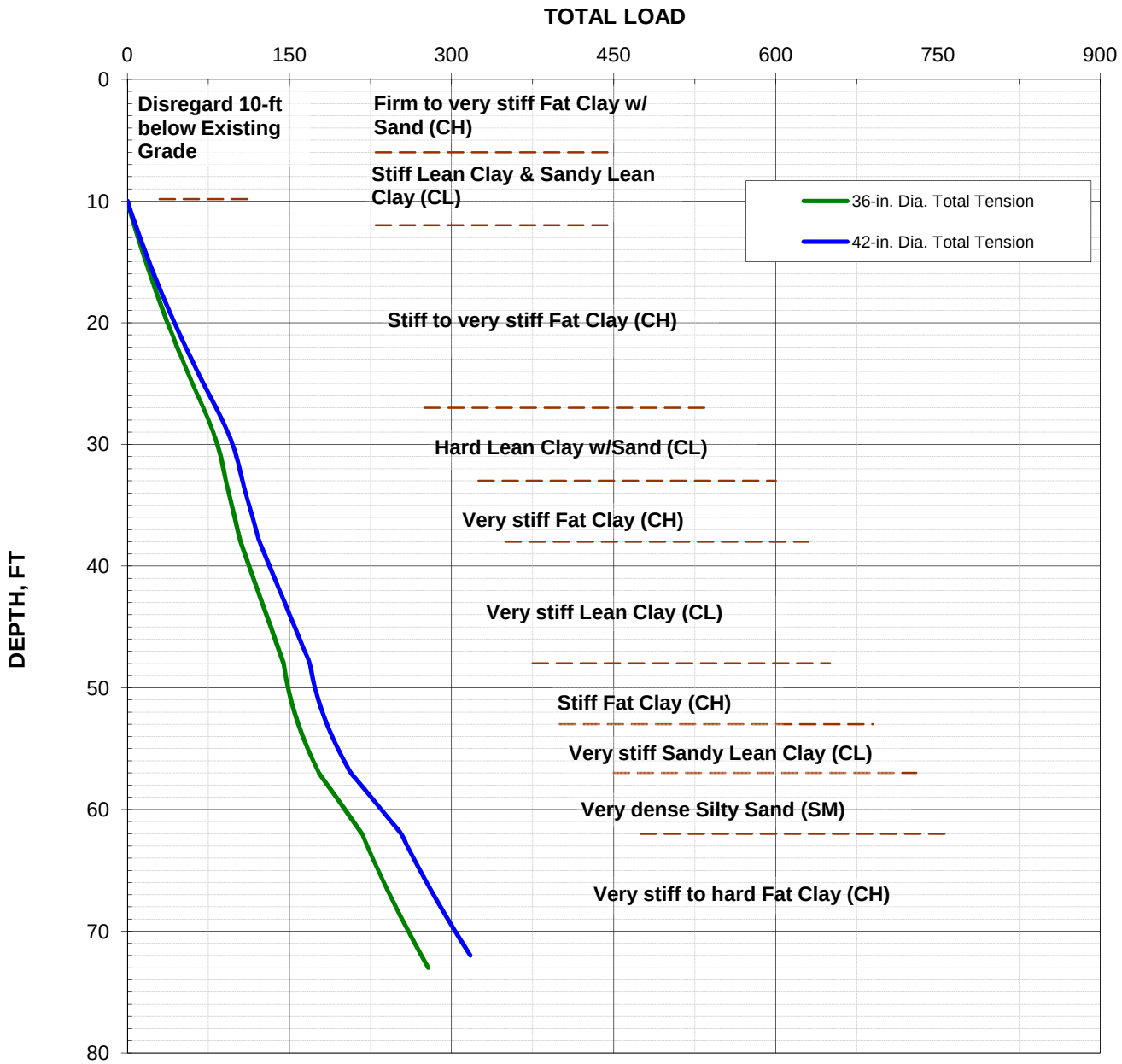



**Soil Profile Boring B-3**

## NOTES

**1.0** Allowable axial compression loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 10-ft was neglected.
**4.0** Allowable axial compression dead load plus sustained live load shown in this figure takes into account factors of safety (F.S) of 2.0 for shaft friction and 3.0 for end bearing.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The difference between soil unit weight and concrete unit weight should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>Houston, Texas | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR, Inc.**<br>**Waller, Texas** | **Allowable Axial Compression Load Drilled Shafts (Boring B-3)** | **FIGURE: 15** |

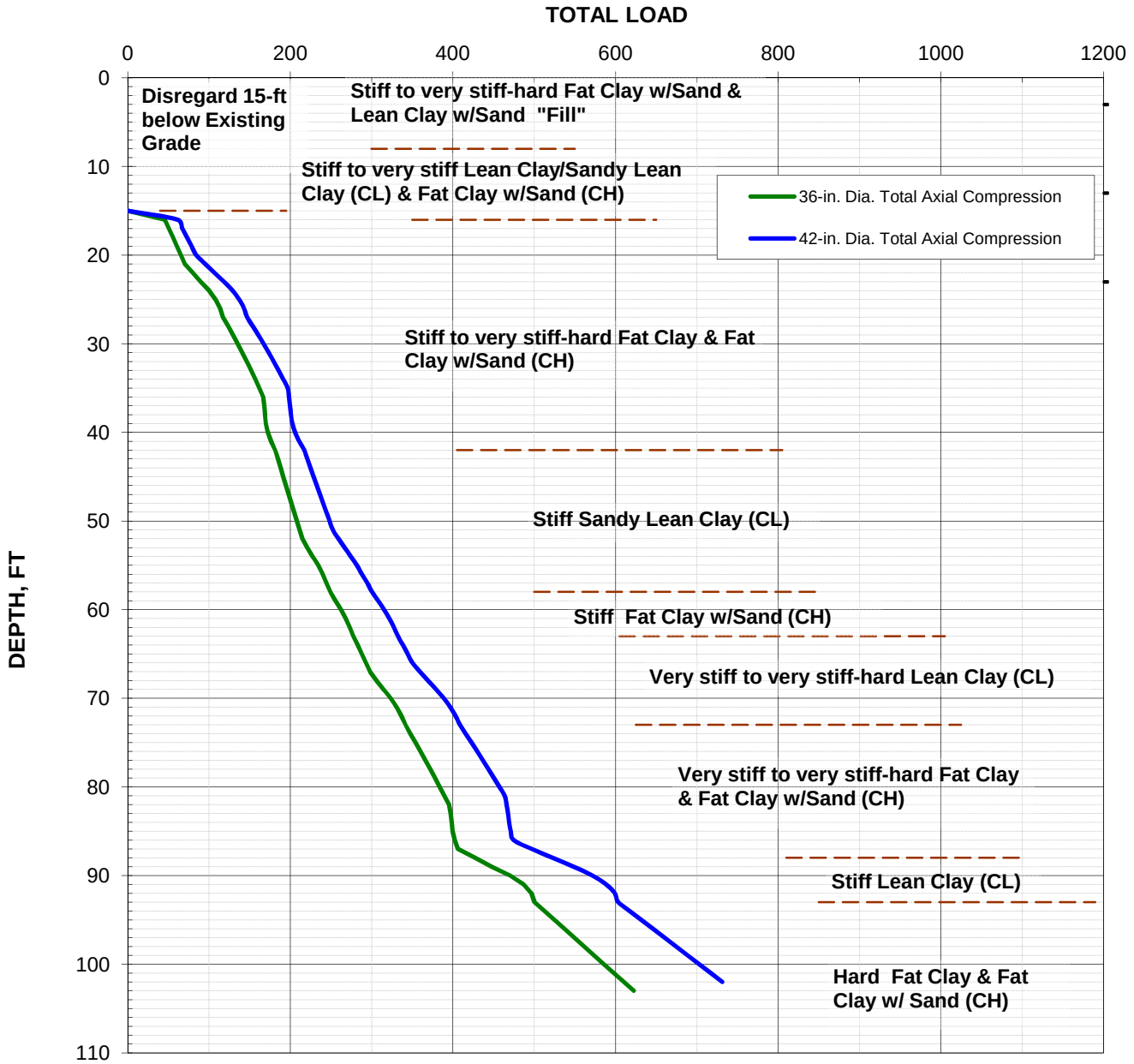



**Soil Profile from Boring B-3**

**NOTES**

**1.0** Allowable axial tension loads shown in this figure are net loads .
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 10-ft was neglected.
**4.0** Allowable axial tension load shown in this figure takes into account a factor of safety (F.S) of 3.0 for shaft friction
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The bouyant weight of the reinforced concrete shaft should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>**Houston, Texas** | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR. Inc.**<br>**Waller, Texas** | **Allowable Axial Tension Load Drilled Shafts Boring B-3** | **FIGURE: 16** |

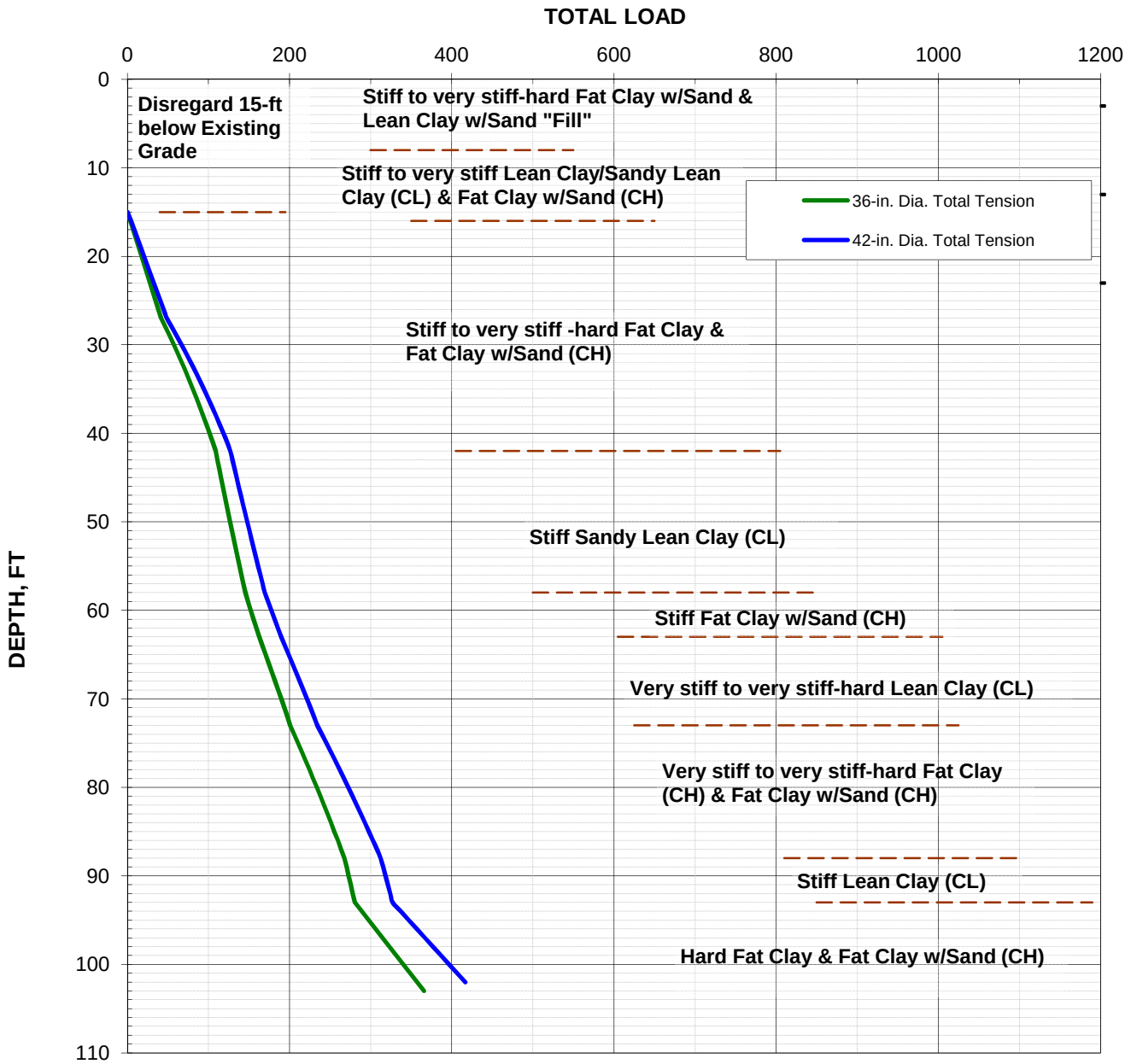



**Soil Profile Boring B-5**

## NOTES

**1.0** Allowable axial compression loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 15-ft was neglected.
**4.0** Allowable axial compression dead load plus sustained live load shown in this figure takes into account factors of safety (F.S) of 2.0 for shaft friction and 3.0 for end bearing.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The difference between soil unit weight and concrete unit weight should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>**Houston, Texas** | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR, Inc.**<br>**Waller, Texas** | **Allowable Axial Compression Load Drilled Shafts (Boring B-5)** | **FIGURE: 17** |

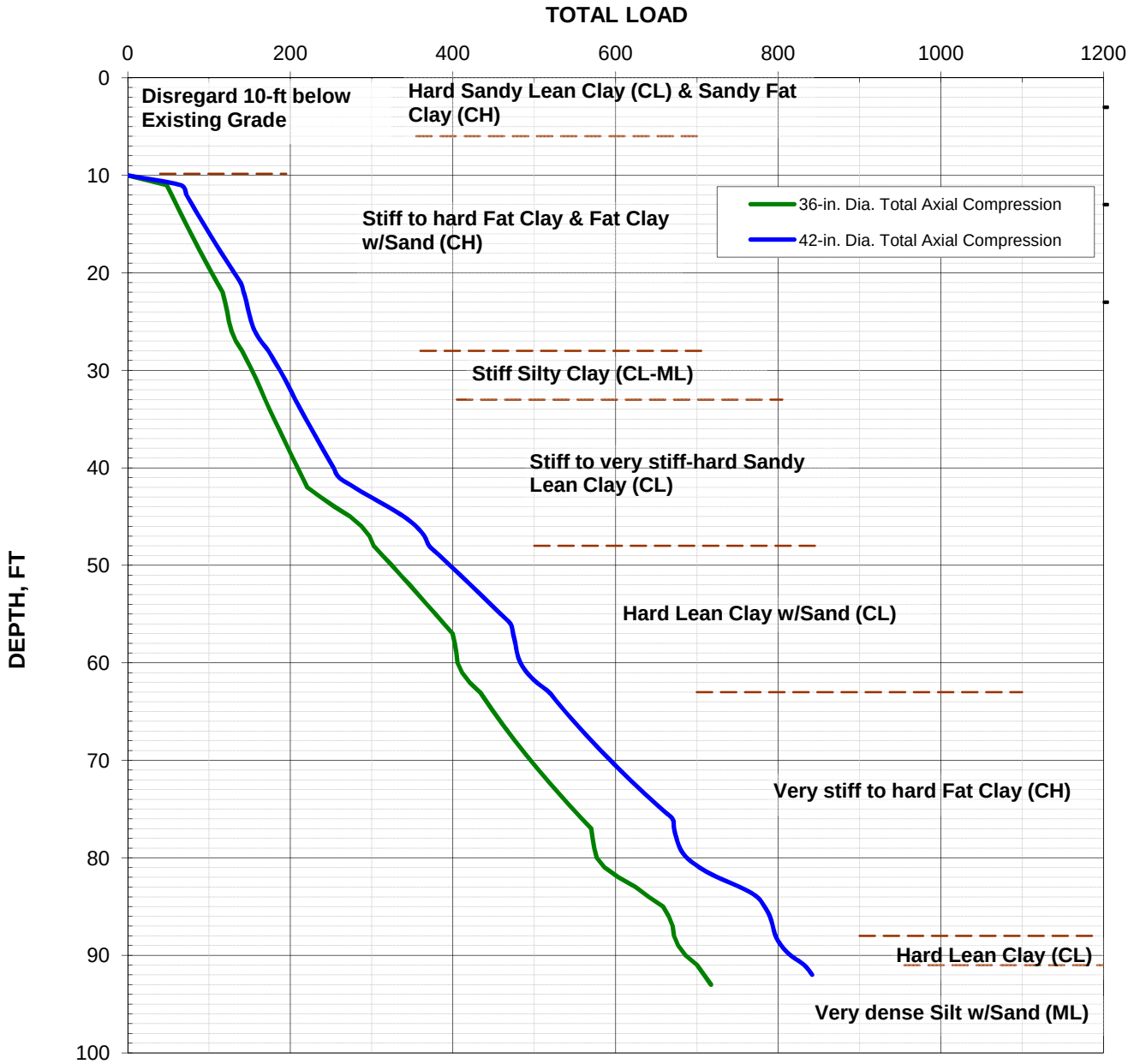



**Soil Profile from Boring B-5**

## NOTES

**1.0** Allowable axial tension loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 15-ft was neglected.
**4.0** Allowable axial tension load shown in this figure takes into account a factor of safety (F.S) of 3.0 for shaft friction.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The bouyant weight of the reinforced concrete shaft should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>**Houston, Texas** | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR. Inc.**<br>**Waller, Texas** | **Allowable Axial Tension Load Drilled Shafts Boring B-5** | **FIGURE: 18** |

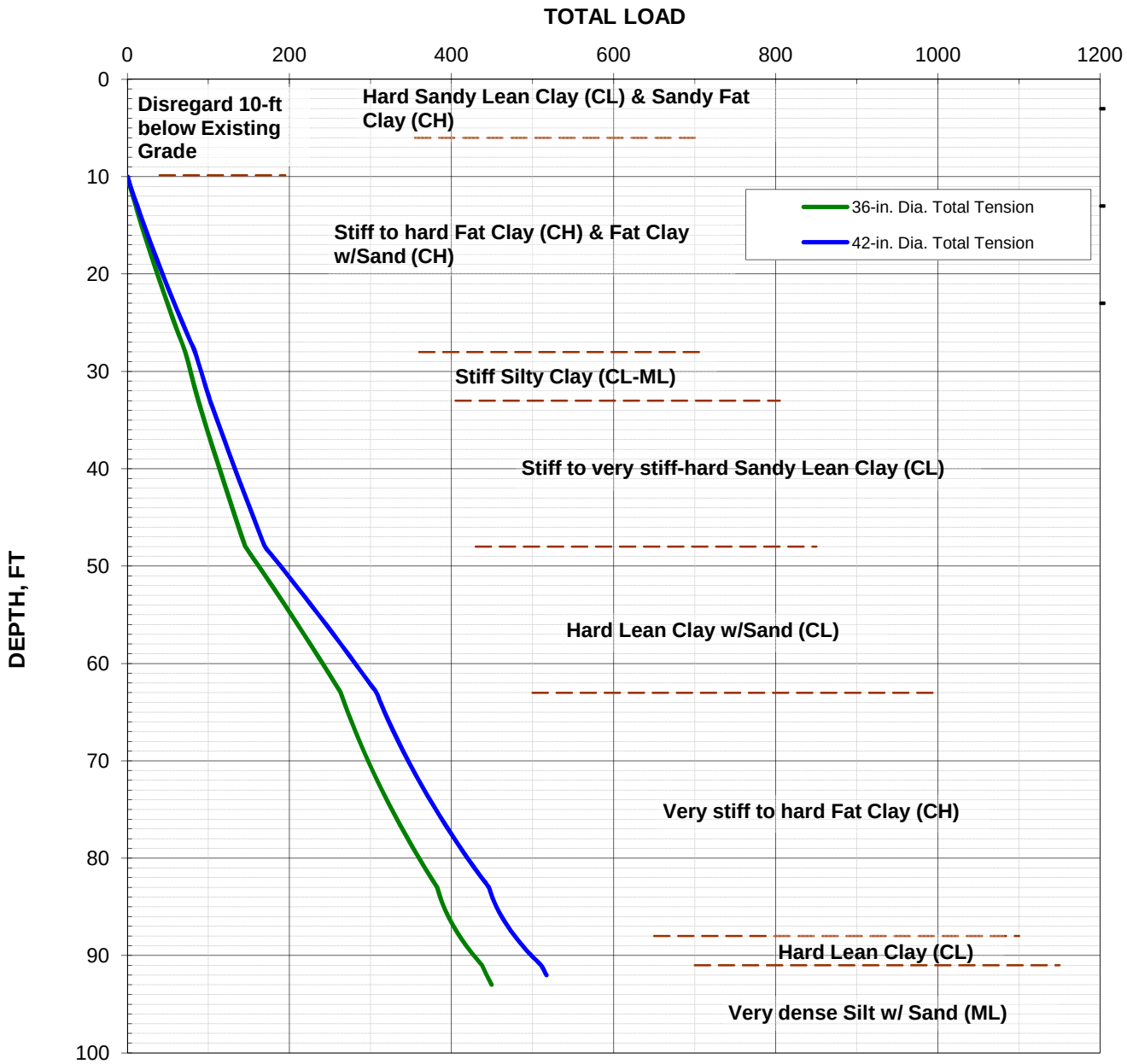



**Soil Profile Boring B-7**

## NOTES

**1.0** Allowable axial compression loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 10-ft was neglected.
**4.0** Allowable axial compression dead load plus sustained live load shown in this figure takes into account factors of safety (F.S) of 2.0 for shaft friction and 3.0 for end bearing.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The difference between soil unit weight and concrete unit weight should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>**Houston, Texas** | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR, Inc.**<br>**Waller, Texas** | **Allowable Axial Compression Load Drilled Shafts (Boring B-7)** | **FIGURE: 19** |

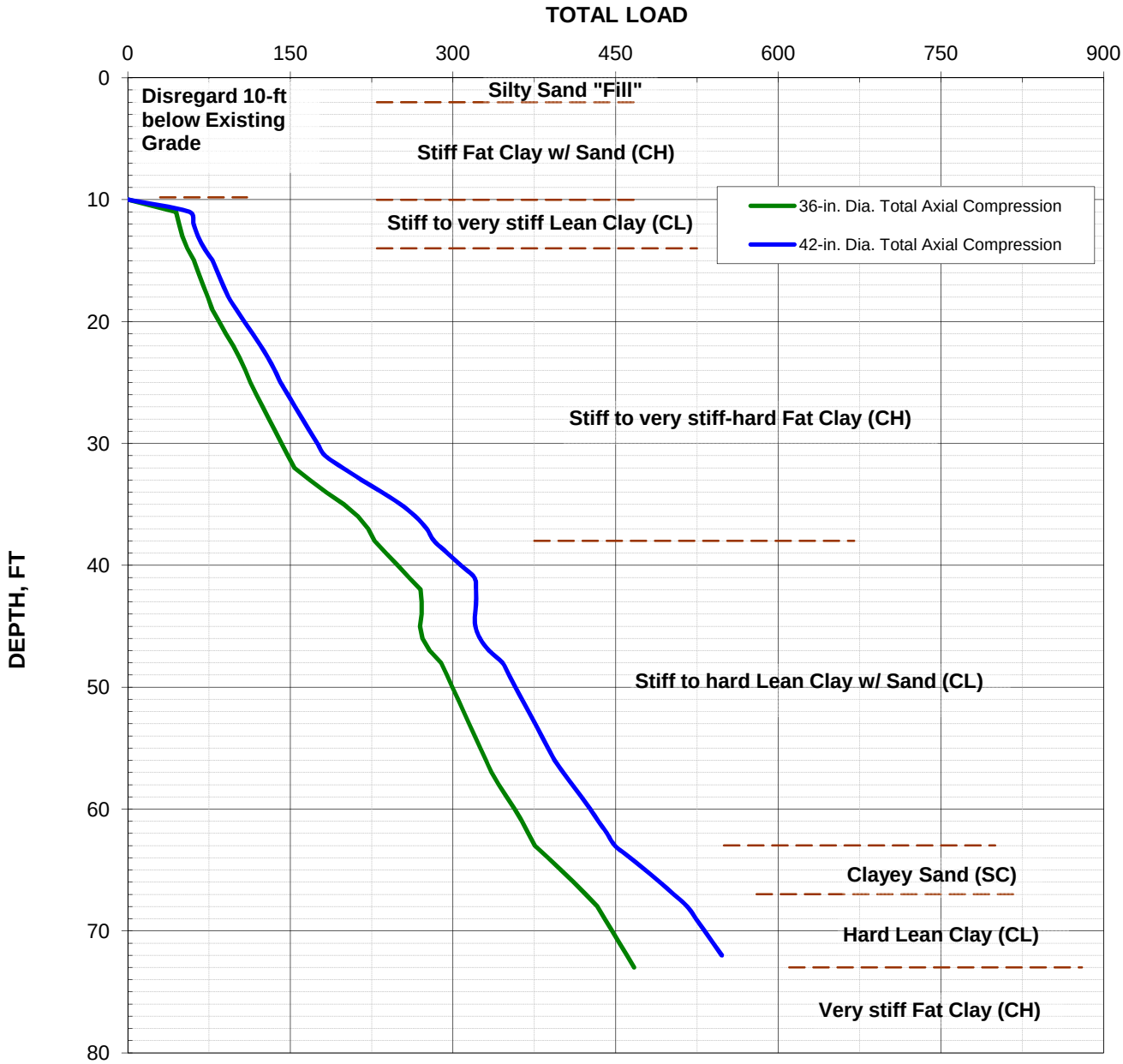



**Soil Profile from Boring B-7**

## NOTES

**1.0** Allowable axial tension loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 10-ft was neglected.
**4.0** Allowable axial tension load shown in this figure takes into account a factor of safety (F.S) of 3.0 for shaft friction.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The bouyant weight of the reinforced concrete shaft should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>**Houston, Texas** | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR. Inc.**<br>**Waller, Texas** | **Allowable Axial Tension Load Drilled Shafts Boring B-7** | **FIGURE: 20** |

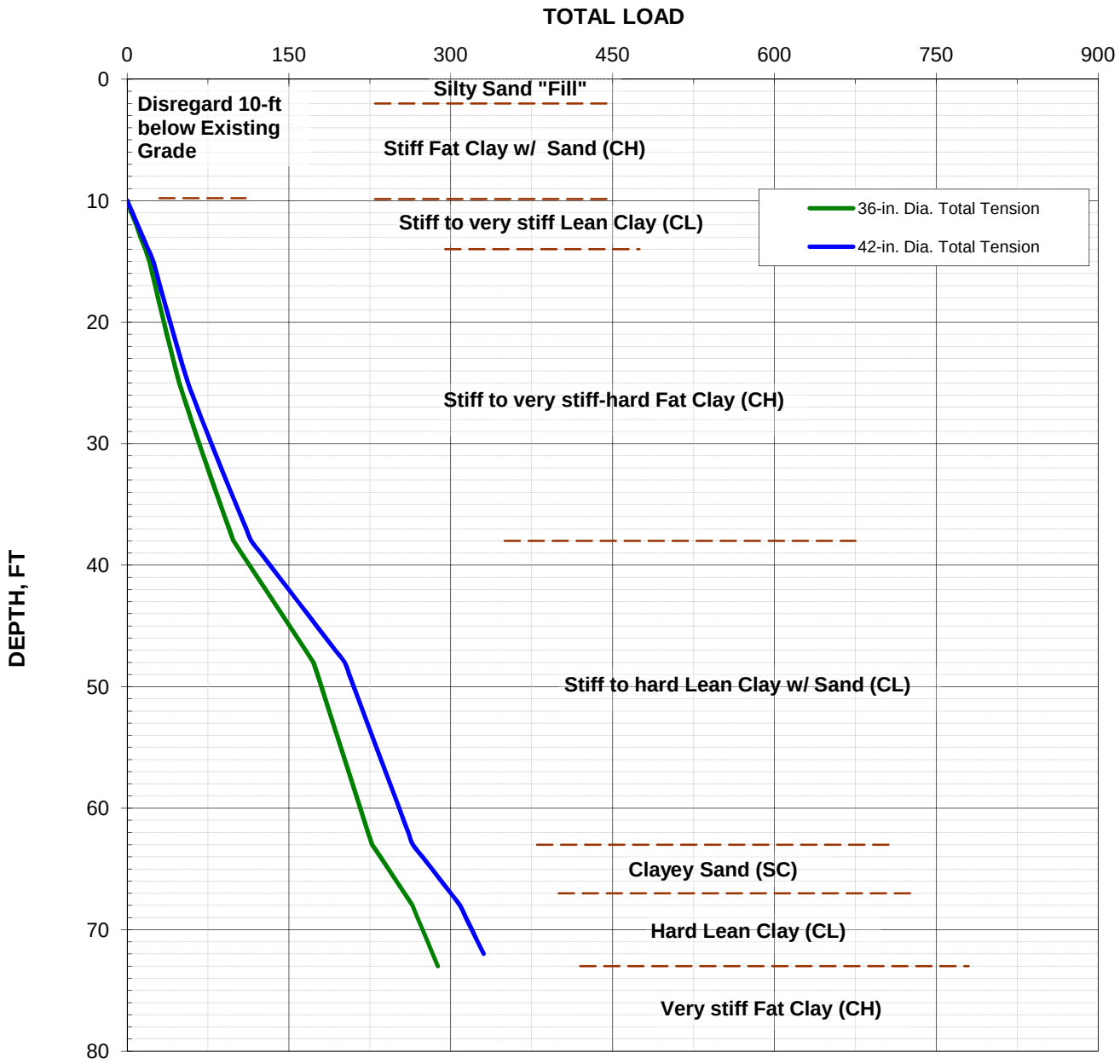



**Soil Profile Boring B-9**

**NOTES**

**1.0** Allowable axial compression loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 10-ft was neglected.
**4.0** Allowable axial compression dead load plus sustained live load shown in this figure takes into account factors of safety (F.S) of 2.0 for shaft friction and 3.0 for end bearing.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The difference between soil unit weight and concrete unit weight should be added to

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>Houston, Texas | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR, Inc.**<br>**Waller, Texas** | **Allowable Axial Compression Load Drilled Shafts (Boring B-9)** | **FIGURE: 21** |




**Soil Profile from Boring B-9**

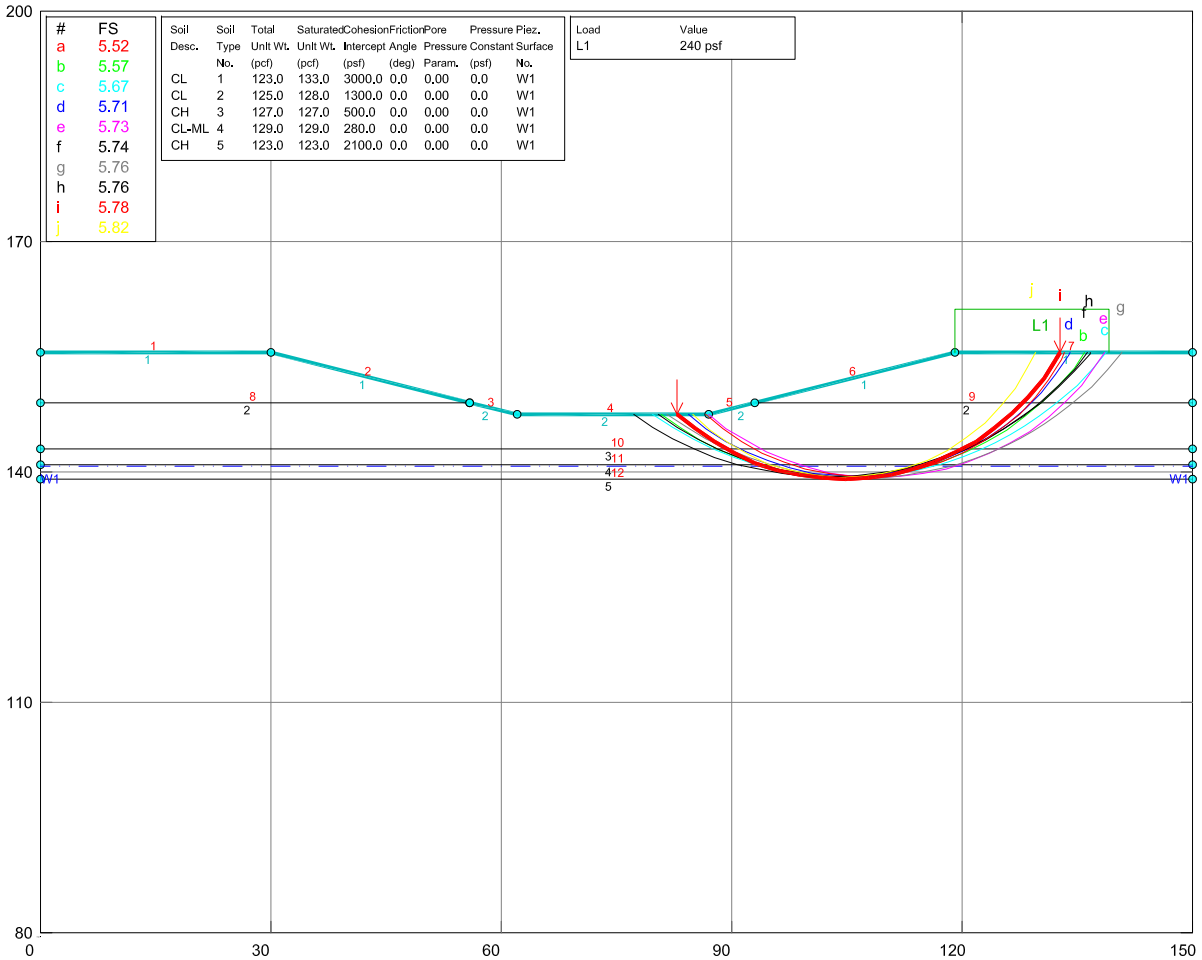
**NOTES**

**1.0** Allowable axial tension loads shown in this figure are net loads.
**2.0** The center to center spacings for the drilled shafts should be greater than three times the drilled shaft diameter.
**3.0** Axial capacity in the top 10-ft was neglected.
**4.0** Allowable axial tension load shown in this figure takes into account a factor of safety (F.S) of 3.0 for shaft friction.
**5.0** The capacities shown above are for a single drilled shaft.
**6.0** The weight of the concrete shaft was not included in this chart. The bouyant weight of the reinforced concrete shaft should be added to the design loads.

| | | |
|---|---|---|
| **Project:**<br>**Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas** | **Tolunay-Wong Engineers, Inc.**<br>**Houston, Texas** | **Project No.: 11.13.180**<br>**Scale: As Shown** |
| **Client: CLR. Inc.**<br>**Waller, Texas** | **Allowable Axial Tension Load Drilled Shafts Boring B-9** | **FIGURE: 22** |

Off-Site Drainage Ditch "A" Stability Analysis, 4H:1V Slope, Short Term, A-1

t:\geotechnical\projects\2011\11.13.180\slope_a\short term (a-1).pl2 Run By: MI 1/12/2012 10:19AM




GSTABL7 v.2 FSmin=5.52

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

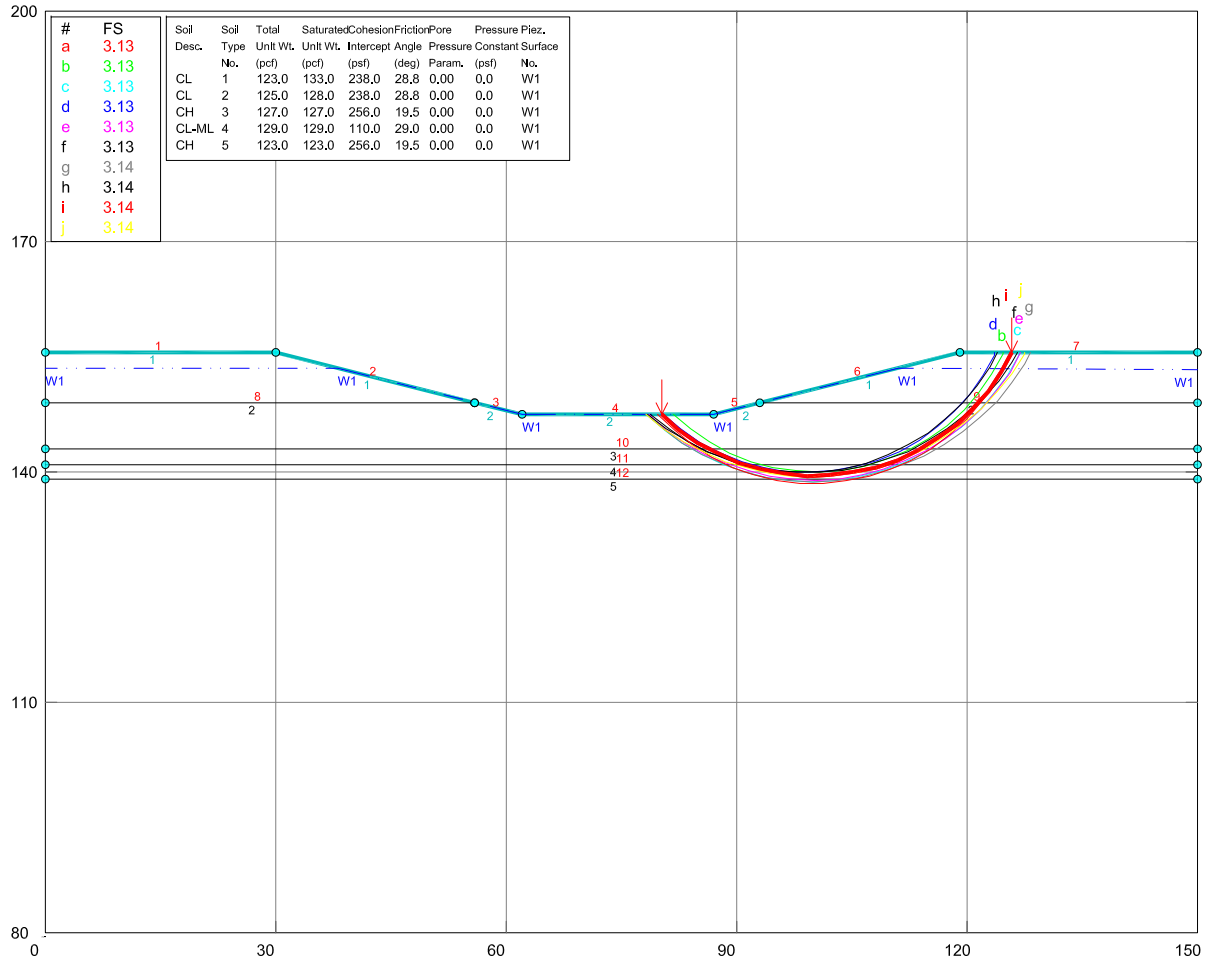
SHORT TERM (ST) CONDITION, OFF-SITE DRAINAGE DITCH "A" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING A-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 27

Off-Site Drainage Ditch "A" Stability Analysis,4H:1V Slope, Rapid Drawdown, A-1

t:\geotechnical\projects\2011\11.13.180\slope_a\rapid drawdown_tot (a-1).pl2 Run By: MI 1/12/2012 10:33AM




| # | FS |
|---|---|
| a | 3.13 |
| b | 3.13 |
| c | 3.13 |
| d | 3.13 |
| e | 3.13 |
| f | 3.13 |
| g | 3.14 |
| h | 3.14 |
| i | 3.14 |
| j | 3.14 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| CL | 1 | 123.0 | 133.0 | 238.0 | 28.8 | 0.00 | 0.0 | W1 |
| CL | 2 | 125.0 | 128.0 | 238.0 | 28.8 | 0.00 | 0.0 | W1 |
| CH | 3 | 127.0 | 127.0 | 256.0 | 19.5 | 0.00 | 0.0 | W1 |
| CL-ML | 4 | 129.0 | 129.0 | 110.0 | 29.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 123.0 | 123.0 | 256.0 | 19.5 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=3.13

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

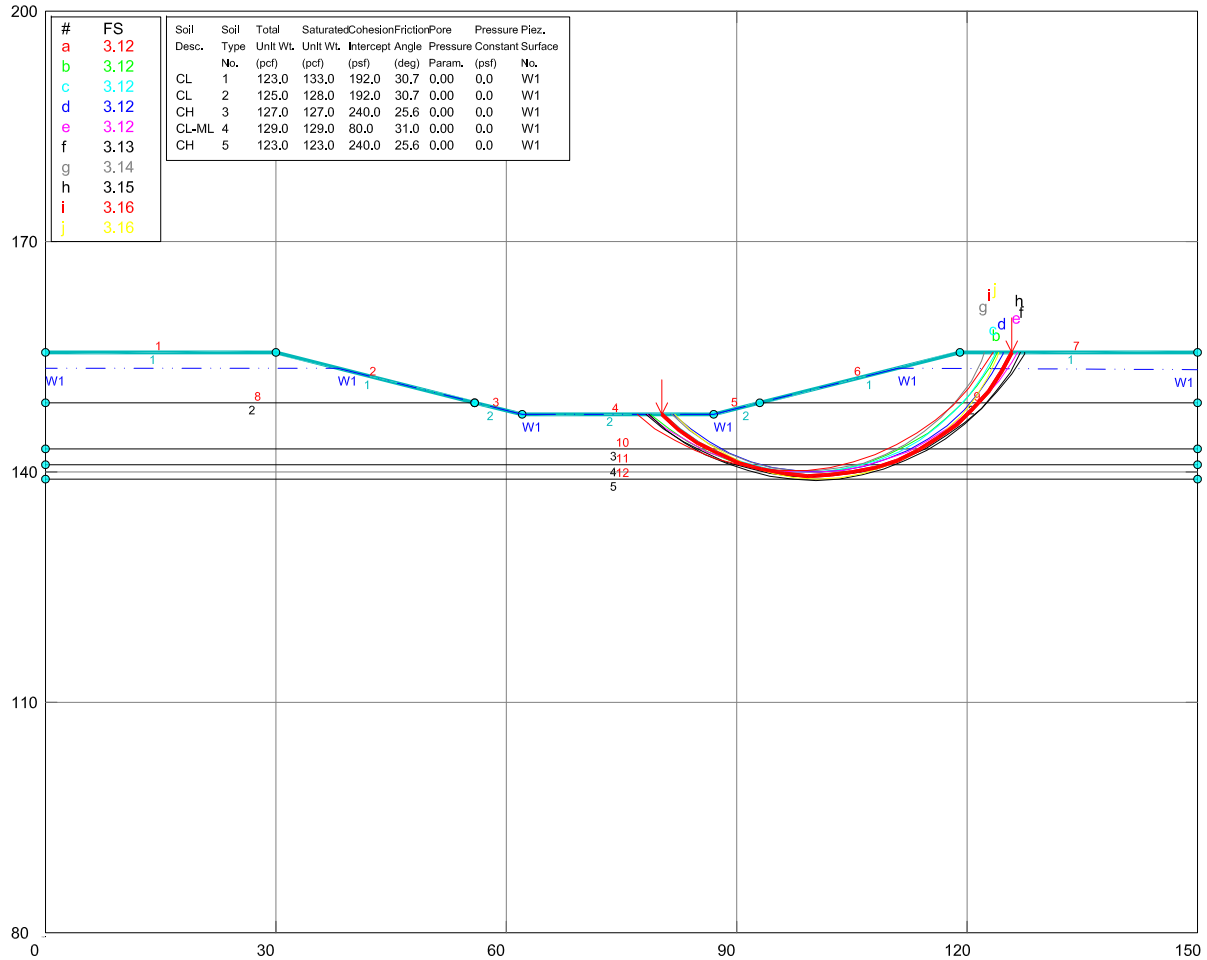
RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "A" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE, TOTAL STRESS SOIL PARAMETERS, BORING A-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 28

Off-Site Drainage Ditch "A" Stability Analysis,4H:1V Slope, Rapid Drawdown, A-1

t:\geotechnical\projects\2011\11.13.180\slope_a\rapid drawdown_effc (a-1).pl2 Run By: MI 1/12/2012 10:31AM




| # | FS |
|---|---|
| a | 3.12 |
| b | 3.12 |
| c | 3.12 |
| d | 3.12 |
| e | 3.12 |
| f | 3.13 |
| g | 3.14 |
| h | 3.15 |
| i | 3.16 |
| j | 3.16 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| CL | 1 | 123.0 | 133.0 | 192.0 | 30.7 | 0.00 | 0.0 | W1 |
| CL | 2 | 125.0 | 128.0 | 192.0 | 30.7 | 0.00 | 0.0 | W1 |
| CH | 3 | 127.0 | 127.0 | 240.0 | 25.6 | 0.00 | 0.0 | W1 |
| CL-ML | 4 | 129.0 | 129.0 | 80.0 | 31.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 123.0 | 123.0 | 240.0 | 25.6 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=3.12

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

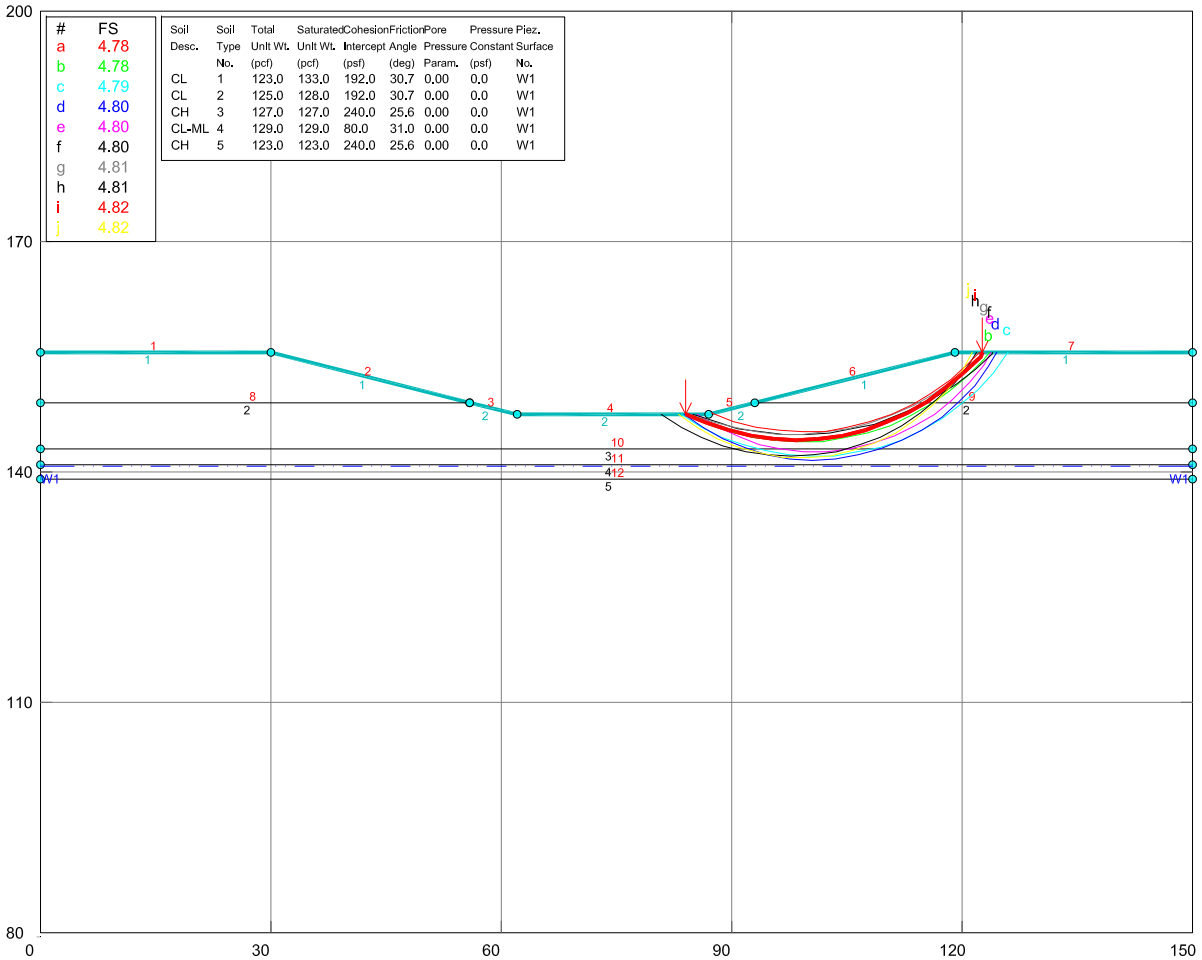
RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "A" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE, EFFECTIVE STRESS SOIL PARAMETERS, BORING A-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 29

Off-Site Drainage Ditch "A" Stability Analysis, 4H:1V Slope, Long Term, A-1

t:\geotechnical\projects\2011\11.13.180\slope_a\long term (a-1).pl2 Run By: MI 1/12/2012 10:30AM




| # | FS |
|---|---|
| a | 4.78 |
| b | 4.78 |
| c | 4.79 |
| d | 4.80 |
| e | 4.80 |
| f | 4.80 |
| g | 4.81 |
| h | 4.81 |
| i | 4.82 |
| j | 4.82 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| CL | 1 | 123.0 | 133.0 | 192.0 | 30.7 | 0.00 | 0.0 | W1 |
| CL | 2 | 125.0 | 128.0 | 192.0 | 30.7 | 0.00 | 0.0 | W1 |
| CH | 3 | 127.0 | 127.0 | 240.0 | 25.6 | 0.00 | 0.0 | W1 |
| CL-ML | 4 | 129.0 | 129.0 | 80.0 | 31.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 123.0 | 123.0 | 240.0 | 25.6 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=4.78

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

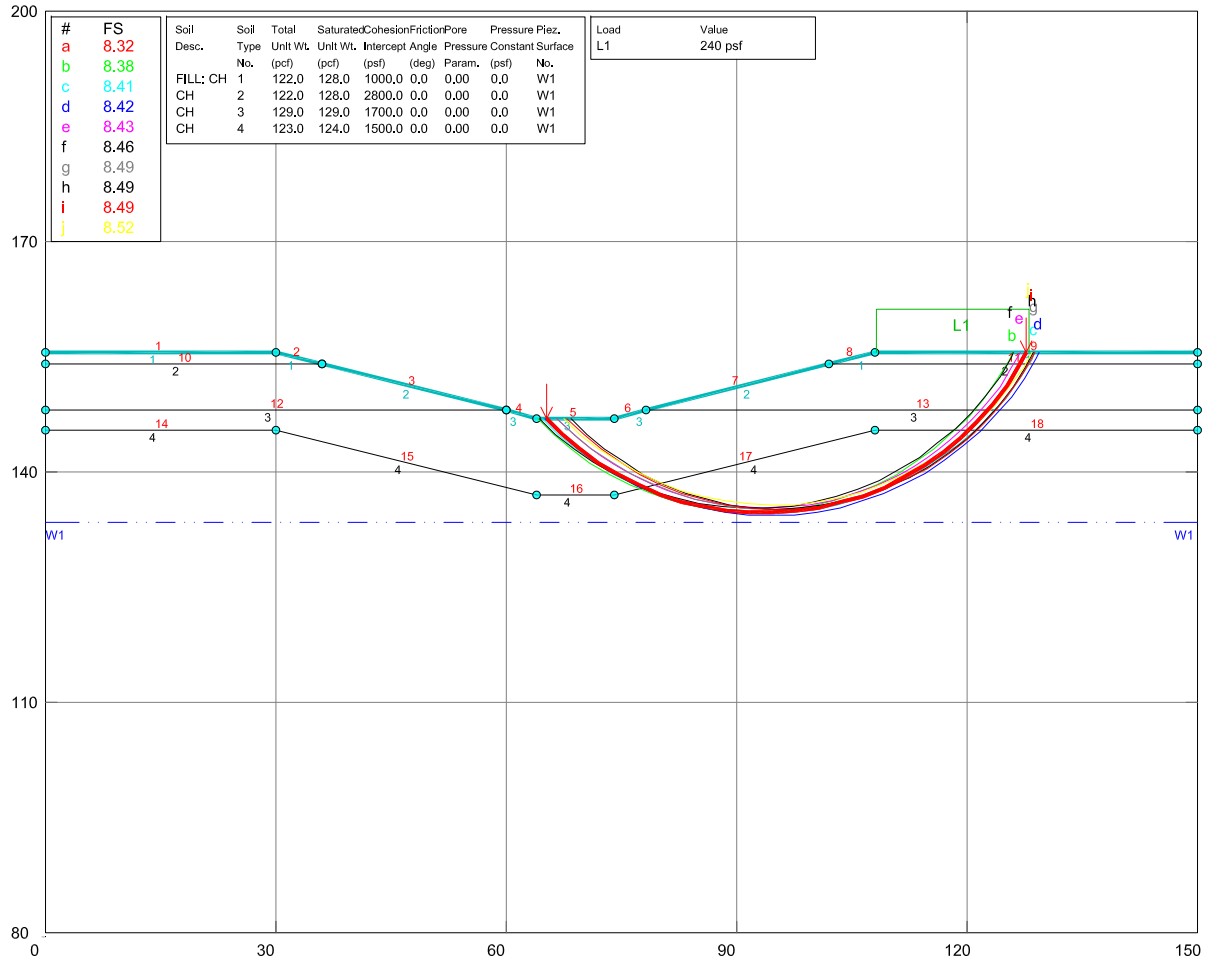
LONG TERM (LT) CONDITION, OFF-SITE DRAINAGE
DITCH "A" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING A-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 30

Off-Site Drainage Ditch "B" Stability Analysis,4H:1V Slope, Short Term, BB-1

t:\geotechnical\projects\2011\11.13.180\slope_b\short term (bb-1).pl2 Run By: MI 1/12/2012 02:11PM



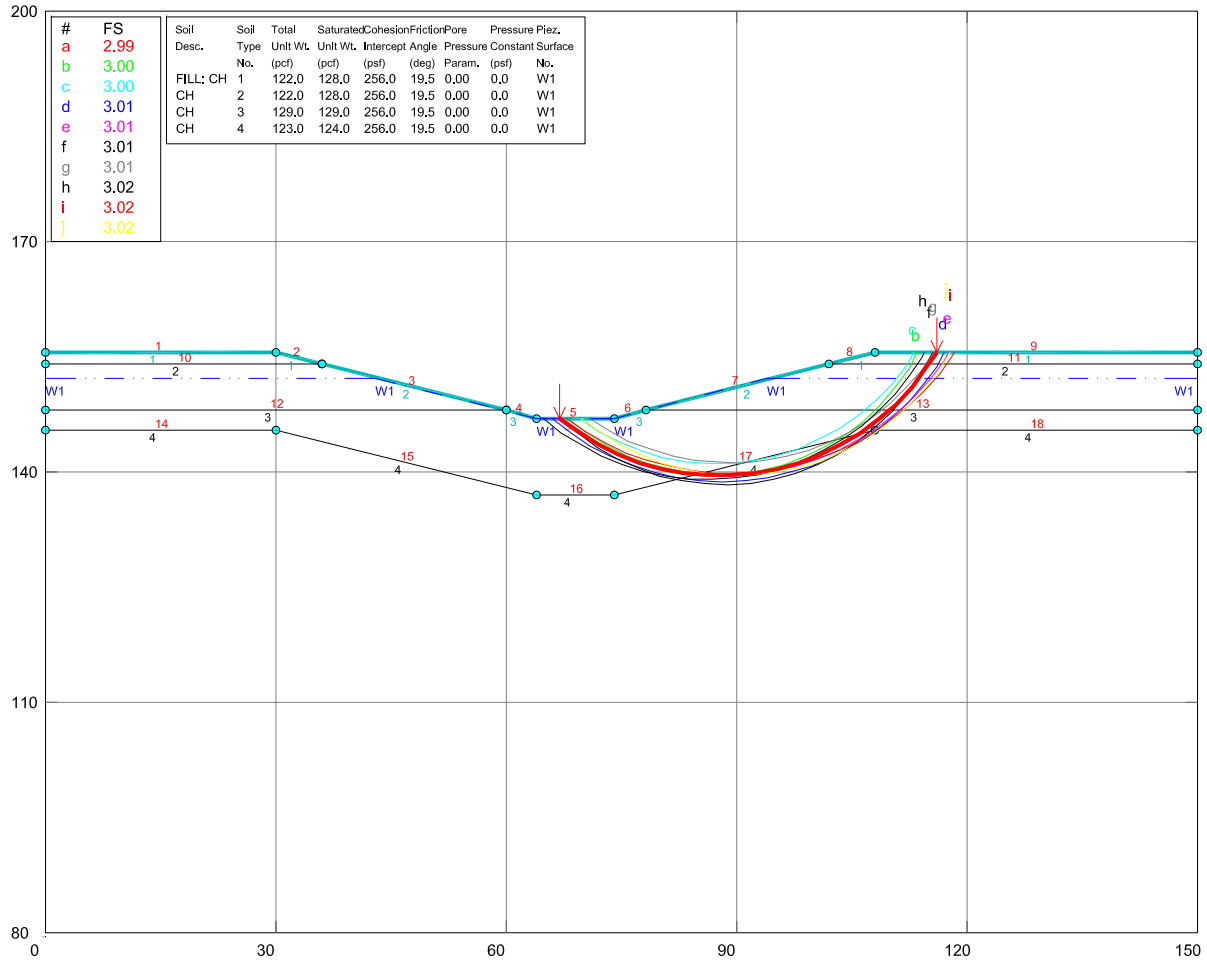

GSTABL7 v.2 FSmin=8.32

Safety Factors Are Calculated By The Modified Bishop Method

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | SHORT TERM (ST) CONDITION, OFF-SITE DRAINAGE<br>DITCH "B" SLOPE STABILITY ANALYSIS<br>4H:1V GRASS LINED SLOPE<br>BORING BB-1 SOIL PROFILE |
| CLR, INC.<br>WALLER, TEXAS | | TWEI PROJECT NO.: 11.13.180 / FIGURE 31 |

Off-Site Drainage Ditch "B" Stability Analysis,4H:1V Slope, Rapid Drawdown, BB-1

t:\geotechnical\projects\2011\11.13.180\slope_b\rapid drawdown_tot (bb-1).pl2 Run By: MI 1/12/2012 02:10PM




| # | FS |
|---|---|
| a | 2.99 |
| b | 3.00 |
| c | 3.00 |
| d | 3.01 |
| e | 3.01 |
| f | 3.01 |
| g | 3.01 |
| h | 3.02 |
| i | 3.02 |
| j | 3.02 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL: CH | 1 | 122.0 | 128.0 | 256.0 | 19.5 | 0.00 | 0.0 | W1 |
| CH | 2 | 122.0 | 128.0 | 256.0 | 19.5 | 0.00 | 0.0 | W1 |
| CH | 3 | 129.0 | 129.0 | 256.0 | 19.5 | 0.00 | 0.0 | W1 |
| CH | 4 | 123.0 | 124.0 | 256.0 | 19.5 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.99

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

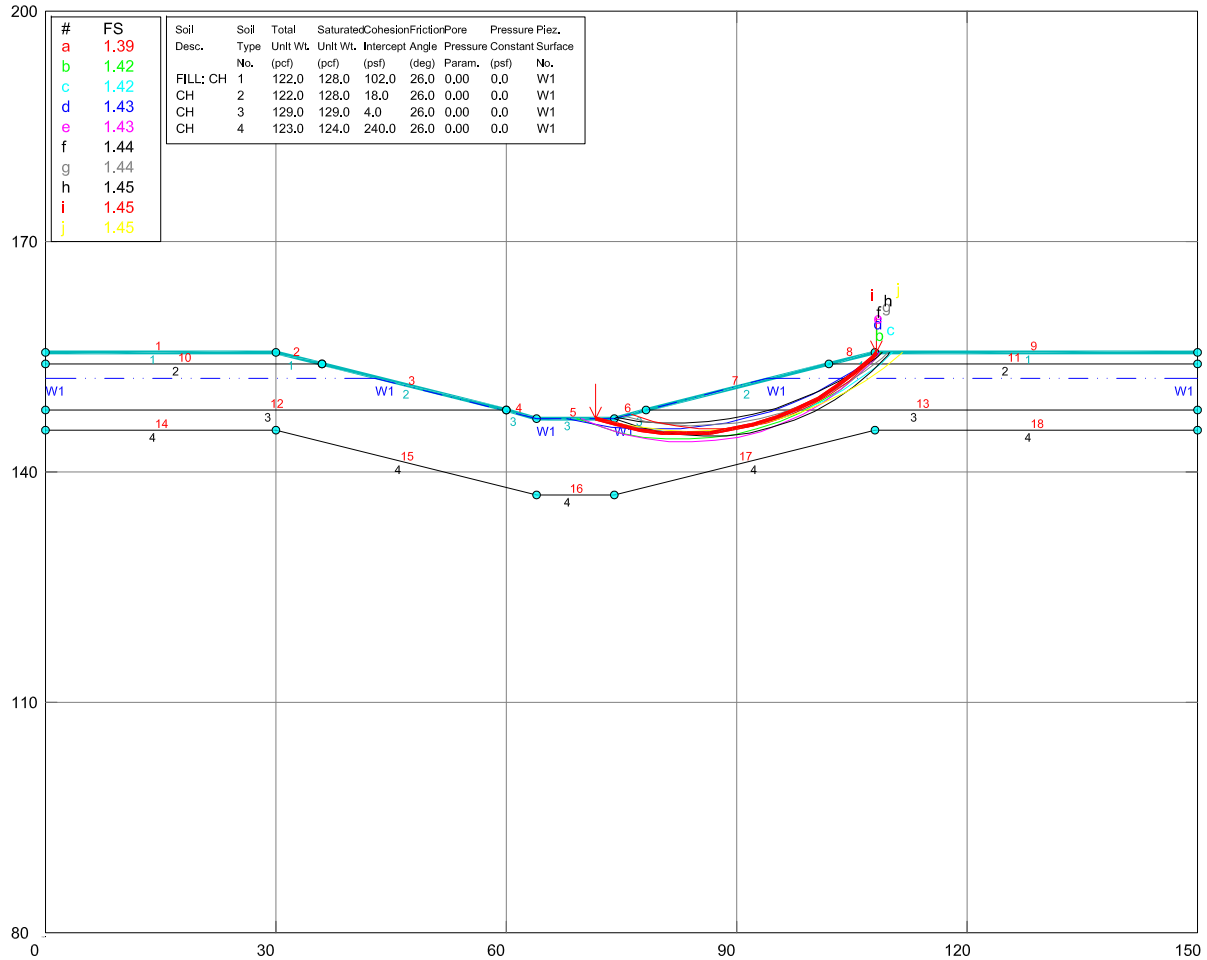
RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "B" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE, TOTAL STRESS SOIL PARAMETERS, BORING BB-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 32

Off-Site Drainage Ditch "B" Stability Analysis,4H:1V Slope, Rapid Drawdown, BB-1

t:\geotechnical\projects\2011\11.13.180\slope_b\rapid drawdown_effc (bb-1).pl2 Run By: MI 1/12/2012 02:11PM




| # | FS |
|---|---|
| a | 1.39 |
| b | 1.42 |
| c | 1.42 |
| d | 1.43 |
| e | 1.43 |
| f | 1.44 |
| g | 1.44 |
| h | 1.45 |
| i | 1.45 |
| j | 1.45 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Piez. Constant (psf) | Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL: CH | 1 | 122.0 | 128.0 | 102.0 | 26.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 122.0 | 128.0 | 18.0 | 26.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 129.0 | 129.0 | 4.0 | 26.0 | 0.00 | 0.0 | W1 |
| CH | 4 | 123.0 | 124.0 | 240.0 | 26.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=1.39

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

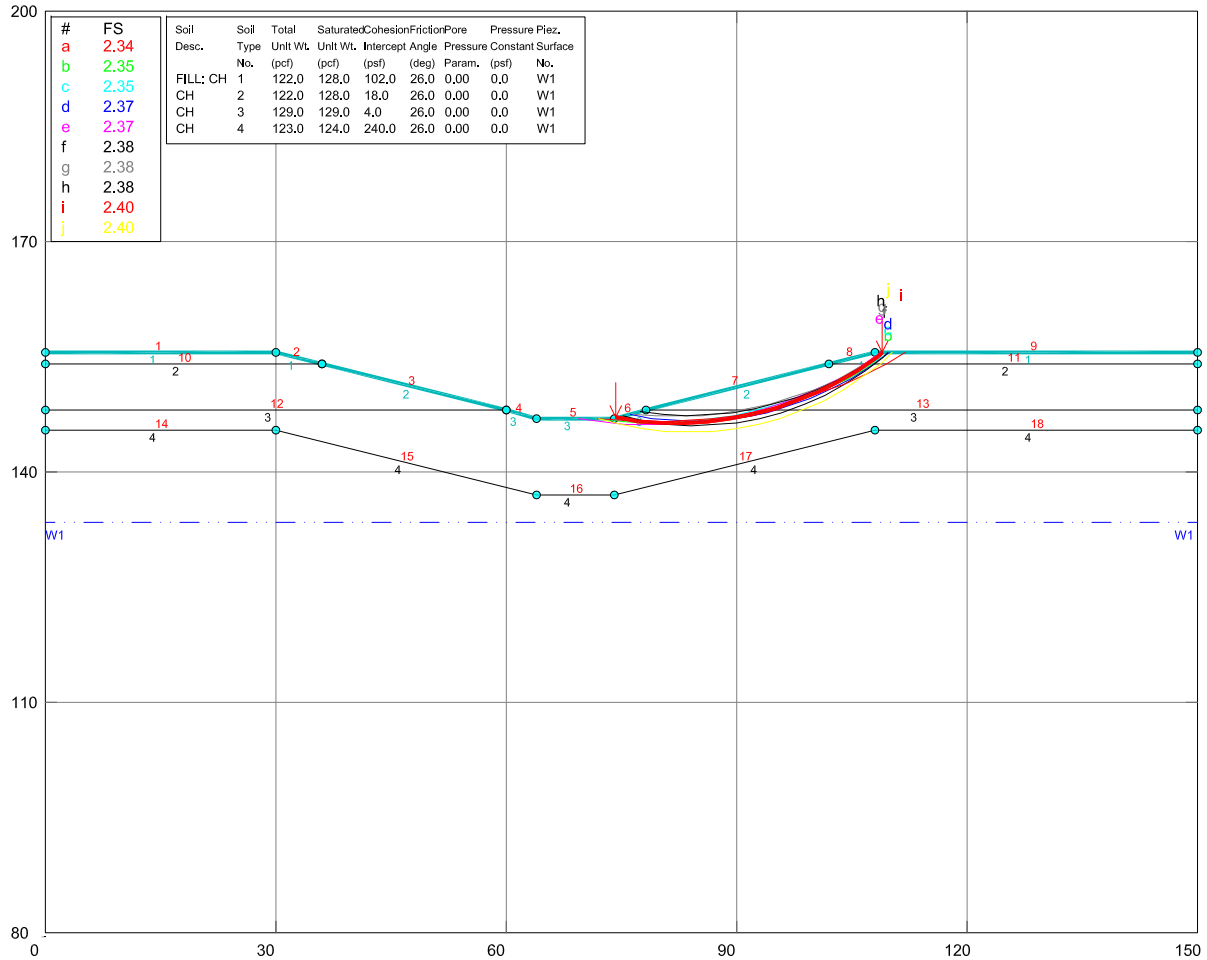
RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "B" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE, EFFECTIVE STRESS SOIL PARAMETERS, BORING BB-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 33

Off-Site Drainage Ditch "B" Stability Analysis,4H:1V Slope, Long Term, BB-1

t:\geotechnical\projects\2011\11.13.180\slope_b\long term (bb-1).pl2 Run By: MI 1/12/2012 02:12PM




| # | FS |
|---|---|
| a | 2.34 |
| b | 2.35 |
| c | 2.35 |
| d | 2.37 |
| e | 2.37 |
| f | 2.38 |
| g | 2.38 |
| h | 2.38 |
| i | 2.40 |
| j | 2.40 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL: CH | 1 | 122.0 | 128.0 | 102.0 | 26.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 122.0 | 128.0 | 18.0 | 26.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 129.0 | 129.0 | 4.0 | 26.0 | 0.00 | 0.0 | W1 |
| CH | 4 | 123.0 | 124.0 | 240.0 | 26.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.34

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

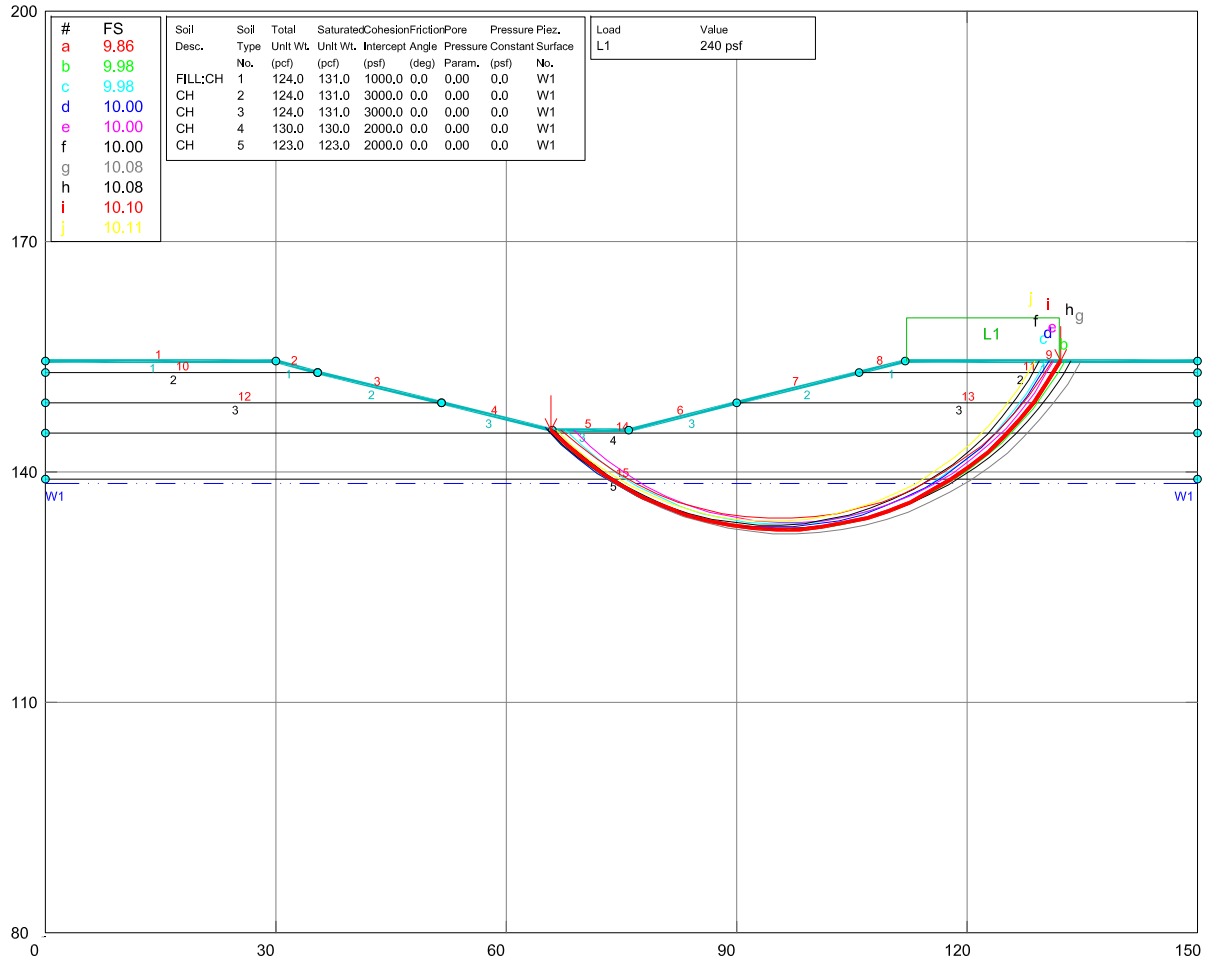
LONG TERM (LT) CONDITION, OFF-SITE DRAINAGE
DITCH "B" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING BB-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 34

Off-Site Drainage Ditch "C" Stability Analysis, 4H:1V Slope, Short Term, C-2

t:\geotechnical\projects\2011\11.13.180\slope_c\short term (c-2).pl2 Run By: MI 1/12/2012 10:59AM




| # | FS |
|---|---|
| a | 9.86 |
| b | 9.98 |
| c | 9.98 |
| d | 10.00 |
| e | 10.00 |
| f | 10.00 |
| g | 10.08 |
| h | 10.08 |
| i | 10.10 |
| j | 10.11 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL:CH | 1 | 124.0 | 131.0 | 1000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 124.0 | 131.0 | 3000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 3000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 4 | 130.0 | 130.0 | 2000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 123.0 | 123.0 | 2000.0 | 0.0 | 0.00 | 0.0 | W1 |

| Load | Value |
|---|---|
| L1 | 240 psf |

GSTABL7 v.2 FSmin=9.86

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

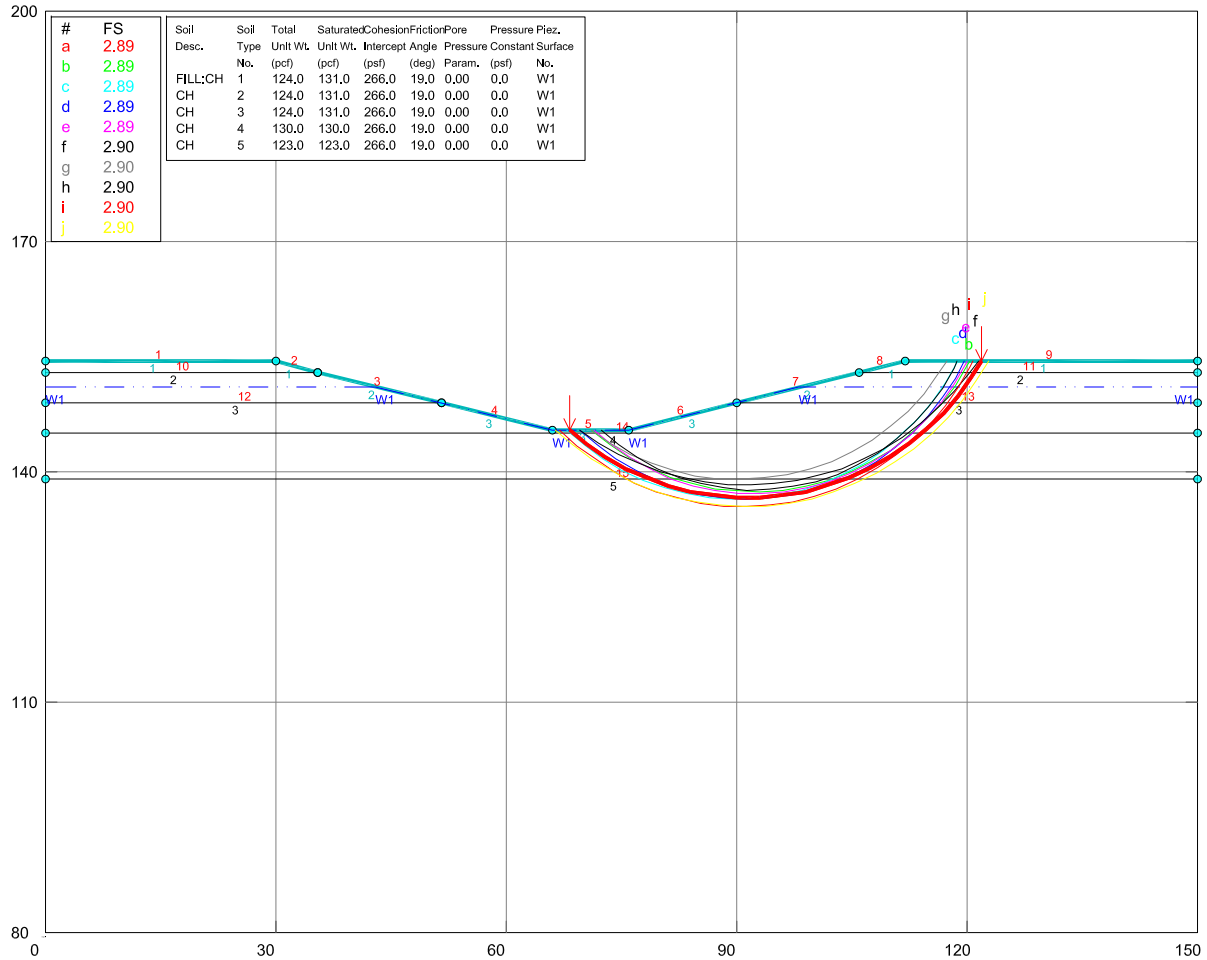
SHORT TERM (ST) CONDITION, OFF-SITE DRAINAGE DITCH "C" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING C-2 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 35

Off-Site Drainage Ditch "C" Stability Analysis, 4H:1V Slope, Rapid Drawdown, C-2

t:\geotechnical\projects\2011\11.13.180\slope_c\rapid drawdown_tot (c-2).pl2 Run By: MI 1/12/2012 11:00AM




| # | FS |
|---|---|
| a | 2.89 |
| b | 2.89 |
| c | 2.89 |
| d | 2.89 |
| e | 2.89 |
| f | 2.90 |
| g | 2.90 |
| h | 2.90 |
| i | 2.90 |
| j | 2.90 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL:CH | 1 | 124.0 | 131.0 | 266.0 | 19.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 124.0 | 131.0 | 266.0 | 19.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 266.0 | 19.0 | 0.00 | 0.0 | W1 |
| CH | 4 | 130.0 | 130.0 | 266.0 | 19.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 123.0 | 123.0 | 266.0 | 19.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.89

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

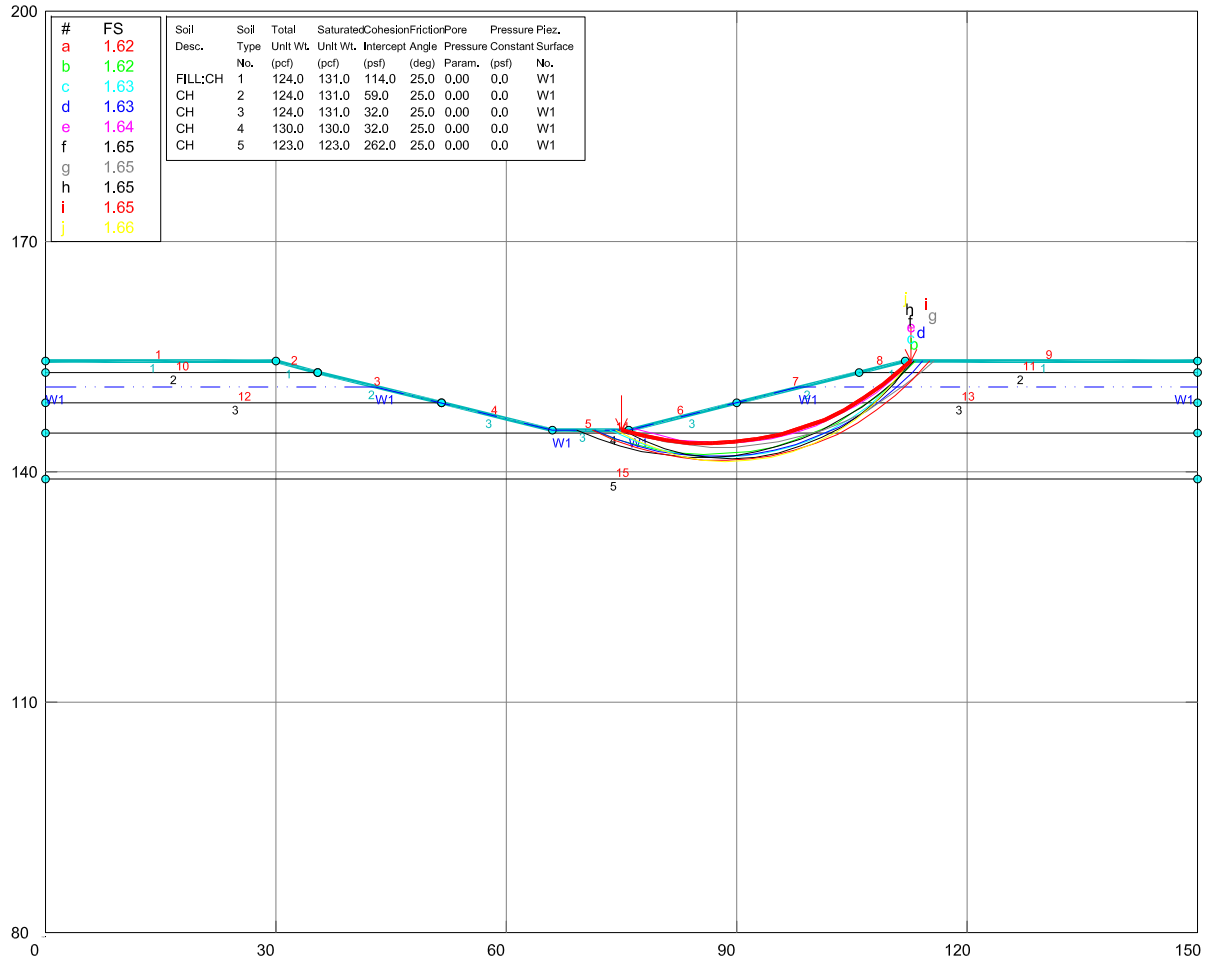
RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "C" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE, TOTAL STRESS SOIL PARAMETERS, BORING C-2 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 36

Off-Site Drainage Ditch "C" Stability Analysis, 4H:1V Slope, Rapid Drawdown, C-2

t:\geotechnical\projects\2011\11.13.180\slope_c\rapid drawdown_effc (c-2).pl2 Run By: MI 1/12/2012 11:01AM



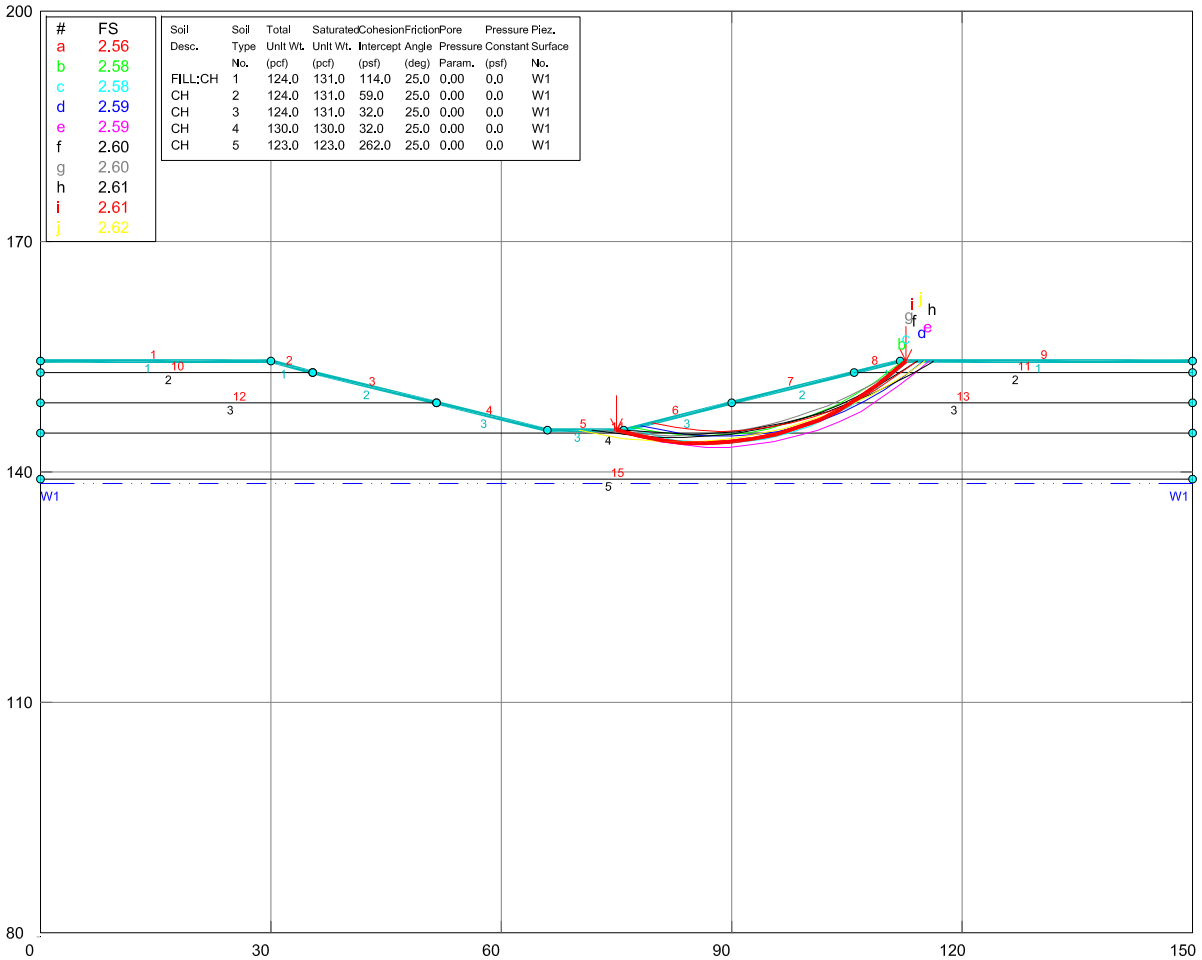

GSTABL7 v.2 FSmin=1.62

Safety Factors Are Calculated By The Modified Bishop Method

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "C" SLOPE STABILITY ANALYSIS<br>4H:1V GRASS LINED SLOPE, EFFECTIVE STRESS SOIL PARAMETERS, BORING C-2 SOIL PROFILE |
| CLR, INC.<br>WALLER, TEXAS | | TWEI PROJECT NO.: 11.13.180 / FIGURE 37 |

Off-Site Drainage Ditch "C" Stability Analysis, 4H:1V Slope, Long Term, C-2

t:\geotechnical\projects\2011\11.13.180\slope_c\long term (c-2).pl2 Run By: MI 1/14/2012 11:16AM




| # | FS |
|---|---|
| a | 2.56 |
| b | 2.58 |
| c | 2.58 |
| d | 2.59 |
| e | 2.59 |
| f | 2.60 |
| g | 2.60 |
| h | 2.61 |
| i | 2.61 |
| j | 2.62 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL:CH | 1 | 124.0 | 131.0 | 114.0 | 25.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 124.0 | 131.0 | 59.0 | 25.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 32.0 | 25.0 | 0.00 | 0.0 | W1 |
| CH | 4 | 130.0 | 130.0 | 32.0 | 25.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 123.0 | 123.0 | 262.0 | 25.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.56

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

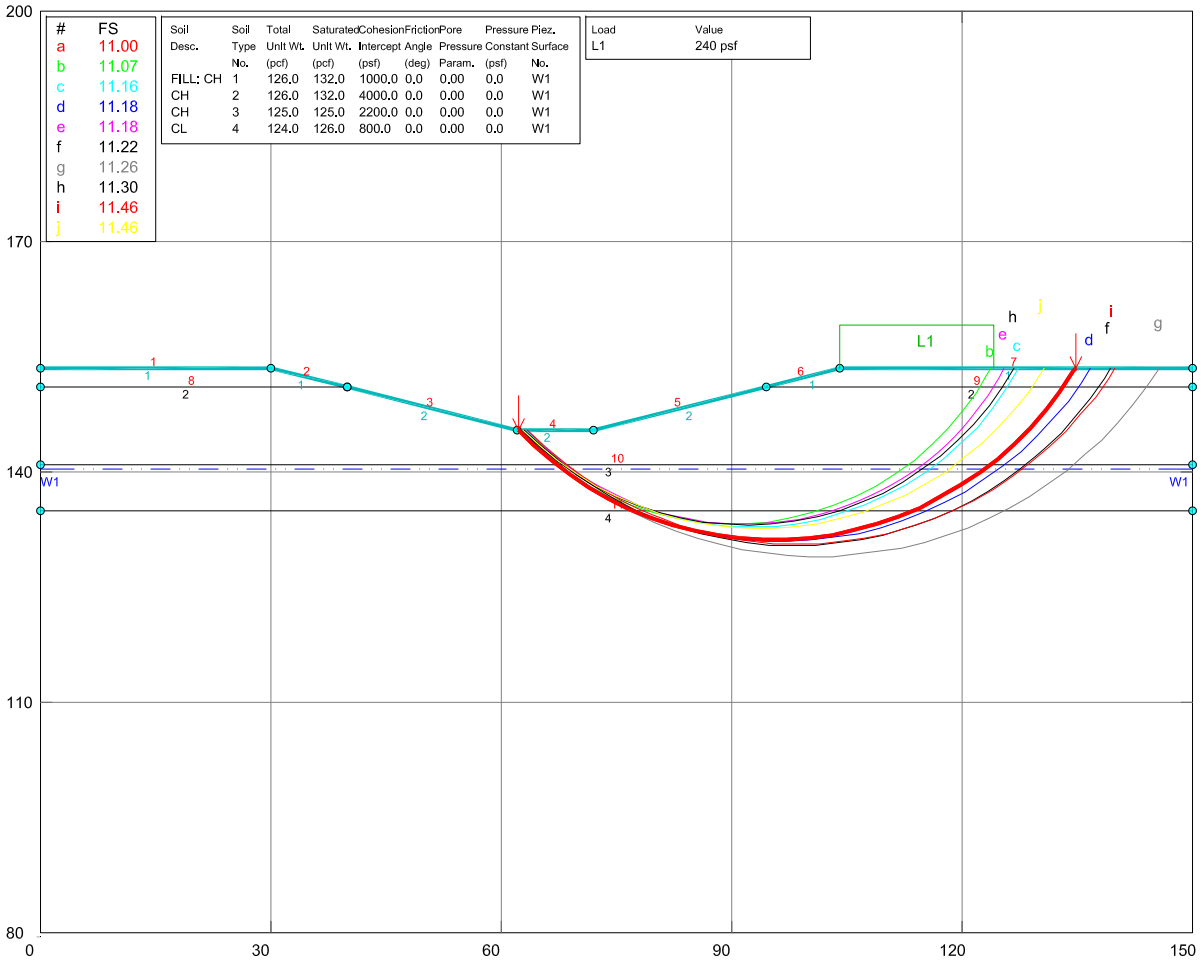
LONG TERM (LT) CONDITION, OFF-SITE DRAINAGE
DITCH "C" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING C-2 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 38

Off-Site Drainage Ditch "D" Stability Analysis, 4H:1V Slope, Short Term, D-3

t:\geotechnical\projects\2011\11.13.180\slope_d\short term (d-1).pl2 Run By: MI 1/14/2012 11:23AM




| # | FS |
|---|---|
| a | 11.00 |
| b | 11.07 |
| c | 11.16 |
| d | 11.18 |
| e | 11.18 |
| f | 11.22 |
| g | 11.26 |
| h | 11.30 |
| i | 11.46 |
| j | 11.46 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL: CH | 1 | 126.0 | 132.0 | 1000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 126.0 | 132.0 | 4000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 125.0 | 125.0 | 2200.0 | 0.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 124.0 | 126.0 | 800.0 | 0.0 | 0.00 | 0.0 | W1 |

| Load | Value |
|---|---|
| L1 | 240 psf |

GSTABL7 v.2 FSmin=11.00

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

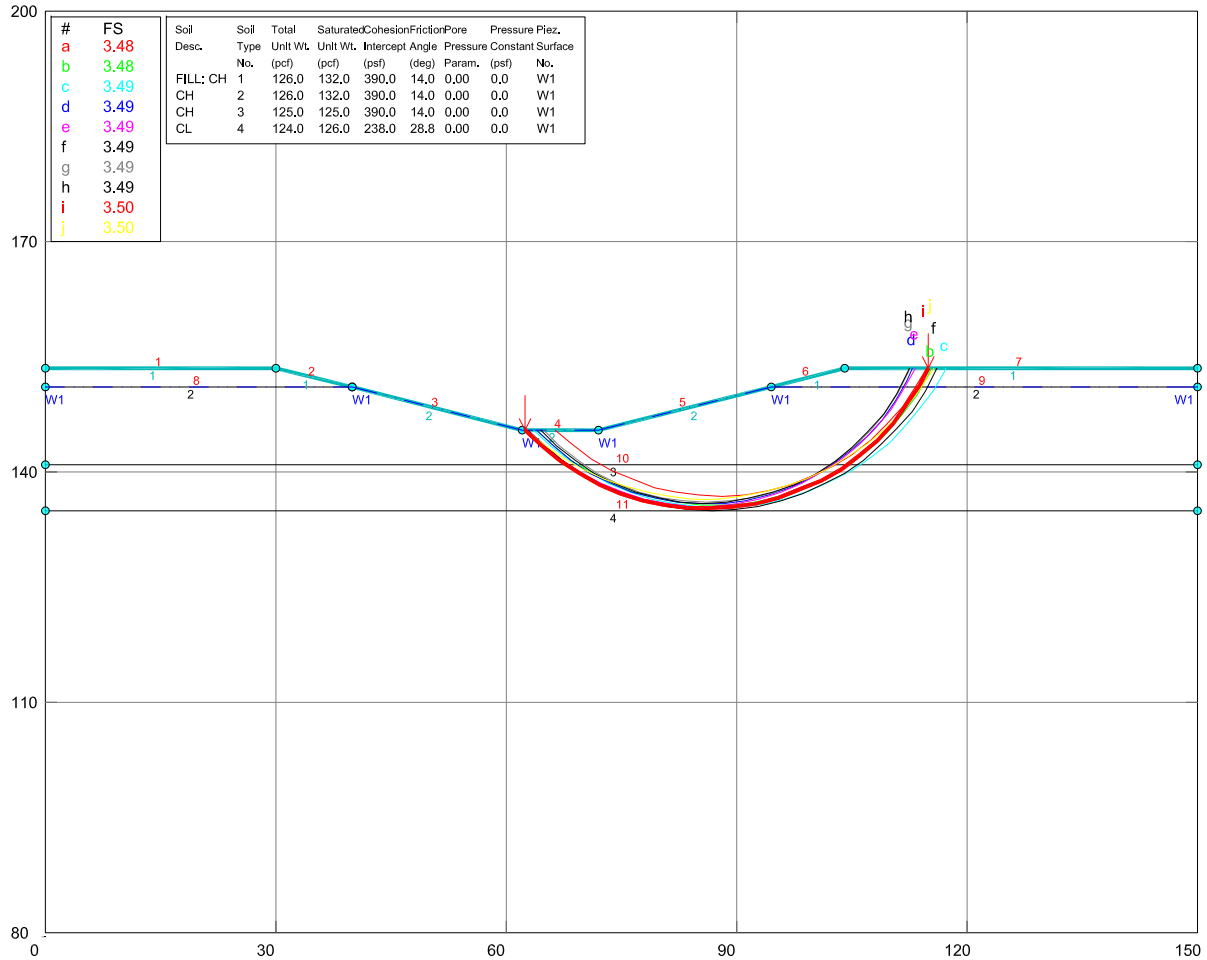
SHORT TERM (ST) CONDITION, OFF-SITE DRAINAGE DITCH "D" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING D-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 39

Off-Site Drainage Ditch "D" Stability Analysis, 4H:1V Slope, Rapid Drawdown, D-3

t:\geotechnical\projects\2011\11.13.180\slope_d\rapid drawdown_tot (d-1).pl2 Run By: MI 1/14/2012 11:27AM




| # | FS |
|---|---|
| a | 3.48 |
| b | 3.48 |
| c | 3.49 |
| d | 3.49 |
| e | 3.49 |
| f | 3.49 |
| g | 3.49 |
| h | 3.49 |
| i | 3.50 |
| j | 3.50 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL: CH | 1 | 126.0 | 132.0 | 390.0 | 14.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 126.0 | 132.0 | 390.0 | 14.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 125.0 | 125.0 | 390.0 | 14.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 124.0 | 126.0 | 238.0 | 28.8 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=3.48

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

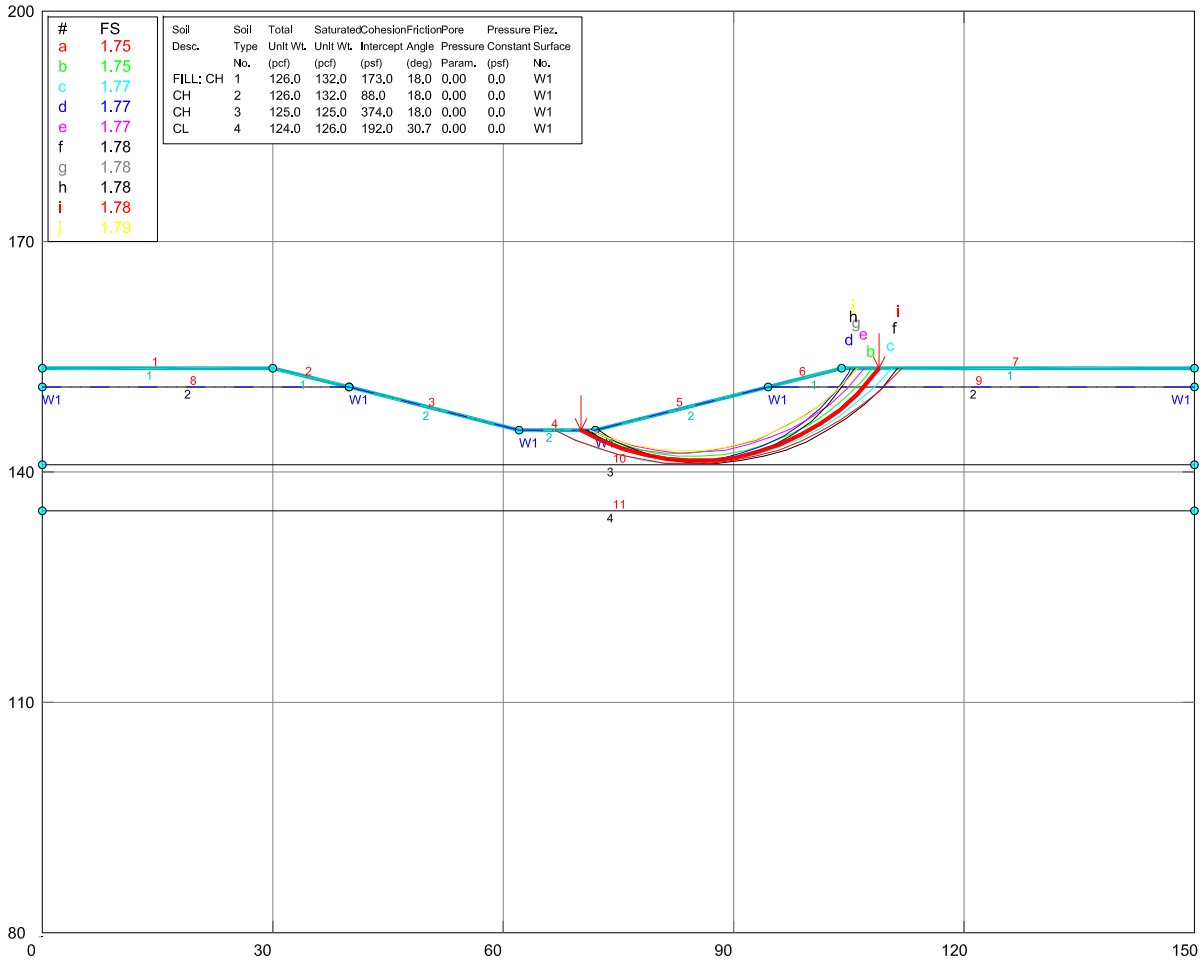
RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "D" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE, TOTAL STRESS SOIL PARAMETERS, BORING D-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 40

Off-Site Drainage Ditch "D" Stability Analysis, 4H:1V Slope, Rapid Drawdown, D-3

t:\geotechnical\projects\2011\11.13.180\slope_d\rapid drawdown_effc (d-1).pl2 Run By: MI 1/14/2012 11:29AM



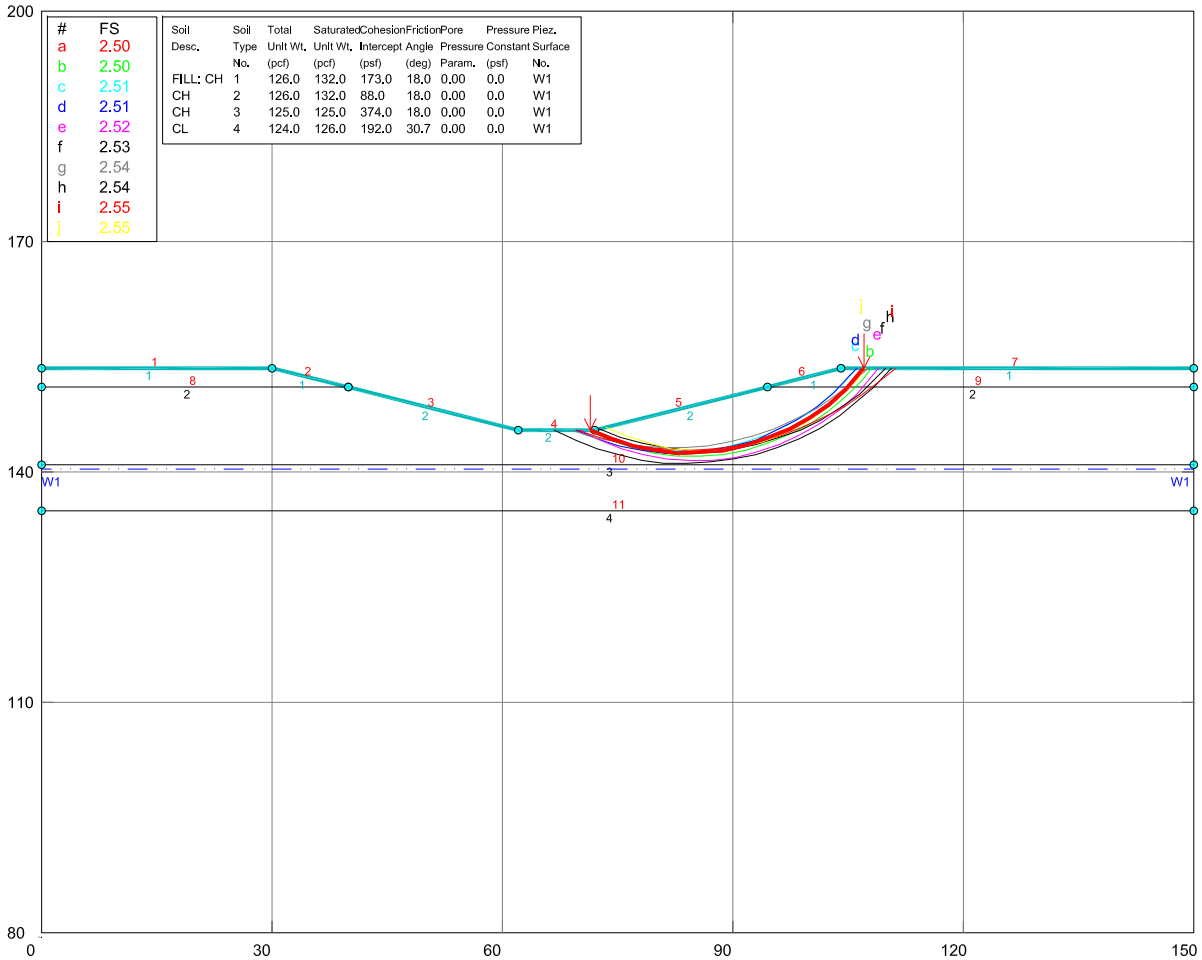

GSTABL7 v.2 FSmin=1.75

Safety Factors Are Calculated By The Modified Bishop Method

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | RAPID DRAWDOWN (RDD) CONDITION, OFF-SITE DRAINAGE DITCH "D" SLOPE STABILITY ANALYSIS<br>4H:1V GRASS LINED SLOPE, EFFECTIVE STRESS SOIL PARAMETERS, BORING D-3 SOIL PROFILE |
| CLR, INC.<br>WALLER, TEXAS | | TWEI PROJECT NO.: 11.13.180 / FIGURE 41 |

Off-Site Drainage Ditch "D" Stability Analysis, 4H;1V Slope, Long Term, D-3

t:\geotechnical\projects\2011\11.13.180\slope_d\long term (d-1).pl2 Run By: MI 1/14/2012 11:31AM




| # | FS |
|---|---|
| a | 2.50 |
| b | 2.50 |
| c | 2.51 |
| d | 2.51 |
| e | 2.52 |
| f | 2.53 |
| g | 2.54 |
| h | 2.54 |
| i | 2.55 |
| j | 2.55 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Piez. Constant (psf) | Surface No. |
|---|---|---|---|---|---|---|---|---|
| FILL: CH | 1 | 126.0 | 132.0 | 173.0 | 18.0 | 0.00 | 0.0 | W1 |
| CH | 2 | 126.0 | 132.0 | 88.0 | 18.0 | 0.00 | 0.0 | W1 |
| CH | 3 | 125.0 | 125.0 | 374.0 | 18.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 124.0 | 126.0 | 192.0 | 30.7 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.50

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

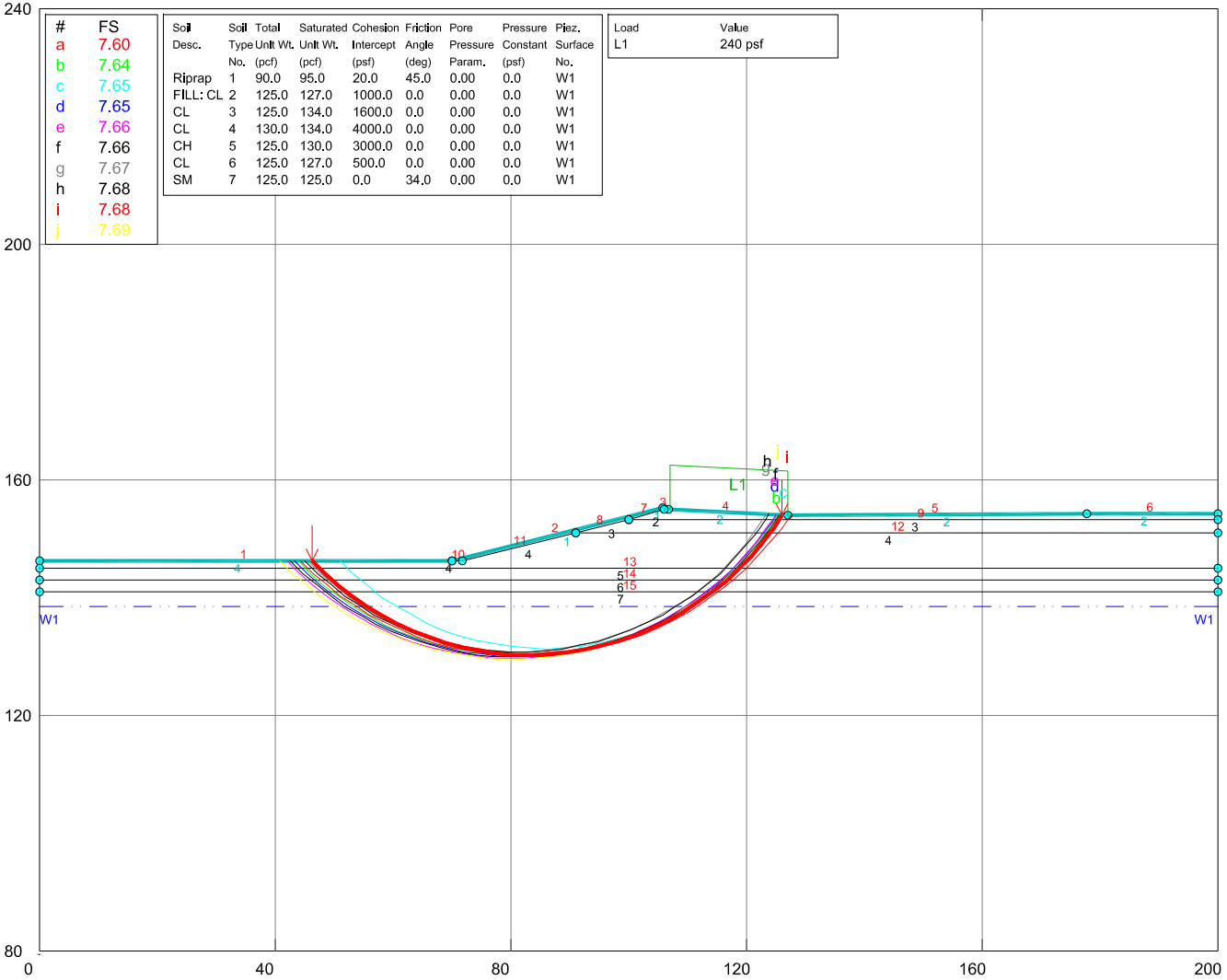
LONG TERM (LT) CONDITION, OFF-SITE DRAINAGE
DITCH "D" SLOPE STABILITY ANALYSIS
4H:1V GRASS LINED SLOPE
BORING D-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 42

Box Sewer Outfall Stability Analysis, Drainage Ditch"C", Inside,Short Term,C-1

t:\geotechnical\projects\2011\11.13.180\slope_bs\short term (c-1).pl2 Run By: MI 1/17/2012 05:31PM




| # | FS |
|---|---|
| a | 7.60 |
| b | 7.64 |
| c | 7.65 |
| d | 7.65 |
| e | 7.66 |
| f | 7.66 |
| g | 7.67 |
| h | 7.68 |
| i | 7.68 |
| j | 7.69 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Riprap | 1 | 90.0 | 95.0 | 20.0 | 45.0 | 0.00 | 0.0 | W1 |
| FILL: CL | 2 | 125.0 | 127.0 | 1000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CL | 3 | 125.0 | 134.0 | 1600.0 | 0.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 130.0 | 134.0 | 4000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 125.0 | 130.0 | 3000.0 | 0.0 | 0.00 | 0.0 | W1 |
| CL | 6 | 125.0 | 127.0 | 500.0 | 0.0 | 0.00 | 0.0 | W1 |
| SM | 7 | 125.0 | 125.0 | 0.0 | 34.0 | 0.00 | 0.0 | W1 |

| Load | Value |
|---|---|
| L1 | 240 psf |

GSTABL7 v.2 FSmin=7.60

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

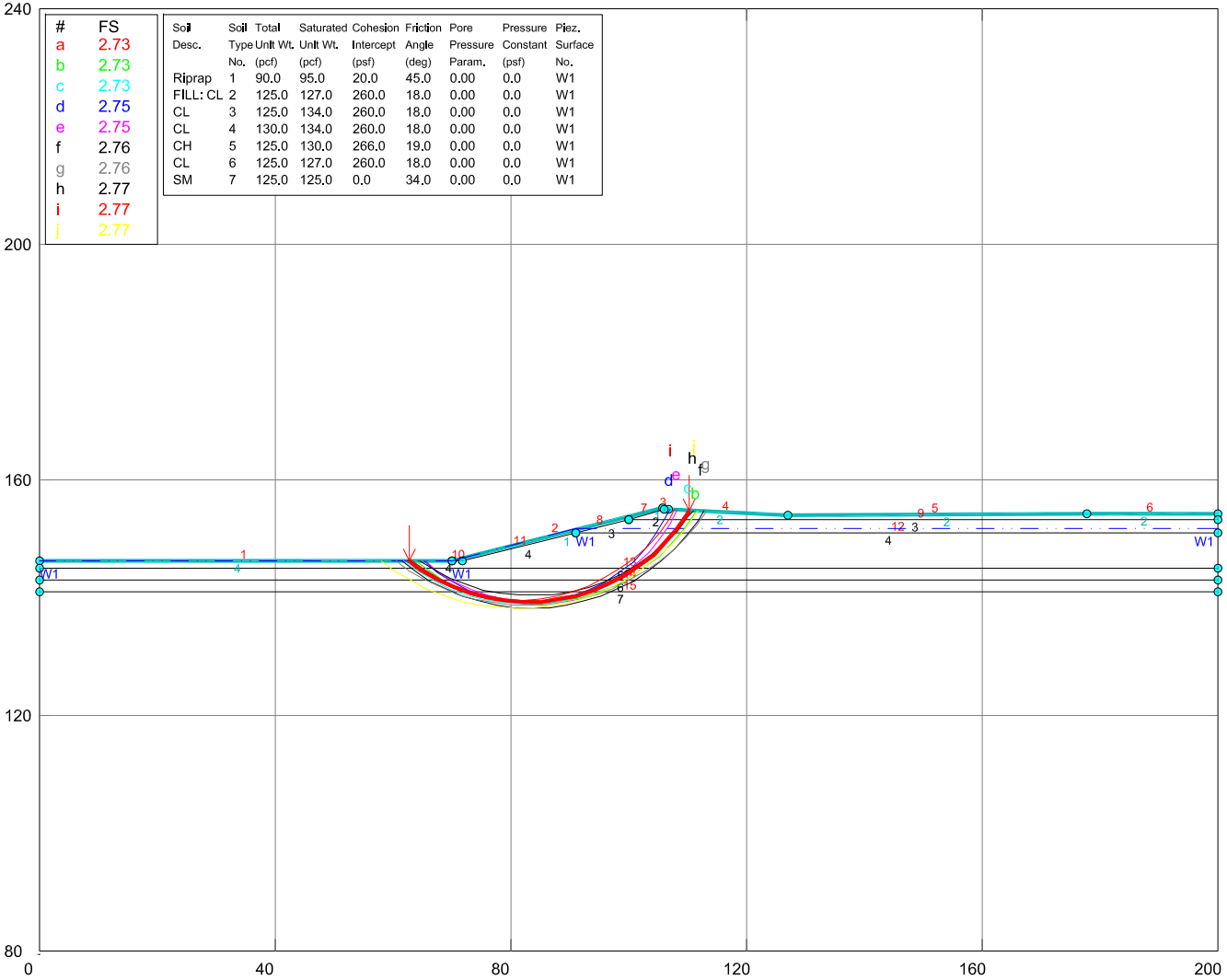
SHORT TERM (ST) CONDITION, BOX SEWER OUTFALL
STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C"
4H:1V RIPRAP LINED SLOPE, INSIDE,
BORING C-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 43

Box Sewer Outfall Stability Analysis, DrainageDitch"C",Inside,Rapid Drawdown,C-1

t:\geotechnical\projects\2011\11.13.180\slope_bs\rapid drawdown_tot (c-1).pl2 Run By: MI 1/16/2012 12:26PM




| # | FS |
|---|---|
| a | 2.73 |
| b | 2.73 |
| c | 2.73 |
| d | 2.75 |
| e | 2.75 |
| f | 2.76 |
| g | 2.76 |
| h | 2.77 |
| i | 2.77 |
| j | 2.77 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Riprap | 1 | 90.0 | 95.0 | 20.0 | 45.0 | 0.00 | 0.0 | W1 |
| FILL: CL | 2 | 125.0 | 127.0 | 260.0 | 18.0 | 0.00 | 0.0 | W1 |
| CL | 3 | 125.0 | 134.0 | 260.0 | 18.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 130.0 | 134.0 | 260.0 | 18.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 125.0 | 130.0 | 266.0 | 19.0 | 0.00 | 0.0 | W1 |
| CL | 6 | 125.0 | 127.0 | 260.0 | 18.0 | 0.00 | 0.0 | W1 |
| SM | 7 | 125.0 | 125.0 | 0.0 | 34.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.73

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

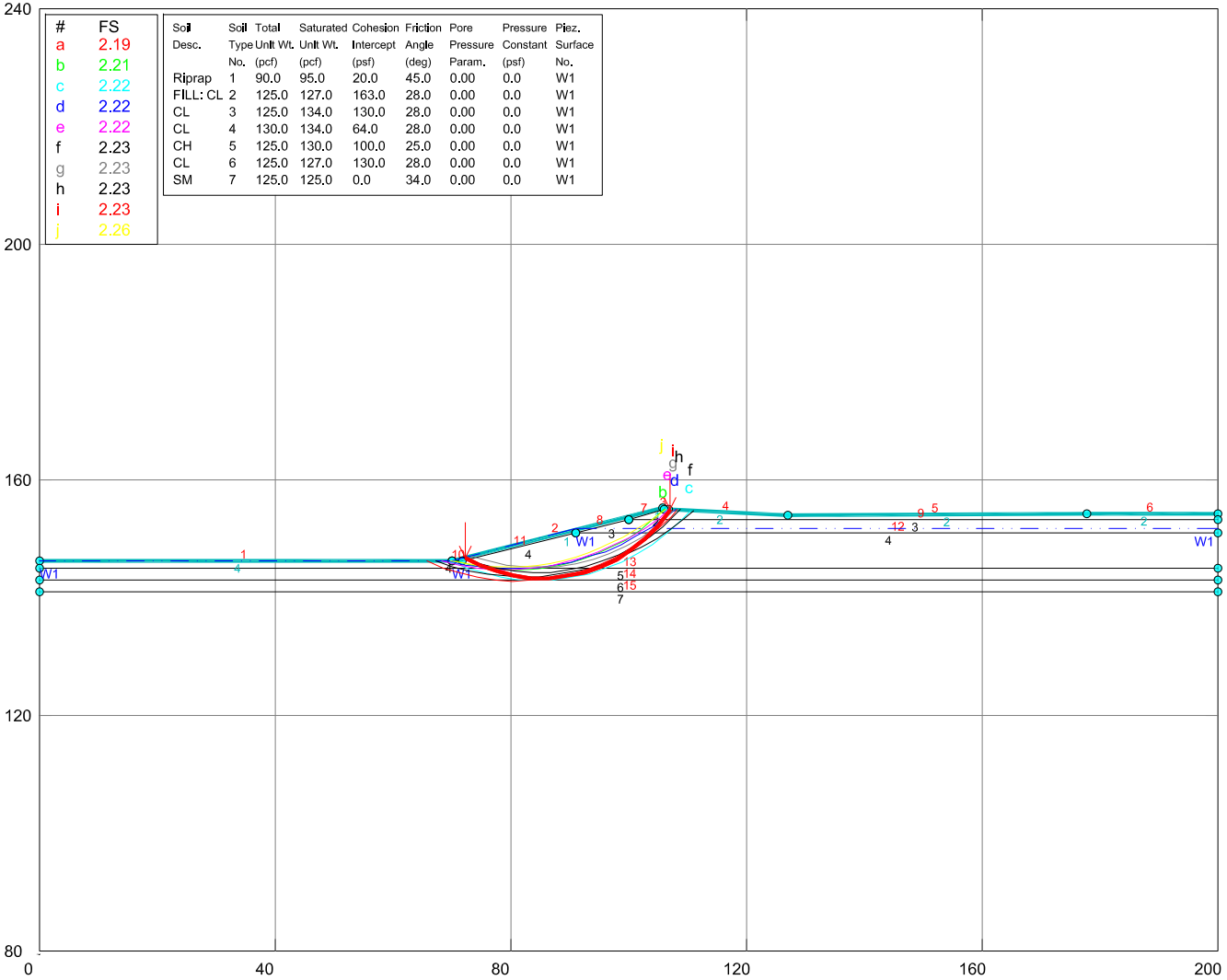
RAPID DRAWDOWN (RDD) CONDITION, BOX SEWER OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C", 4H:1V RIPRAP LINED SLOPE, INSIDE, TOTAL STRESS SOIL PARAMETERS, BORING C-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 44

Box Sewer Outfall Stability Analysis, DrainageDitch"C",Inside,Rapid Drawdown,C-1

t:\geotechnical\projects\2011\11.13.180\slope_bs\rapid drawdown_effc (c-1).pl2 Run By: MI 1/16/2012 08:08AM




| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Riprap | 1 | 90.0 | 95.0 | 20.0 | 45.0 | 0.00 | 0.0 | W1 |
| FILL: CL | 2 | 125.0 | 127.0 | 163.0 | 28.0 | 0.00 | 0.0 | W1 |
| CL | 3 | 125.0 | 134.0 | 130.0 | 28.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 130.0 | 134.0 | 64.0 | 28.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 125.0 | 130.0 | 100.0 | 25.0 | 0.00 | 0.0 | W1 |
| CL | 6 | 125.0 | 127.0 | 130.0 | 28.0 | 0.00 | 0.0 | W1 |
| SM | 7 | 125.0 | 125.0 | 0.0 | 34.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=2.19

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

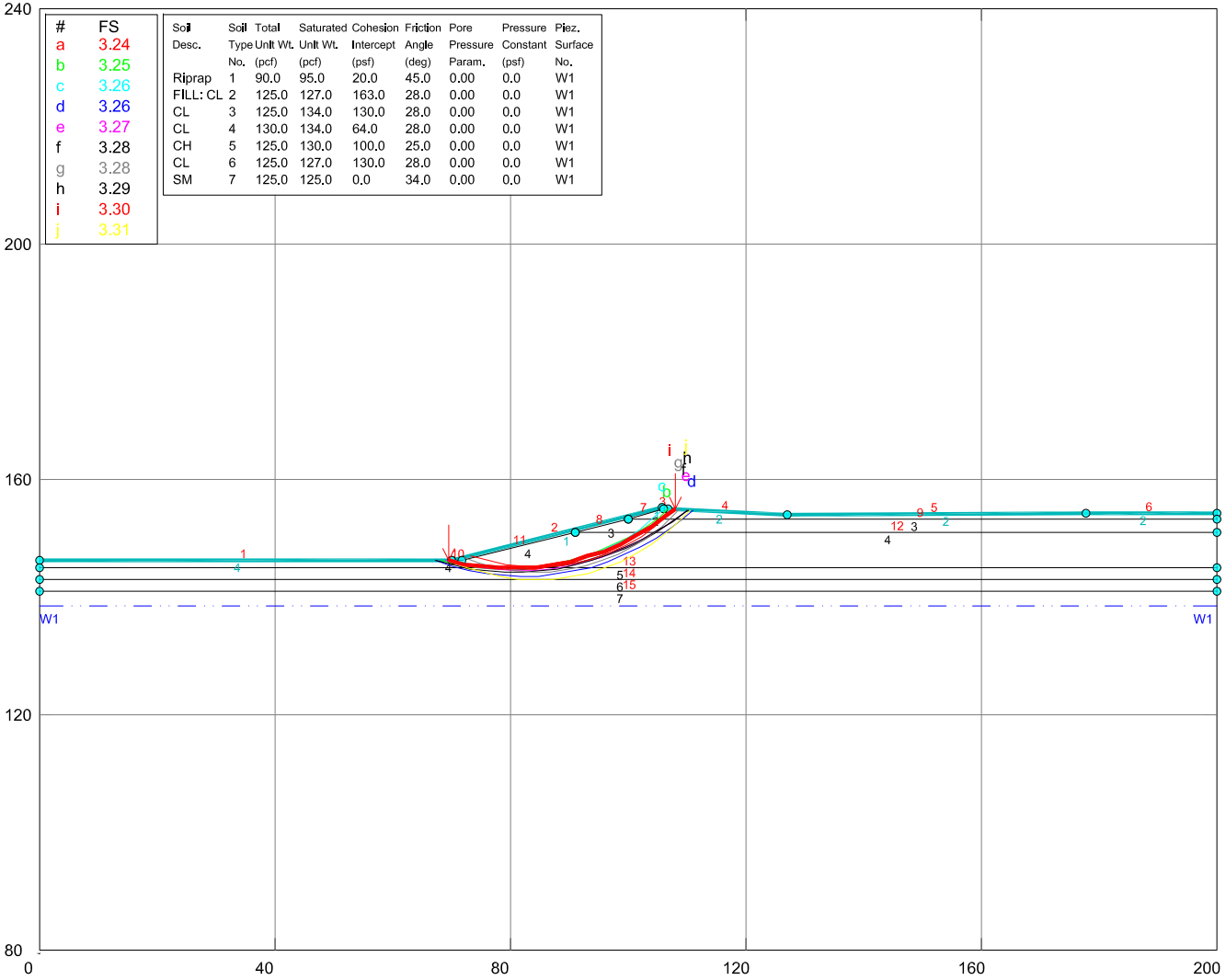
RAPID DRAWDOWN (RDD) CONDITION, BOX SEWER OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C", 4H:1V RIPRAP LINED SLOPE, INSIDE, EFFECTIVE STRESS SOIL PARAMETERS, BORING C-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 45

Box Sewer Outfall Stability Analysis, Drainage Ditch"C", Inside, Long Term,C-1

t:\geotechnical\projects\2011\11.13.180\slope_bs\long term (c-1).pl2 Run By: MI 1/16/2012 08:08AM




| # | FS |
|---|---|
| a | 3.24 |
| b | 3.25 |
| c | 3.26 |
| d | 3.26 |
| e | 3.27 |
| f | 3.28 |
| g | 3.28 |
| h | 3.29 |
| i | 3.30 |
| j | 3.31 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Riprap | 1 | 90.0 | 95.0 | 20.0 | 45.0 | 0.00 | 0.0 | W1 |
| FILL: CL | 2 | 125.0 | 127.0 | 163.0 | 28.0 | 0.00 | 0.0 | W1 |
| CL | 3 | 125.0 | 134.0 | 130.0 | 28.0 | 0.00 | 0.0 | W1 |
| CL | 4 | 130.0 | 134.0 | 64.0 | 28.0 | 0.00 | 0.0 | W1 |
| CH | 5 | 125.0 | 130.0 | 100.0 | 25.0 | 0.00 | 0.0 | W1 |
| CL | 6 | 125.0 | 127.0 | 130.0 | 28.0 | 0.00 | 0.0 | W1 |
| SM | 7 | 125.0 | 125.0 | 0.0 | 34.0 | 0.00 | 0.0 | W1 |

GSTABL7 v.2 FSmin=3.24

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

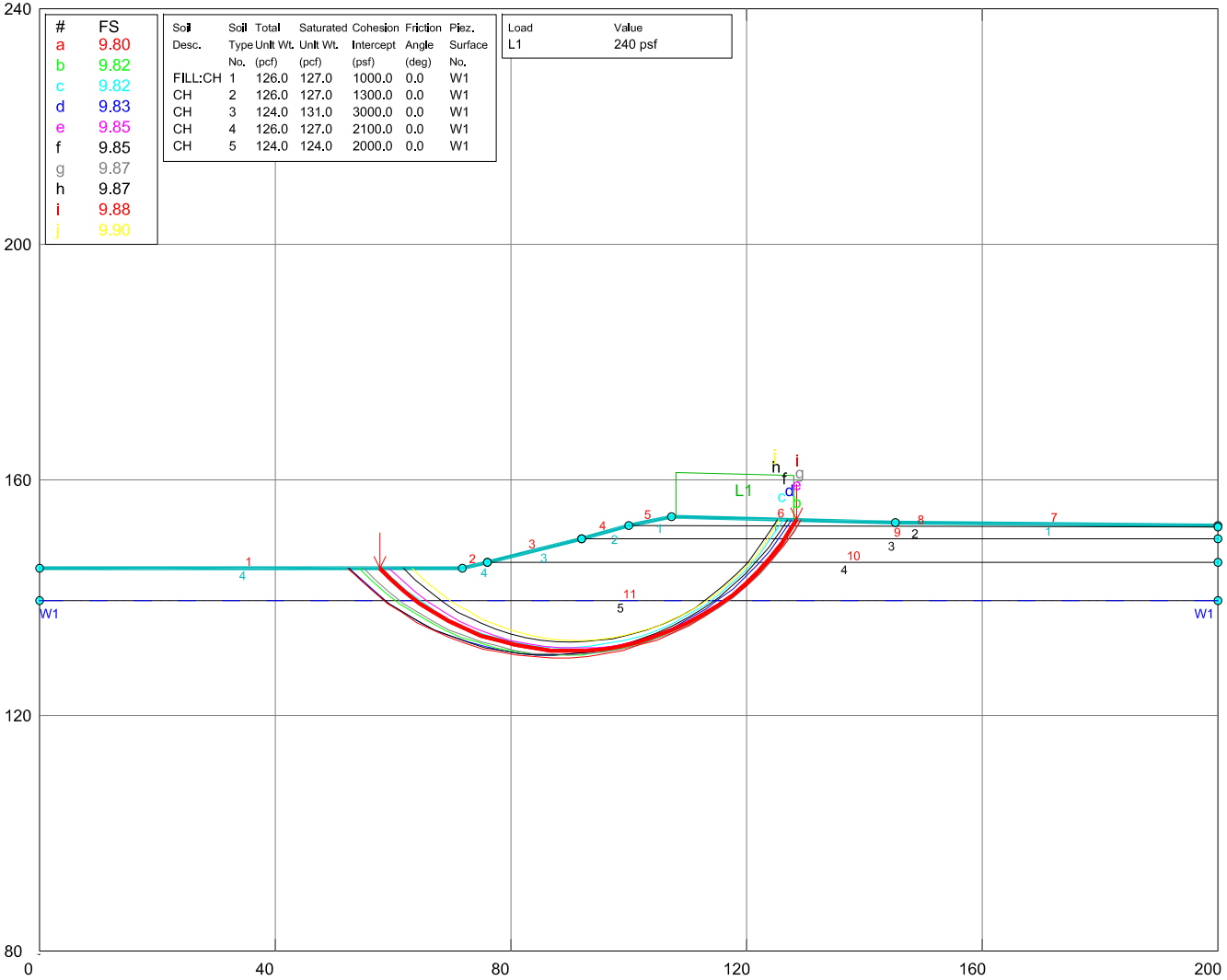
LONG TERM (LT) CONDITION, BOX SEWER OUTFALL SLOPE STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C", 4H:1V RIPRAP LINED SLOPE, INSIDE, BORING C-1 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 46

## Pipe Outfall Stability Analysis,DrainageDitch "C", Inside, Short Term, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\in_short term (c-3).pl2 Run By: MI 1/16/2012 11:21AM



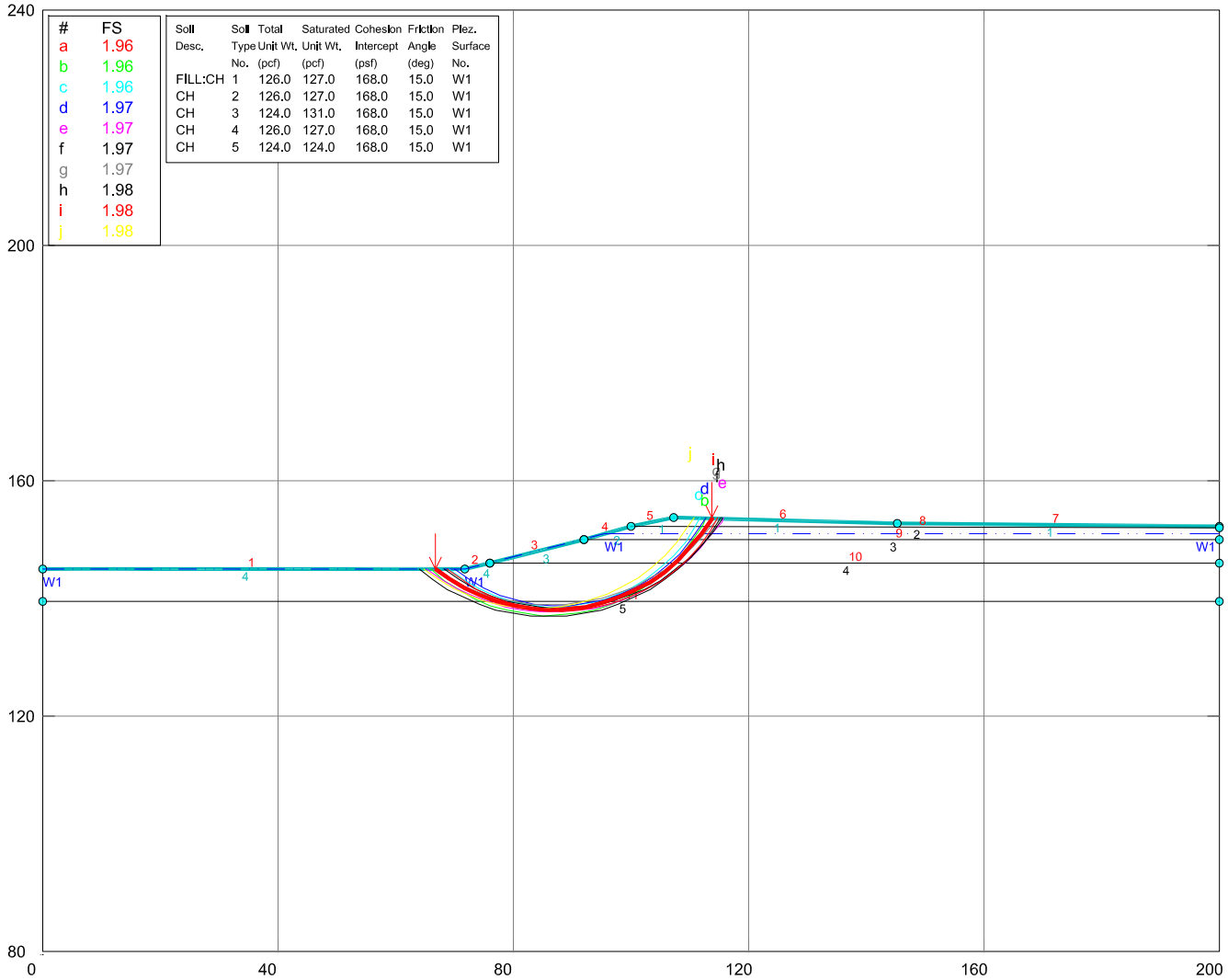

GSTABL7 v.2 FSmin=9.80

Safety Factors Are Calculated By The Modified Bishop Method

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | SHORT TERM (ST) CONDITION, PIPE OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C", 4H:1V GRASS LINED SLOPE, INSIDE, BORING C-3 SOIL PROFILE |
| CLR, INC.<br>WALLER, TEXAS | | TWEI PROJECT NO.: 11.13.180 / FIGURE 47 |

Pipe Outfall Stability Analysis,DrainageDitch "C", Inside,Rapid Drawdown, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\in_rapid drawdown_tot (c-3).pl2 Run By: MI 1/16/2012 10:52AM




GSTABL7 v.2 FSmin=1.96

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

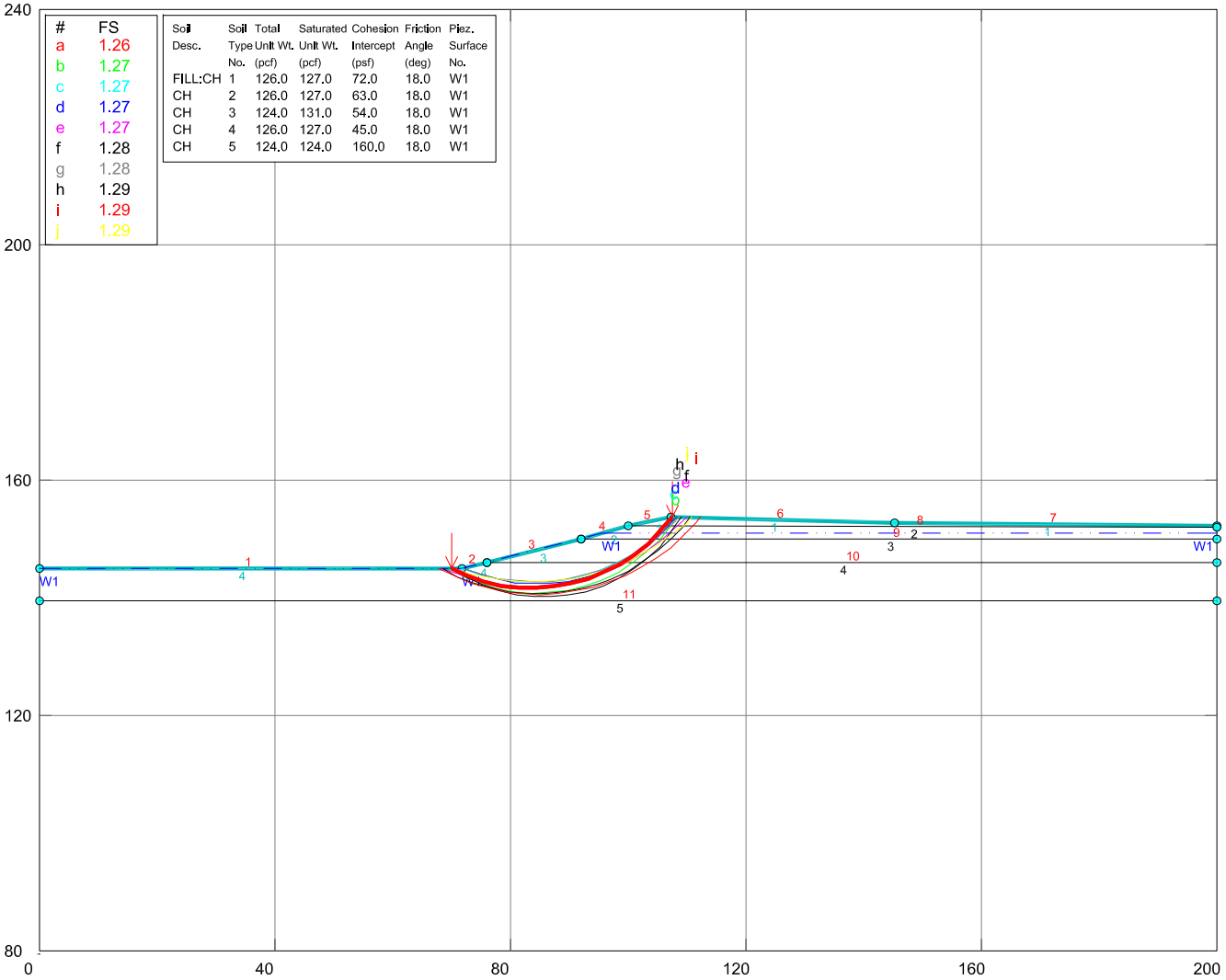
RAPID DRAWDOWN (RDD) CONDITION, PIPE OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C" 4H:1V GRASS LINED SLOPE, INSIDE, TOTAL STRESS SOIL PARAMETERS, BORING C-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 48

Pipe Outfall Stability Analysis,DrainageDitch "C", Inside,Rapid Drawdown, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\in_rapid drawdown_effc (c-3).pl2 Run By: MI 1/16/2012 10:48AM




| # | FS |
|---|---|
| a | 1.26 |
| b | 1.27 |
| c | 1.27 |
| d | 1.27 |
| e | 1.27 |
| f | 1.28 |
| g | 1.28 |
| h | 1.29 |
| i | 1.29 |
| j | 1.29 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| FILL:CH | 1 | 126.0 | 127.0 | 72.0 | 18.0 | W1 |
| CH | 2 | 126.0 | 127.0 | 63.0 | 18.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 54.0 | 18.0 | W1 |
| CH | 4 | 126.0 | 127.0 | 45.0 | 18.0 | W1 |
| CH | 5 | 124.0 | 124.0 | 160.0 | 18.0 | W1 |

GSTABL7 v.2 FSmin=1.26

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

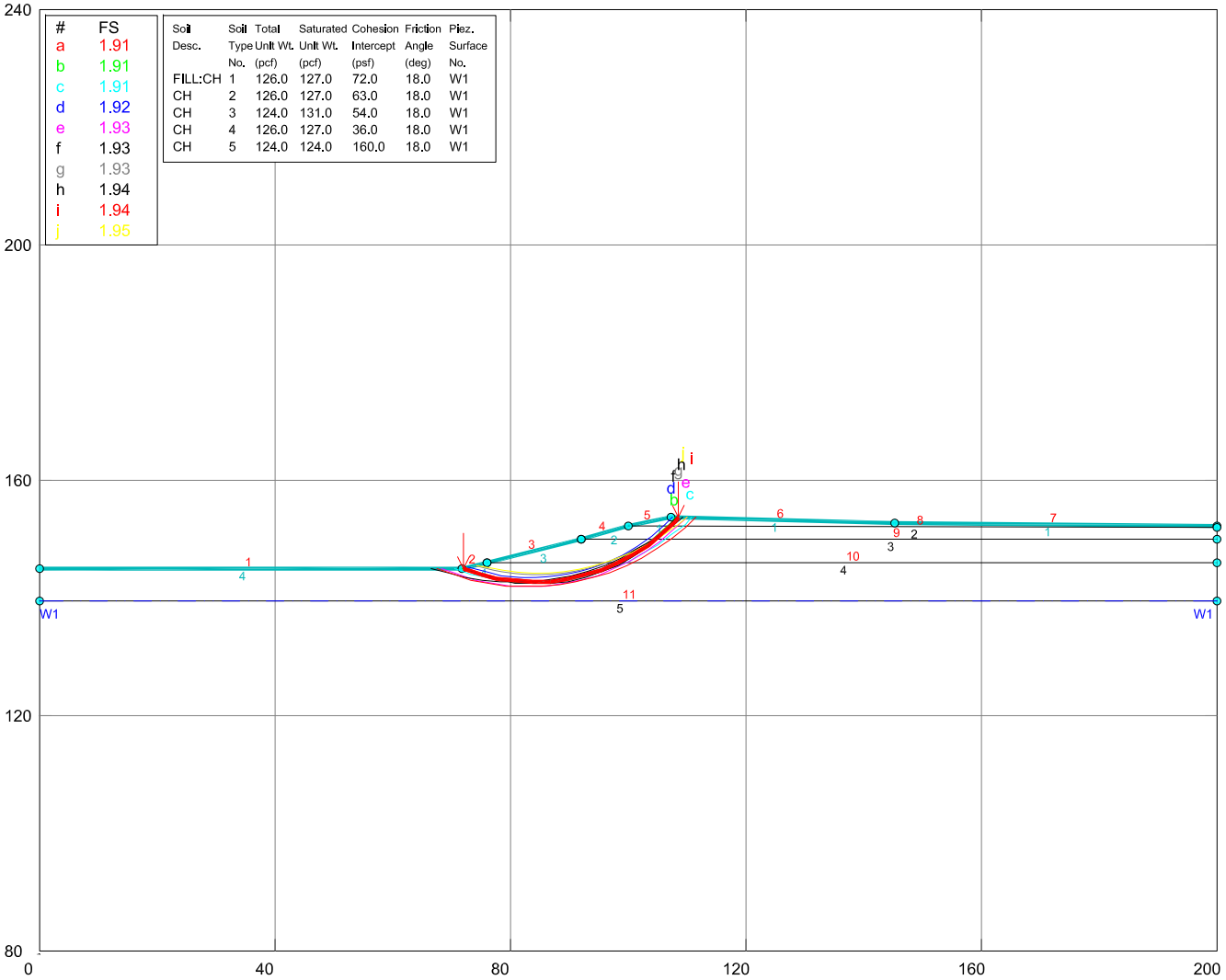
RAPID DRAWDOWN (RDD) CONDITION, PIPE OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C" 4H:1V GRASS LINED SLOPE, INSIDE, EFFECTIVE STRESS SOIL PARAMETERS, BORING C-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 49

Pipe Outfall Stability Analysis,DrainageDitch "C", Inside, Long Term, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\in_long term (c-3).pl2 Run By: MI 1/16/2012 10:50AM




| # | FS |
|---|---|
| a | 1.91 |
| b | 1.91 |
| c | 1.91 |
| d | 1.92 |
| e | 1.93 |
| f | 1.93 |
| g | 1.93 |
| h | 1.94 |
| i | 1.94 |
| j | 1.95 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| FILL:CH | 1 | 126.0 | 127.0 | 72.0 | 18.0 | W1 |
| CH | 2 | 126.0 | 127.0 | 63.0 | 18.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 54.0 | 18.0 | W1 |
| CH | 4 | 126.0 | 127.0 | 36.0 | 18.0 | W1 |
| CH | 5 | 124.0 | 124.0 | 160.0 | 18.0 | W1 |

GSTABL7 v.2 FSmin=1.91

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

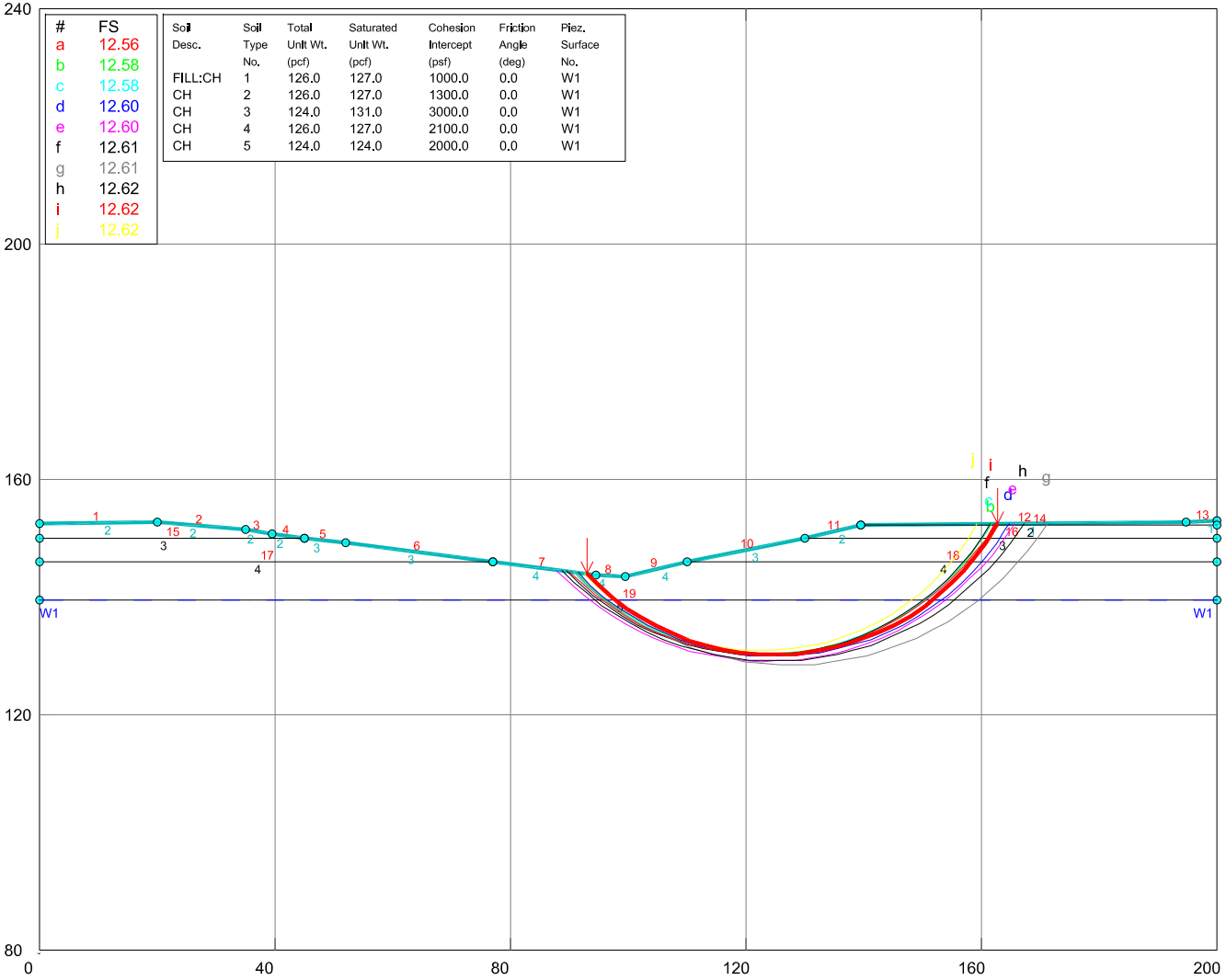
LONG TERM (LT) CONDITION, PIPE OUTFALL SLOPE
STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C"
4H:1V GRASS LINED SLOPE, INSIDE,
BORING C-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 50

Pipe Outfall Stability Analysis,DrainageDitch"C", Out Side, Short Term, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\out_short term (c-3).pl2 Run By: MI 1/17/2012 05:33PM




| # | FS |
|---|---|
| a | 12.56 |
| b | 12.58 |
| c | 12.58 |
| d | 12.60 |
| e | 12.60 |
| f | 12.61 |
| g | 12.61 |
| h | 12.62 |
| i | 12.62 |
| j | 12.62 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| FILL:CH | 1 | 126.0 | 127.0 | 1000.0 | 0.0 | W1 |
| CH | 2 | 126.0 | 127.0 | 1300.0 | 0.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 3000.0 | 0.0 | W1 |
| CH | 4 | 126.0 | 127.0 | 2100.0 | 0.0 | W1 |
| CH | 5 | 124.0 | 124.0 | 2000.0 | 0.0 | W1 |

GSTABL7 v.2 FSmin=12.56

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

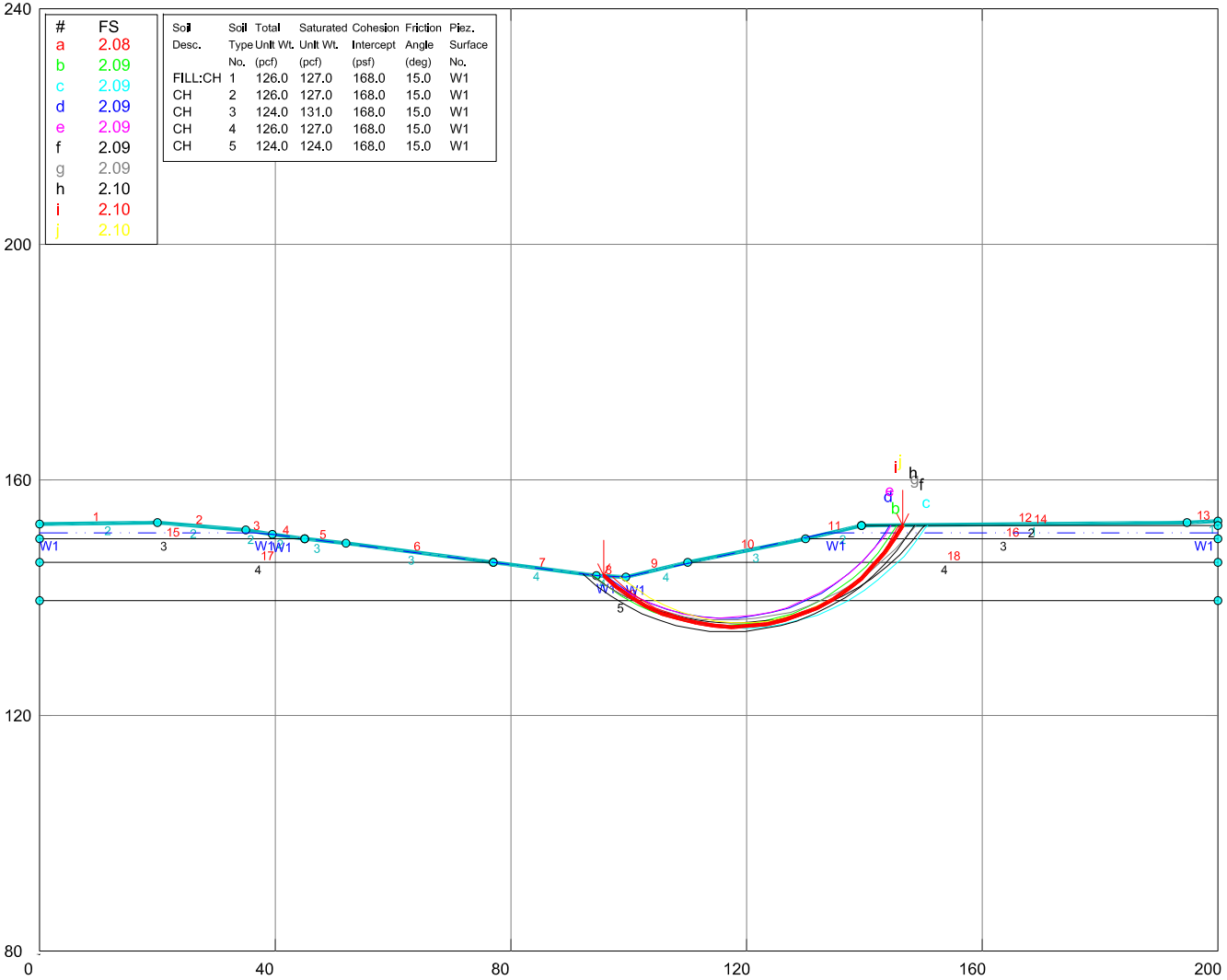
SHORT TERM (ST) CONDITION, PIPE OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C", 4.5H:1V GRASS LINED SLOPE, OUTSIDE, BORING C-3 SOIL PROFILE

TWEI PROJECT NO.: 11.13.180

FIGURE 51

Pipe Outfall Stability Analysis,DrainageDitch"C", Out Side,Rapid Drawdown, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\out_rapid drawdown_tot (c-3).pl2 Run By: MI 1/16/2012 11:14AM



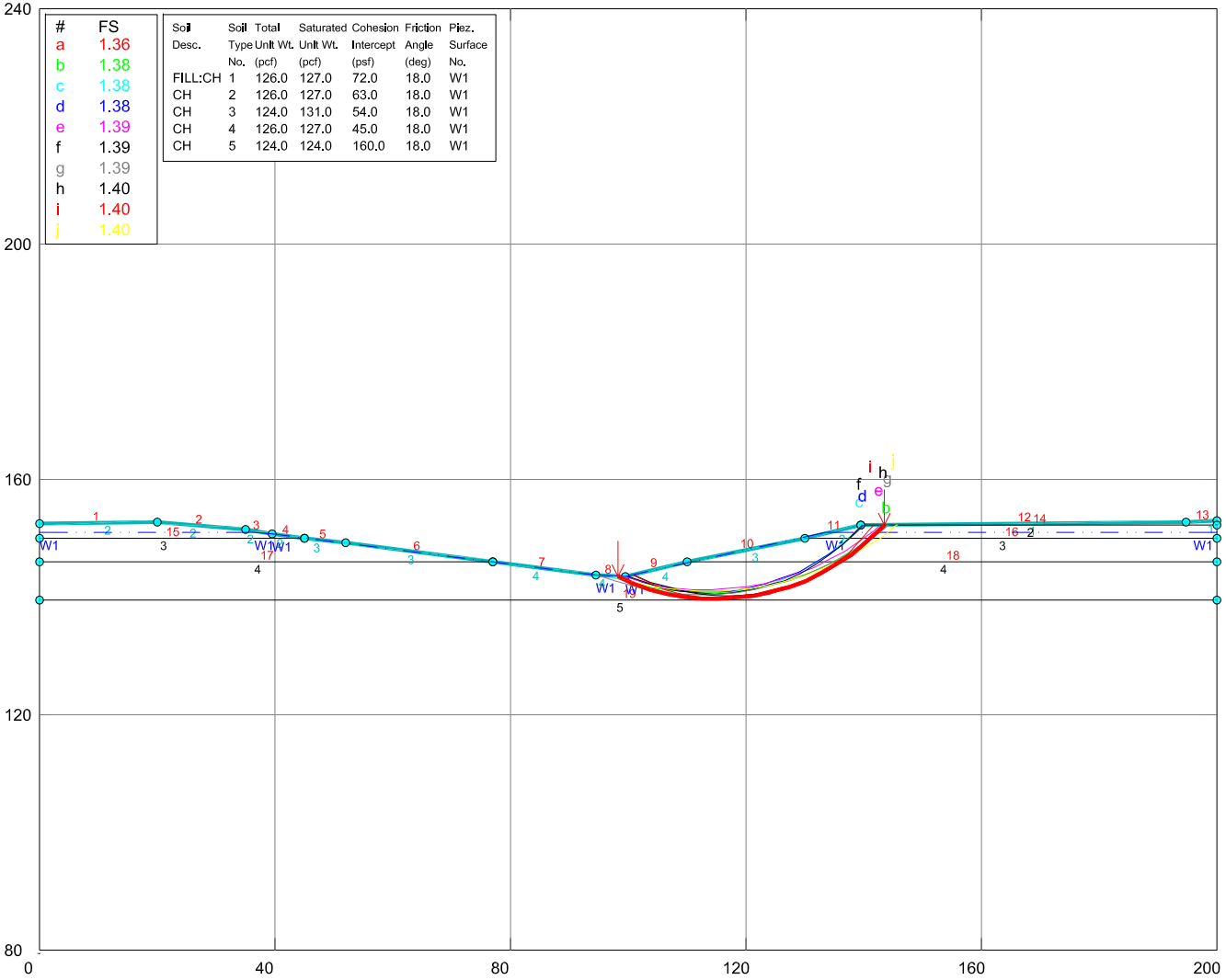

GSTABL7 v.2 FSmin=2.08

Safety Factors Are Calculated By The Modified Bishop Method

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | RAPID DRAWDOWN (RDD) CONDITION, PIPE OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C"<br>4.5H:1V GRASS LINED SLOPE, OUTSIDE, TOTAL STRESS SOIL PARAMETERS, BORING C-3 SOIL PROFILE |
| CLR, INC.<br>WALLER, TEXAS | | TWEI PROJECT NO.: 11.13.180 / FIGURE 52 |

Pipe Outfall Stability Analysis,DrainageDitch"C", Out Side,Rapid Drawdown, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\out_rapid drawdown_effc (c-3).pl2 Run By: MI 1/16/2012 11:13AM



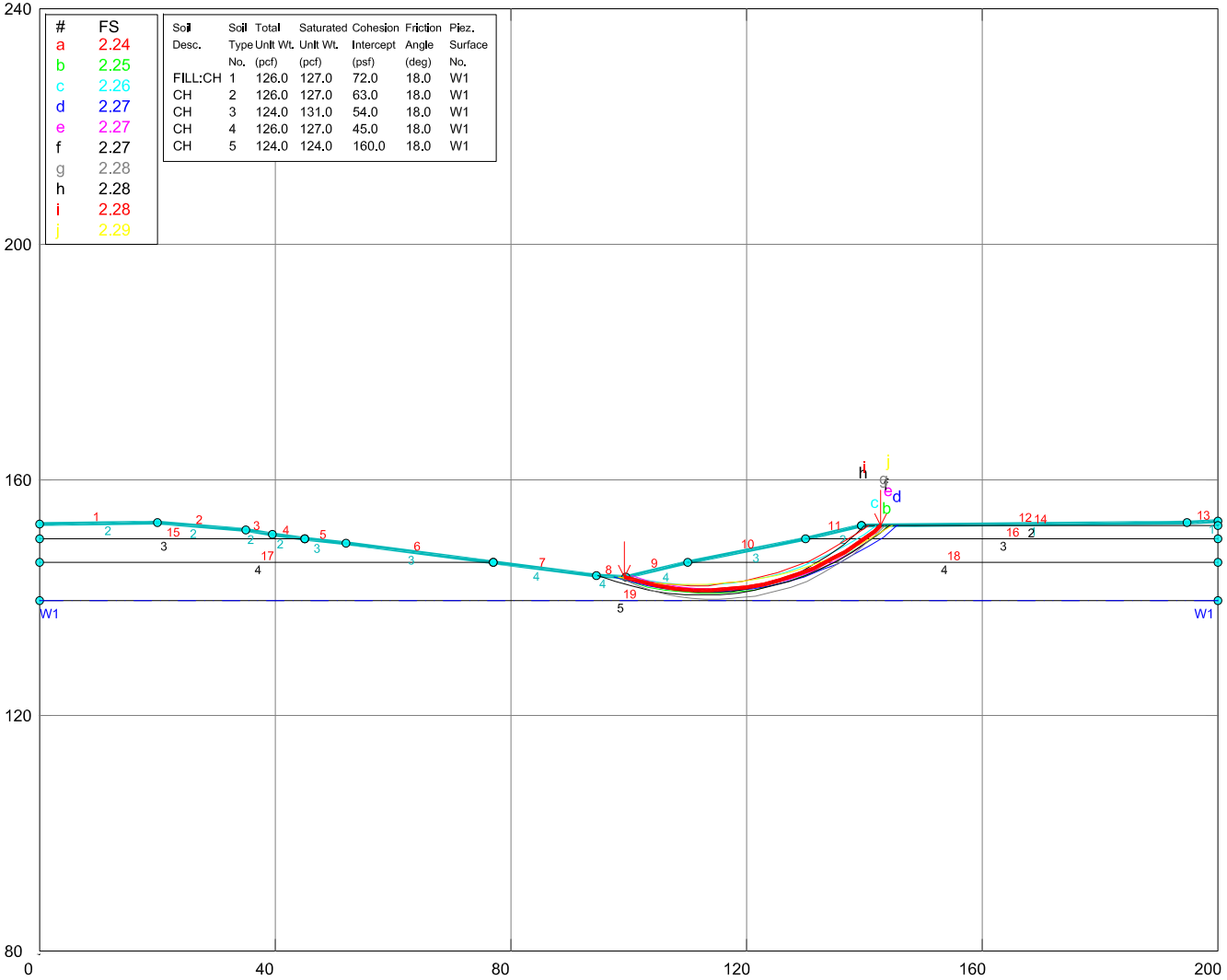

GSTABL7 v.2 FSmin=1.36

Safety Factors Are Calculated By The Modified Bishop Method

| | | |
|---|---|---|
| BUFFALO SPEEDWAY EXTENSION<br>FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.<br>STORM SEWER, WATERLINE BRIDGE OVERPASS &<br>OFF-SITE DRAINAGE DITCHES<br>HOUSTON, TEXAS | Tolunay-Wong Engineers, Inc.<br>Houston, Texas | RAPID DRAWDOWN (RDD) CONDITION, PIPE OUTFALL STABILITY ANALYSIS, OFF-SITE DRAINAGE DITCH "C" 4.5H:1V GRASS LINED SLOPE, OUTSIDE, EFFECTIVE STRESS SOIL PARAMETERS, BORING C-3 SOIL PROFILE |
| CLR, INC.<br>WALLER, TEXAS | | TWEI PROJECT NO.: 11.13.180 / FIGURE 53 |

Pipe Outfall Stability Analysis,DrainageDitch"C", Out Side, Long Term, C-3

t:\geotechnical\projects\2011\11.13.180\slope_cgmp\out_long term (c-3).pl2 Run By: MI 1/16/2012 11:06AM




| # | FS |
|---|---|
| a | 2.24 |
| b | 2.25 |
| c | 2.26 |
| d | 2.27 |
| e | 2.27 |
| f | 2.27 |
| g | 2.28 |
| h | 2.28 |
| i | 2.28 |
| j | 2.29 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| FILL:CH | 1 | 126.0 | 127.0 | 72.0 | 18.0 | W1 |
| CH | 2 | 126.0 | 127.0 | 63.0 | 18.0 | W1 |
| CH | 3 | 124.0 | 131.0 | 54.0 | 18.0 | W1 |
| CH | 4 | 126.0 | 127.0 | 45.0 | 18.0 | W1 |
| CH | 5 | 124.0 | 124.0 | 160.0 | 18.0 | W1 |

GSTABL7 v.2 FSmin=2.24

Safety Factors Are Calculated By The Modified Bishop Method

BUFFALO SPEEDWAY EXTENSION
FROM W. AIRPORT BLVD. TO WILLOWBEND BLVD.
STORM SEWER, WATERLINE BRIDGE OVERPASS &
OFF-SITE DRAINAGE DITCHES
HOUSTON, TEXAS

CLR, INC.
WALLER, TEXAS

Tolunay-Wong Engineers, Inc.
Houston, Texas

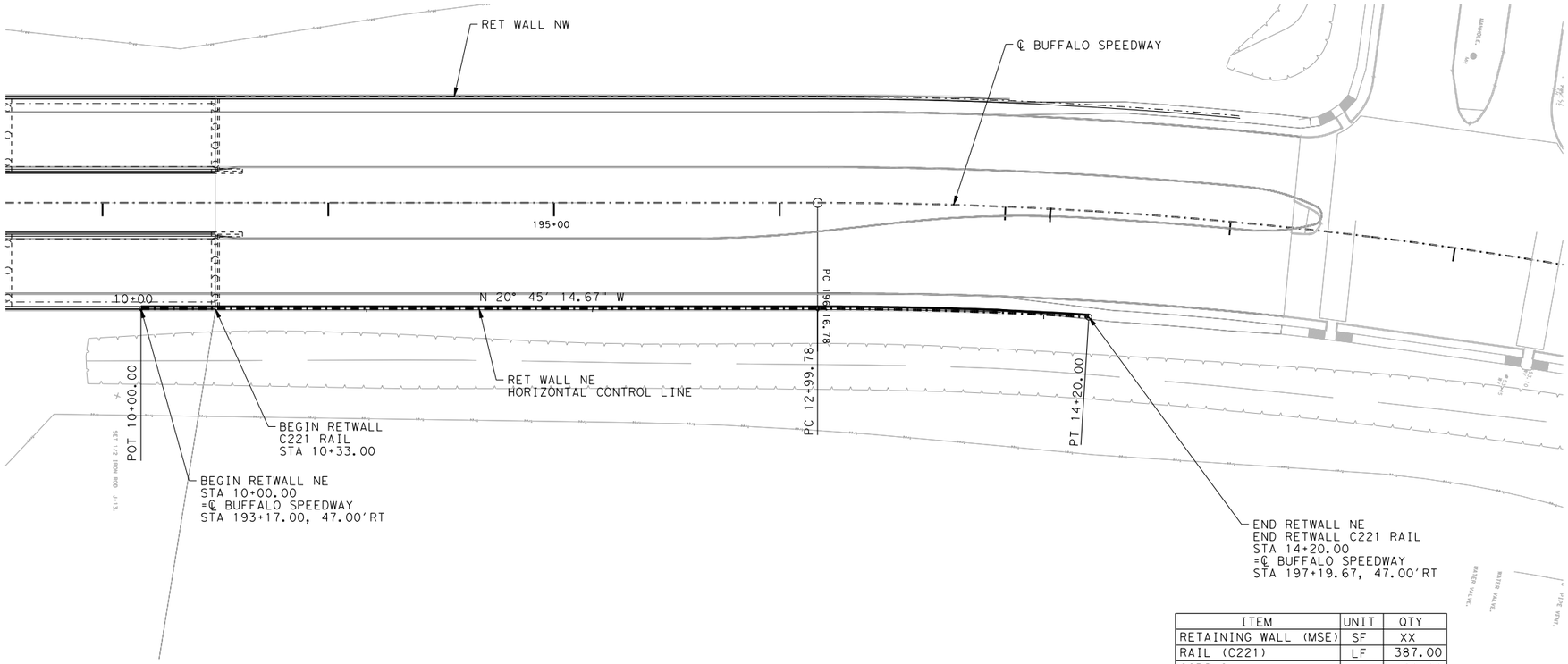
LONG TERM (LT) CONDITION, PIPE OUTFALL
SLOPE STABILITY ANALYSIS, OFF-SITE DRAINAGE
DITCH "C", 4.5H:1V GRASS LINED SLOPE, OUTSIDE,
BORING C-3 SOIL PROFILE

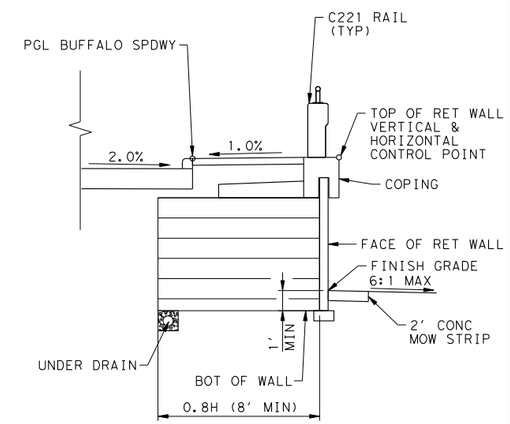
TWEI PROJECT NO.: 11.13.180

FIGURE 54

# APPENDIX A

# LAYOUTS OF MSE RETAINING WALLS AT BUFFALO SPEEDWAY BRIDGE OVERPASS CROSSING HOLMES ROAD

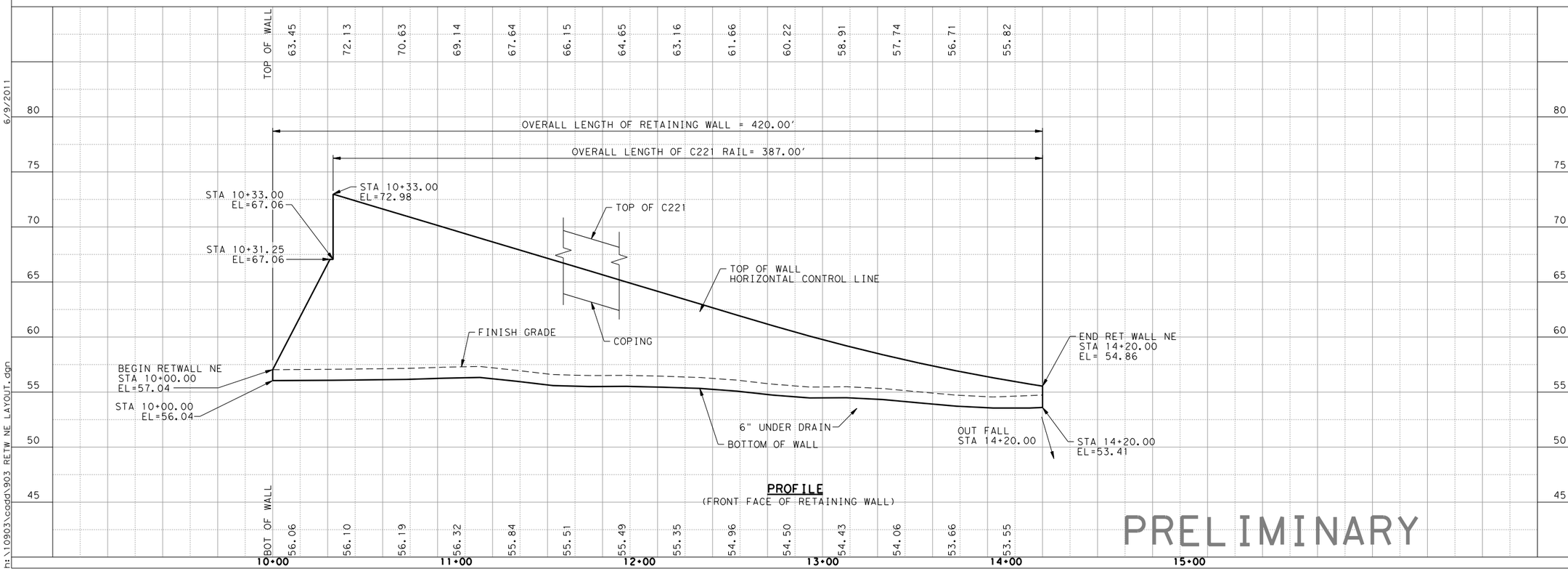



**TYPICAL MSE SECTION**

| ITEM | UNIT | QTY |
|---|---|---|
| RETAINING WALL (MSE) | SF | XX |
| RAIL (C221) | LF | 387.00 |
| COPING | LF | 420.00 |

HL 93 LOADING




**PROFILE**
(FRONT FACE OF RETAINING WALL)

PRELIMINARY

| No. | Date | Revisions | App. |
|---|---|---|---|

AGUIRRE & FIELDS LP
TRANSPORTATION • CIVIL • STRUCTURAL
ENGINEERS AND PLANNERS

CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275

SURVEYED BY:
FB NO:

ISSUED FOR INTERIM REVIEW ONLY
THIS PLAN IS NOT COMPLETE AND IS NOT INTENDED FOR BIDDING PURPOSES.
ENGINEER: OSCAR R.AGUIRRE
TX. REG. NO. 80138
DATE ISSUED: 6/9/2011
AGUIRRE & FIELDS LP #739

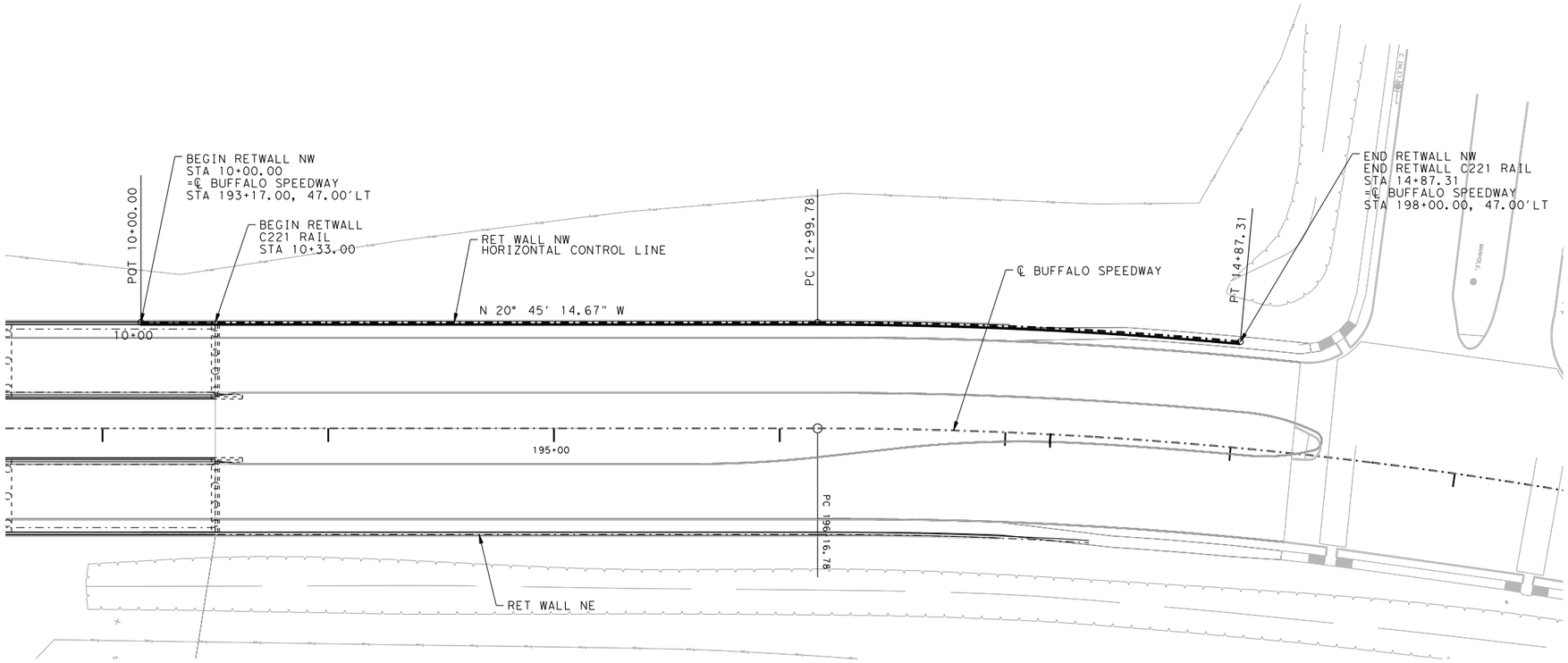
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

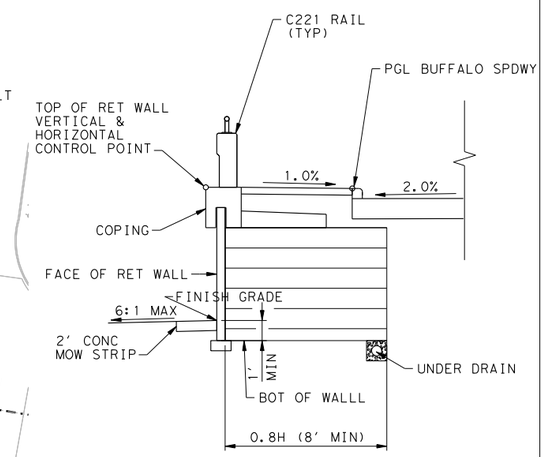
# BUFFALO SPEEDWAY RETAINING WALL NE LAYOUT

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| S-000000-0000-4 | |
| DRAWING SCALE | |
| HORIZONTAL 1"=30' VERTICAL 1"=6" | |
| CITY OF HOUSTON PM | |
| JOHN DOE, PE | |

LOG NO. XX-XXXX

5:52:28 PM
6/9/2011
n:\10903\cadd\903 RETW NE LAYOUT.dgn

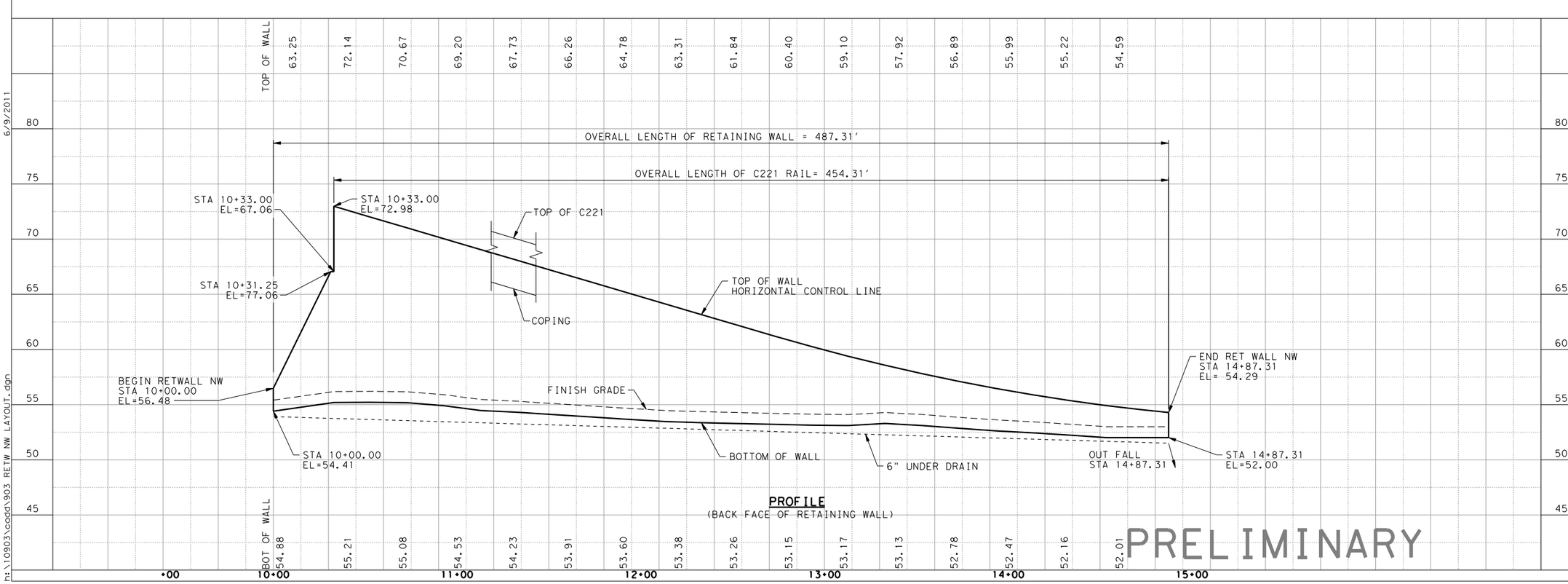



**TYPICAL MSE SECTION**

| ITEM | UNIT | QTY |
|---|---|---|
| RETAINING WALL (MSE) | SF | XX |
| RAIL (C221) | LF | 451.31 |
| COPING | LF | 487.31 |

HL 93 LOADING




**PROFILE**
(BACK FACE OF RETAINING WALL)

PRELIMINARY

| No. | Date | Revisions | App. |
|---|---|---|---|

**AGUIRRE & FIELDS LP**
TRANSPORTATION • CIVIL • STRUCTURAL
ENGINEERS AND PLANNERS

**CLR, Inc.**
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275

ISSUED FOR INTERIM REVIEW ONLY
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ENGINEER: OSCAR R.AGUIRRE
TX. REG. NO. 80138
DATE ISSUED: 6/9/2011
AGUIRRE & FIELDS LP #739

SURVEYED BY:
FB NO:

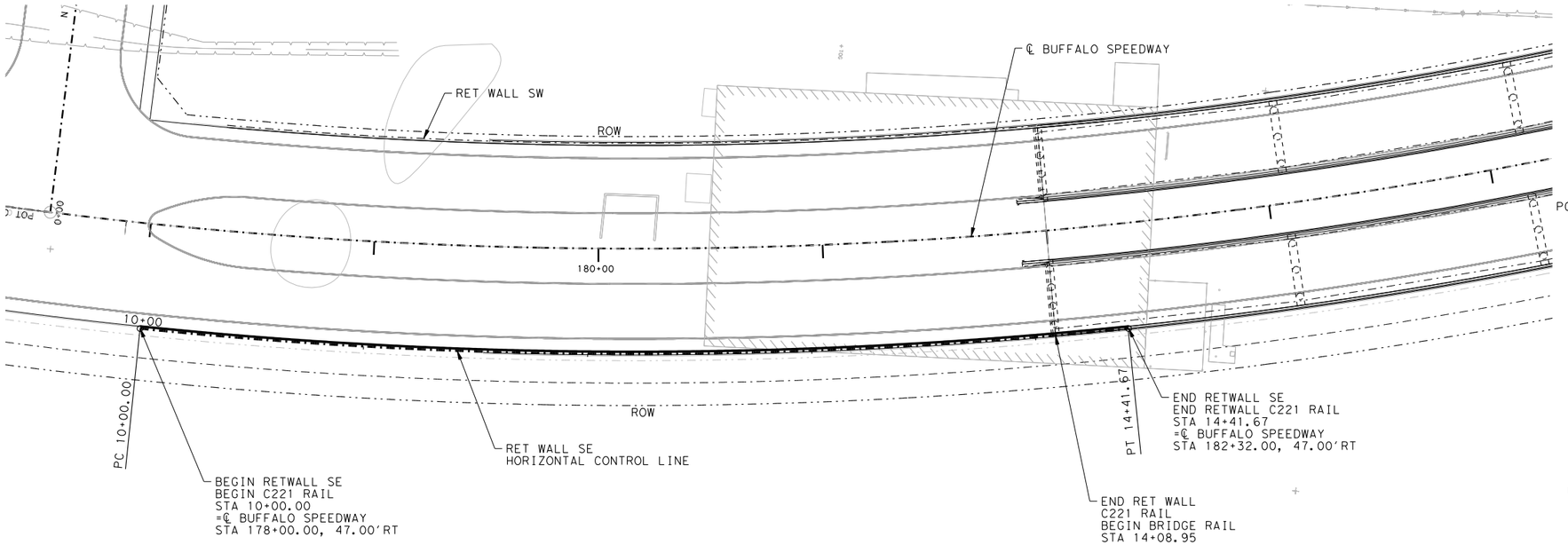
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY RETAINING WALL NW LAYOUT

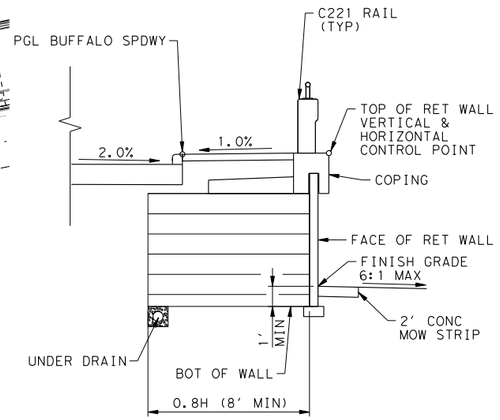
| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| S-000000-0000-4 | |
| DRAWING SCALE | |
| HORIZONTAL 1"=30' VERTICAL 1"=6' | |
| CITY OF HOUSTON PM | |
| JOHN DOE, PE | |

LOG NO. XX-XXXX

5:52:44 PM
6/9/2011
h:\10903\cadd\903 RETW NW LAYOUT.dgn

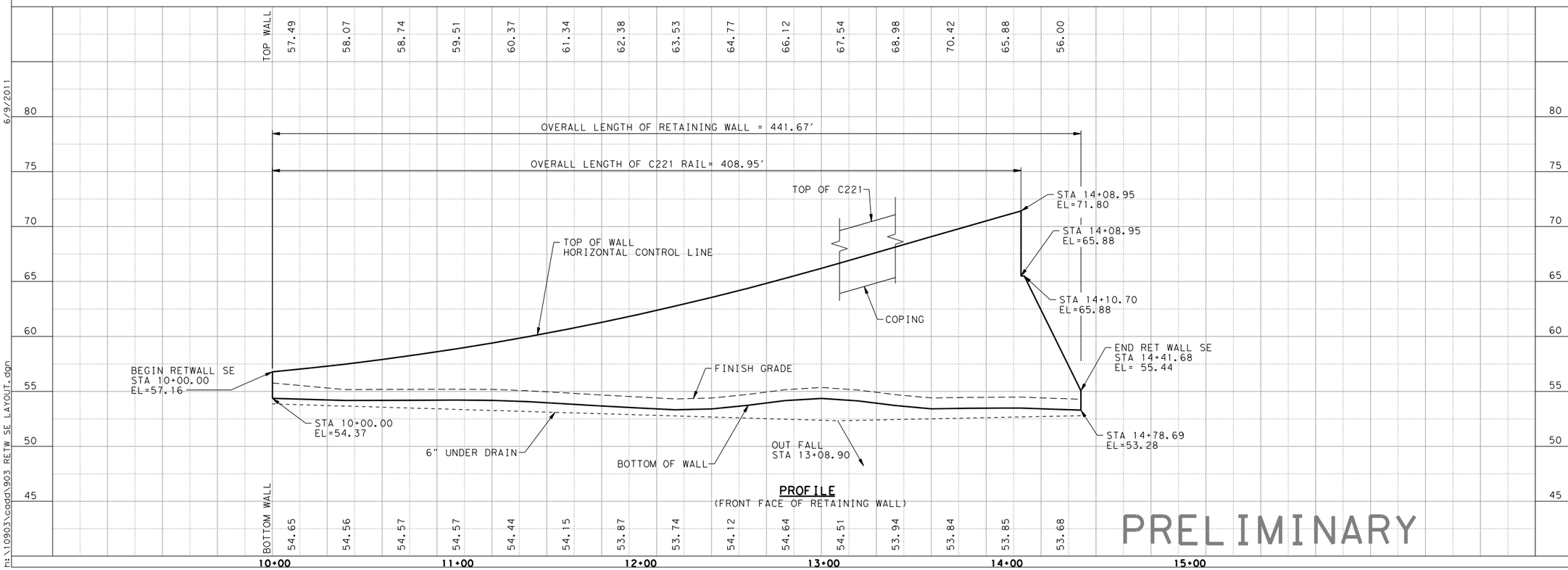



PLAN




TYPICAL MSE SECTION

| ITEM | UNIT | QTY |
|---|---|---|
| RETAINING WALL (MSE) | SF | XX |
| RAIL (C221) | LF | 408.95 |
| COPING | LF | 441.67 |




PROFILE
(FRONT FACE OF RETAINING WALL)

PRELIMINARY

HL 93 LOADING

| No. | Date | Revisions | App. |
|---|---|---|---|

AGUIRRE & FIELDS LP
TRANSPORTATION • CIVIL • STRUCTURAL
ENGINEERS AND PLANNERS

CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 482-0993
TX FIRM NO. 275

SURVEYED BY:
FB NO:

ISSUED FOR INTERIM REVIEW ONLY
THIS PLAN IS NOT COMPLETE AND IS NOT INTENDED FOR BIDDING PURPOSES.
ENGINEER: OSCAR R.AGUIRRE
TX. REG. NO. 80138
DATE ISSUED: 6/9/2011
AGUIRRE & FIELDS LP #739

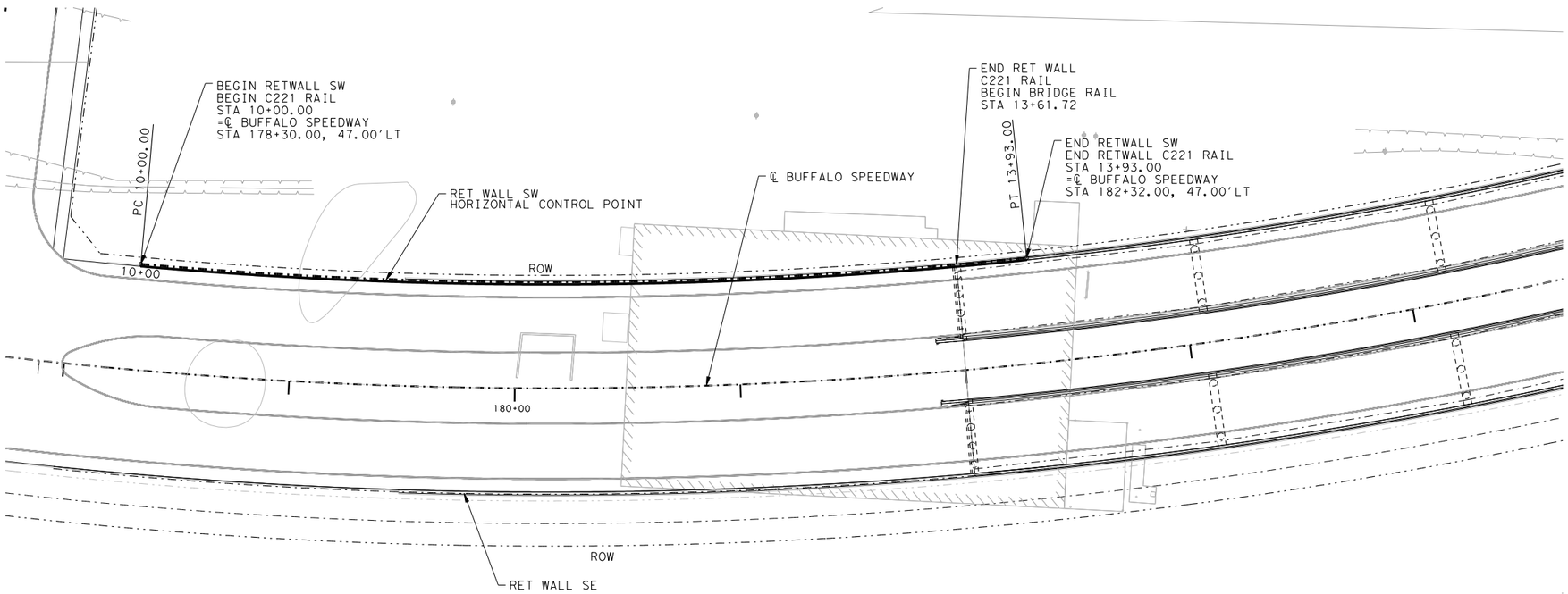
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

BUFFALO SPEEDWAY
RETAINING WALL
SE LAYOUT

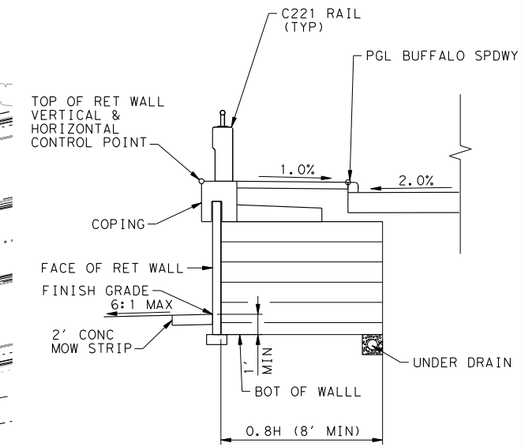
| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| S-000000-0000-4 | |
| DRAWING SCALE | |
| HORIZONTAL 1"=30' VERTICAL 1"=6" | |
| CITY OF HOUSTON PM | |
| JOHN DOE, PE | |

LOG NO. XX-XXXX

5:53:00 PM
6/9/2011
n:\10903\cadd\903 RETW SE LAYOUT.dgn

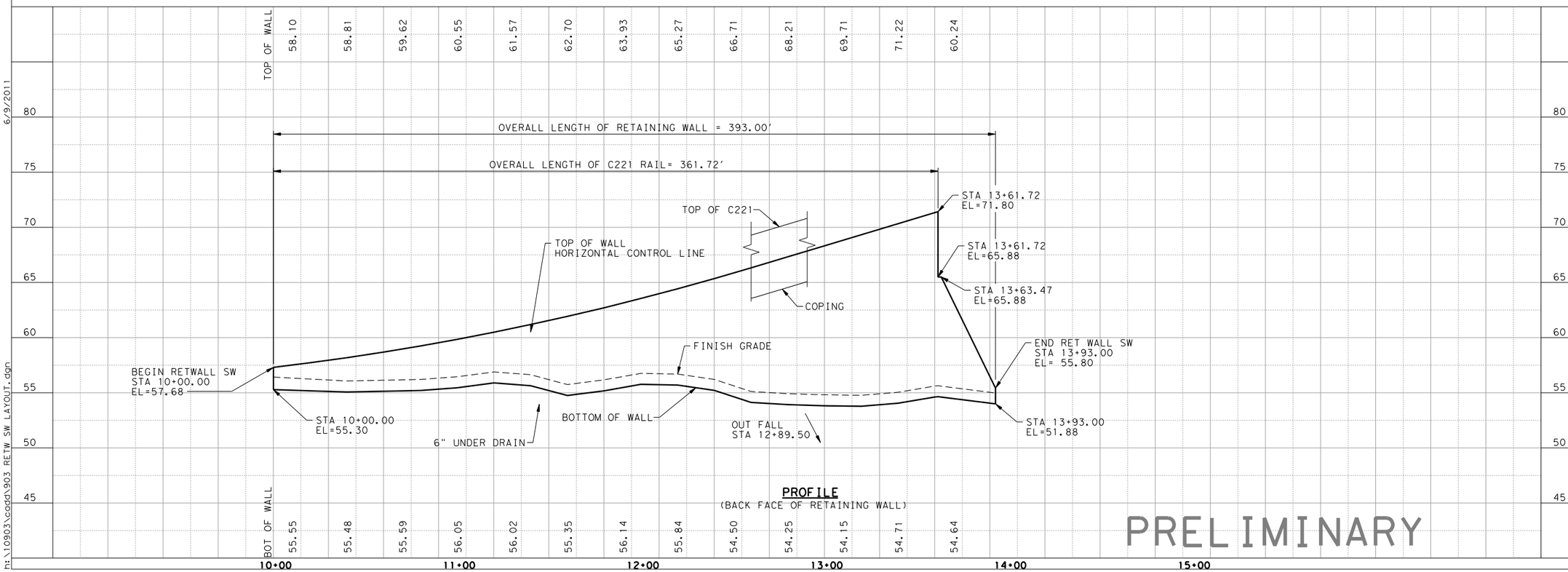



**PLAN**




**TYPICAL MSE SECTION**

| ITEM | UNIT | QTY |
|---|---|---|
| RETAINING WALL (MSE) | SF | XX |
| RAIL (C221) | LF | 361.72 |
| COPING | LF | 393.00 |




**PROFILE**
(BACK FACE OF RETAINING WALL)

PRELIMINARY

HL 93 LOADING

| No. | Date | Revisions | App. |
|---|---|---|---|

AGUIRRE & FIELDS LP
TRANSPORTATION • CIVIL • STRUCTURAL
ENGINEERS AND PLANNERS

CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 482-0993
TX FIRM NO. 275

ISSUED FOR INTERIM REVIEW ONLY
THIS PLAN IS NOT COMPLETE AND IS NOT INTENDED FOR BIDDING PURPOSES.

ENGINEER: OSCAR R.AGUIRRE
TX. REG. NO. 80138
DATE ISSUED: 6/9/2011
AGUIRRE & FIELDS LP #739

SURVEYED BY:
FB NO:

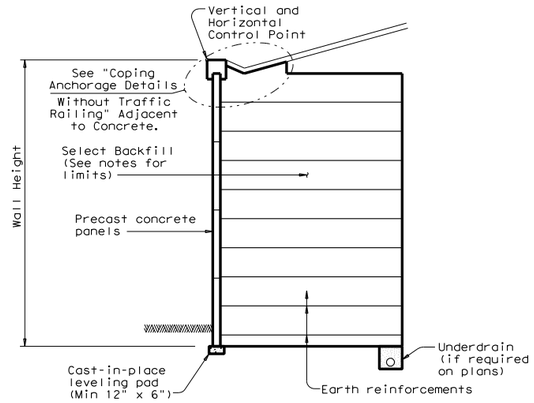
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

BUFFALO SPEEDWAY
RETAINING WALL
SW LAYOUT

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| S-000000-0000-4 | |
| DRAWING SCALE | |
| HORIZONTAL 1"=30' VERTICAL 1"=6" | |
| CITY OF HOUSTON PM | |
| JOHN DOE, PE | |

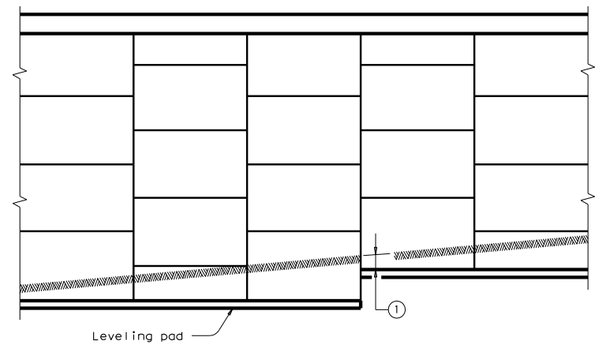
LOG NO. XX-XXXX

5:53:22 PM
6/9/2011
n:\10903\cadd\903 RETW SW LAYOUT.dgn




## TYPICAL SECTION

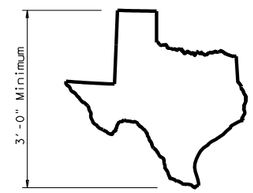
(Wall at bottom of slope)



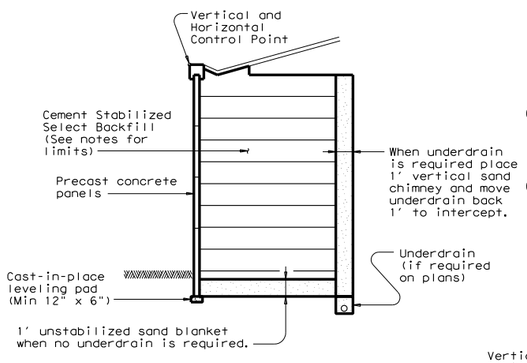

## ELEVATION

1. Unless noted elsewhere in the plans, 1' minimum cover shall be provided from the top of leveling pad to finish grade.
2. Map of Texas emblem shall be formed into a wall panel next to each bridge abutment. The exact location of each emblem shall be approved by the Engineer. The cost of forming the emblems will not be paid for directly, but shall be incidental to the Item "Retaining Wall". The map of Texas shall be inset a minimum of ¾" into the face of the panel, and shall receive a smooth finish. The inset area shall be finished in a contrasting color as approved by the Engineer.
3. Precast coping shall be anchored to prevent rotation or displacement. Use these details to develop custom anchorage for precast copings. Details shall include coping reinforcement. Concrete flume (if required) shall be paid for separately from Item 423.
4.

| SELECT BACKFILL UNIT WEIGHT | | | |
|---|---|---|---|
| Type A, B & D | Unit Weight | Inernal Stability | External Stability |
| | 105 PCF | Pullout | Sliding, Overturning, Eccentricity |
| | 125 PCF | Rupture | Bearing |

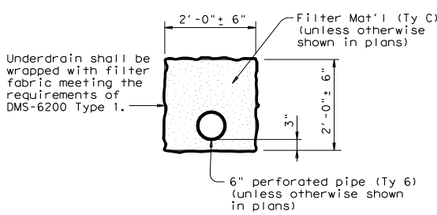



## MAP OF TEXAS EMBLEM 2

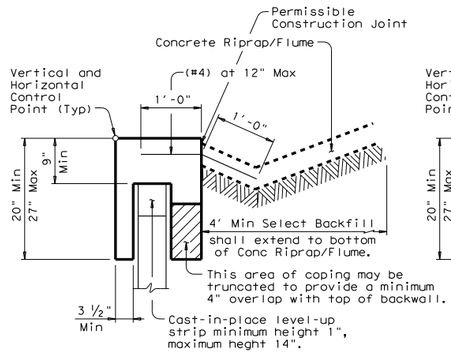



## SPECIAL DRAINAGE PROVISIONS

(When cement stabilized backfill is used)

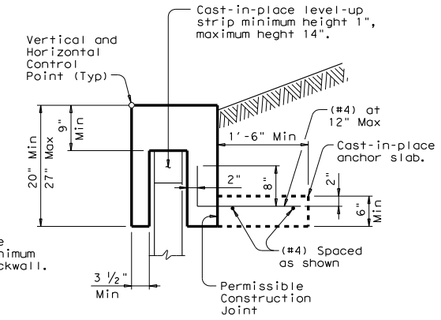



## UNDERDRAIN DETAIL




ADJACENT TO CONCRETE

(Excluding Concrete Pavement)




ADJACENT TO SOIL

## COPING ANCHORAGE DETAILS WITHOUT TRAFFIC RAILING 3

## DESIGN PARAMETERS:

Design of retaining walls shall be based on the following design parameters unless stated elsewhere in the plans:

| | |
|---|---|
| Random Backfill, Foundation Soil | unit weight = 125 pcf<br>Ø = 30° c = 0 psf |
| Select Backfill | unit weight = See Table 4<br>Ø = 34° c = 0 psf |
| Cement Stabilized Select Backfill | unit weight = 125 pcf<br>Ø = 45° c = 0 psf |

Stress in steel and concrete shall be in accordance with current AASHTO Standard and Interim Specifications.

The minimum length of earth reinforcements shall be 8'-0" or 70% of the wall design height, whichever is greater. Wall height and wall design height may differ depending on project geometry and loading conditions.

## STABILITY CRITERIA:

Factor of safety in sliding along the base of the structure shall be greater than or equal to 1.5.

Factor of safety in overturning shall be greater than or equal to 2.0.

The base pressure resultant shall fall within the middle third of the retaining wall.

The factor of safety against pullout of the earth reinforcements shall be greater than or equal to 1.5 at each level. Pullout resistance shall be determined from test data evaluated at ¾ inch strain.

## CORROSION CRITERIA:

The earth reinforcement elements shall be designed to have a minimum design life of 75 years.

Stress calculations (rupture) shall be done on the calculated earth reinforcement section remaining after 75 years. Pullout calculations may be based on non corroded section.

## GENERAL NOTES:

Section and elevation shown is for informational purposes only. Specific geometry is to be determined based on wall layouts and other plan information.

The select backfill specified for use within the mechanically stabilized earth volume shall extend horizontally from the back of the panels to the end of the earth reinforcements. The select backfill shall extend vertically from the top of the leveling pad or 4" below the lowest earth reinforcement, whichever is lower, to the top of panels.

The uppermost earth reinforcements shall be no more than 3.0' below the top of wall.

The lowest level of earth reinforcements shall be no more than 2.0' above the top of the leveling pad.

Minimum wire size for earth reinforcements shall be W7.0. If different longitudinal and cross wires are used in an earth reinforcement mesh, the smaller wire shall have at least 50% of the cross sectional area of the larger wire.

A maximum of four wire mesh configurations (wire sizes) will be allowed on a project. Each mesh configuration shall have a unique transverse bar spacing, differing from other configurations by a minimum of 3". Earth reinforcement lengths shall be stepped in increments no finer than 12".

Standard precast concrete panels shall have a maximum height of 6', and a maximum surface area of 50 sq ft. Top and bottom panels may exceed these limitations as necessary to achieve required wall grades. Maximum height of any panel shall be 7'-6". Minimum panel thickness shall be 5". Panels shall be arranged to provide offset horizontal joints.

An open joint shall be provided around the perimeter of the concrete panels. The nominal joint opening shall be between ⅜" and ¾". The joint configuration shall be such that the filter fabric or pad materials are not exposed at the wall face.

A one-piece corner panel shall be provided for wall angle changes of greater than 30 degrees. Butting of chamfered panels will be allowed for angle changes of 30 degrees or less.

Concrete coping shall be provided along the top of wall, at the vertical steps at bridge backwalls, and at other vertical steps along the top of wall. The joints between all coping segments shall be sealed to prevent infiltration of water into the retaining wall backfill. Sealing shall be in accordance with the DMS-6310 "Joint Sealants and Fillers", using Class 4 joint sealant.

Concrete must be Class "C".

All reinforcing steel must be Grade 60.

Coping and anchor slabs must be considered subsidiary to the Item "Retaining Wall".

DISCLAIMER:
The use of this standard is governed by the "Texas Engineering Practice Act". No warranty of any kind is made by TxDOT for any purpose whatsoever. TxDOT assumes no responsibility for the conversion of this standard to other formats or for incorrect results or damages resulting from its use.

PATH:

LEVELS DISPLAYED

Texas Department of Transportation
Bridge Division

# MECHANICALLY STABILIZED EARTH RETAINING WALL

## RW(MSE)

| FILE: rwstde01.dgn | DN: TxDOT | CK: TxDOT | DW: JGD | CK: MJG |
|---|---|---|---|---|
| © TxDOT March 2010 | DISTRICT | FEDERAL AID PROJECT | | SHEET |
| REVISIONS | | | | |
| 04-11: Added Table & Corrosion Criteria. | COUNTY | CONTROL | SECT | JOB | HIGHWAY |

HL 93 LOADING

| No. | Date | Revisions | App. |
|---|---|---|---|

AGUIRRE & FIELDS LP
TRANSPORTATION • CIVIL • STRUCTURAL
ENGINEERS AND PLANNERS

CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275

ISSUED FOR INTERIM REVIEW ONLY
THIS PLAN IS NOT COMPLETE AND IS NOT INTENDED FOR BIDDING PURPOSES.
ENGINEER: OSCAR R.AGUIRRE
TX. REG. NO. 80138
DATE ISSUED: 6/9/2011
AGUIRRE & FIELDS LP #739

SURVEYED BY:
FB NO:

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

MECHANICALLY STABILIZED EARTH RETAINING WALL

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| S-000000-0000-4 | |
| DRAWING SCALE | |
| | |
| CITY OF HOUSTON PM | |
| JOHN DOE, PE | |

PRELIMINARY

LOG NO. XX-XXXX

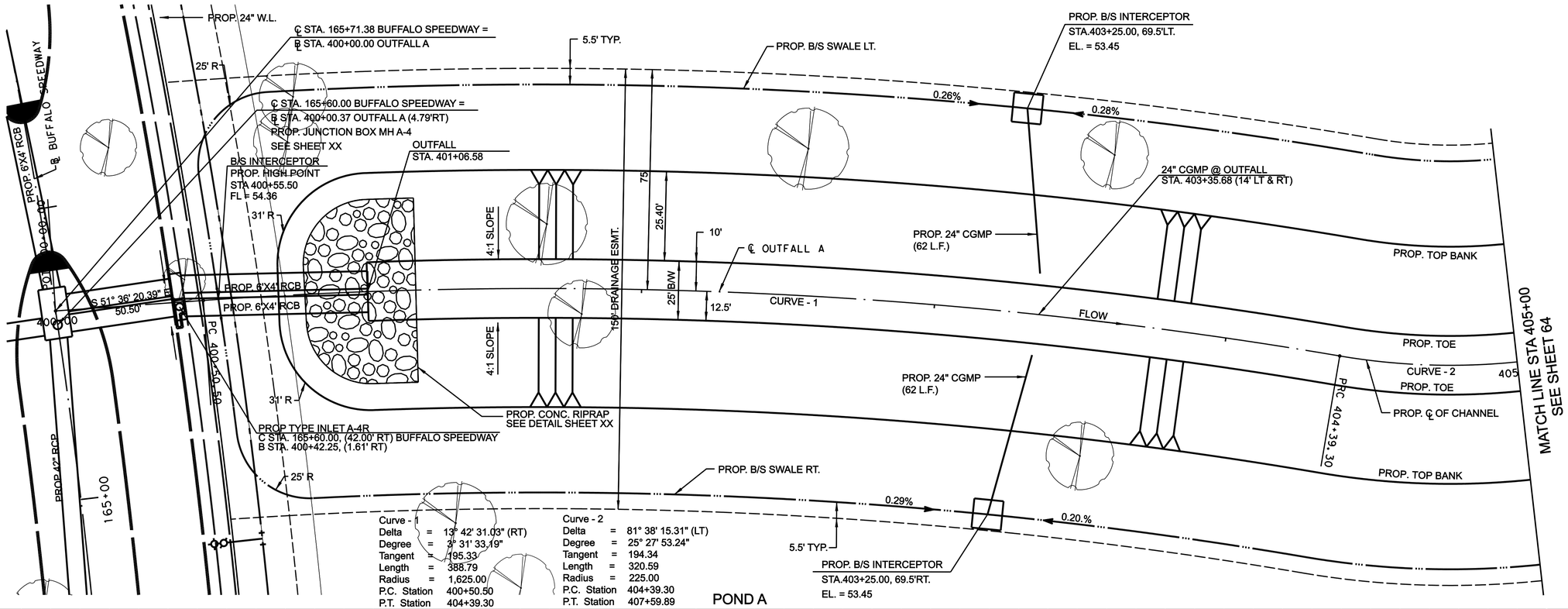
5:42:11 PM 6/9/2011 H:\10903\CADD\Standards\RWSTDE01.DGN

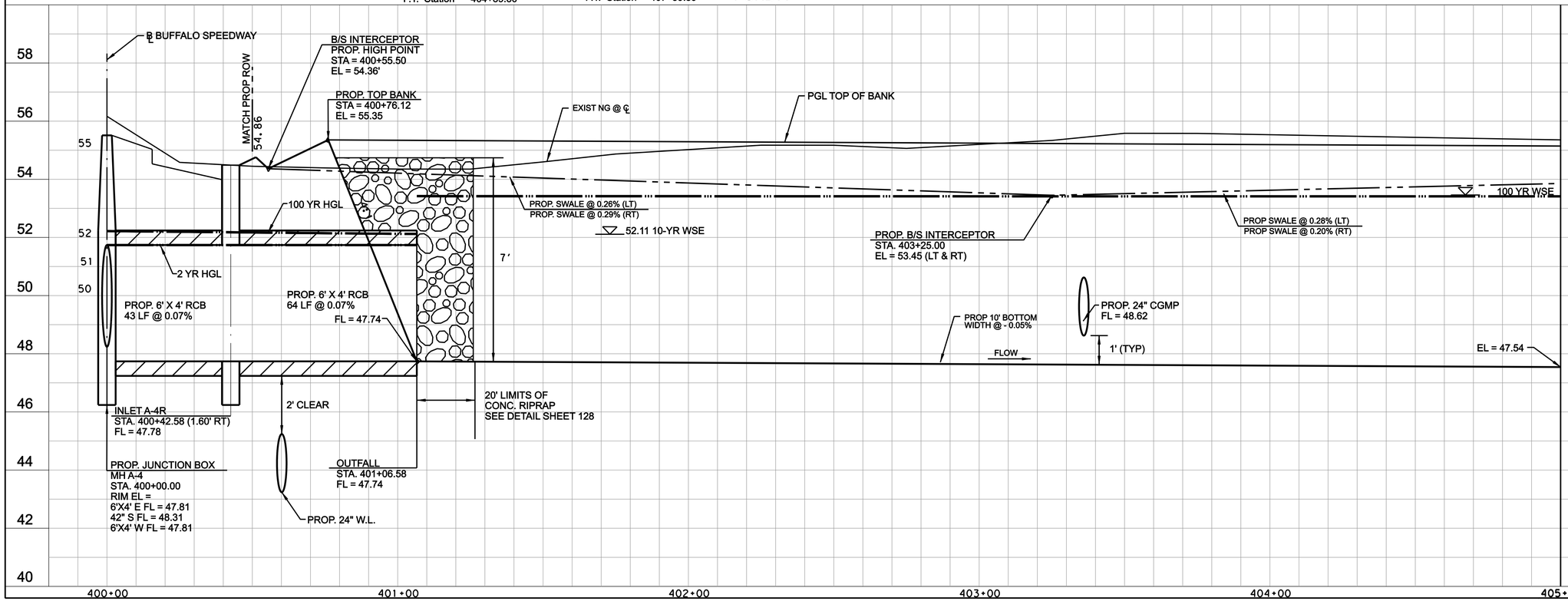
# APPENDIX B

# PLAN AND PROFILES OF OFF-SITE DRAINAGE DITCHES (A, B, C AND D)

NOTES:
1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. J368
SET 5/8" IR W/CAP LOCATED AT CHANNEL A
CL STA. 400+50.73, R 1.43
ELEV. = 53.78




| No. | Date | Revisions | App. |
|---|---|---|---|

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN
AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:
CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:
Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:
CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:
CABLE COMPANY


CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275


ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

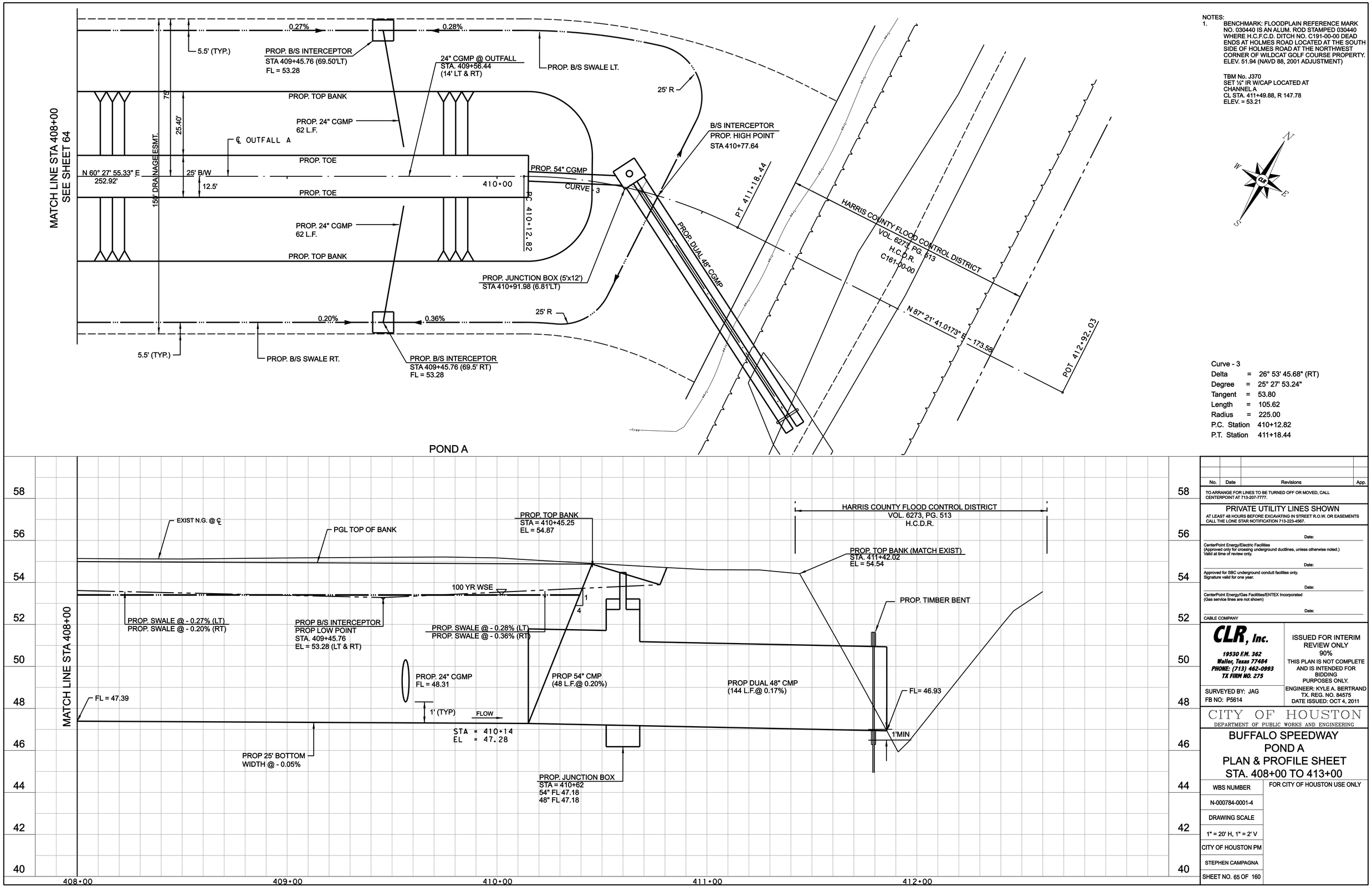
SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY
# POND A
# PLAN & PROFILE SHEET
# STA. 400+00 TO 405+00

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA,PE | |
| SHEET NO. 63 OF 160 | |




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN

AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:

CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:

Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:

CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:

CABLE COMPANY

**CLR, Inc.**
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275

ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

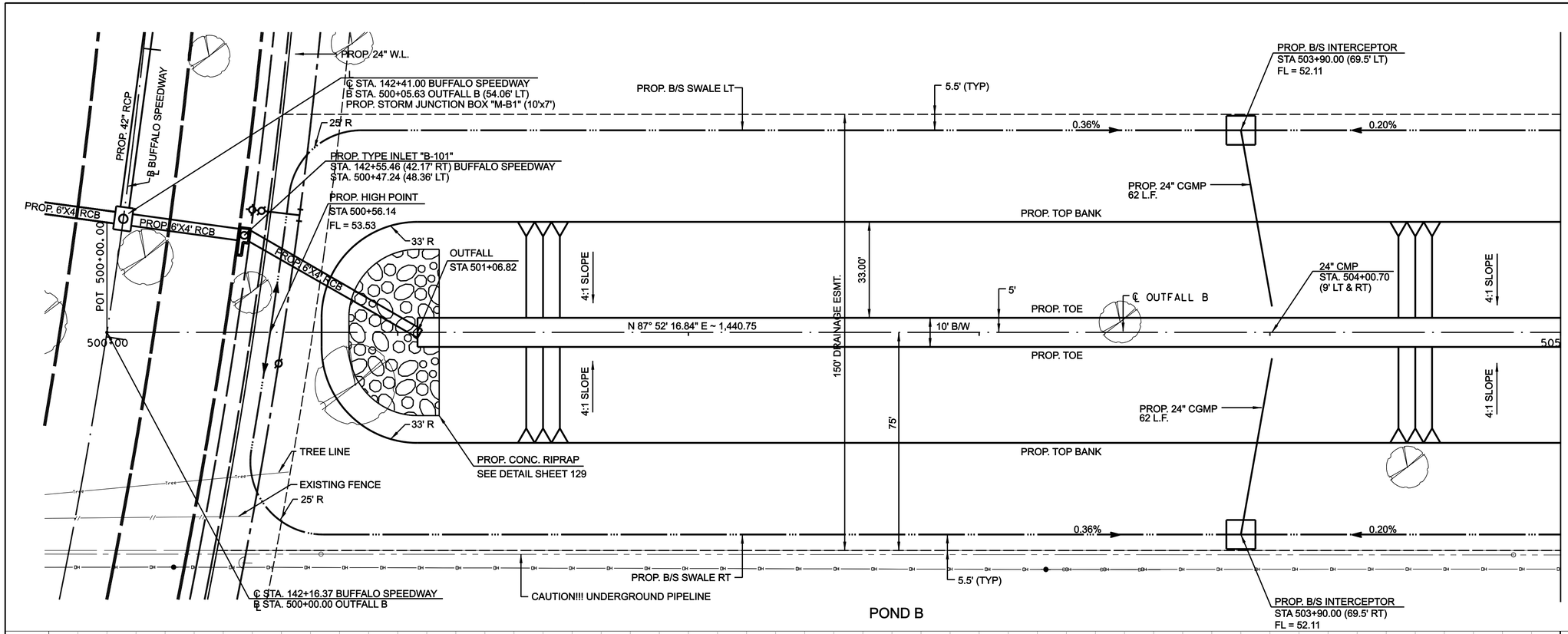
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

BUFFALO SPEEDWAY
POND A
PLAN & PROFILE SHEET
STA. 408+00 TO 413+00

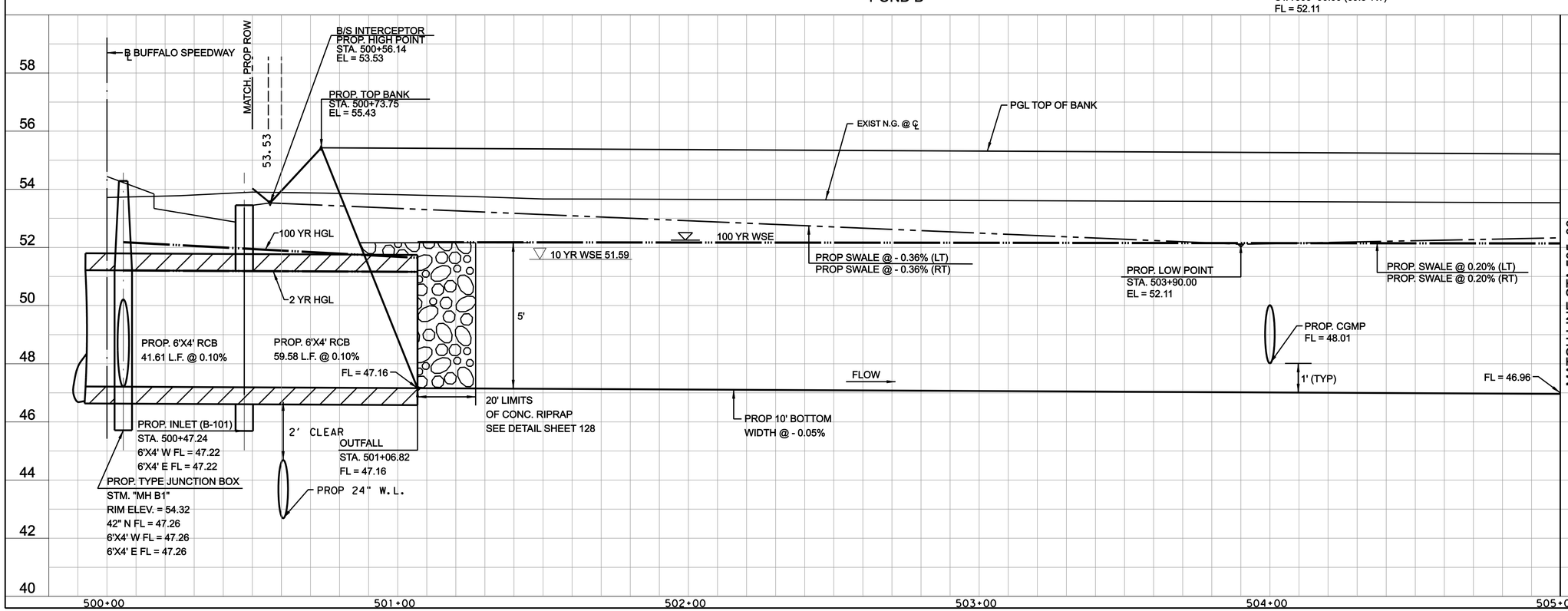
| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA | |
| SHEET NO. 65 OF 160 | |

NOTES:
1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. 359
SET 5/8" IR W/CAP LOCATED AT
POND B
CL STA. 500+50.52, R 92.93
ELEV. = 53.89




POND B




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN
AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:
CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:
Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:
CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:
CABLE COMPANY

**CLR, Inc.**
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275

ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

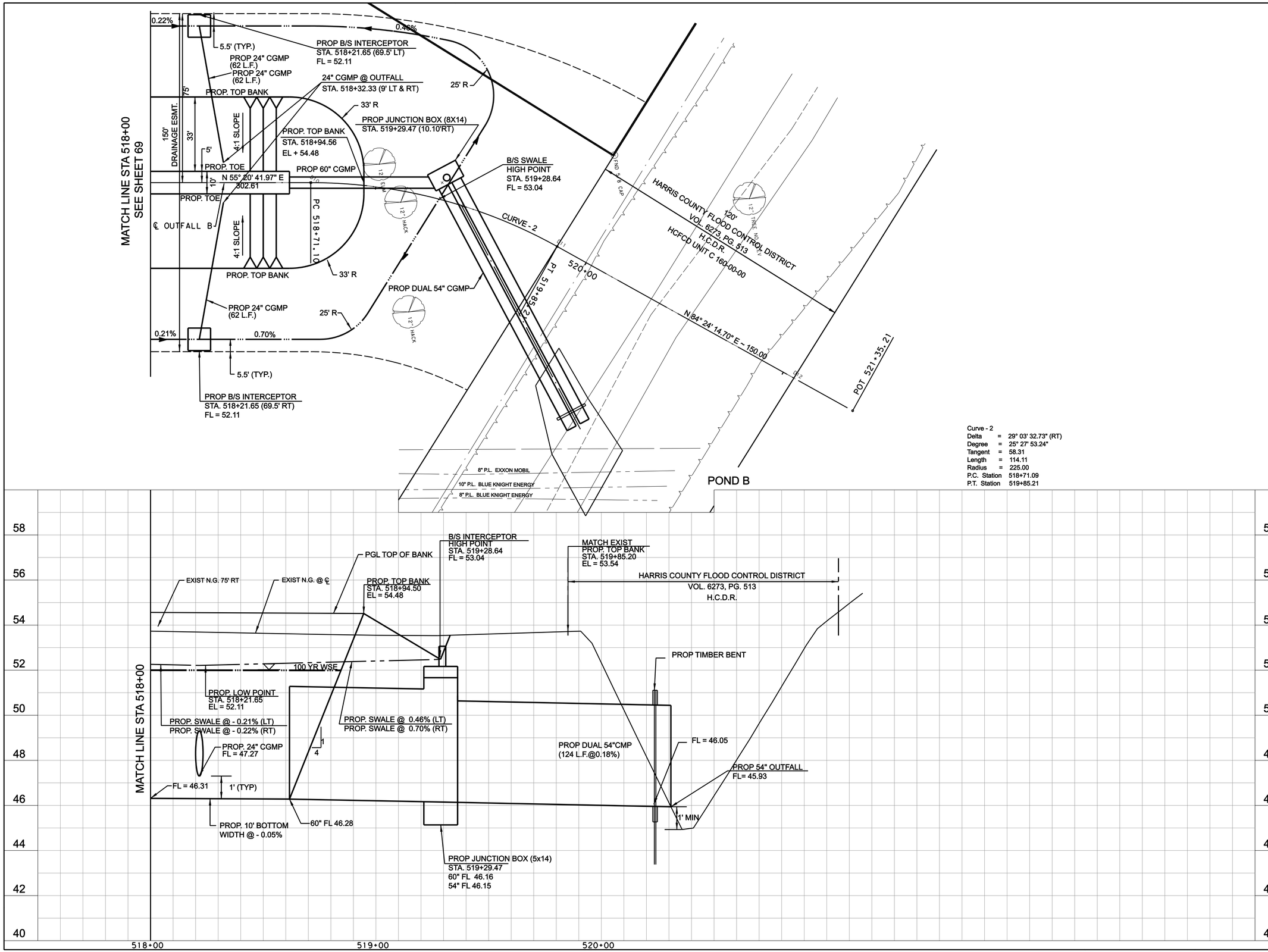
SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY
# POND B
# PLAN & PROFILE SHEET
# STA. 500+00 TO 505+00

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA,PE | |
| SHEET NO. 66 OF 160 | |




NOTES:

1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. 358
SET 5/8" IR W/CAP LOCATED AT
POND B
CL STA. 519+94.51, R 116.38
ELEV. = 53.92

NOTES:

1. EXXON MOBILE PIPELINE CO.
8" REGULAR GASOLINE PIPELINE
CONTACT:
KYLE COMBS 281-925-3816 OR 713-824-6219

2. BLUEKNIGHT ENERGY PARTNERS, LP/SEMPIPE
10" CRUDE OIL PIPELINE
8" CRUDE OIL PIPELINE (IDLE)
CONTACT:
BRIAN JORDON 281-450-7787

Curve - 2

| | | |
|---|---|---|
| Delta | = | 29° 03' 32.73" (RT) |
| Degree | = | 25° 27' 53.24" |
| Tangent | = | 58.31 |
| Length | = | 114.11 |
| Radius | = | 225.00 |
| P.C. Station | | 518+71.09 |
| P.T. Station | | 519+85.21 |

| No. | Date | Revisions | App. |
|---|---|---|---|

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN
AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:

CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:

Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:

CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:

CABLE COMPANY


CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275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90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

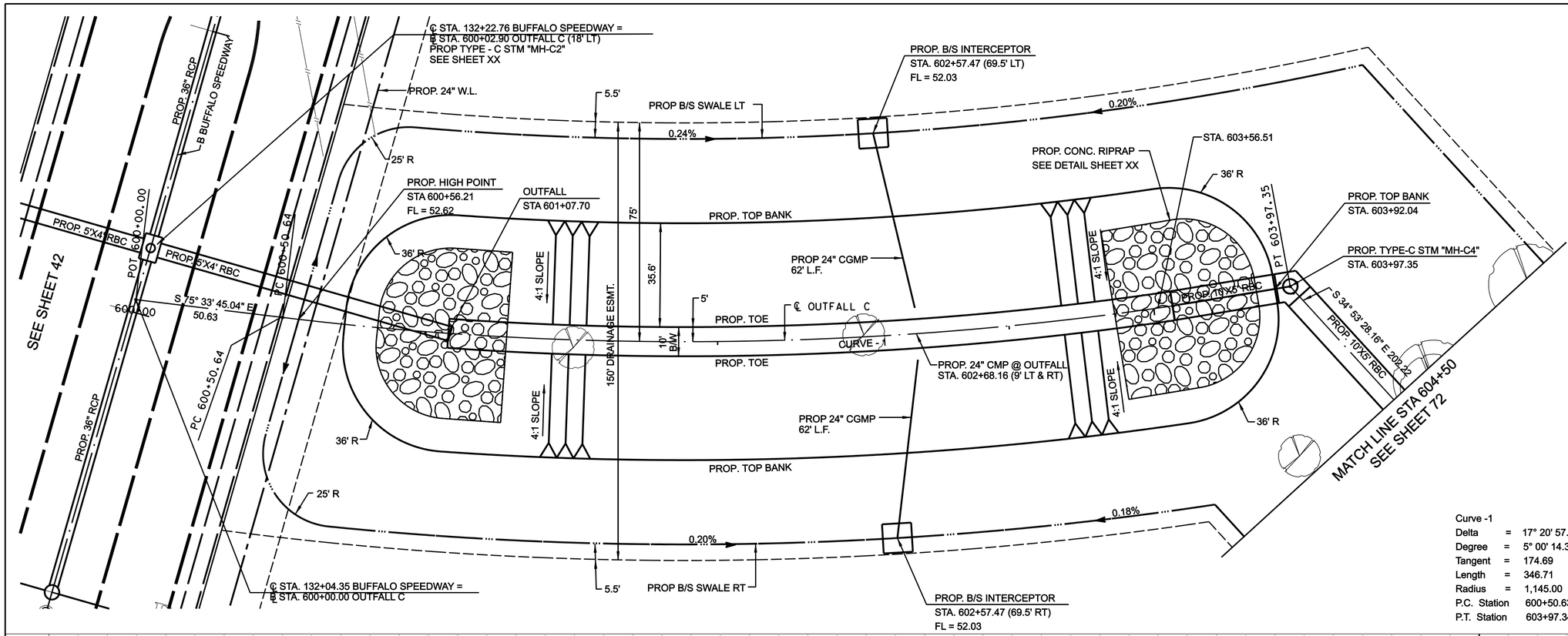
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY
# POND B
# PLAN & PROFILE SHEET
# STA. 518+00 TO 521+35

| | |
|---|---|
| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA | |
| SHEET NO. 70 OF 160 | |

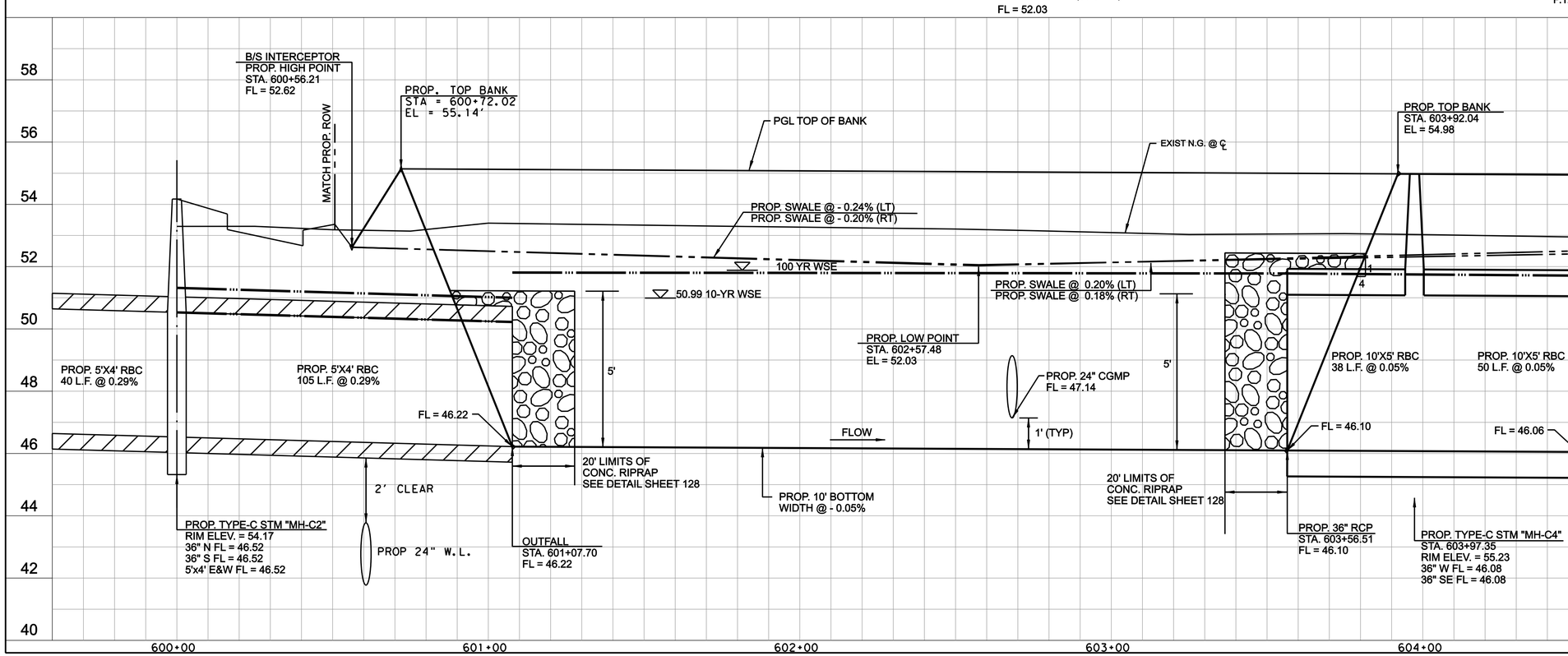
NOTES:
1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. J364
SET 5/8" IR W/CAP LOCATED AT CHANNEL C
CL STA. 600+50.64, L 0.01
ELEV. = 52.84




Curve -1

| | | |
|---|---|---|
| Delta | = | 17° 20' 57.80" (LT) |
| Degree | = | 5° 00' 14.36" |
| Tangent | = | 174.69 |
| Length | = | 346.71 |
| Radius | = | 1,145.00 |
| P.C. Station | | 600+50.63 |
| P.T. Station | | 603+97.34 |




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN
AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:
CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:
Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:
CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:
CABLE COMPANY


CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275


ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

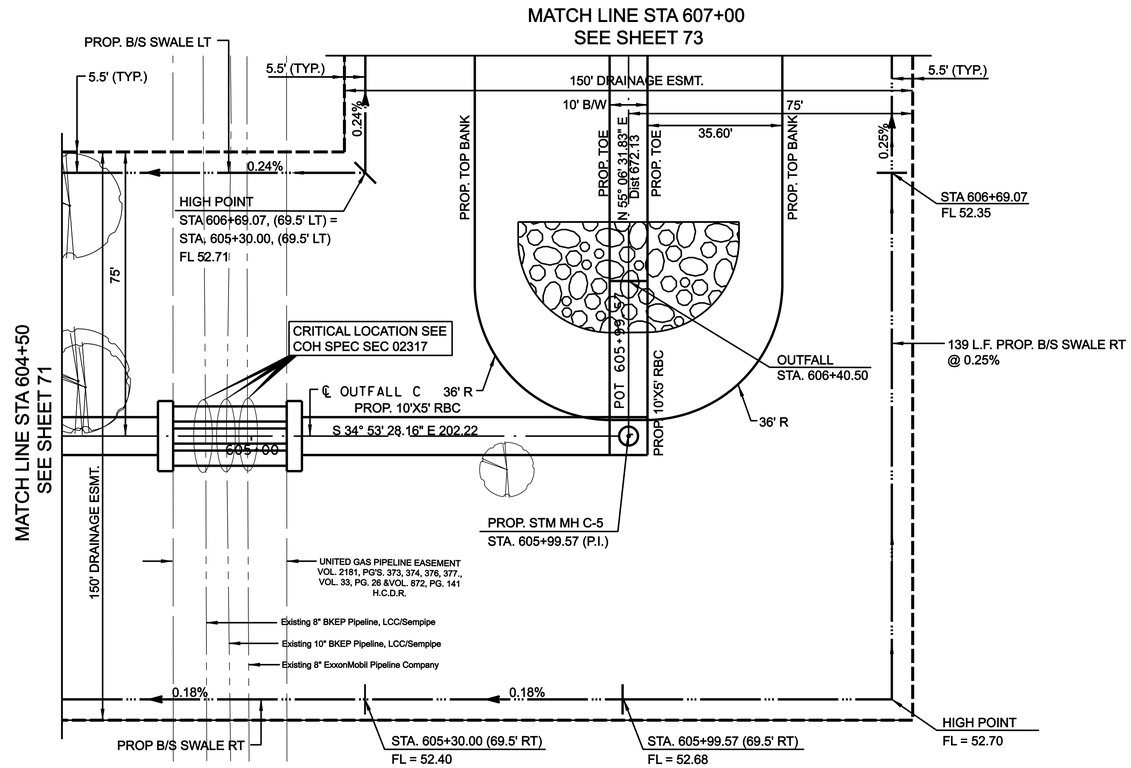
SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY
# POND C
# PLAN & PROFILE SHEET
# STA. 600+00 TO 604+50

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA | |
| SHEET NO. 71 OF 160 | |

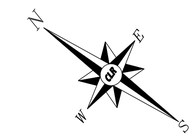



NOTES:

1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

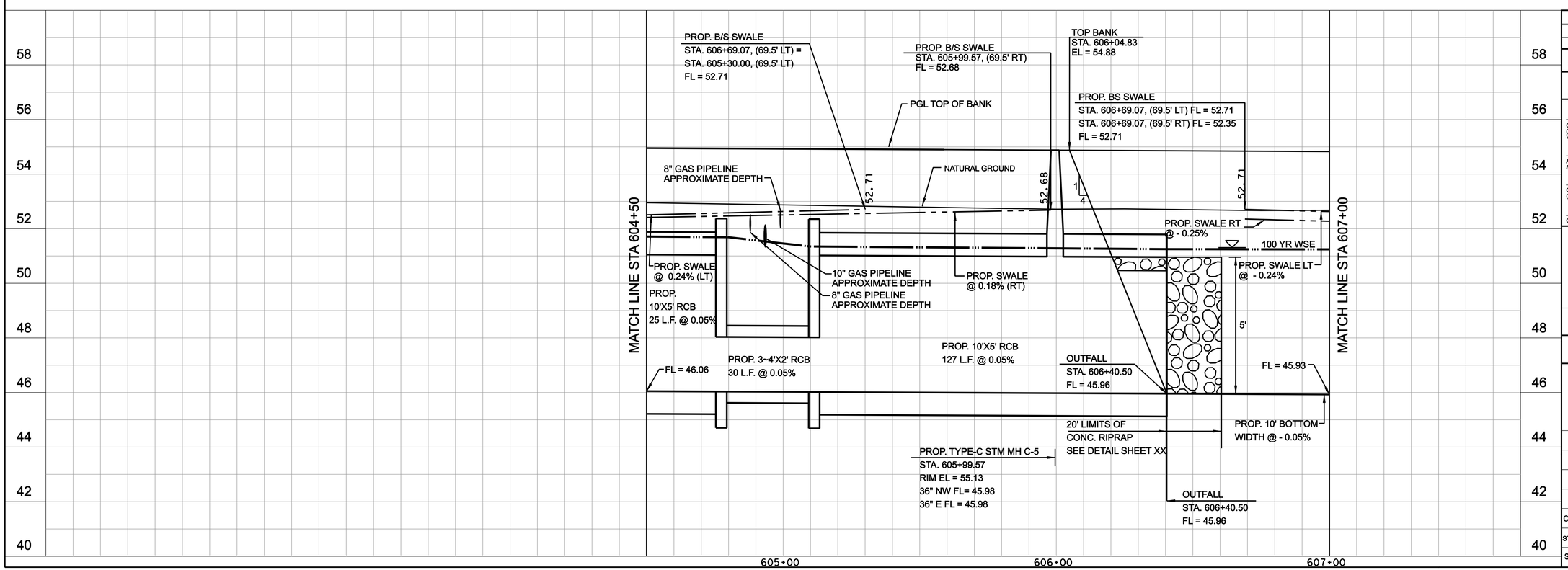
TBM No. J363
SET ½" IR W/CAP LOCATED AT
CHANNEL C
CL STA. 604+03.90, L 0.67
ELEV. = 53.17

TBM No. 361
SET 5/8" IR W/CAP LOCATED AT
CHANNEL C
CL STA. 604+94.59, L 81.90
ELEV. = 52.91




2. EXXON MOBILE PIPELINE CO.
8" REGULAR GASOLINE PIPELINE
CONTACT:
RICHARD RICHARDSON XXX XXX-XXXX (O) OR XXX XXX-XXXX
XXXX@XXXX.NET

3. BLUEKNIGHT ENERGY PARTNERS, LP/AND SEMPIPE
10" CRUDE OIL PIPELINE
8" CRUDE OIL PIPELINE (IDLE)
CONTACT:
PAT WISDOM XXX XXX-XXXX (O) OR XXX XXX-XXXX
XXXX@XXXX.NET




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN

AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:

CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:

Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:

CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:

CABLE COMPANY

**CLR, Inc.**
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275

ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

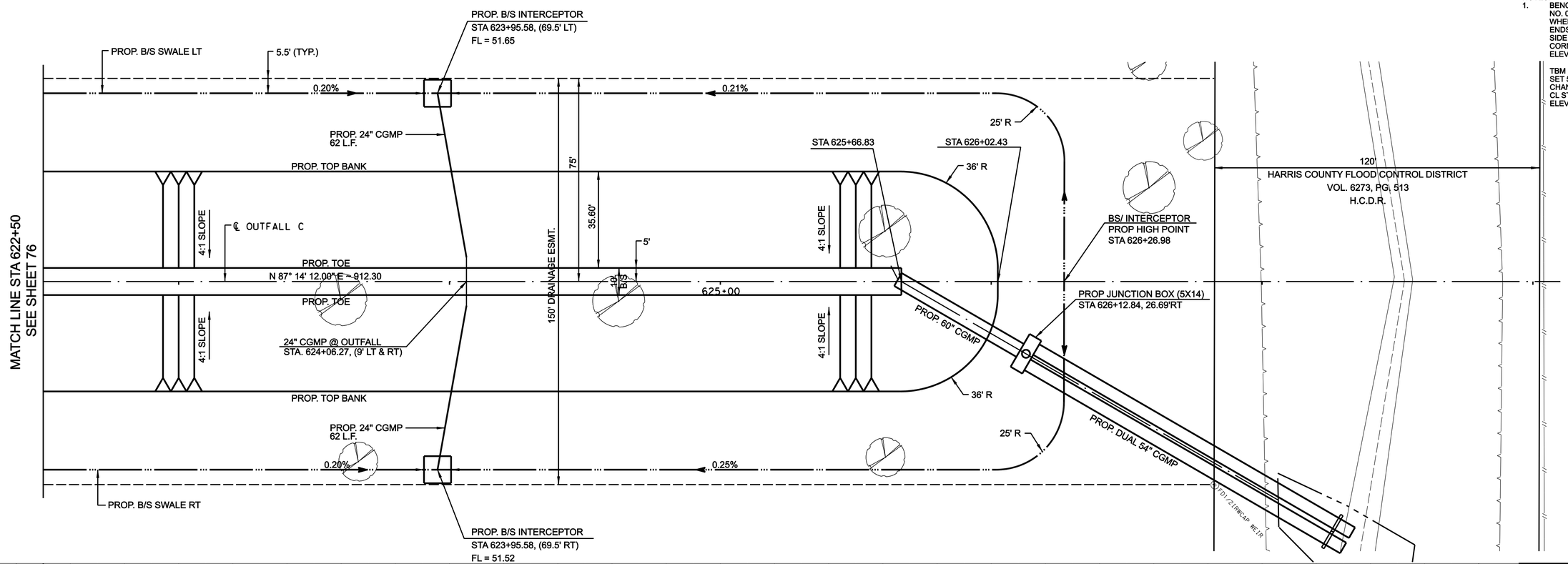
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

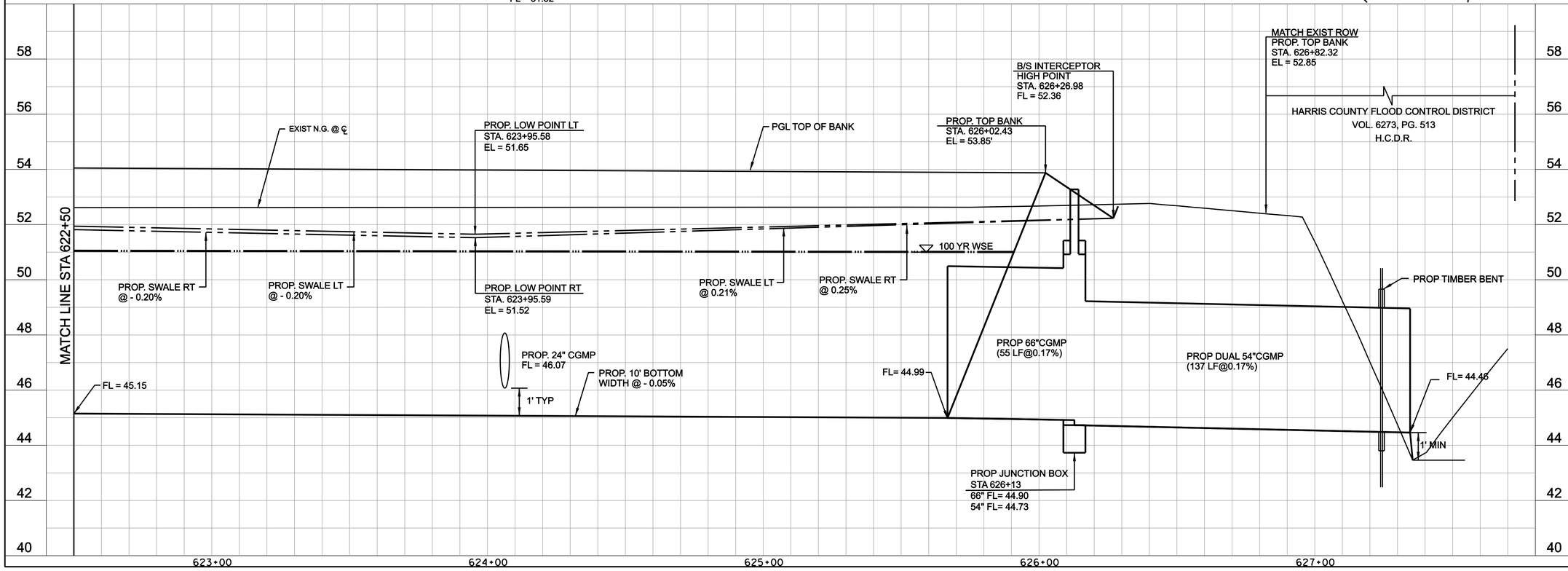
# BUFFALO SPEEDWAY
# POND C
# PLAN & PROFILE SHEET
# STA. 604+50 TO 607+00

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA,PE | |
| SHEET NO. 72 OF 160 | |

NOTES:
1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. 362
SET 5/8" IR W/CAP LOCATED AT CHANNEL C
CL STA. 626+98.14, L 100.05
ELEV. = 52.63




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN
AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:
CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:
Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:
CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:
CABLE COMPANY


CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275


ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

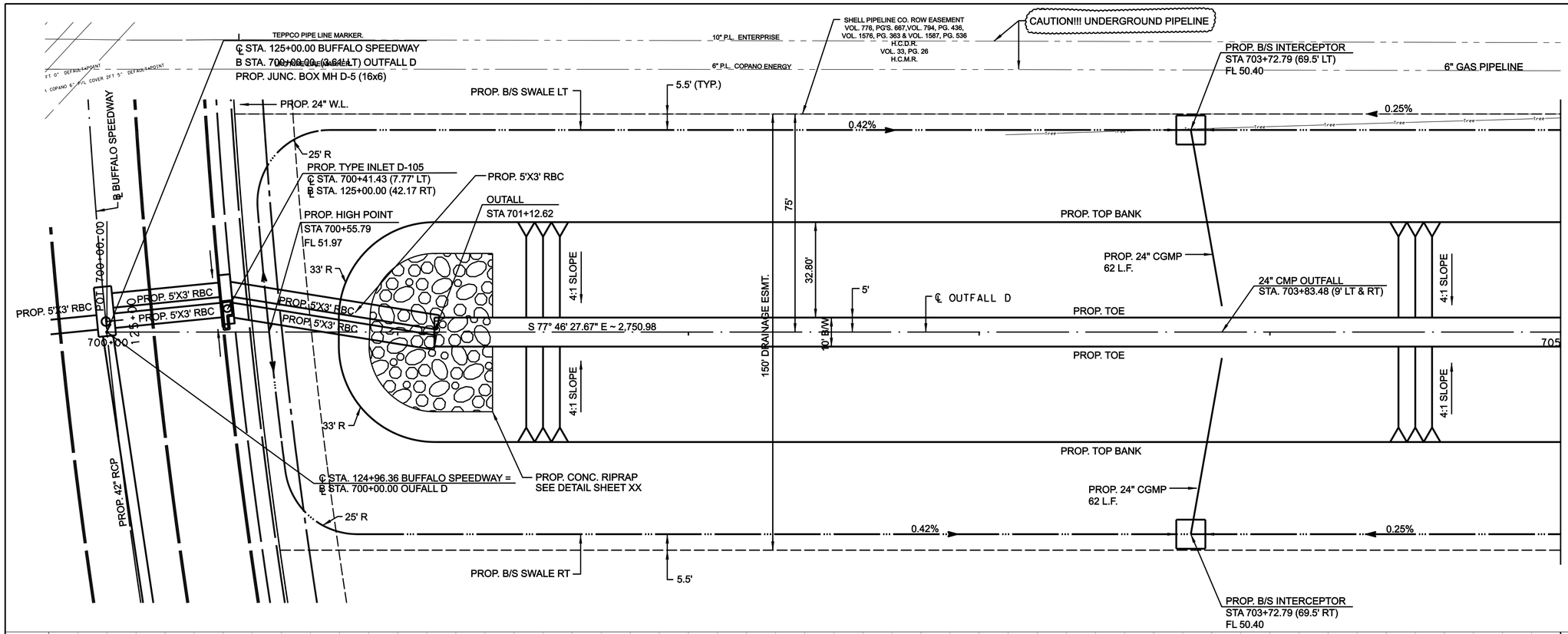
SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY
# POND C
# PLAN & PROFILE SHEET
# STA. 622+50 TO 628+00

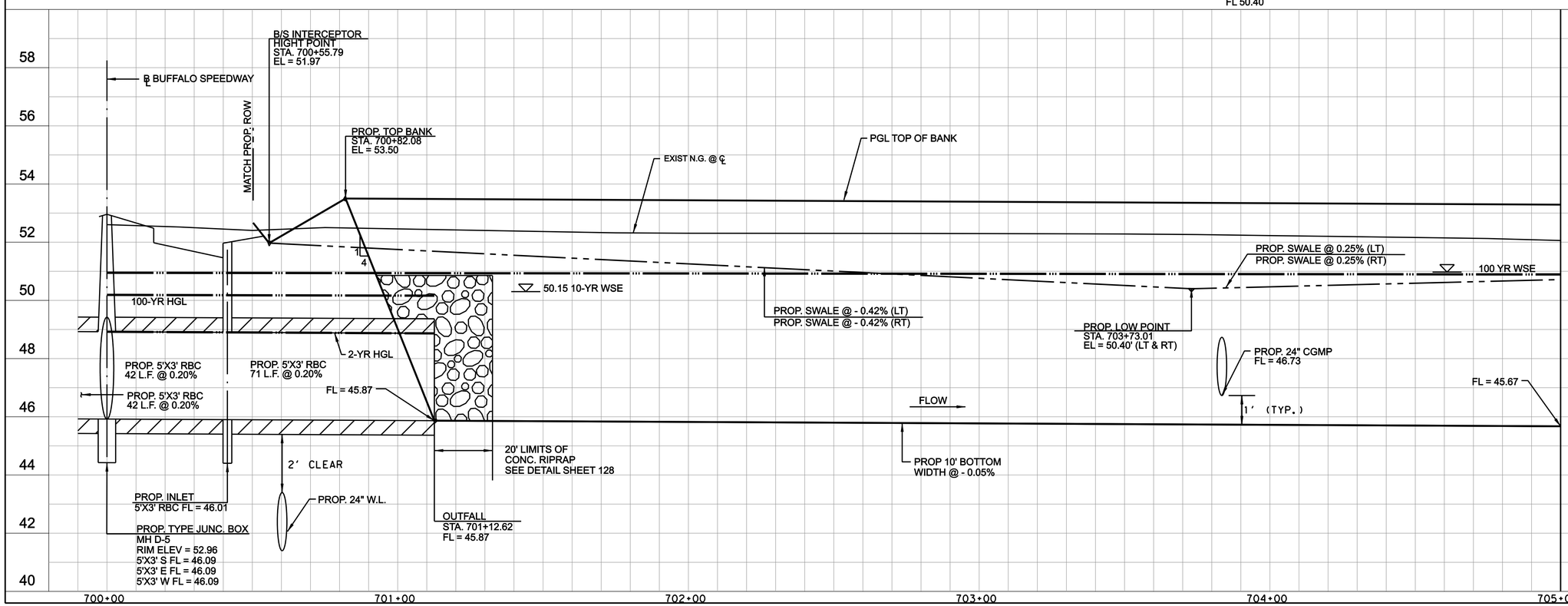
| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA,PE | |
| SHEET NO. 77 OF 160 | |




NOTES:

1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. 350
SET 5/8" IR W/CAP LOCATED AT
POND D
CL STA. 704+45.44, L 95.83
ELEV. = 51.79




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN

AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:

CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:

Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:

CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:

CABLE COMPANY


**CLR, Inc.**
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275


ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

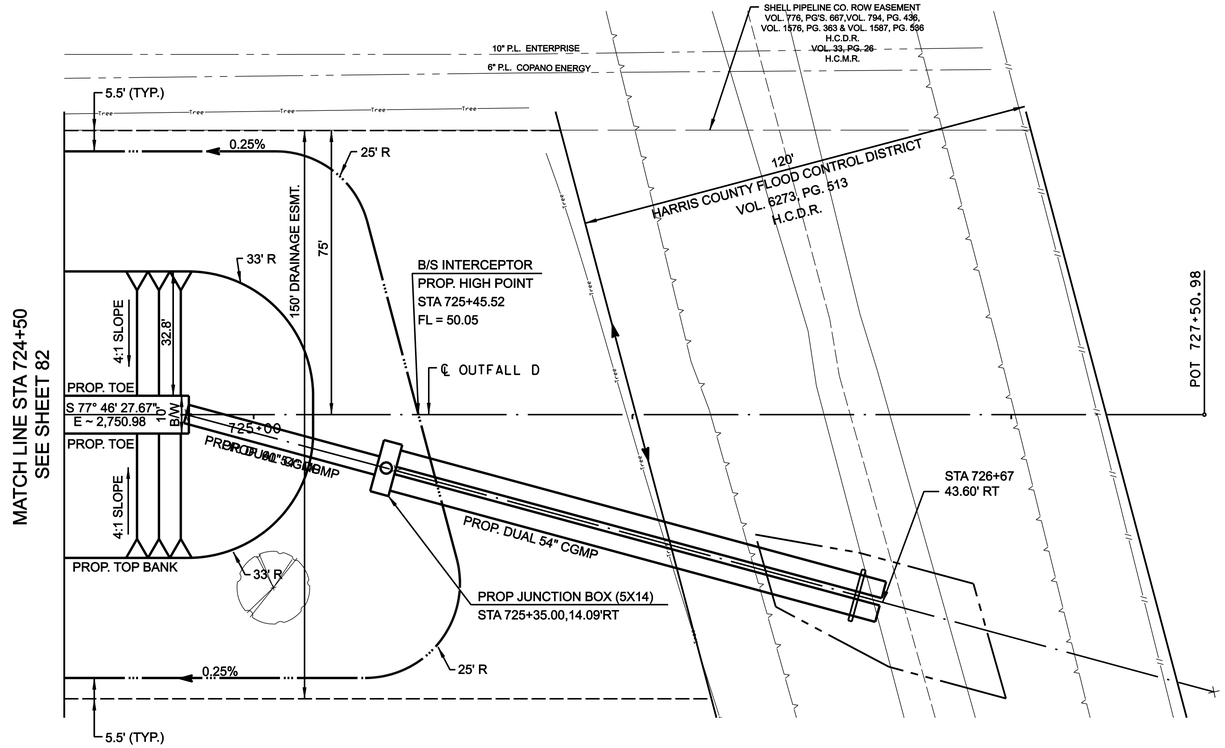
CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

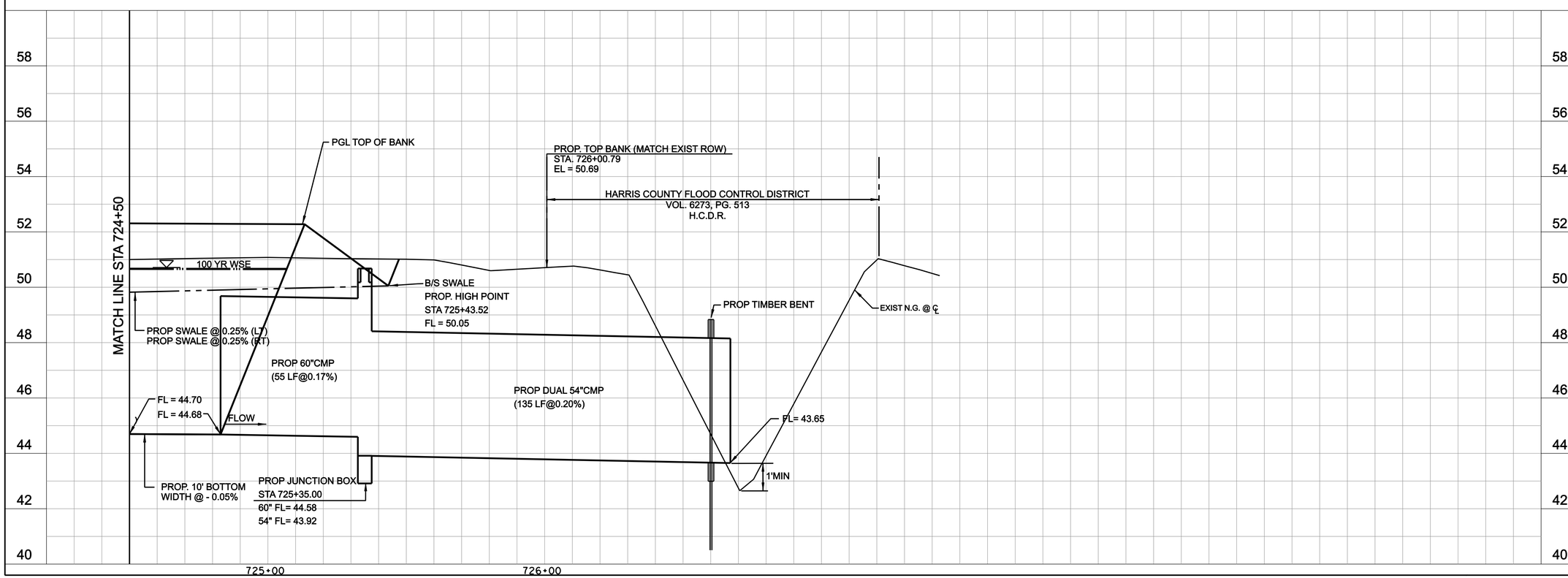
# BUFFALO SPEEDWAY
# POND D
# PLAN & PROFILE SHEET
# STA. 700+00 TO 705+00

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA,PE | |
| SHEET NO. 78 OF 160 | |

NOTES:
1. BENCHMARK: FLOODPLAIN REFERENCE MARK NO. 030440 IS AN ALUM. ROD STAMPED 030440 WHERE H.C.F.C.D. DITCH NO. C191-00-00 DEAD ENDS AT HOLMES ROAD LOCATED AT THE SOUTH SIDE OF HOLMES ROAD AT THE NORTHWEST CORNER OF WILDCAT GOLF COURSE PROPERTY. ELEV. 51.94 (NAVD 88, 2001 ADJUSTMENT)

TBM No. 354
SET 5/8" IR W/CAP LOCATED AT
POND D
CL STA. 725+27.70, L 94.81
ELEV. = 51.02




| No. | Date | Revisions | App. |
|---|---|---|---|
| | | | |
| | | | |

TO ARRANGE FOR LINES TO BE TURNED OFF OR MOVED, CALL CENTERPOINT AT 713-207-7777.

PRIVATE UTILITY LINES SHOWN
AT LEAST 48 HOURS BEFORE EXCAVATING IN STREET R.O.W. OR EASEMENTS CALL THE LONE STAR NOTIFICATION 713-223-4567.

Date:
CenterPoint Energy/Electric Facilities
(Approved only for crossing underground ductlines, unless otherwise noted.)
Valid at time of review only.

Date:
Approved for SBC underground conduit facilites only.
Signature valid for one year.

Date:
CenterPoint Energy/Gas Facilities/ENTEX Incorporated
(Gas service lines are not shown)

Date:
CABLE COMPANY


CLR, Inc.
19530 F.M. 362
Waller, Texas 77484
PHONE: (713) 462-0993
TX FIRM NO. 275


ISSUED FOR INTERIM REVIEW ONLY
90%
THIS PLAN IS NOT COMPLETE AND IS INTENDED FOR BIDDING PURPOSES ONLY.

SURVEYED BY: JAG
FB NO: P5614

ENGINEER: KYLE A. BERTRAND
TX. REG. NO. 84575
DATE ISSUED: OCT 4, 2011

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

# BUFFALO SPEEDWAY
# POND D
# PLAN & PROFILE SHEET
# STA. 724+50 TO 728+00

| WBS NUMBER | FOR CITY OF HOUSTON USE ONLY |
|---|---|
| N-000784-0001-4 | |
| DRAWING SCALE | |
| 1" = 20' H, 1" = 2' V | |
| CITY OF HOUSTON PM | |
| STEPHEN CAMPAGNA,PE | |
| SHEET NO. 83 OF 160 | |

# APPENDIX C

# WELL REPORTS SUBMITTD TO TEXAS DEPARTMENT OF LICENSING AND REGULATIONS

Attention Owner: Confidentiality Privilege Notice on reverse side of owner's copy.

# Texas Department of Licensing and Regulation

Water Well Driller/Pump Installer Section
P.O. Box 12157 Austin, Texas 78711 (512)463-7880 FAX (512)463-8616
Toll free (800)803-9202
Email address: water.well@license.state.tx.us Web address: www.license.state.tx.us

This form must be completed and filed with the department and owner within 60 days upon completion of the well.

## WELL REPORT

### A. WELL IDENTIFICATION AND LOCATION DATA

**1) OWNER**

| Name: | Address: | City: | State: | Zip: |
|---|---|---|---|---|
| CITY OF HOUSTON c/o CLR INC. | 19530 FM 362 | WALLER | TX | 77484 |

**2) WELL LOCATION**

| Well # or # of wells drilled | County: | Physical Address: | City: |
|---|---|---|---|
| PZ B4 | HARRIS | | HOUSTON |

| Lat. | Long. | Grid # |
|---|---|---|
| 3103546.8 | 13807396.9 | |

**3) Type of Work**
[X] New Well [ ] Reconditioning [ ] Replacement [ ] Deepening

**4) Proposed Use (check)** [X] Monitor [ ] Environmental Soil Boring [ ] Domestic [ ] Extraction [ ] Industrial [ ] Irrigation [ ] Injection [ ] Closed-Loop Geothermal [ ] De-watering [ ] Testwell [ ] Rig Supply [ ] Stock [ ] Public Supply – If Public Supply, were plans approved? [ ] Yes [ ] No

5) NT

**6) Drilling Date**
Started 9 / 20 / 11
Completed 9 / 20 / 11

**Diameter of Hole**

| Dia.(in) | From (ft) | To (ft) |
|---|---|---|
| 4 | Surface | 80 |

**7) Drilling Method (check)**
[ ] Driven [ ] Air Rotary [ ] Mud Rotary [ ] Bored [ ] Air Hammer [ ] Cable Tool [ ] Jetted [ ] Hollow Stem Auger [ ] Reverse Circulation [X] Other

| From (ft) | To (ft) | Description and color of formation material |
|---|---|---|
| 0 | 6 | DARK GRAY/LEAN CLAY W/SAND |
| 6 | 10 | TAN & GRAY LEAN CLAY w/sand |
| 10 | 27 | REDDISH BROWN FAT CLAY |
| 27 | 33 | REDDISH BROWN SILT w/sand |
| 33 | 38 | TAN & GRAY LEAN CLAY |
| 38 | 43 | LIGHT GRAY & REDDISH BROWN FAT CLAY w/sand |
| 43 | 73 | REDDISH BROWN/GRAY LEAN CLAY |
| 73 | 80 | REDDISH BROWN FAT CLAY |

(Use reverse side of Well Owner's copy, If necessary)

**8) Borehole Completion** [ ] Open Hole [ ] Straight Wall [ ] Under-reamed [ ] Gravel Packed [ ] Other
Gravel packed interval from : ft. to: ft. Size:

**Casing, Blank Pipe, and Well Screen Data**

| Dia. (in.) | New Or Used | Steel, Plastic, etc. Perf., Slotted, etc Screen Mfg., if commercial | Setting (ft) From | Setting (ft) To | Gage Casing Screen |
|---|---|---|---|---|---|
| 1 | N | PVC RISER | 0 | 20 | |
| 1 | N | PVC SCREEN | 20 | 30 | .010 |
| 1 | N | PVC RISER | 30 | 80 | |

**9) Annular Seal Data:** i.e. (from 0 ft to 100 ft #sacks & material 15 cement)
from 0 ft. to 18 ft. #sacks & material 3 BENOTITE
from 18 ft. to 80 ft. #sacks & material 8 SILICA SAN
from ft. to ft. #sacks & material
Method Used Performed By
Distance to septic field or other concentrated contamination ft.
Distance to Property Line ft
Method Verified:

**13) Plugged** [ ] Well plugged within 48 hours
Casing left in well: Cement/Bentonite placed in well:

| From (ft) | To (ft) | From (ft) | To (ft) | # Sacks & Material used |
|---|---|---|---|---|
| | | | | |

**10) Surface Completion** (If steel cased, leave blank)
[ ] Surface Slab Installed [ ] Surface Sleeve Installed [ ] Pitless Adapter Used [ ] Alternative Procedure Used

**14) Type Pump** NA
[ ] Turbine [ ] Jet [ ] Submersible [ ] Cylinder [ ] Other
Depth to pump bowls, cylinder, jet etc.. ft.

**11) Water Level**
Static level 15-3 ft. Date: 11 / 28 / 11
Artesian Flow NA gpm

**12) Packers:**

| Type | Depth | Type | Depth |
|---|---|---|---|
| | | | |

**15) Water Test** NA
Type test [ ] Pump [ ] Bailer [ ] Jetted [ ] Estimated
Yield: gpm with ft. drawdown after hrs.

**16) Water Quality** NA
Type of water Depth of Strata: Was a chemical analysis made? [ ] Yes [ ] No
Did you knowingly penetrate a strata which contains undesirable constituents? [ ] Yes [ ] No If yes, Continue:
Check One: [ ] Naturally poor-quality groundwater – type [ ] Hydrocarbons (i.e. gas, oil, etc.)
[ ] Hazardous material/waste contamination encountered [ ] Other (describe)

[ ] *I certify that while drilling, deepening, or otherwise altering the above described well, undesirable water or constituents was encountered and the landowner was informed that such well must be completed or plugged in such a manner as to avoid injury or pollution.*

By signing this well report, I certify that I drilled or supervised the drilling of this well and that each and all of the statements herein are true and correct.

Company & Individual's Name: (type or print) RONNIE LINDER TRIANGLE RESOURCES INC Lic. No.: 2987

Address : 9871 HWY 90 City: BEAUMONT State: TX Zip 77713

Signature: Licensed Driller/Pump Installer 01/16/12 Date Signature: Apprentice Apprentice Reg. Number

TDLR FORM 001WWD / 7-08 TDLR (Original) Landowner (copy) Driller/Pump Installer (copy)

Attention Owner: Confidentiality Privilege Notice on reverse side of owner's copy.

# Texas Department of Licensing and Regulation

Water Well Driller/Pump Installer Section
P.O. Box 12157 Austin, Texas 78711 (512)463-7880 FAX (512)463-8616
Toll free (800)803-9202
Email address: water.well@license.state.tx.us Web address: www.license.state.tx.us

This form must be completed and filed with the department and owner within 60 days upon completion of the well.

## WELL REPORT

### A. WELL IDENTIFICATION AND LOCATION DATA

**1) OWNER**

| Name: | Address: | City: | State: | Zip: |
|---|---|---|---|---|
| CITY OF HOUSTON c/o CLR INC. | 19530 FM 362 | WALLER | TX | 77484 |

**2) WELL LOCATION**

| Well # or # of wells drilled | County: | Physical Address: | City: |
|---|---|---|---|
| PZ B10 | HARRIS | | |
| | Lat. 3103905.70 | Long. 13806157.55 | Grid # |

**3) Type of Work**
[X] New Well [ ] Reconditioning
[ ] Replacement [ ] Deepening

**4) Proposed Use (check)** [X] Monitor [ ] Environmental Soil Boring [ ] Domestic [ ] Extraction
[ ] Industrial [ ] Irrigation [ ] Injection [ ] Closed-Loop Geothermal [ ] De-watering [ ] Testwell
[ ] Rig Supply [ ] Stock [ ] Public Supply – If Public Supply, were plans approved? [ ] Yes [ ] No

5) NT

**6) Drilling Date**
Started 9 / 22 / 11
Completed 9 / 22 / 11

**Diameter of Hole**

| Dia.(in) | From (ft) | To (ft) |
|---|---|---|
| 4 | Surface | 30 |

**7) Drilling Method (check)**
[ ] Driven [ ] Air Rotary [ ] Mud Rotary
[ ] Bored [ ] Air Hammer [ ] Cable Tool
[ ] Jetted [ ] Hollow Stem Auger
[ ] Reverse Circulation
[X] Other

| From (ft) | To (ft) | Description and color of formation material |
|---|---|---|
| 0 | 2 | GRAY & TAN FAT CLAY w/SAND |
| 2 | 4 | GRAY FAT CLAY W/ SAND |
| 4 | 12 | GRAY & TAN LEAN CLAY W/SAND |
| 12 | 30 | REDDISH BROWN/GRAY FAT CLAY |

(Use reverse side of Well Owner's copy, If necessary)

**8) Borehole Completion** [ ] Open Hole [ ] Straight Wall
[ ] Under-reamed [ ] Gravel Packed [ ] Other
Gravel packed interval from : ft. to: ft. Size:

**Casing, Blank Pipe, and Well Screen Data**

| Dia. (in.) | New Or Used | Steel, Plastic, etc. Perf., Slotted, etc Screen Mfg., if commercial | Setting (ft) From | Setting (ft) To | Gage Casing Screen |
|---|---|---|---|---|---|
| 1 | N | PVC RISER | 0 | 20 | .010 |
| 1 | N | PVC RISER | 20 | 30 | |

**9) Annular Seal Data:** i.e. (from 0 ft to 100 ft #sacks & material 13 cement)
from 0 ft. to 18 ft. #sacks & material 4 SACKS
from 18 ft. to 30 ft. #sacks & material 4 SILICA
from ft. to ft. #sacks & material
Method Used Performed By
Distance to septic field or other concentrated contamination ft.
Distance to Property Line ft
Method Verified:

**13) Plugged** [ ] Well plugged within 48 hours
Casing left in well: Cement/Bentonite placed in well:

| From (ft) | To (ft) | From (ft) | To (ft) | # Sacks & Material used |
|---|---|---|---|---|
| | | | | |

**10) Surface Completion** (If steel cased, leave blank)
[ ] Surface Slab Installed [ ] Surface Sleeve Installed
[ ] Pitless Adapter Used [ ] Alternative Procedure Used

**14) Type Pump**
[ ] Turbine [ ] Jet [ ] Submersible [ ] Cylinder NA
[ ] Other
Depth to pump bowls, cylinder, jet etc. ft.

**11) Water Level**
Static level 13.7 ft. Date: 9 / 23 / 11
Artesian Flow NA gpm

**12) Packers:**

| Type | Depth | Type | Depth |
|---|---|---|---|
| | | | |

**15) Water Test**
Type test [ ] Pump [ ] Bailer [ ] Jetted [ ] Estimated NA
Yield: gpm with ft. drawdown after hrs.

**16) Water Quality** NA
Type of water Depth of Strata: Was a chemical analysis made? [ ] Yes [ ] No
Did you knowingly penetrate a strata which contains undesirable constituents? [ ] Yes [ ] No If yes, Continue:
Check One: [ ] Naturally poor-quality groundwater – type [ ] Hydrocarbons (i.e. gas, oil, etc.)
[ ] Hazardous material/waste contamination encountered [ ] Other (describe)

[ ] *I certify that while drilling, deepening, or otherwise altering the above described well, undesirable water or constituents was encountered and the landowner was informed that such well must be completed or plugged in such a manner as to avoid injury or pollution.*

**By signing this well report, I certify that I drilled or supervised the drilling of this well and that each and all of the statements herein are true and correct.**

Company & Individual's Name: (type or print) RONNIE LINDER TRIANGLE RESOURCES INC Lic. No.: 2987

Address : 9871 HWY 90 City: BEAUMONT State: TX Zip 77713

Signature: Licensed Driller/Pump Installer Date 01/16/12 Signature: Apprentice Apprentice Reg. Number

TDLR FORM 001WWD / 7-08 TDLR (Original) Landowner (copy) Driller/Pump Installer (copy)

Attention Owner:
Confidentiality Privilege Notice on reverse side of owner's copy.

# Texas Department of Licensing and Regulation

Water Well Driller/Pump Installer Section
P.O. Box 12157 Austin, Texas 78711 (512)463-7880 FAX (512)463-8616
Toll free (800)803-9202
Email address: water.well@license.state.tx.us Web address: www.license.state.tx.us

This form must be completed and filed with the department and owner within 60 days upon completion of the well.

## WELL REPORT

### A. WELL IDENTIFICATION AND LOCATION DATA

**1) OWNER**

| Name: | Address: | City: | State: | Zip: |
|---|---|---|---|---|
| CITY OF HOUSTON c/o CLR INC. | 19530 FM 362 | WALLER | TX | 77484 |

**2) WELL LOCATION**

| Well # or # of wells drilled | County: | Physical Address: | City: |
|---|---|---|---|
| PZ B19 | HARRIS | | HOUSTON |
| | Lat. 3102413.81 | Long. 13803789.97 | Grid # |

**3) Type of Work**
[X] New Well [ ] Reconditioning
[ ] Replacement [ ] Deepening

**4) Proposed Use (check)** [X] Monitor [ ] Environmental Soil Boring [ ] Domestic [ ] Extraction
[ ] Industrial [ ] Irrigation [ ] Injection [ ] Closed-Loop Geothermal [ ] De-watering [ ] Testwell
[ ] Rig Supply [ ] Stock [ ] Public Supply – If Public Supply, were plans approved? [ ] Yes [ ] No

5) NT

**6) Drilling Date**
Started 9 / 21 / 11
Completed 9 / 21 / 11

**Diameter of Hole**

| Dia.(in) | From (ft) | To (ft) |
|---|---|---|
| 4 | Surface | 17 ft |

**7) Drilling Method (check)**
[ ] Driven [ ] Air Rotary [ ] Mud Rotary
[ ] Bored [ ] Air Hammer [ ] Cable Tool
[ ] Jetted [ ] Hollow Stem Auger
[ ] Reverse Circulation
[X] Other

| From (ft) | To (ft) | Description and color of formation material |
|---|---|---|
| 0 | 6 | GRAY LEAN CLAY w/sand |
| 6 | 10 | LIGHT GRAY & REDDISH BROWN FAT CLAY w/sand |
| 10 | 15 | REDDISH BROWN & LIGHT GRAY FAT CLAY |

(Use reverse side of Well Owner's copy, If necessary)

**8) Borehole Completion** [X] Open Hole [ ] Straight Wall
[ ] Under-reamed [ ] Gravel Packed [ ] Other
Gravel packed interval from : ft. to: ft. Size:

**Casing, Blank Pipe, and Well Screen Data**

| Dia. (in.) | New Or Used | Steel, Plastic, etc. Perf., Slotted, etc Screen Mfg., If commercial | Setting (ft) From | Setting (ft) To | Gage Casing Screen |
|---|---|---|---|---|---|
| 1 | N | PVC RISER | 0 | 7 | |
| 1 | N | PVC SCREEN | 7 | 17 | .010 |

**9) Annular Seal Data:** i.e. (from 0 ft to 100 ft #sacks & material 13 cement)
from 0 ft. to 7 ft. #sacks & material 1 1/2 SACKS
from 0 ft. to 17 ft. #sacks & material 3 SILICA
from ft. to ft. #sacks & material
Method Used Performed By
Distance to septic field or other concentrated contamination ft.
Distance to Property Line ft
Method Verified:

**13) Plugged** [ ] Well plugged within 48 hours
Casing left in well: Cement/Bentonite placed in well:

| From (ft) | To (ft) | From (ft) | To (ft) | # Sacks & Material used |
|---|---|---|---|---|
| | | | | |

**10) Surface Completion** (If steel cased, leave blank)
[ ] Surface Slab Installed [ ] Surface Sleeve Installed
[ ] Pitless Adapter Used [X] Alternative Procedure Used

**14) Type Pump**
[ ] Turbine [ ] Jet [ ] Submersible [ ] Cylinder NA
[ ] Other
Depth to pump bowls, cylinder, jet etc.. ft.

**11) Water Level**
Static level 15.7 ft. Date: 11 / 28 / 11
Artesian Flow NA gpm

**12) Packers:**

| Type | Depth | Type | Depth |
|---|---|---|---|
| | | | |

**15) Water Test**
Type test [ ] Pump [ ] Bailer [ ] Jetted [ ] Estimated NA
Yield: gpm with ft. drawdown after hrs.

**16) Water Quality** NA
Type of water Depth of Strata: Was a chemical analysis made? [ ] Yes [ ] No
Did you knowingly penetrate a strata which contains undesirable constituents? [ ] Yes [ ] No If yes, Continue:
Check One: [ ] Naturally poor-quality groundwater – type [ ] Hydrocarbons (i.e. gas, oil, etc.)
[ ] Hazardous material/waste contamination encountered [ ] Other (describe)

[ ] *I certify that while drilling, deepening, or otherwise altering the above described well, undesirable water or constituents was encountered and the landowner was informed that such well must be completed or plugged in such a manner as to avoid injury or pollution.*

**By signing this well report, I certify that I drilled or supervised the drilling of this well and that each and all of the statements herein are true and correct.**

| Company & Individual's Name: (type or print) | RONNIE LINDER TRIANGLE RESOURCES INC | Lic. No.: | 2987 |
|---|---|---|---|
| Address : 9871 HWY 90 | City: BEAUMONT | State: TX | Zip 77713 |

| Signature: Licensed Driller/Pump Installer | Date: 01/16/12 | Signature: Apprentice | Apprentice Reg. Number |
|---|---|---|---|

Attention Owner: Confidentiality Privilege Notice on reverse side of owner's copy.

# Texas Department of Licensing and Regulation

*Water Well Driller/Pump Installer Section*
*P.O. Box 12157 Austin, Texas 78711 (512)463-7880 FAX (512)463-8616*
*Toll free (800)803-9202*
Email address: water.well@license.state.tx.us Web address: www.license.state.tx.us

This form must be completed and filed with the department and owner within 60 days upon completion of the well.

## WELL REPORT

### A. WELL IDENTIFICATION AND LOCATION DATA

**1) OWNER**

| Name: | Address: | City: | State: | Zip: |
|---|---|---|---|---|
| CITY OF HOUSTON c/o CLR INC. | 19530 FM 362 | WALLER | TX | 77484 |

**2) WELL LOCATION**

| Well # or # of wells drilled | County: | Physical Address: | City: |
|---|---|---|---|
| P2-BB2 | HARRIS | | |

| Lat. | Long. | Grid # |
|---|---|---|
| 3104164.32 | 13802925.33 | |

**3) Type of Work**
[X] New Well [ ] Reconditioning [ ] Replacement [ ] Deepening

**4) Proposed Use (check)** [X] Monitor [ ] Environmental Soil Boring [ ] Domestic [ ] Extraction [ ] Industrial [ ] Irrigation [ ] Injection [ ] Closed-Loop Geothermal [ ] De-watering [ ] Testwell [ ] Rig Supply [ ] Stock [ ] Public Supply – If Public Supply, were plans approved? [ ] Yes [ ] No

5) NT

**6) Drilling Date**
Started 9 / 20 / 11
Completed 9 / 20 / 11

**Diameter of Hole**

| Dia.(in) | From (ft) | To (ft) |
|---|---|---|
| 4 | Surface | 22 |

**7) Drilling Method (check)**
[ ] Driven [ ] Air Rotary [ ] Mud Rotary [ ] Bored [ ] Air Hammer [ ] Cable Tool [ ] Jetted [ ] Hollow Stem Auger [ ] Reverse Circulation [X] Other

| From (ft) | To (ft) | Description and color of formation material |
|---|---|---|
| 0 | 6 | GRAY FAT CLAY w/sand |
| 6 | 20 | REDDISH BROWN FAT CLAY |

(Use reverse side of Well Owner's copy, If necessary)

**8) Borehole Completion** [ ] Open Hole [ ] Straight Wall
[ ] Under-reamed [ ] Gravel Packed [ ] Other
Gravel packed interval from : ft. to: ft. Size:

**Casing, Blank Pipe, and Well Screen Data**

| Dia. (in.) | New Or Used | Steel, Plastic, etc. Perf., Slotted, etc Screen Mfg., if commercial | Setting (ft) From | Setting (ft) To | Gage Casing Screen |
|---|---|---|---|---|---|
| 1 | N | PVC RISER | 0 | 12 | |
| 1 | N | PVC SCREEN | 12 | 22 | .01 |

**9) Annular Seal Data:** i.e. *(from 0 ft to 100 ft #sacks & material, 13 cement)*
from 0 ft. to 10 ft. #sacks & material 2 SACKS
from 10 ft. to 22 ft. #sacks & material 4 SILICA
from ft. to ft. #sacks & material
Method Used Performed By
Distance to septic field or other concentrated contamination ft.
Distance to Property Line ft
Method Verified:

**13) Plugged** [ ] Well plugged within 48 hours
Casing left in well: Cement/Bentonite placed in well:

| From (ft) | To (ft) | From (ft) | To (ft) | # Sacks & Material used |
|---|---|---|---|---|
| | | | | |

**10) Surface Completion** (If steel cased, leave blank)
[ ] Surface Slab Installed [ ] Surface Sleeve Installed [ ] Pitless Adapter Used [ ] Alternative Procedure Used

**14) Type Pump** NA
[ ] Turbine [ ] Jet [ ] Submersible [ ] Cylinder
[ ] Other
Depth to pump bowls, cylinder, jet etc., ft.

**11) Water Level**
Static level 19.9 ft. Date: 11 / 28 / 11
Artesian Flow NA gpm

**12) Packers:**

| Type | Depth | Type | Depth |
|---|---|---|---|
| | | | |

**15) Water Test** NA
Type test [ ] Pump [ ] Bailer [ ] Jetted [ ] Estimated
Yield: gpm with ft. drawdown after hrs.

**16) Water Quality** NA
Type of water Depth of Strata: Was a chemical analysis made? [ ] Yes [ ] No
Did you knowingly penetrate a strata which contains undesirable constituents? [ ] Yes [ ] No If yes, Continue:
Check One: [ ] Naturally poor-quality groundwater – type [ ] Hydrocarbons (i.e. gas, oil, etc.)
[ ] Hazardous material/waste contamination encountered [ ] Other (describe)

[ ] *I certify that while drilling, deepening, or otherwise altering the above described well, undesirable water or constituents was encountered and the landowner was informed that such well must be completed or plugged in such a manner as to avoid injury or pollution.*

By signing this well report, I certify that I drilled or supervised the drilling of this well and that each and all of the statements herein are true and correct.

Company & Individual's Name: (type or print) RONNIE LINDER TRIANGLE RESOURCES INC Lic. No.: 2987

Address : 9871 HWY 90 City: BEAUMONT State: TX Zip 77713

Signature: (Licensed Driller/Pump Installer) Date: 0 / 1 / 6 / 12 Signature: (Apprentice) Apprentice Reg. Number

TDLR FORM 001WWD / 7-98 TDLR (Original) Landowner (copy) Driller/Pump Installer (copy)

Attention Owner:
Confidentiality Privilege Notice on reverse side of owner's copy.

# Texas Department of Licensing and Regulation

Water Well Driller/Pump Installer Section
P.O. Box 12157 Austin, Texas 78711 (512)463-7880 FAX (512)463-8616
Toll free (800)803-9202
Email address: water.well@license.state.tx.us Web address: www.license.state.tx.us

This form must be completed and filed with the department and owner within 60 days upon completion of the well.

## WELL REPORT

### A. WELL IDENTIFICATION AND LOCATION DATA

**1) OWNER**

| Name: | Address: | City: | State: | Zip: |
|---|---|---|---|---|
| CITY OF HOUSTON | 19530 FM 362 | WALLER | TX | 77484 |

**2) WELL LOCATION** C/O CLR INC.

| Well # or # of wells drilled | County: | Physical Address: | City: |
|---|---|---|---|
| PZ-D2 | HARRIS | | |

| Lat. | Long. | Grid # |
|---|---|---|
| 3103645.22 | 13800893.65 | |

**3) Type of Work**
[X] New Well [ ] Reconditioning
[ ] Replacement [ ] Deepening

**4) Proposed Use (check)** [X] Monitor [ ] Environmental Soil Boring [ ] Domestic [ ] Extraction
[ ] Industrial [ ] Irrigation [ ] Injection [ ] Closed-Loop Geothermal [ ] De-watering [ ] Testwell
[ ] Rig Supply [ ] Stock [ ] Public Supply – If Public Supply, were plans approved? [ ] Yes [ ] No

5) NT

**6) Drilling Date**
Started 9 / 20 / 11
Completed 9 / 20 / 11

**Diameter of Hole**

| Dia.(in) | From (ft) | To (ft) |
|---|---|---|
| 4 | Surface | 22 |

**7) Drilling Method (check)**
[ ] Driven [ ] Air Rotary [ ] Mud Rotary
[ ] Bored [ ] Air Hammer [ ] Cable Tool
[ ] Jetted [ ] Hollow Stem Auger
[ ] Reverse Circulation
[X] Other FLIGHT AUGER

| From (ft) | To (ft) | Description and color of formation material |
|---|---|---|
| 0 | 6 | GRAY FAT CLAY W/SAND |
| 6 | 20 | REDISH BROWN & LIGHT GRAY FAT CLAY |

(Use reverse side of Well Owner's copy, If necessary)

**8) Borehole Completion** [ ] Open Hole [ ] Straight Wall
[ ] Under-reamed [ ] Gravel Packed [ ] Other
Gravel packed interval from : ft. to: ft. Size:

**Casing, Blank Pipe, and Well Screen Data**

| Dia. (in.) | New Or Used | Steel, Plastic, etc. Perf., Slotted, etc Screen Mfg., if commercial | Setting (ft) From | Setting (ft) To | Gage Casing Screen |
|---|---|---|---|---|---|
| 1 | N | RISER PVCS | 0 | 12 | – |
| 1 | N | .01 PVC | 12 | 22 | .01 |

**9) Annular Seal Data:** i.e. (from 0 ft to 100 ft #sacks & material 13 cement)
from 0 ft. to 10 ft. #sacks & material 2 SACKS SAKR
from 10 ft. to 22 ft. #sacks & material 4 SILICA
from ft. to ft. #sacks & material
Method Used Performed By
Distance to septic field or other concentrated contamination ft.
Distance to Property Line ft
Method Verified:

**13) Plugged** [ ] Well plugged within 48 hours
Casing left in well: Cement/Bentonite placed in well:

| From (ft) | To (ft) | From (ft) | To (ft) | # Sacks & Material used |
|---|---|---|---|---|
| | | | | |

**10) Surface Completion** (If steel cased, leave blank)
[ ] Surface Slab Installed [ ] Surface Sleeve Installed
[ ] Pitless Adapter Used [X] Alternative Procedure Used

**14) Type Pump**
[ ] Turbine [ ] Jet [ ] Submersible [ ] Cylinder NA
[ ] Other
Depth to pump bowls, cylinder, jet etc., ft.

**11) Water Level**
Static level 12-10 ft Date: 11 / 28 / 11
Artesian Flow NA gpm

**12) Packers:**

| Type | Depth | Type | Depth |
|---|---|---|---|
| | | | |

**15) Water Test**
Type test [ ] Pump [ ] Bailer [ ] Jetted [ ] Estimated NA
Yield: gpm with ft. drawdown after hrs.

**16) Water Quality** NA
Type of water Depth of Strata: Was a chemical analysis made? [ ] Yes [ ] No
Did you knowingly penetrate a strata which contains undesirable constituents? [ ] Yes [ ] No If yes, Continue:
Check One: [ ] Naturally poor-quality groundwater – type [ ] Hydrocarbons (i.e. gas, oil, etc.)
[ ] Hazardous material/waste contamination encountered [ ] Other (describe)

[ ] *I certify that while drilling, deepening, or otherwise altering the above described well, undesirable water or constituents was encountered and the landowner was informed that such well must be completed or plugged in such a manner as to avoid injury or pollution.*

**By signing this well report, I certify that I drilled or supervised the drilling of this well and that each and all of the statements herein are true and correct.**

| Company & Individual's Name: (type or print) | RONNIE LINDER/TRIANGLE RESOURCES INC | Lic. No.: 2987 |
|---|---|---|

| Address : | City: | State: | Zip |
|---|---|---|---|
| 9871 HWY 90 | BEAUMONT | TX | 77713 |

| Signature: Licensed Driller/Pump Installer | Date | Signature: Apprentice | Apprentice Reg. Number |
|---|---|---|---|
| | 01/12/12 | | |

TDLR FORM 001WWD / 7-98 TDLR (Original) Landowner (copy) Driller/Pump Installer (copy)

# APPENDIX D

# BORING LOGS FOR PAVEMENT AND UTILITIES

# (B-1 AND B-11 THROUGH B-28)

# LOG OF BORING B-1

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 53.79 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 23 hours (1)
**Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 1.75 | Stiff gray SANDY LEAN CLAY (CL) w/ ferrous nodules | 18 | | | | | | |
| | | 2.00 | | 20 | 107 | | | | | |
| 50 | | 2.25 | Stiff tan & gray LEAN CLAY w/ SAND (CL) w/ ferrous nodules | 18 | | | | 42 | 24 | 76 |
| 5 | | 4.50 | -hard @ 6'-8' | 16 | | | | | | |
| | | 2.75 | Stiff to very stiff reddish-brown & gray FAT CLAY (CL) w/ ferrous nodules | 30 | | | | | | |
| 45 | | | | | | | | | | |
| 10 | | 2.25 | | 27 | | | | | | |
| | | 2.25 | | 34 | 88 | 2.77 (11) | 15 | | | |
| 40 | | 2.75 | -tan & light gray, w/ sand seams below 14' | 20 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 198+04.20
Offset: 8.51 ft

Coordinates: N: 13807899.5; E:3103365.3



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-11

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 10.3.2011
**Elevation:** 55.23 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 25.75 hours (1)

**Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 / 0 | | | Gray SANDY LEAN CLAY "FILL" w/ limestone, stabilized sand & gravel | 14 | | | | | | |
| | | 1.50 | Stiff gray SANDY LEAN CLAY (CL) | 23 | | | | | | |
| | | 1.50 | | 20 | | | | 45 | 27 | 64 |
| 50 / 5 | | 1.50 | -reddish-brown & tan @ 6'-8' | 21 | | | | | | |
| | | 1.75 | Stiff reddish-brown & gray FAT CLAY (CH) | 21 | 103 | 1.18 | 8 | | | |
| 45 / 10 | | 2.50 | | 26 | | | | 61 | 39 | |
| | | 1.50 | | 33 | 88 | | | | | |
| | | 3.00 | -very stiff below 14' | 30 | | | | | | |
| 40 / 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 / 20 | | | | | | | | | | |
| 30 / 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 13+84.82
Offset: -7.8 ft

Coordinates: N: 13806798.65; E:3103033.83



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-12

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 57.24 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 18 hours (1) **Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard tan & gray SANDY LEAN CLAY "FILL" | 9 | | | | | | |
| 55 | | 4.50 | Hard gray SANDY LEAN CLAY (CL)<br>w/ sand partings & calcareous nodules | 12 | | | | | | |
| | | 4.00 | -very stiff below 4' | 16 | | | | | | |
| 5 | | 4.50 | Hard tan & gray LEAN CLAY w/ SAND (CL) | 16 | | | | 42 | 25 | 75 |
| 50 | | 4.50 | | 15 | | | | | | |
| 10 | | 2.00 | Stiff reddish-brown & gray FAT CLAY (CH)<br>-slickensided @ 10'-12'<br>-w/ silt pockets @ 10'-14' | 27 | 96 | 1.09<br>(10) | 10 * | | | |
| 45 | | 2.00 | | 26 | | | | | | |
| | | 2.50 | | 29 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 40 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 35 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 9+49.55
Offset: -2.14 ft

Coordinates: N: 13806393.63; E:3103193.37



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-13

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 57.76 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 17 hours (1) **Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Very stiff-hard gray & tan FAT CLAY w/ SAND "FILL" w/ calcareous nodules | 16 | | | | 59 | 38 | 84 |
| 55 | | 4.50 | Hard tan & gray SANDY LEAN CLAY (CL) w/ calcareous nodules | 11 | | | | | | |
| 5 | | 4.50 | | 11 | 111 | 5.59 | 3 | | | |
| | | 4.50 | | 13 | | | | | | |
| 50 | | 4.50 | | 13 | | | | | | |
| 10 | | 4.50 | Very stiff-hard tan & gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 15 | | | | | | 73 |
| 45 | | 2.00 | Stiff reddish-brown & gray SANDY SILTY CLAY (CL-ML) | 26 | | | | | | |
| 15 | | 1.00 | Firm reddish-brown FAT CLAY w/ SAND (CH) w/ silty clay seams | 25 | | | | | | |
| | | | Boring terminated @ 15 ft | | | | | | | |
| 40 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 35 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 5+09.93
Offset: -20.65 ft

Coordinates: N: 13806016.14; E:3103418.11



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-14

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 55.91 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 21 hours (1) **Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray & tan SANDY LEAN CLAY (CL) w/ calcareous nodules | 10 | | | | | | |
| | | 4.50 | | 7 | | | | | | |
| | | 4.50 | Hard tan & gray LEAN CLAY w/ SAND (CL) w/ ferrous & calcareous nodules | 13 | | | | 45 | 28 | 78 |
| 5 | | 4.50 | | 16 | 111 | 4.01 | 2 | | | |
| | | 4.00 | -very stiff below 8' | 17 | | | | | | |
| 10 | | 4.00 | Very stiff reddish-brown & gray FAT CLAY (CH) w/ calcareous nodules | 23 | | | | | | |
| | | 3.00 | | 25 | 101 | | | | | |
| | | 3.00 | | 29 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 20 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 174+12.40
Offset: -15.59 ft

Coordinates: N: 13805604.53; E:3103870.53



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-15

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 54.61 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 21.5 hours (1)

**Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray SANDY LEAN CLAY (CL) w/ calcareous nodules | 9 | | | | 37 | 21 | |
| | | 4.50 | | 13 | 113 | 6.68 | 2 | | | |
| 50 5 | | 4.50 | | 12 | 115 | | | | | |
| | | 4.50 | | 11 | | | | | | |
| | | 4.50 | | 15 | 106 | 10.73 (8) | 4 | | | |
| 45 10 | | 4.50 | Very stiff-hard reddish-brown & gray FAT CLAY (CH) w/ sand partings | 22 | | | | 59 | 38 | 99 |
| | | 4.50 | | 20 | | | | | | |
| 40 15 | | 4.25 | -very stiff below 14' | 26 | | | | | | |
| | | | Boring terminated @ 15 ft | | | | | | | |
| 35 20 | | | | | | | | | | |
| 30 25 | | | | | | | | | | |
| 25 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 169+11.60
Offset: -5.19 ft

Coordinates: N: 13805127.58; E:3103729.89



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-16

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 55.79 ft

**Dry Augered:** 0 **to** 15.5 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 22.5 hours (1)

**Caving at:** 13.0 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 / 55 | | | Gray CLAYEY SAND (SC) | 5 | | | | | | |
| | | 5/6" 7/6" 8/6" | -loose @ 2.5'-4' | 10 | | | | | | |
| | | | -w/ ferrous nodules below 4' | 10 | | | | 31 | 15 | 43 |
| 5 / 50 | | | Tan & gray SILTY SAND (SM) w/ clay seams | 12 | 111 | | | | | |
| | | 9/6" 12/6" 16/6" | -medium dense below 8.5' | 11 | | | | | | |
| 10 / 45 | | | Tan & gray CLAYEY SAND (SC) | 15 | | | | | | 23 |
| | | 7/6" 11/6" 21/6" | Medium dense reddish-brown & tan SILTY SAND (SM) | 22 | | | | | | |
| 15 / 40 | | 6/6" 10/6" 18/6" | | | | | | | | 16 |
| | | | Boring terminated @ 15.5 ft | | | | | | | |
| 20 / 35 | | | | | | | | | | |
| 25 / 30 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 163+80.84
Offset: 10.66 ft

Coordinates: N: 13804668.32; E:3103464.81



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-17

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 54.73 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 23 hours (1) **Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | Gray SANDY LEAN CLAY (CL) w/ silty sand seams & gravel | 14 | | | | | | |
| | | 4.50 | Hard gray & tan LEAN CLAY w/ SAND (CL) w/ ferrous nodules | 14 | | | | | | |
| 50 / 5 | | 4.50 | | 14 | | | | | | 71 |
| | | 4.50 | Hard reddish-brown & gray SANDY LEAN CLAY (CL) w/ silty sand seams & ferrous nodules | 13 | | | | 43 | 27 | |
| | | 4.50 | -very stiff @ 8'-10' | 14 | 107 | 2.74 (8) | 14 | | | |
| 45 / 10 | | 4.00 | Very stiff reddish-brown & gray FAT CLAY (CH) w/ silt seams | 23 | | | | | | |
| | | 3.50 | | 25 | | | | 66 | 45 | |
| 40 / 15 | | 2.50 | -stiff w/ silt pockets below 14' | 30 | | | | | | |
| | | | Boring terminated @ 15 ft | | | | | | | |
| 35 / 20 | | | | | | | | | | |
| 30 / 25 | | | | | | | | | | |
| 25 / 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 158+72.78
Offset: -14.05 ft Coordinates: N: 13804322.67; E:3103091.57



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-18

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.23.2011
**Elevation:** 55.45 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 24 hours (1)
**Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 / 0 | | 4.50 | Very stiff-hard gray & tan SANDY LEAN CLAY (CL) w/ calcareous nodules | 11 | | | | | | |
| | | 4.50 | | 11 | 100 | 3.96 | 2 | | | |
| | | 4.50 | Hard gray & tan LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 10 | | | | | | |
| 50 / 5 | | 4.50 | | 11 | | | | 39 | 22 | 78 |
| | | 4.50 | | 11 | | | | | | |
| 45 / 10 | | 4.50 | Very stiff-hard reddish-brown FAT CLAY (CH) | 24 | | | | | | |
| | | 3.00 | -stiff to very stiff below 12'<br>-slickensided @ 12'-14' | 24 | 102 | 1.32 | 3 * | | | |
| | | 2.75 | -w/ silt partings & seams @ 14'-15' | 25 | | | | | | |
| 40 / 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 / 20 | | | | | | | | | | |
| 30 / 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 153+38.92
Offset: -165.68 ft

Coordinates: N: 13804064.90; E:3102600.09



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-19

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.21.2011
**Elevation:** 54.93 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** N/A **Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray LEAN CLAY w/ SAND (CL) w/ sand seams & calcareous nodules | 11 | | | | | | |
| | | 4.50 | | 13 | | | | | | |
| 50 — 5 | | 4.25 | -very stiff, w/ ferrous nodules below 4' | 15 | | | | 40 | 21 | 72 |
| | | 4.25 | Very stiff light gray & reddish brown FAT CLAY w/ SAND (CH) | 18 | 108 | 2.31 (6) | 12 | | | |
| | | 3.50 | -w/ calcareous nodules @ 8'-10' | 17 | | | | | | 79 |
| 45 — 10 | | 3.00 | Very stiff reddish-brown & light gray FAT CLAY (CH) w/ calcareous nodules -slickensided @ 10'-12' | 24 | 101 | 1.81 | 5 * | | | |
| | | 3.00 | | 25 | | | | | | |
| | | 4.50 | -very stiff-hard below 14' | 24 | | | | | | |
| 40 — 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 — 20 | | | | | | | | | | |
| 30 — 25 | | | | | | | | | | |
| 25 — 30 | | | | | | | | | | |

Note(s): (1) Borehole was converted into standpipe piezometer PZ-B19 upon completion of drilling.

Station: 151+59.48
Offset: -219.59 ft Coordinates: N: 13803789.97; E:3102413.81



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-20

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.21.2011
**Elevation:** 55.41 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 30.5 hours (1)

**Caving at:** 14.4 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 / 0 | | 4.50 | Hard dark gray LEAN CLAY w/ SAND (CL) w/ ferrous nodules & fine roots | 13 | | | | | | |
| | | 4.50 | | 13 | | | | | | |
| 50 / 5 | | 4.50 | Very stiff-hard gray & tan FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | 16 | | | | | | |
| | | 2.75 | Stiff reddish-brown & light gray FAT CLAY (CH) | 21 | | | | 55 | 34 | 86 |
| | | 4.00 | -very stiff below 8' | 21 | 107 | 2.29 (8) | 15 | | | |
| 45 / 10 | | 4.00 | | 26 | | | | | | |
| | | 3.00 | | 27 | | | | | | |
| | | 3.00 | | 30 | | | | | | |
| 40 / 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 / 20 | | | | | | | | | | |
| 30 / 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 153+35.77
Offset: 192.38 ft

Coordinates: N: 13803803.14; E:3102844.42



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-21

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 54.77 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 4.25 hours **Caving at:** 14.3 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Very stiff-hard gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 19 | | | | | | |
| | | 4.50 | -hard below 2' | 12 | | | | | | |
| 50 5 | | 4.50 | | 7 | | | | | | |
| | | 4.50 | Hard reddish-brown FAT CLAY (CH) w/ calcareous nodules -slickensided @ 6'-8' | 15 | 116 | 4.42 | 2 * | | | |
| | | 4.50 | -very stiff-hard @ 8'-12' | 17 | | | | 59 | 39 | 94 |
| 45 10 | | 4.50 | | 17 | | | | | | |
| | | 4.25 | -very stiff @ 12'-14' | 18 | | | | | | |
| | | 2.75 | -stiff below 14' | 28 | | | | | | |
| 40 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 20 | | | | | | | | | | |
| 30 25 | | | | | | | | | | |
| 25 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 147+06.67
Offset: -3.14 ft Coordinates: N: 13803349.37; E:3102654.14



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-22

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 53.73 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 5.5 hours

**Caving at:** 14.1 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Very stiff dark gray FAT CLAY w/ SAND (CH) w/ fine roots to 2' | 22 | | | | 65 | 44 | 82 |
| | | 4.25 | | 20 | | | | | | |
| 50 | | 4.50 | -w/ ferrous & calcareous nodules below 4' | 19 | | | | | | |
| 5 | | 4.00 | | 17 | | | | 51 | 31 | |
| | | 3.00 | Very stiff reddish-brown FAT CLAY (CH) w/ calcareous nodules | 21 | 107 | | | | | |
| 45 | | | | | | | | | | |
| 10 | | 2.75 | -stiff below 10' | 28 | | | | | | |
| | | 2.25 | -slickensided @ 12'-14' | 29 | 94 | 1.13 (11) | 6 * | | | |
| 40 | | 2.50 | | 28 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 142+14.27
Offset: -5.03 ft

Coordinates: N: 13802858.42; E:3102652.04



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-23

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.20.2011
**Elevation:** 53.71 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 57 hours (1) **Caving at:** 13.5 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray LEAN CLAY w/ SAND (CL) w/ organics & calcareous nodules | 14 | | | | 39 | 20 | 76 |
| | | 4.50 | | 8 | | | | | | |
| 50 | | 4.50 | Hard tan & light gray SANDY LEAN CLAY (CL) w/ ferrous & calcareous nodules | 13 | 115 | | | | | |
| 5 | | 4.50 | | 15 | 110 | 4.31 | 3 | | | |
| 45 | | 4.50 | | 9 | | | | | | |
| 10 | | 16/6" 20/6" 24/6" | Hard reddish-brown tan SANDY SILTY CLAY (CL-ML) | 13 | | | | | | |
| | | 7/6" 8/6" 8/6" | Stiff tan SILTY CLAY w/ SAND (CL-ML) w/ sand seams | 24 | | | | | | |
| 40 | | 1.50 | Stiff tan & light gray FAT CLAY (CH) w/ silt pockets | 24 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 136+03.03
Offset: -5.19 ft

Coordinates: N: 13802271.90; E:3102494.39



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-24

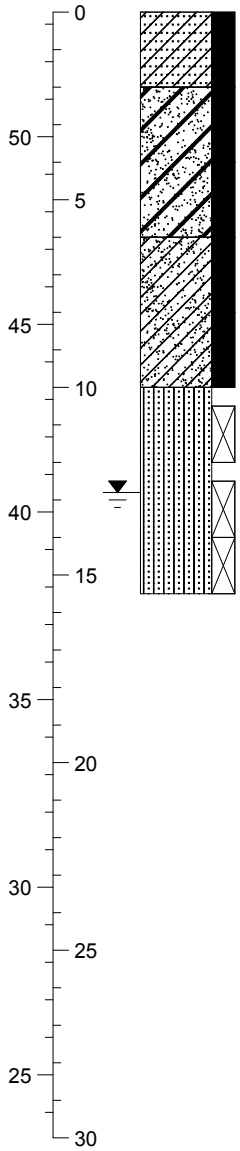
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.20.2011
**Elevation:** 53.32 ft

**Dry Augered:** 0 **to** 15.5 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Damp after 73.5 hours (1)

**Caving at:** 12.8 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray LEAN CLAY w/ SAND (CL) | 11 | | | | 41 | 22 | 75 |
| | | 4.50 | Hard light gray & tan FAT CLAY w/ SAND (CH) w/ calcareous nodules | 14 | | | | | | |
| 50 | | 4.50 | | 18 | 110 | 4.41 | 4 | | | |
| 5 | | 4.50 | Hard light gray & reddish-brown LEAN CLAY w/ SAND (CL) | 16 | | | | 41 | 22 | 84 |
| 45 | | 4.50 | -w/ silt seams below 8' | 14 | | | | | | |
| 10 | | 11/6" 17/6" 22/6" | Dense reddish-brown SILTY SAND (SM) | 15 | | | | | | 14 |
| | | 10/6" 18/6" 23/6" | | 19 | | | | | | |
| 40 | | 13/6" 21/6" 19/6" | | 24 | | | | | | |
| 15 | | | Boring terminated @ 15.5 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 131+08.90
Offset: -5.8 ft

Coordinates: N: 13801819.07; E:3102296.63



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-25

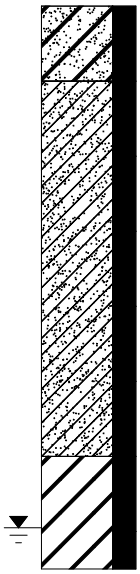
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 53.03 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Damp after 74 hours (1)

**Caving at:** 13.9 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray FAT CLAY w/ SAND (CH) w/ calcareous nodules & fine roots | 15 | | | | | | |
| | | 4.50 | Hard gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 11 | | | | 49 | 30 | 76 |
| 50 | | 4.50 | | 13 | | | | | | |
| 5 | | 4.50 | | 14 | 108 | 6.07 (6) | 6 | | | |
| 45 | | 4.50 | | 15 | | | | | | |
| 10 | | 4.50 | | 13 | | | | 40 | 22 | 71 |
| | | 4.50 | Very stiff-hard reddish-brown FAT CLAY (CH) | 27 | | | | | | |
| 40 | | 3.00 | -very stiff below 14' | 26 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 126+95.18
Offset: -1.15 ft

Coordinates: N: 13801424.34; E:3102172.82



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-26

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 51.62 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 74.5 hours (1)

**Caving at:** 14.5 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray SANDY LEAN CLAY (CL) -w/ fine roots to 2' | 11 | | | | | | |
| 50 | | 4.50 | | 13 | | | | | | |
| | | 4.50 | Hard gray & tan FAT CLAY w/ SAND (CH) w/ calcareous nodules | 14 | | | | | | |
| 5 | | | | | | | | | | |
| 45 | | 4.50 | | 12 | | | | 56 | 37 | 80 |
| | | 4.50 | | 14 | 117 | 5.65 (8) | 2 | | | |
| 10 | | 4.50 | Very stiff-hard reddish-brown & light gray FAT CLAY (CH) | 20 | 109 | | | | | |
| 40 | | 2.50 | -stiff, slickensided @ 12'-14' | 26 | 98 | 1.34 | 4 * | | | |
| | | 3.50 | -very stiff below 14' | 26 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 121+25.84
Offset: 6.25 ft

Coordinates: N: 13800858.36; E:3102140.40



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-27

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 52.18 ft

**Dry Augered:** 0 **to** 15 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** Dry after 75.5 hours (1)

**Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray FAT CLAY w/ SAND (CH) w/ calcareous nodules | 12 | | | | | | |
| 50 | | 4.50 | | 15 | | | | 52 | 33 | 79 |
| | | 4.50 | -w/ ferrous nodules below 4' | 13 | | | | | | |
| 5 | | 4.50 | | 13 | | | | | | |
| 45 | | 4.25 | Very stiff reddish-brown & light gray FAT CLAY (CH) | 22 | 105 | 2.89 (8) | 2 | | | |
| 10 | | 3.00 | | 21 | 102 | | | | | |
| 40 | | 3.00 | -reddish-brown below 12' | 29 | | | | | | |
| | | 3.00 | | 27 | | | | | | |
| 15 | | | Boring terminated @ 15 ft | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 116+26.43
Offset: 4.96 ft

Coordinates: N: 13800359.59; E:3102165.79



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-28

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 54.04 ft

**Dry Augered:** 0 **to** 15 **ft** **Free Water During Drilling at:** Dry
**Washed Bored:** **to** **ft** **Water at:** Dry after 76 hours (1) **Caving at:**

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 4.50 | Hard gray & tan LEAN CLAY w/ SAND "FILL" w/ calcareous nodules | 12 | | | | 44 | 25 | 79 |
| | | 4.50 | Hard gray & tan LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 13 | | | | | | |
| 50 / 5 | | 4.50 | | 11 | | | | | | |
| | | 4.50 | | 12 | | | | 45 | 28 | 82 |
| | | 4.50 | Hard reddish-brown & gray FAT CLAY w/ SAND (CH) w/ calcareous nodules | 13 | 118 | 9.22 | 3 | | | |
| 45 / 10 | | 4.50 | -very stiff-hard @ 10'-12' | 16 | | | | | | |
| | | 4.50 | Very stiff-hard reddish-brown FAT CLAY (CH) | 24 | | | | | | |
| 40 / 15 | | 2.25 | -stiff @ 14'-15' | 27 | | | | | | |
| | | | Boring terminated @ 15 ft | | | | | | | |
| 35 / 20 | | | | | | | | | | |
| 30 / 25 | | | | | | | | | | |
| 25 / 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 111+16.65
Offset: 4.34 ft

Coordinates: N: 13799850.51; E:3102192.41



**TOLUNAY-WONG ENGINEERS, INC.**

# APPENDIX E

# BORING LOGS FOR BRIDGE OVERPASS

# (B-2 THROUGH B-10)

# LOG OF BORING B-2

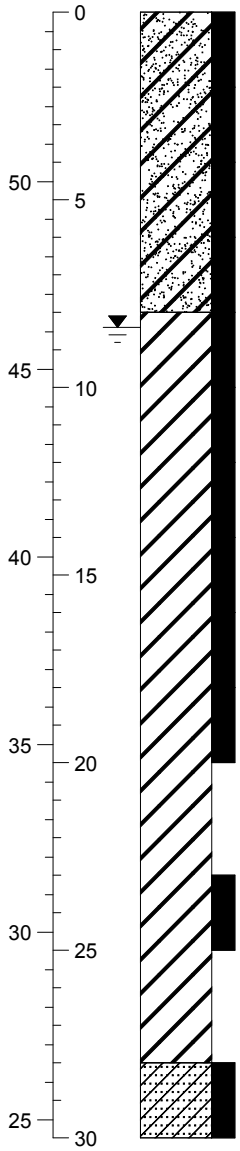
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.29.2011
**Elevation:** 54.52 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** 8.4 ft after 22.25 hours (1)

**Caving at:** 26.2 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 2.00 | Stiff to very stiff gray & tan FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | 22 | | | | 54 | 34 | 78 |
| | | 3.25 | | 20 | | | | | | |
| 50 5 | | 3.00 | | 18 | 112 | 1.92 | 7 | | | |
| | | 3.00 | -reddish-brown & gray below 6' | 20 | | | | | | |
| | | 3.75 | Stiff to very stiff reddish-brown FAT CLAY (CH) w/ calcareous nodules | 23 | 102 | | | | | |
| 45 10 | | 3.25 | | 26 | | | | 61 | 41 | |
| | | 3.00 | | 28 | 97 | 1.68 (11) | 5 | | | |
| 40 15 | | 3.00 | | 22 | 103 | | | 51 | 31 | 90 |
| | | 2.75 | -w/ ferrous nodules @ 16'-20' | 23 | | | | | | |
| | | 2.75 | | 20 | | | | 51 | 32 | 89 |
| 35 20 | | | | | | | | | | |
| | | 4.50 | -very stiff-hard, slickensided @ 23'-25' | 24 | 104 | 0.98 | 1 * | | | |
| 30 25 | | | | | | | | | | |
| | | 1.00 | Firm reddish-brown SANDY LEAN CLAY (CL) w/ silt seams | 26 | | | | 28 | 12 | |
| 25 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 195+44.86
Offset: -34.77 ft

Coordinates: N: 13807639.5; E:3103408.2

# LOG OF BORING B-2

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.29.2011
**Elevation:** 54.52 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** Dry
**Water at:** 8.4 ft after 22.25 hours (1)

**Caving at:** 26.2 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | | | Boring terminated @ 30 ft | | | | | | | |
| 20 / 35 | | | | | | | | | | |
| 15 / 40 | | | | | | | | | | |
| 10 / 45 | | | | | | | | | | |
| 5 / 50 | | | | | | | | | | |
| 0 / 55 | | | | | | | | | | |
| -5 / 60 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 195+44.86
Offset: -34.77 ft

Coordinates: N: 13807639.5; E:3103408.2



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-3

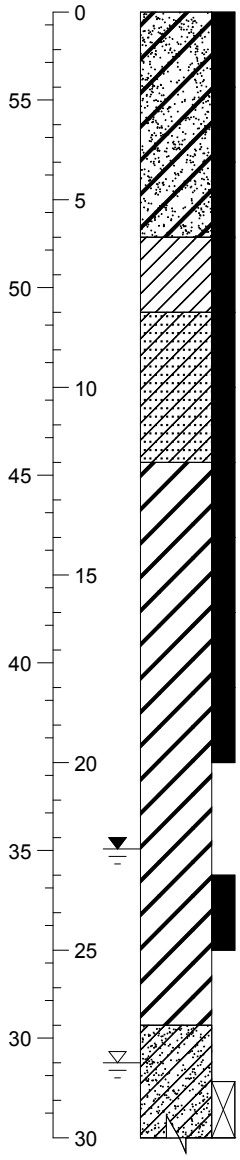
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.15.2011
**Elevation:** 57.34 ft

**Dry Augered:** 0 **to** 28 **ft**
**Washed Bored:** 28 **to** 80 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 22.3 ft after 15 minutes

**Caving at:** 27.7 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 2.00 | Stiff dark gray FAT CLAY w/ SAND (CH) w/ ferrous nodules | 23 | | | | 54 | 35 | 79 |
| 55 | | 1.00 | -firm to stiff @ 2'-4' | 21 | 103 | 1.74 | 9 | | | |
| | | 3.00 | -very stiff @ 4'-6' | 19 | | | | | | |
| 5 | | 2.75 | Stiff dark gray LEAN CLAY (CL) w/ ferrous nodules | 18 | | | | 49 | 31 | 86 |
| 50 | | 2.50 | Stiff tan & reddish-brown SANDY LEAN CLAY (CL) w/ ferrous nodules | 20 | | | | | | |
| 10 | | 2.00 | | 27 | 94 | 1.71 | 5 | | | |
| 45 | | 2.25 | Stiff reddish-brown FAT CLAY (CH) w/ ferrous nodules & calcareous nodules | 32 | | | | | | |
| | | 2.75 | | 20 | 105 | | | 74 | 52 | 99 |
| 15 | | 4.25 | -very stiff below 16' | | | | | | | |
| 40 | | 3.25 | | 20 | 107 | 2.87 (16) | 4 | | | |
| 20 | | | | | | | | | | |
| 35 | | 3.25 | | 23 | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | Hard tan & gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | | | | | | | |
| 30 | | 18/6" 23/6" 23/6" | -w/ sand layer @ 27'-28' | 17 | | | | | | 74 |

Note(s): (1) Borehole was dry with caving depth of 8.2-ft 24.25 hours after completion of drilling. Borehole was backfilled with cement/bentonite grout.

Station: 193+52.70
Offset: 46.72 ft

Coordinates: N: 13807488.7; E:3103552.5

# LOG OF BORING B-3

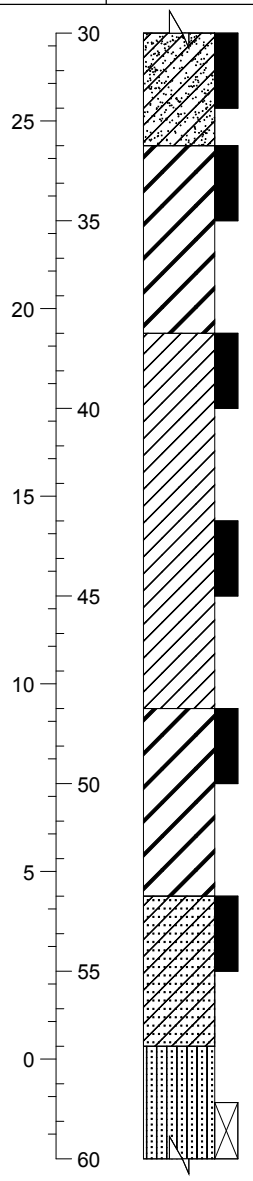
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.15.2011
**Elevation:** 57.34 ft

**Dry Augered:** 0 **to** 28 **ft**
**Washed Bored:** 28 **to** 80 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 22.3 ft after 15 minutes

**Caving at:** 27.7 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | | 2.25 | Stiff tan & gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 17 | | | | | | |
| 25 | | 3.00 | Very stiff tan FAT CLAY (CH) w/ ferrous nodules | 22 | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | 4.50 | Very stiff tan & light gray LEAN CLAY (CL) w/ ferrous nodules | 14 | 120 | 2.29 | 3 | | | |
| 40 | | | | | | | | | | |
| 15 | | 4.00 | | 16 | | | | 43 | 26 | 88 |
| 45 | | | | | | | | | | |
| 10 | | 1.50 | Stiff tan & reddish-brown FAT CLAY (CH) w/ ferrous nodules | 26 | | | | | | |
| 50 | | | | | | | | | | |
| 5 | | 1.50 | Very stiff tan & light gray SANDY LEAN CLAY (CL) w/ ferrous & calcareous nodules | 24 | 104 | 3.04 (47) | 15 | | | |
| 55 | | | | | | | | | | |
| 0 | | 28/6" 32/6" 31/6" | Very dense reddish-brown & gray SILTY SAND (SM) w/ lean clay pockets | 20 | | | | | | |
| 60 | | | | | | | | | | |

Note(s): (1) Borehole was dry with caving depth of 8.2-ft 24.25 hours after completion of drilling. Borehole was backfilled with cement/bentonite grout.

Station: 193+52.70
Offset: 46.72 ft

Coordinates: N: 13807488.7; E:3103552.5

# LOG OF BORING B-3

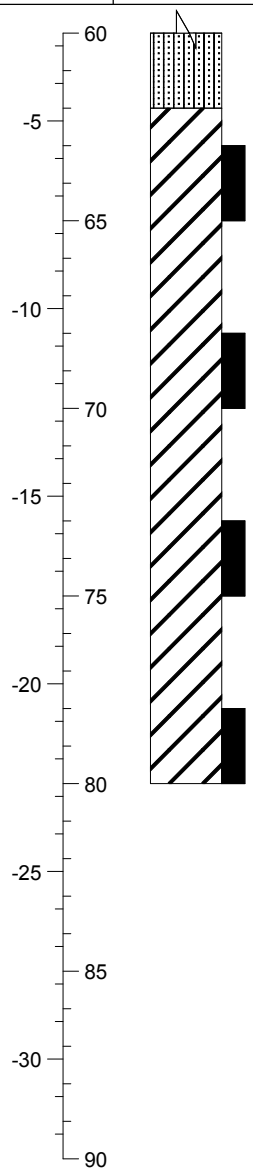
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.15.2011
**Elevation:** 57.34 ft

**Dry Augered:** 0 **to** 28 **ft**
**Washed Bored:** 28 **to** 80 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 22.3 ft after 15 minutes

**Caving at:** 27.7 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Very dense reddish-brown & gray SILTY SAND (SM) w/ lean clay balls | | | | | | | |
| | | 4.50 | Very stiff reddish-brown & gray FAT CLAY (CH) w/ ferrous & calcareous nodules -slickensided @ 63'-65' | 21 | 106 | 2.64 (56) | 15 * | | | |
| | | 4.50 | -very stiff-hard @ 68'-70' | 22 | | | | 62 | 41 | 99 |
| | | 4.50 | -hard below 73' | 22 | 109 | 4.00 | 4 | | | |
| | | 4.50 | -w/ silt pockets below 78' | 20 | | | | | | |
| | | | Boring terminated @ 80 ft | | | | | | | |

Note(s): (1) Borehole was dry with caving depth of 8.2-ft 24.25 hours after completion of drilling. Borehole was backfilled with cement/bentonite grout.

Station: 193+52.70
Offset: 46.72 ft

Coordinates: N: 13807488.7; E:3103552.5



**TOLUNAY-WONG ENGINEERS, INC.**

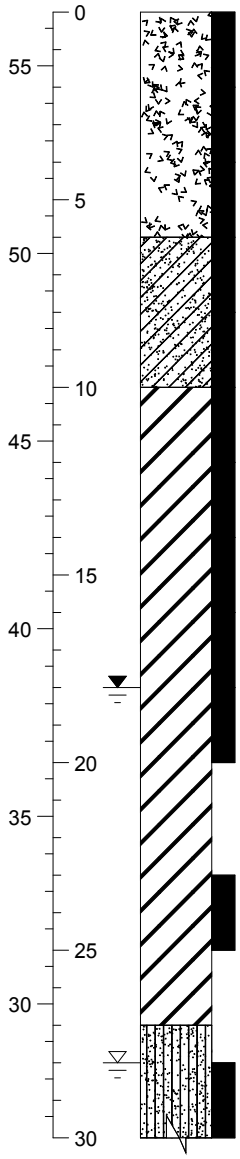
# LOG OF BORING B-4

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 56.43 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 80 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 18.0 ft after 15 minutes
**Caving at:** 28.5 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4.50 | Very stiff-hard dark gray LEAN CLAY w/ SAND "FILL" w/ ferrous nodules | 14 | | | | | | |
| | | 4.50 | | 15 | | | | | | |
| | | 3.00 | -very stiff @ 4'-6' | 18 | | | | 46 | 29 | 76 |
| | | 3.25 | Very stiff tan & gray LEAN CLAY w/ SAND (CL) w/ ferrous & calcareous nodules | 16 | | | | | | |
| | | 2.50 | | 18 | 112 | 2.32 | 15 | | | |
| | | 3.00 | Very stiff reddish-brown FAT CLAY (CH) w/ ferrous nodules | 18 | | | | | | |
| | | 3.25 | | 22 | 105 | | | | | |
| | | 3.25 | -tan, gray & reddish-brown @ 14'-18' | 23 | | | | 59 | 38 | 89 |
| | | 2.50 | | 23 | 104 | 2.59 (15) | 15 | | | |
| | | 2.75 | -stiff @ 18'-20'<br>-reddish-brown below 18' | 22 | | | | | | |
| | | 2.50 | -slickensided @ 23'-25' | 22 | 105 | 2.29 | 6 * | | | |
| | | | -w/ sand layer @ 26'-27' | | | | | | | |
| | | | Reddish-brown SILT w/ SAND (ML) w/ calcareous nodules | 23 | | | | | | 85 |

Note(s): (1) Borehole was converted into piezometer PZ-B4 after completion of drilling.

Station: 192+68.80
Offset: 8.9 ft

Coordinates: N: 13807396.9; E:3103546.8



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-4

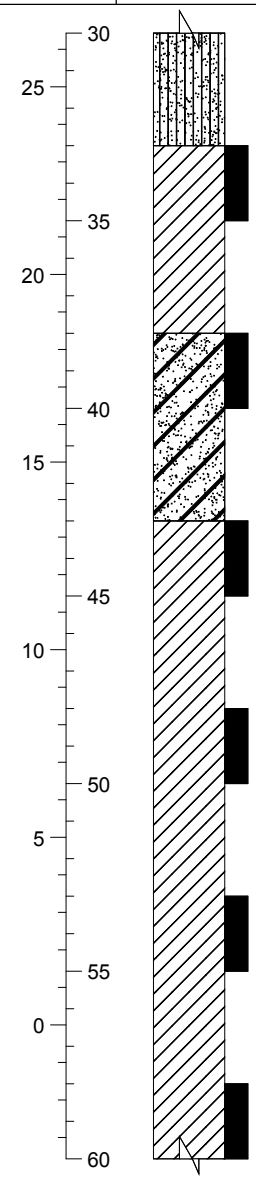
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 56.43 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 80 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 18.0 ft after 15 minutes

**Caving at:** 28.5 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reddish-brown SILT w/ SAND (ML) w/ calcareous nodules | | | | | | | |
| | | 3.50 | Very stiff tan & gray LEAN CLAY (CL) slickensided w/ ferrous & calcareous nodules | 20 | 110 | 3.49 (30) | 7 * | 49 | 31 | |
| | | 4.50 | Hard light gray & reddish-brown FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | 17 | | | | | | |
| | | 4.50 | Hard reddish-brown & gray LEAN CLAY (CL) w/ ferrous & calcareous nodules | 15 | 119 | 4.70 | 3 | | | |
| | | 4.50 | | 15 | | | | 42 | 24 | 92 |
| | | 4.50 | | 15 | | | | | | |
| | | 3.25 | -very stiff-hard @ 58'-60' | 16 | 117 | 3.73 (51) | 6 | 38 | 21 | 76 |

Note(s): (1) Borehole was converted into piezometer PZ-B4 after completion of drilling.

Station: 192+68.80
Offset: 8.9 ft

Coordinates: N: 13807396.9; E:3103546.8

# LOG OF BORING B-4

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.16.2011
**Elevation:** 56.43 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 80 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 18.0 ft after 15 minutes

**Caving at:** 28.5 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | | | Very stiff-hard reddish-brown & gray LEAN CLAY (CL) w/ ferrous & calcareous nodules | | | | | | | |
| -5 | | 4.50 | | 21 | | | | | | |
| 65 | | | | | | | | | | |
| -10 | | 4.50 | | 18 | | | | 32 | 15 | 99 |
| 70 | | | | | | | | | | |
| -15 | | 4.50 | Hard reddish-brown FAT CLAY (CH) w/ ferrous & calcareous nodules -slickensided @ 73'-75' | 22 | 105 | 4.69 | 3 * | | | |
| 75 | | | | | | | | | | |
| -20 | | 4.50 | -very stiff-hard @ 78'-80' | 26 | | | | | | |
| 80 | | | Boring terminated @ 80 ft | | | | | | | |
| -25 | | | | | | | | | | |
| 85 | | | | | | | | | | |
| -30 | | | | | | | | | | |
| 90 | | | | | | | | | | |

Note(s): (1) Borehole was converted into piezometer PZ-B4 after completion of drilling.

Station: 192+68.80
Offset: 8.9 ft

Coordinates: N: 13807396.9; E:3103546.8



**TOLUNAY-WONG ENGINEERS, INC.**

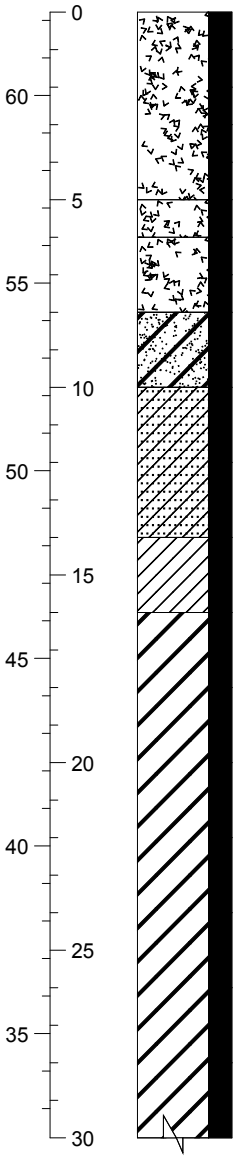
# LOG OF BORING B-5

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.29.2011
**Elevation:** 62.22 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 110 **ft**

**Free Water During Drilling at:** N/A
**Water at:** N/A
**Caving at:**



| ELEVATION/ DEPTH | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2.50 | Stiff to very stiff-hard gray & tan FAT CLAY w/ SAND "FILL" | 18 | 98 | | | | | |
| | 3.25 | | 18 | 106 | | | 51 | 30 | 78 |
| 60 | 3.50 | | 28 | 100 | 2.37 | 8 | | | |
| | 4.50 | | 17 | 111 | | | | | |
| | 3.00 | | 27 | 96 | | | | | |
| 5 | 2.50 | Very stiff dark gray LEAN CLAY w/ SAND "FILL" | 14 | 110 | 2.71 (6) | 12 | 40 | 23 | |
| | 1.75 | Stiff gray FAT CLAY w/ SAND "FILL" | 20 | 105 | | | | | |
| 55 | 2.75 | | 21 | 95 | | | | | |
| | 1.75 | Stiff tan & gray FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | 22 | 102 | 1.51 | 15 | | | |
| 10 | 2.75 | Very stiff tan SANDY LEAN CLAY (CL) w/ ferrous & calcareous nodules | 14 | 119 | | | | | |
| 50 | 1.50 | | 14 | 121 | 2.12 | 5 | | | |
| | 3.00 | Very stiff tan & reddish-brown LEAN CLAY (CL) w/ calcareous nodules | 19 | | | | 40 | 23 | 88 |
| 15 | 3.50 | Stiff to very stiff reddish-brown FAT CLAY (CH) w/ ferrous & calcareous nodules | 22 | | | | | | |
| 45 | 4.00 | | 28 | | | | | | |
| 20 | 2.75 | | 27 | | | | | | |
| 40 | 3.00 | -slickensided @ 22'-24' | 28 | 95 | 1.94 (20) | 5 * | | | |
| | 2.25 | | 24 | | | | 59 | 39 | 93 |
| 25 | 3.00 | | 24 | | | | | | |
| 35 | 4.50 | -very stiff-hard @ 28'-30' | 17 | 114 | 3.77 | 8 | | | |
| 30 | | | | | | | | | |

Note(s): (1) Borehole was dry augered to 30 ft and wet rotary was used after that depth. The next day water level was measured at 7.2 ft with caving depth of 42.7 ft. Borehole was backfilled with cement/bentonite grout.

Station: 191+06.69
Offset: 6.82 ft

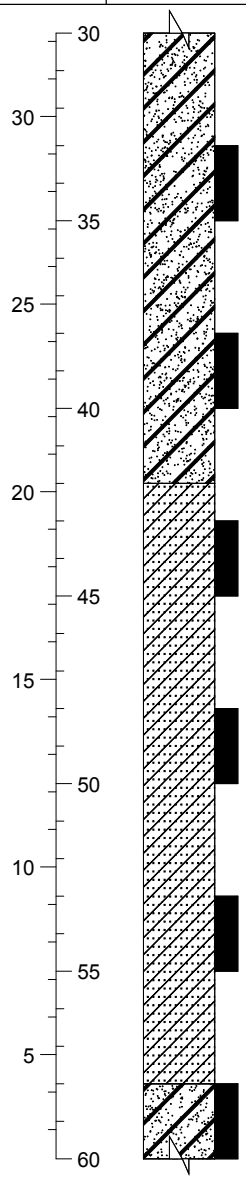
Coordinates: N: 13807244.5; E:3103602.3

# LOG OF BORING B-5

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.29.2011
**Elevation:** 62.22 ft

**Dry Augered:** 0 **to** 30 **ft** **Free Water During Drilling at:** N/A
**Washed Bored:** 30 **to** 110 **ft** **Water at:** N/A **Caving at:**



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | | | Very stiff tan & light gray FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | | | | | | | |
| | | 3.50 | | 21 | 106 | | | 60 | 40 | |
| | | 4.50 | -very stiff-hard below 38' | 29 | | | | | | |
| | | | Stiff light gray & tan SANDY LEAN CLAY (CL) w/ ferrous & calcareous nodules | | | | | | | |
| | | 1.00 | | 19 | 114 | 1.22 | 15 | | | |
| | | 2.75 | | 16 | | | | | | |
| | | 2.50 | | 21 | | | | | | |
| | | 2.00 | Stiff light gray & tan FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | 25 | 103 | 1.96 (51) | 15 | | | |

Note(s): (1) Borehole was dry augered to 30 ft and wet rotary was used after that depth. The next day water level was measured at 7.2 ft with caving depth of 42.7 ft. Borehole was backfilled with cement/bentonite grout.

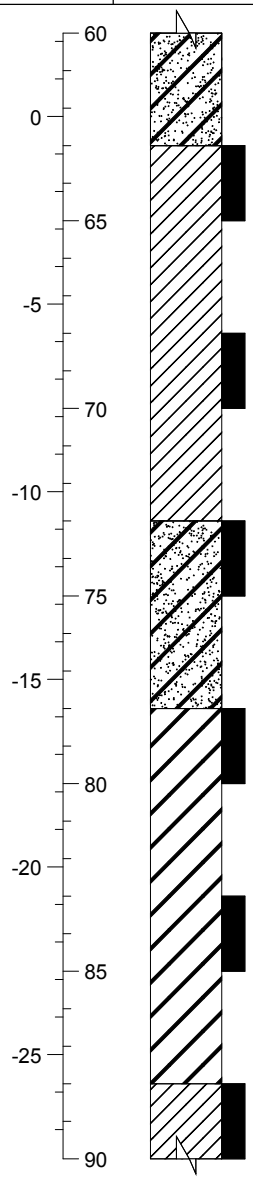
Station: 191+06.69
Offset: 6.82 ft Coordinates: N: 13807244.5; E:3103602.3

# LOG OF BORING B-5

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.29.2011
**Elevation:** 62.22 ft

**Dry Augered:** 0 **to** 30 **ft** **Free Water During Drilling at:** N/A
**Washed Bored:** 30 **to** 110 **ft** **Water at:** N/A **Caving at:**




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stiff light gray & tan FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | | | | | | | |
| | | 4.50 | Very stiff-hard gray & tan LEAN CLAY (CL) w/ ferrous & calcareous nodules | 17 | 116 | | | | | |
| | | 4.00 | -very stiff below 68' | 18 | | | | 38 | 22 | 87 |
| | | 2.00 | Very stiff reddish-brown FAT CLAY w/ SAND (CH) slickensided, w/ sand seams, ferrous & calcareous nodules | 21 | 110 | 2.70 | 1 * | | | |
| | | 4.50 | Very stiff-hard reddish-brown FAT CLAY (CH) w/ ferrous & calcareous nodules | 22 | | | | | | |
| | | 4.50 | | 22 | | | | | | |
| | | 2.75 | Stiff reddish-brown LEAN CLAY (CL) w/ ferrous & calcareous nodules | 17 | | | | 42 | 25 | 88 |

Note(s): (1) Borehole was dry augered to 30 ft and wet rotary was used after that depth. The next day water level was measured at 7.2 ft with caving depth of 42.7 ft. Borehole was backfilled with cement/bentonite grout.

Station: 191+06.69
Offset: 6.82 ft Coordinates: N: 13807244.5; E:3103602.3

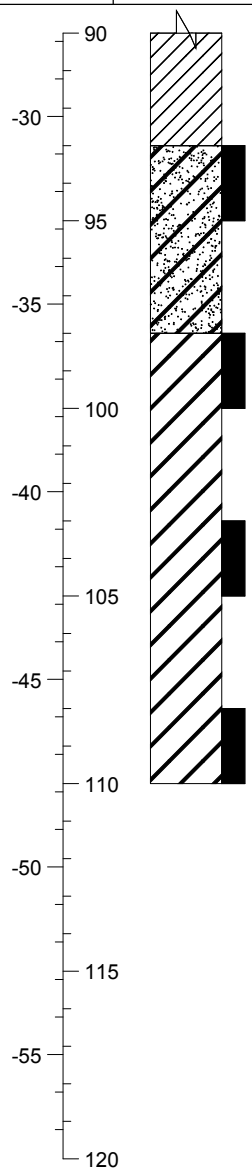
# LOG OF BORING B-5

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.29.2011
**Elevation:** 62.22 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 110 **ft**

**Free Water During Drilling at:** N/A
**Water at:** N/A
**Caving at:**




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stiff reddish-brown LEAN CLAY (CL) w/ ferrous & calcareous nodules | | | | | | | |
| | | 4.50 | Hard reddish-brown FAT CLAY w/ SAND (CH) w/ ferrous & calcareous nodules | 19 | 114 | 5.97 (82) | 15 | | | |
| | | 4.50 | Hard reddish-brown & tan FAT CLAY (CH) w/ silt seams | 26 | | | | | | |
| | | 4.50 | -slickensided @ 103'-105' | 26 | 102 | 4.70 | 6 * | | | |
| | | 4.50 | | 27 | | | | | | |
| | | | Boring terminated @ 110 ft | | | | | | | |

Note(s): (1) Borehole was dry augered to 30 ft and wet rotary was used after that depth. The next day water level was measured at 7.2 ft with caving depth of 42.7 ft. Borehole was backfilled with cement/bentonite grout.

Station: 191+06.69
Offset: 6.82 ft

Coordinates: N: 13807244.5; E:3103602.3



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-6

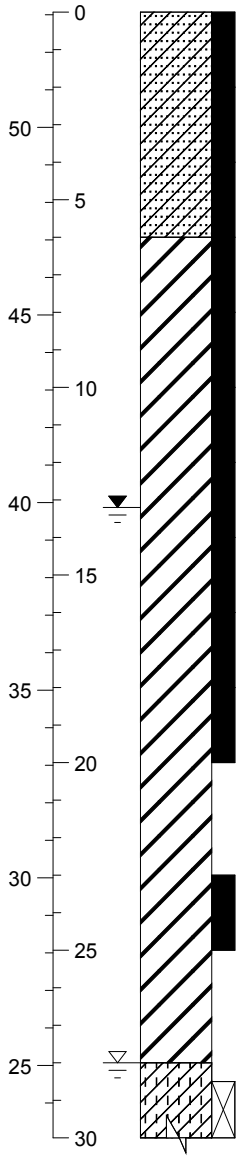
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.23.2011
**Elevation:** 53.07 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes

**Caving at:** 25.8 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4.50 | Hard tan & gray SANDY LEAN CLAY (CL) | 12 | | | | | | |
| | | 4.50 | | 8 | 118 | | | | | |
| | | 4.50 | | 11 | | | | | | |
| | | 3.50 | Very stiff reddish-brown & gray FAT CLAY (CH) w/ calcareous nodules -w/ sand partings @ 6'-8' | 23 | | | | 55 | 35 | 88 |
| | | 4.00 | -w/ silt pockets @ 8'-10' | 19 | | | | | | |
| | | 3.50 | -slickensided @ 10'-12' | 25 | 100 | 1.21 | 2 * | | | |
| | | 3.00 | | 29 | 94 | | | | | |
| | | 2.00 | -stiff @ 14'-16' | 27 | | | | | | |
| | | 3.00 | -very stiff @ 16'-20' | 25 | | | | 62 | 39 | 94 |
| | | 2.75 | | 25 | 99 | 2.53 (16) | 10 | | | |
| | | 4.50 | -very stiff-hard, slickensided w/ silty clay seams @ 23'-25' | 21 | 104 | 0.77 | 1 * | | | |
| | | 9/6" 14/6" 16/6" | Very stiff reddish-brown & gray SILTY CLAY (CL-ML) w/ fat clay seams | | | | | | | 100 |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 188+24.78
Offset: 20.52 ft

Coordinates: N: 13806985.77; E:3103715.05



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-6

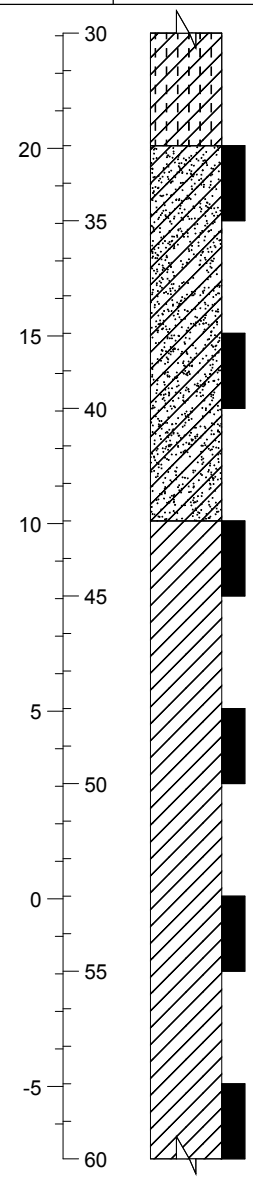
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.23.2011
**Elevation:** 53.07 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes

**Caving at:** 25.8 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Very stiff reddish-brown & gray SILTY CLAY (CL-ML) w/ fat clay seams | | | | | | | |
| | | 1.00 | Firm tan & gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 18 | | | | | | 84 |
| | | 3.00 | -hard below 38' | 17 | 114 | 4.44 (34) | 15 | | | |
| | | 4.50 | Very stiff-hard tan & gray LEAN CLAY (CL) w/ calcareous nodules & sand seams | 14 | | | | 37 | 19 | 90 |
| | | 4.50 | -very stiff below 48' | 18 | 111 | 3.76 | 4 | | | |
| | | 4.50 | | 20 | | | | | | |
| | | 3.25 | | 20 | 107 | 2.74 (51) | 15 | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 188+24.78
Offset: 20.52 ft

Coordinates: N: 13806985.77; E:3103715.05

# LOG OF BORING B-6

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.23.2011
**Elevation:** 53.07 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes

**Caving at:** 25.8 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | | | Very stiff tan & gray LEAN CLAY (CL) w/ calcareous nodules & sand seams | | | | | | | |
| -10 | | 4.50 | Hard reddish-brown & gray FAT CLAY (CH) w/ calcareous nodules, silt seams & pockets | 23 | | | | 65 | 42 | 100 |
| 65 | | | | | | | | | | |
| -15 | | 4.50 | -slickensided @ 68'-75' | 23 | 105 | 2.88 | 2 * | | | |
| 70 | | | | | | | | | | |
| -20 | | 4.50 | | 23 | 103 | 5.21 (64) | 5 * | | | |
| 75 | | | | | | | | | | |
| -25 | | 4.50 | Hard brown & gray LEAN CLAY (CL) | 17 | | | | 43 | 25 | 93 |
| 80 | | | | | | | | | | |
| -30 | | 4.50 | | 17 | 115 | 6.60 | 10 | | | |
| 85 | | | | | | | | | | |
| -35 | | 3.50 | Very stiff reddish-brown & gray FAT CLAY (CH) w/ silt pockets | 23 | | | | | | |
| 90 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 188+24.78
Offset: 20.52 ft

Coordinates: N: 13806985.77; E:3103715.05

# LOG OF BORING B-6

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.23.2011
**Elevation:** 53.07 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes

**Caving at:** 25.8 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | Very stiff reddish-brown & gray FAT CLAY (CH) w/ silt pockets | | | | | | | |
| -40 | | 4.50 | -very stiff-hard below 93' | 27 | 99 | 3.56 (82) | 13 | | | |
| 95 | | | | | | | | | | |
| -45 | | 1.00 | Firm reddish-brown SILTY CLAY (CL-ML) | 21 | | | | 25 | 6 | 91 |
| 100 | | | Boring terminated @ 100 ft | | | | | | | |
| -50 | | | | | | | | | | |
| 105 | | | | | | | | | | |
| -55 | | | | | | | | | | |
| 110 | | | | | | | | | | |
| -60 | | | | | | | | | | |
| 115 | | | | | | | | | | |
| -65 | | | | | | | | | | |
| 120 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 188+24.78
Offset: 20.52 ft

Coordinates: N: 13806985.77; E:3103715.05

# LOG OF BORING B-7

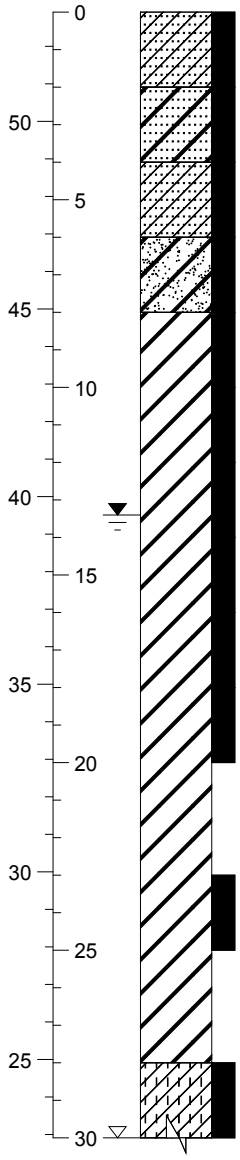
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.26.2011
**Elevation:** 52.91 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 99.25 **ft**

**Free Water During Drilling at:** 30 ft
**Water at:** 13.4 ft after 15 minutes

**Caving at:** 26.4 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4.50 | Hard dark gray SANDY LEAN CLAY (CL) w/ ferrous nodules | 11 | | | | | | |
| | | 4.50 | Hard gray SANDY FAT CLAY (CH) w/ sand seams & ferrous nodules | 13 | | | | 50 | 31 | 70 |
| | | 4.50 | Hard tan & gray SANDY LEAN CLAY (CL) w/ sand pockets & ferrous nodules | 9 | | | | | | |
| | | 4.50 | Hard tan & reddish-brown FAT CLAY w/ SAND (CH) w/ calcareous nodules | 13 | | | | | | |
| | | 4.50 | Very stiff-hard reddish-brown FAT CLAY (CH) w/ calcareous nodules | 17 | | | | 54 | 34 | |
| | | 3.25 | -very stiff @ 10'-12' | 22 | 106 | 1.89 (10) | 4 | | | |
| | | 2.75 | -stiff @ 12'-18' | 29 | | | | | | |
| | | 2.50 | | 33 | | | | | | |
| | | 2.75 | -gray & tan @ 16'-20' | 28 | | | | 63 | 43 | 94 |
| | | 3.50 | -very stiff @ 18'-20' | 27 | 98 | 2.53 | 10 | | | |
| | | 4.50 | -hard, reddish-brown & gray below 23' | 22 | | | | | | |
| | | 1.00 | Stiff tan SILTY CLAY (CL-ML) w/ siltstones | 22 | 108 | 1.78 (25) | 15 | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 186+28.73
Offset: 26.26 ft

Coordinates: N: 13806804.48; E:3103789.89

# LOG OF BORING B-7

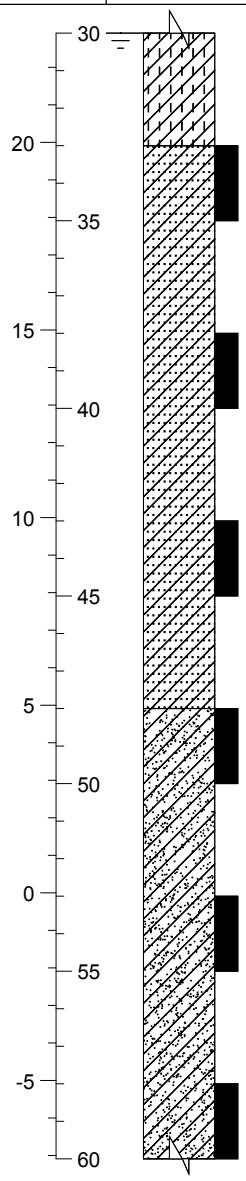
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.26.2011
**Elevation:** 52.91 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 99.25 **ft**

**Free Water During Drilling at:** 30 ft
**Water at:** 13.4 ft after 15 minutes

**Caving at:** 26.4 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stiff tan SILTY CLAY (CL-ML) w/ siltstones | | | | | | | |
| | | 2.00 | Stiff light gray & tan SANDY LEAN CLAY (CL) w/ ferrous & calcareous nodules | 18 | | | | 29 | 13 | |
| | | 1.75 | -very stiff @ 38'-40' | 18 | 113 | 2.09 | 15 | | | |
| | | 4.50 | -very stiff-hard below 43' | 16 | 115 | | | | | |
| | | 3.50 | Hard tan, gray & reddish-brown LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 16 | 114 | 4.69 (43) | 13 | | | |
| | | 4.50 | | 14 | | | | 43 | 25 | 73 |
| | | 2.75 | | 19 | 113 | 4.15 | 5 | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 186+28.73
Offset: 26.26 ft

Coordinates: N: 13806804.48; E:3103789.89

# LOG OF BORING B-7

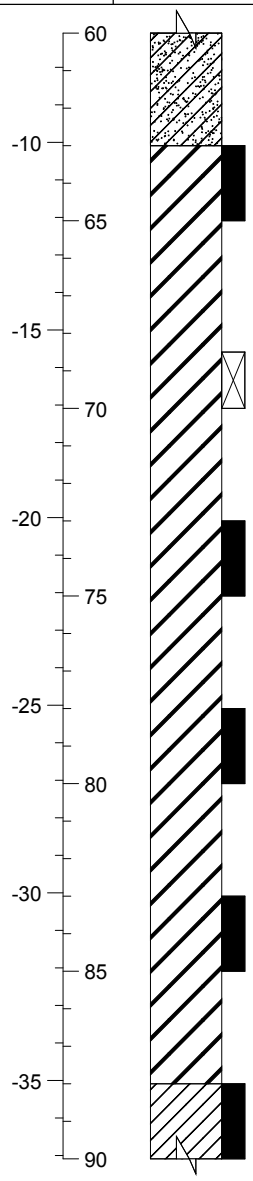
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.26.2011
**Elevation:** 52.91 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 99.25 **ft**

**Free Water During Drilling at:** 30 ft
**Water at:** 13.4 ft after 15 minutes

**Caving at:** 26.4 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hard reddish-brown & gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | | | | | | | |
| | | 4.50 | Hard reddish-brown & light gray FAT CLAY (CH) w/ calcareous nodules | 22 | | | | 61 | 41 | |
| | | 20/6" 19/6" 24/6" | | 26 | | | | 66 | 45 | |
| | | 4.50 | | 23 | 106 | | | | | |
| | | 4.50 | -slickensided @ 78'-80' | 24 | 104 | 4.28 | 3 * | | | |
| | | 3.00 | -very stiff @ 83'-85' | 22 | | | | | | |
| | | 2.75 | Hard reddish-brown LEAN CLAY (CL) w/ silt seams, ferrous & calcareous nodules | 21 | 108 | 5.69 (77) | 15 | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 186+28.73
Offset: 26.26 ft

Coordinates: N: 13806804.48; E:3103789.89

# LOG OF BORING B-7

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.26.2011
**Elevation:** 52.91 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 99.25 **ft**

**Free Water During Drilling at:** 30 ft
**Water at:** 13.4 ft after 15 minutes
**Caving at:** 26.4 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | Hard reddish-brown LEAN CLAY (CL) w/ ferrous & calcareous nodules | | | | | | | |
| | | | Very dense reddish-brown SILT w/ SAND (ML) | | | | | | | |
| -40 | | 29/6" 39/6" 44/6" | | | | | | | | 81 |
| 95 | | | | | | | | | | |
| -45 | | 34/6" 50/3" | | 19 | | | | | | |
| 100 | | | Boring terminated @ 99.25 ft | | | | | | | |
| -50 | | | | | | | | | | |
| 105 | | | | | | | | | | |
| -55 | | | | | | | | | | |
| 110 | | | | | | | | | | |
| -60 | | | | | | | | | | |
| 115 | | | | | | | | | | |
| -65 | | | | | | | | | | |
| 120 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 186+28.73
Offset: 26.26 ft

Coordinates: N: 13806804.48; E:3103789.89



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-8

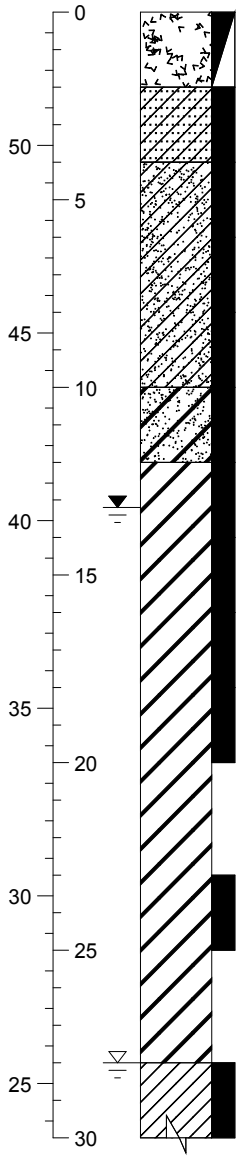
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.28.2011
**Elevation:** 53.55 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes

**Caving at:** 26.5 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | Tan SANDY LEAN CLAY "FILL" w/ limestone & stabilized sand | | | | | | | |
| | | 2.00 | Stiff tan & gray SANDY LEAN CLAY (CL) w/ ferrous nodules | 22 | | | | | | |
| 50 | | 4.50 | Very stiff-hard gray & tan LEAN CLAY w/ SAND (CL) w/ sand seams & calcareous nodules | 16 | | | | | | |
| 5 | | 3.25 | -very stiff @ 6'-8' | 20 | | | | 45 | 27 | 85 |
| 45 | | 2.50 | -stiff @ 8'-10' | 22 | 105 | 1.43 | 7 | | | |
| 10 | | 3.00 | Very stiff reddish-brown FAT CLAY w/ SAND (CH) w/ calcareous nodules | 25 | | | | | | |
| | | 2.75 | Stiff reddish-brown FAT CLAY (CH) w/ calcareous nodules | 32 | | | | 74 | 52 | 99 |
| 40 | | 3.00 | -very stiff @ 14'-20' | 26 | | | | | | |
| 15 | | 2.75 | -tan & gray below 16' | 26 | 98 | 2.47 (15) | 8 | | | |
| 35 | | 3.00 | | 30 | | | | 65 | 45 | 97 |
| 20 | | | | | | | | | | |
| 30 | | 2.75 | -stiff, slickensided @ 23'-25' | 25 | 101 | 1.14 | 2 * | | | |
| 25 | | | | | | | | | | |
| 25 | | 2.50 | Stiff reddish-brown & tan LEAN CLAY (CL) w/ silt seams | 25 | | | | 49 | 32 | 97 |
| 30 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 184+17.11
Offset: -29.58 ft

Coordinates: N: 13806587.01; E:3103806.83

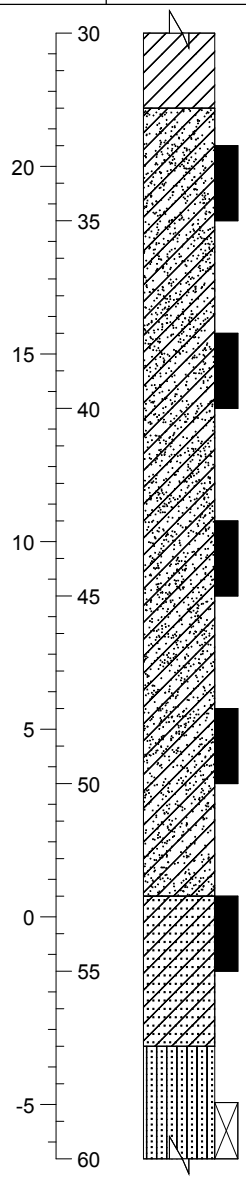
# LOG OF BORING B-8

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.28.2011
**Elevation:** 53.55 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes
**Caving at:** 26.5 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stiff reddish-brown & tan LEAN CLAY (CL) w/ silt seams | | | | | | | |
| | | 3.25 | Very stiff light gray & tan LEAN CLAY w/ SAND (CL) w/ ferrous & calcareous nodules | 18 | 115 | | | | | |
| | | 1.50 | -stiff below 38' | 18 | 114 | 1.26 (34) | 15 | | | |
| | | 2.25 | | 18 | | | | 32 | 15 | 85 |
| | | 2.25 | | 17 | | | | | | |
| | | 4.50 | Hard tan SANDY LEAN CLAY (CL) w/ ferrous & calcareous nodules | 13 | 125 | 7.33 | 9 | | | |
| | | 29/6" 39/6" 50/6" | Very dense tan SILTY SAND (SM) | | | | | | | 16 |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 184+17.11
Offset: -29.58 ft

Coordinates: N: 13806587.01; E:3103806.83

# LOG OF BORING B-8

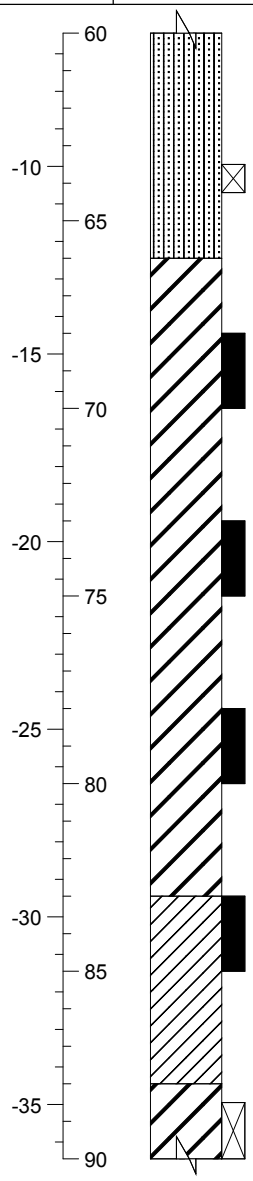
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.28.2011
**Elevation:** 53.55 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes

**Caving at:** 26.5 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | | | Very dense tan SILTY SAND (SM) | | | | | | | |
| -10 / 65 | | 50/6" 50/3" | | 23 | | | | | | |
| | | | Hard reddish brown FAT CLAY (CH) w/ ferrous & calcareous nodules | | | | | | | |
| -15 / 70 | | 4.50 | | 25 | 101 | 4.89 | 5 | | | |
| -20 / 75 | | 4.50 | | 27 | | | | | | |
| -25 / 80 | | 4.50 | | 24 | 103 | 5.50 (69) | 5 | | | |
| -30 / 85 | | 3.25 | Very stiff reddish-brown LEAN CLAY (CL) | 18 | 112 | | | 29 | 13 | |
| -35 / 90 | | 18/6" 25/6" 30/6" | Hard reddish-brown FAT CLAY (CH) w/ silt seams | 28 | | | | 68 | 46 | 97 |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 184+17.11
Offset: -29.58 ft

Coordinates: N: 13806587.01; E:3103806.83

# LOG OF BORING B-8

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.28.2011
**Elevation:** 53.55 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** 30 **to** 100 **ft**

**Free Water During Drilling at:** 28 ft
**Water at:** 13.2 ft after 15 minutes
**Caving at:** 26.5 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | Hard reddish-brown FAT CLAY (CH) w/ silt seams | | | | | | | |
| -40 | | 4.50 | -slickensided @ 93'-95' | 27 | 98 | 4.25 | 6 * | | | |
| 95 | | | | | | | | | | |
| -45 | | 4.50 | -very stiff-hard @ 98'-100' | 32 | | | | | | |
| 100 | | | Boring terminated @ 100 ft | | | | | | | |
| -50 | | | | | | | | | | |
| 105 | | | | | | | | | | |
| -55 | | | | | | | | | | |
| 110 | | | | | | | | | | |
| -60 | | | | | | | | | | |
| 115 | | | | | | | | | | |
| -65 | | | | | | | | | | |
| 120 | | | | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 184+17.11
Offset: -29.58 ft

Coordinates: N: 13806587.01; E:3103806.83

# LOG OF BORING B-9

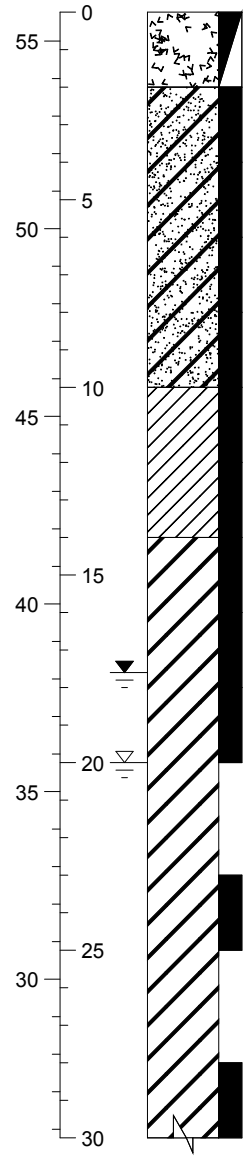
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.27.2011
**Elevation:** 55.77 ft

**Dry Augered:** 0 **to** 20 **ft**
**Washed Bored:** 20 **to** 80 **ft**

**Free Water During Drilling at:** 20 ft
**Water at:** 17.6 ft after 15 minutes

**Caving at:** 18.0 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Light gray SILTY SAND "FILL" w/ limestone & stabilized sand | | | | | | | |
| | | 2.25 | Stiff dark gray FAT CLAY w/ SAND (CH) w/ calcareous nodules | 24 | | | | 62 | 42 | |
| | | 1.00 | -firm @ 4'-8' | 23 | 102 | 0.93 | 5 | | | |
| | | 1.25 | | 21 | 108 | | | | | |
| | | 2.00 | -stiff @ 8'-10' | 22 | | | | | | |
| | | 2.25 | Stiff to very stiff tan, reddish-brown & gray LEAN CLAY (CL) w/ ferrous & calcareous nodules | 19 | 112 | 2.30 (10) | 15 | | | |
| | | 2.00 | | 22 | | | | 49 | 31 | 89 |
| | | 2.25 | Stiff gray & tan FAT CLAY (CH) w/ ferrous nodules | 29 | | | | | | |
| | | 2.50 | | 29 | | | | | | |
| | | 2.50 | -slickensided @ 18'-20' | 27 | 98 | 1.40 | 2 * | | | |
| | | 3.25 | -very stiff @ 23'-30' | 24 | | | | 63 | 43 | 93 |
| | | 4.00 | | 25 | 102 | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 181+86.84
Offset: 75.27 ft

Coordinates: N: 13806385.17; E:3103962.89



**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-9

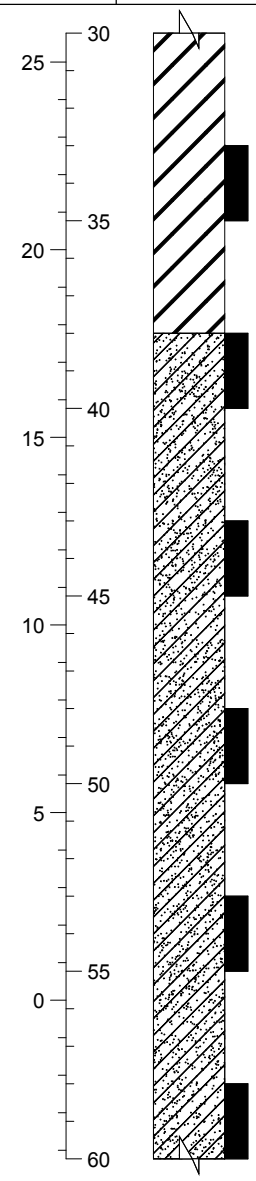
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.27.2011
**Elevation:** 55.77 ft

**Dry Augered:** 0 **to** 20 **ft**
**Washed Bored:** 20 **to** 80 **ft**

**Free Water During Drilling at:** 20 ft
**Water at:** 17.6 ft after 15 minutes

**Caving at:** 18.0 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4.50 | Very stiff-hard gray & tan FAT CLAY (CH) w/ ferrous nodules | 22 | | | | | | |
| | | 3.00 | Hard tan & gray LEAN CLAY w/ SAND (CL) w/ calcareous nodules | 12 | 122 | 4.09 (34) | 15 | | | |
| | | 3.00 | -very stiff @ 43'-55' | 10 | 123 | | | 41 | 23 | 79 |
| | | 3.25 | | 16 | | | | | | |
| | | 3.00 | | 16 | | | | | | |
| | | 1.50 | -stiff below 58' | 16 | 117 | 1.99 | 6 | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 181+86.84
Offset: 75.27 ft

Coordinates: N: 13806385.17; E:3103962.89

# LOG OF BORING B-9

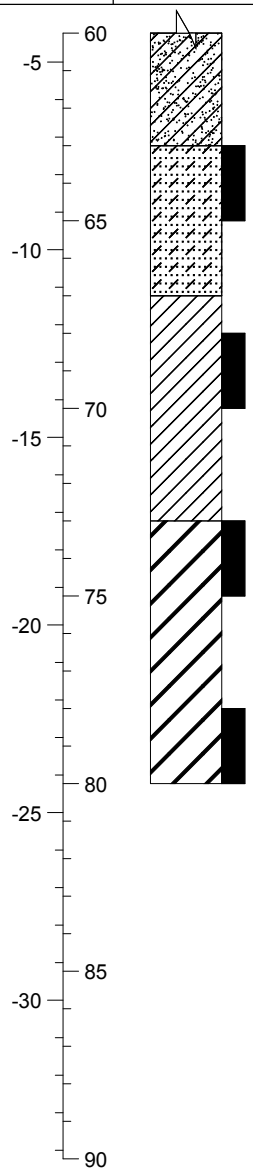
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.27.2011
**Elevation:** 55.77 ft

**Dry Augered:** 0 **to** 20 **ft**
**Washed Bored:** 20 **to** 80 **ft**

**Free Water During Drilling at:** 20 ft
**Water at:** 17.6 ft after 15 minutes

**Caving at:** 18.0 ft




| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stiff tan LEAN CLAY w/ SAND (CL) | | | | | | | |
| | | | Light gray & tan CLAYEY SAND (SC) w/ calcareous nodules | 13 | | | | 32 | 16 | 43 |
| | | 4.50 | Hard reddish-brown LEAN CLAY (CL) w/ calcareous nodules | 16 | | | | 47 | 29 | 99 |
| | | 4.50 | Very stiff reddish-brown FAT CLAY (CH) | 24 | 103 | 2.62 (64) | 7 | | | |
| | | 4.50 | | 24 | 100 | | | 64 | 44 | 100 |
| | | | Boring terminated @ 80 ft | | | | | | | |

Note(s): (1) Borehole was backfilled with cement/bentonite grout at the end of fieldwork day.

Station: 181+86.84
Offset: 75.27 ft

Coordinates: N: 13806385.17; E:3103962.89



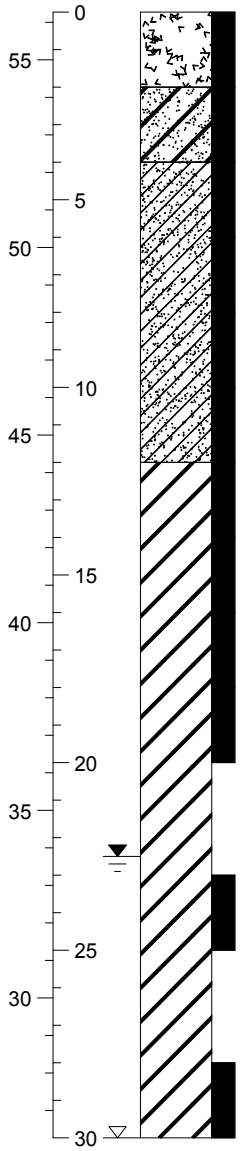
**TOLUNAY-WONG ENGINEERS, INC.**

# LOG OF BORING B-10

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 56.27 ft

**Dry Augered:** 0 **to** 30 **ft** **Free Water During Drilling at:** 30 ft
**Washed Bored:** **to** **ft** **Water at:** 22.5 ft after 15 minutes **Caving at:** 29.3 ft



| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 1.00 | Firm gray & tan FAT CLAY w/ SAND "FILL" | 27 | | | | | | |
| 55 | | 1.50 | Stiff gray FAT CLAY w/ SAND (CH) | 23 | | | | 53 | 33 | 76 |
| | | 1.25 | Firm gray & tan LEAN CLAY w/ SAND (CL) w/ calcareous & ferrous nodules | 17 | | | | | | |
| 5 | | | | | | | | | | |
| 50 | | 1.50 | -stiff @ 6'-10' | 18 | | | | | | |
| | | 2.00 | | 17 | | | | | | |
| 10 | | 3.50 | -stiff to very stiff @ 10'-12' | 17 | 109 | 1.32 | 3 | | | |
| 45 | | 3.50 | Stiff to very stiff reddish-brown & gray FAT CLAY (CH) | 25 | | | | 59 | 38 | 92 |
| | | 3.00 | | 27 | 96 | 1.83 (13) | 7 | | | |
| 15 | | | | | | | | | | |
| 40 | | 3.50 | | 28 | | | | | | |
| | | 2.50 | | 27 | 95 | | | | | |
| 20 | | | | | | | | | | |
| 35 | | | | | | | | | | |
| | | 3.00 | | 25 | | | | | | |
| 25 | | | | | | | | | | |
| 30 | | | | | | | | | | |
| | | 4.50 | -w/ silt seams @ 28'-30' | 14 | 113 | 2.43 | 3 | | | |
| 30 | | | | | | | | | | |

Note(s): (1) Open borehole was converted into standpipe piezometer PZ-B10 upon completion of drilling.

Station: 179+71.69
Offset: -10.89 ft Coordinates: N: 13806157.55; E:3103905.70

# LOG OF BORING B-10

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas
**Client:** CLR, Inc., Waller, Texas

**Project No.:** 11.13.180
**Date:** 09.22.2011
**Elevation:** 56.27 ft

**Dry Augered:** 0 **to** 30 **ft**
**Washed Bored:** **to** **ft**

**Free Water During Drilling at:** 30 ft
**Water at:** 22.5 ft after 15 minutes
**Caving at:** 29.3 ft

| ELEVATION/ DEPTH | SOIL/SAMPLER SYMBOLS & FIELD DATA | POCKET PEN. (tsf) or SPT | DESCRIPTION | Wc (%) | Dens. (pcf) | Qu or UU (tsf) | Str. (%) | LL | PI | Pass #200 (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | | | Boring terminated @ 30 ft | | | | | | | |
| 25 | | | | | | | | | | |
| 35 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 40 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| 45 | | | | | | | | | | |
| 10 | | | | | | | | | | |
| 50 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 55 | | | | | | | | | | |
| 0 | | | | | | | | | | |
| 60 | | | | | | | | | | |

Note(s): (1) Open borehole was converted into standpipe piezometer PZ-B10 upon completion of drilling.

Station: 179+71.69
Offset: -10.89 ft

Coordinates: N: 13806157.55; E:3103905.70

# APPENDIX F

# BORING LOGS FOR OFF-SITE DRAINAGE DITCHES

# (A-1, BB-1, BB-2, C-1 THROUGH C-3 AND D-1 THROUGH D-3)

Tolunay-Wong Engineers, Inc.

# LOG OF BORING A-1



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/22/11

SURFACE ELEVATION: +55.24 ft

## LOCATION

Northing: 13804444.32 Easting: 3104139.66

See Figure 2

## MATERIAL DESCRIPTION

| DEPTH (ft.) | USC | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | CL | **SANDY LEAN CLAY(CL)**, hard, medium plasticity, gray, w/ ferrous & calcareous nodules, moist | P=4.50 | 113 | | | | 9 | 37 | 18 | 19 | 62 | 0' - 2': Crumb Test: Grade 1 Pinhole Test: ND3 Double Hydro. Test: 0% Dispersion |
| | | -light gray @ 2'-4' | P=4.50 | 128 | | | | 6 | 29 | 16 | 13 | 57 | |
| | | -light gray & tan below 4' | P=4.50 | | | | | 15 | | | | | |
| 5 | | -very stiff @ 6'-8' | P=3.25 | | | | | 18 | | | | | 2' - 4': Crumb Test: Grade 2 Pinhole Test: ND2 Double Hydro. Test: 0% Dispersion |
| | | -stiff below 8' | P=2.00 | 105 | | | | 19 | 35 | 18 | 17 | 62 | |
| 10 | CL | **LEAN CLAY WITH SAND(CL)**, stiff, medium plasticity, light gray & reddish brown, w/ ferrous nodules, moist | P=2.00 | 103 | 0.56 | 15 | 10 | 22 | | | | | 8'- 10': CU test $c_T$=238 psf $Ø_T$=28.8° c'=192 psf Ø'=30.7° Sample bulged at failure. |
| | CH | **FAT CLAY WITH SAND(CH)**, firm, high plasticity, reddish brown & tan, w/ lean clay pockets & ferrous nodules, moist | P=0.75 | | | | | 27 | | | | | |
| 15 | CL ML | **SANDY SILTY CLAY(CL-ML)**, soft to firm, slight plasticity, reddish brown & light gray, moist | P=1.00 | 105 | 0.14 | 14 | 0 | 23 | | | | | 10' - 12': Sample bulged at failure. |
| | CH | **FAT CLAY(CH)**, stiff to very stiff, high plasticity, reddish brown & gray, moist | N=20 | | | | | 37 | | | | | 14' - 16': Sample failed along diagonal shear plane. |
| | | | P=2.50 | | | | | 32 | | | | | |
| 20 | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Ground water was measured at a depth of 14.4' & the borehole was open to a depth of 15.0' 8 hours after completion of drilling.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC Logger: G. Love, TWEI
The borehole was damp at 18.4' depth during drilling.

Tolunay-Wong Engineers, Inc.

# LOG OF BORING BB-1



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +53.82 ft

## LOCATION

Northing: 13802874.93 Easting: 3103406.62

See Figure 2

| DEPTH (ft.) | SAMPLES | USC | WATER LEVEL | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | ATTERBERG LIMITS(%) LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | CH | | **FAT CLAY WITH SAND (CH)**, very stiff, high plasticity, tan, gray & brown, w/ organics, moist | P=3.75 | 105 | | | | 20 | 61 | 21 | 40 | 84 | 0' - 2': Crumb Test: Grade 1 Pinhole Test: ND1 Double Hydro. Test: 0% Dispersion |
| | | | | -hard w/ calcareous nodules below 2' | P=4.50 | | | | | 17 | | | | | |
| | | | | -reddish-brown & gray below 4' | P=4.50 | | | | | 15 | | | | | |
| 5 | | CH | | **FAT CLAY (CH)**, stiff to very stiff, high plasticity, reddish-brown & gray, moist | P=2.50 | | | | | 24 | 58 | 22 | 36 | 88 | |
| | | | | -slickensided @ 8'-12' | P=3.50 | 102 | 0.85 | 11* | 0 | 26 | | | | | * Sample failed along slickensides. |
| 10 | | | | | P=3.00 | 96 | 0.76 | 3* | 10 | 28 | | | | | * Sample failed along slickensides. |
| | | | | | P=2.75 | | | | | 26 | | | | | |
| | | | | | P=2.50 | 94 | | | | 30 | | | | | |
| 15 | | | | -light gray & tan below 16' | P=2.75 | | | | | 28 | | | | | |
| | | | | | P=3.25 | | | | | 27 | | | | | |
| 20 | | | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: No ground water was oberved & the borehole was open to a depth of 18.3' 24 hours after completion of drilling.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING BB-2



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +53.13 ft

## LOCATION

Northing: 13802925.33 Easting: 3104164.32

See Figure 2

| DEPTH (ft.) | SAMPLES | USC | WATER LEVEL | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | ATTERBERG LIMITS(%) LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | CH | | **FAT CLAY WITH SAND (CH)**, hard, high plasticity, gray, w/ calcareous nodules, moist | P=4.50 | | | | | 17 | | | | | |
| | | | | -gray & tan @ 2'-6' | P=4.50 | 111 | | | | 16 | 57 | 20 | 37 | 81 | 2' - 4': Crumb Test: Grade 3 Pinhole Test: ND3 Double Hydro. Test: 38.4% Dispersion |
| | | | | | P=4.50 | | | | | 14 | | | | | |
| 5 | | | | -tan & reddish-brown below 6' | P=4.50 | | | | | 16 | | | | | |
| | | CH | | **FAT CLAY (CH)**, very stiff, high to very high plasticity, reddish-brown, w/ calcareous nodules, moist | P=4.00 | 103 | | | | 23 | 62 | 22 | 40 | 96 | 8'- 10': CU test $c_T$=256 psf $Ø_T$=19.5° c'=240 psf Ø'=25.6° Sample failed along slickensides. |
| 10 | | | | | P=3.50 | | | | | 28 | | | | | |
| | | | | -hard @ 12'-14' -reddish-brown & light gray below 12' | P=3.25 | 96 | 2.37 | 6 | 11 | 27 | | | | | |
| | | | | | P=3.50 | | | | | 26 | 66 | 22 | 44 | 90 | 12' - 14': Sample bulged at failure. |
| 15 | | | | | P=3.00 | | | | | 24 | | | | | |
| | | | | -stiff below 18' | P=2.75 | | | | | 25 | | | | | |
| 20 | | | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: No ground water was oberved after completion of drilling. The borehole was converted into piezometer PZ-BB2 after completion of drilling.

Sample Key: ☒ SPT ▨ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING C-1



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +53.38 ft

## LOCATION

Northing: 13801778.36 Easting: 3102951.04

See Figure 3

## MATERIAL DESCRIPTION

| Depth (ft.) | USC | Material Description | Field Strength Data | Dry Density (pcf) | UU/UC Shear Strength (tsf) | Failure Strain (%) | Confining Pressure (psi) | Moisture Content (%) | Liquid Limit (LL) | Plastic Limit (PL) | Plasticity Index (PI) | Passing #200 Sieve (%) | Estimated Angle of Internal Friction (°), Other Tests & Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | CL | **LEAN CLAY WITH SAND (CL)**, stiff, high plasticity, dark gray, w/ calcareous nodules, moist | P=2.50 | | | | | 22 | 45 | 20 | 25 | 76 | |
| | | -very stiff-hard @ 2'-6' | P=4.50 | 114 | | | | 10 | | | | | |
| | | -tan & gray below 2' | P=4.50 | | | | | 16 | | | | | |
| 5 | | -hard w/ ferrous nodules below 6' | P=4.50 | 113 | 2.69 | 5 | 6 | 15 | | | | | 6' - 8': Sample failed along diagonal shear plane. * Sample failed along slickensides. |
| | CH | **FAT CLAY WITH SAND (CH)**, very stiff-hard, high plasticity, tan & gray, slickensided w/ calcareous nodules, moist | P=4.50 | 105 | 0.47 | 1* | 0 | 19 | 52 | 22 | 30 | 85 | |
| 10 | CL | **LEAN CLAY (CL)**, firm, medium plasticity, light gray & tan, w/ silty sand seams & ferrous nodules, moist | P=0.75 | | | | | 24 | | | | 91 | |
| | SM | **SILTY SAND (SM)**, medium dense, no plasticity, reddish-brown, moist to wet | N=24 | | | | | 22 | | | | | |
| | | -w/ lean clay seams @ 12.5'-14' | | | | | | | | | | | |
| 15 | | -dense, tan below 14.5' | N=46 | | | | | 22 | | | | | |
| | | | N=46 | | | | | 20 | | | | 27 | |
| | | | N=36 | | | | | 24 | | | | | |
| 20 | | Boring terminated at 20 ft. | | | | | | | | | | | |

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Ground water was measured at a depth of 14.9' & the borehole was open to a depth of 15.0' 30.5 hours after completion of drilling.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING C-2



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +52.54 ft

## LOCATION

Northing: 13801913.67 Easting: 3103608.29

See Figure 3

| DEPTH (ft.) | USC | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | CH | **FAT CLAY (CH)**, very stiff-hard, very high plasticity, gray & brown, moist | P=4.50 | | | | | 16 | | | | | |
| | | | P=4.50 | 106 | | | | 17 | | | | 90 | 2' - 4': Crumb Test: Grade 1 Pinhole Test: ND2 Double Hydro. Test: 7.9% Dispersion |
| 5 | CH | **FAT CLAY WITH SAND (CH)**, hard, very high plasticity, gray, w/ ferrous & calcareous nodules, moist | P=4.50 | | | | | 14 | 62 | 20 | 42 | 74 | |
| | | | P=4.50 | | | | | 14 | | | | | |
| | CH | **FAT CLAY (CH)**, stiff to very stiff, very high plasticity, tan & gray, w/ calcareous nodules, moist | P=3.00 | 107 | 0.625 | 2* | 0 | 23 | | | | | * Sample failed along slickensides. |
| 10 | | -slickensided @ 8'-10' | P=3.25 | 104 | | | | 23 | 63 | 22 | 41 | 98 | 10'- 12': CU test $c_T$=266 sf $Ø_T$=19.2° c'=262 psf Ø'=25.0° Sample failed along slickensides. |
| | | | P=3.50 | | | | | 26 | 69 | 22 | 47 | 99 | |
| 15 | | -slickensided @ 14'-16' | P=3.25 | 94 | 0.945 | 4* | 13 | 31 | | | | | |
| | | | P=3.00 | | | | | 30 | | | | | * Sample failed along slickensides. |
| | | | P=3.00 | | | | | 30 | | | | | |
| 20 | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: No ground water was oberved & the borehole was open to a depth of 19.1' 30.5 hours after completion of drilling.

Sample Key: ☒ SPT ▨ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING C-3



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +52.46 ft

## LOCATION

Northing: 13801053.25 Easting: 3104205.02

See Figure 3

| DEPTH (ft.) | SAMPLES | USC | WATER LEVEL | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | CH | | **FAT CLAY (CH)**, stiff, very high plasticity, dark gray, w/ organics, moist | P=2.00 | 101 | | | | 25 | 63 | 22 | 41 | 87 | 0' - 2': Crumb Test: Grade 1 Pinhole Test: ND1 Double Hydro. Test: 0.4% Dispersion |
| | | CH | | **FAT CLAY WITH SAND (CH)**, very stiff-hard, very high plasticity, gray, w/ calcareous nodules, moist | P=4.50 | | | | | 17 | | | | | |
| | | | | | P=4.50 | | | | | 18 | 63 | 21 | 42 | 83 | |
| 5 | | | | | | | | | | | | | | | |
| | | CH | | **FAT CLAY (CH)**, stiff to very stiff, high plasticity, gray & tan, moist<br>-w/ calcareous nodules @ 6' -10' | P=3.50 | | | | | 20 | | | | | |
| | | | | | P=3.00 | | | | | 20 | | | | | |
| 10 | | | | -reddish brown below 10' | P=3.00 | 101 | | | | 25 | 60 | 22 | 38 | 93 | 10'- 12': CU test $c_T$=168 psf $Ø_T$=15.2° c'=160 psf Ø'=17.8° Sample failed along multiple shear plane. * Sample failed along slickensides. * Sample failed along slickensides. |
| | | | | -slickensided @ 12'-14' | P=3.25 | 102 | 1.03 | 7* | 11 | 24 | | | | | |
| | | | | | P=2.50 | 94 | | | | 30 | | | | | |
| 15 | | | | -slickensided @ 16'-18' | P=3.25 | 99 | 0.715 | 4* | 0 | 27 | | | | | |
| | | | | | P=3.00 | | | | | 26 | | | | | |
| 20 | | | | Boring terminated at 20 ft. | | | | | | | | | | | |

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ $C_u$ (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: No ground water was oberved & the borehole was open to a depth of 18.9' 31.5 hours after completion of drilling.

Sample Key: ☒ SPT ▨ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING D-1



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +51.45 ft

## LOCATION

Northing: 13801062.03 Easting: 3102873.17

See Figure 3

| DEPTH (ft.) | SAMPLES | USC | WATER LEVEL | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | CH | | **FAT CLAY WITH SAND (CH)**, hard, high plasticity, gray & tan, moist | P=4.50 | | | | | 15 | | | | | |
| | | | | -w/ calcareous nodules below 2' | P=4.50 | 119 | | | | 13 | 57 | 20 | 37 | 82 | 2' - 4': Crumb Test: Grade 1 Pinhole Test: ND2 Double Hydro. Test: 0.2% Dispersion |
| | | | | -light gray & tan @ 4'-8' | P=4.50 | | | | | 15 | 55 | 20 | 35 | 84 | |
| 5 | | | | -w/ ferrous nodules below 6' | P=4.50 | | | | | 19 | | | | | |
| | | | | -very stiff, reddish brown & light gray, slickensided @ 8' -10' | P=3.50 | 106 | 1 | 7* | 0 | 22 | | | | | * Sample failed along slickensides. |
| 10 | | CH | | **FAT CLAY (CH)**, very stiff, very high plasticity, reddish-brown, moist | P=3.00 | | | | | 29 | | | | | |
| | | | | -stiff below 12' | P=2.50 | | | | | 32 | 74 | 23 | 51 | 98 | |
| | | | | -slickensided @ 14'-16' | P=2.50 | 93 | 0.61 | 15* | 13 | 31 | | | | | * Sample failed along slickensides. |
| 15 | | | | | P=2.75 | 94 | | | | 29 | | | | | |
| | | | | | P=2.75 | | | | | 29 | | | | | |
| 20 | | | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: No ground water was oberved & the borehole was open to a depth of 18.7' 25 hours after completion of drilling.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING D-2



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +51.58 ft

## LOCATION

Northing: 13800893.65 Easting: 3103645.22

See Figure 3

| DEPTH (ft.) | USC | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | CH | **FAT CLAY WITH SAND (CH)**, stiff, high plasticity, gray, w/ ferrous & calcareous nodules, moist | P=2.00 | | | | | 26 | 58 | 21 | 37 | 84 | |
| | | -very stiff @ 2'-4' | P=4.00 | | | | | 17 | | | | | |
| | | -very stiff-hard below 4' | P=4.50 | | | | | 16 | | | | | |
| 5 | CH | **FAT CLAY (CH)**, very stiff, high plasticity, reddish brown & light gray, w/ ferrous nodules, moist | P=3.50 | 108 | | | | 19 | | | | | |
| | | | P=4.25 | 107 | 1.135 | 14 | 8 | 21 | | | | | 8' - 10': Sample failed along vertical shear plane. |
| 10 | | - stiff @ 10'-14' | P=2.75 | 100 | | | | 26 | 61 | 22 | 39 | 94 | 10'- 12': CU test $c_T$=390 psf $Ø_T$=13.7° c'=374 psf Ø'=18.3° Sample failed along slickensides. |
| | | | P=2.50 | | | | | 29 | | | | | |
| | | -very stiff @ 14'-18' | P=3.50 | | | | | 25 | | | | | |
| 15 | | | P=3.75 | | | | | 25 | 62 | 22 | 40 | 96 | |
| | | -stiff to very stiff, slickensided @ 18'-20' | P=3.75 | 98 | 0.7 | 4* | 0 | 27 | | | | | * Sample failed along slickensides. |
| 20 | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: No ground water was oberved after completion of drilling. The borehole was converted into piezometer PZ-D2 after completion of drilling.

Sample Key: ☒ SPT ▨ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

Tolunay-Wong Engineers, Inc.

# LOG OF BORING D-3



PROJECT: Buffalo Speedway Ext., From W. Airport Blvd. to Willowbend Blvd., Houston, Texas

PROJECT NO.: 11.13.180 BORING TYPE: Auger 0' - 20'

DATE: 9/20/11

SURFACE ELEVATION: +50.79 ft

## LOCATION

Northing: 13800749.23 Easting: 3104345.69

See Figure 3

| DEPTH (ft.) | USC | MATERIAL DESCRIPTION | FIELD STRENGTH DATA | DRY DENSITY (pcf) | UU/UC SHEAR STRENGTH (tsf) | FAILURE STRAIN (%) | CONFINING PRESSURE (psi) | MOISTURE CONTENT (%) | LIQUID LIMIT (LL) | PLASTIC LIMIT (PL) | PLASTICITY INDEX (PI) | PASSING #200 SIEVE (%) | ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | CH | **FAT CLAY WITH SAND (CH)**, hard, high plasticity, gray, moist | P=4.50 | | | | | 16 | | | | | |
| | | | P=4.50 | | | | | 15 | 59 | 22 | 37 | 85 | |
| | | -gray & tan below 4' | P=4.50 | 104 | | | | 15 | 53 | 21 | 32 | 80 | 4' - 6': Crumb Test: Grade 3 Pinhole Test: ND3 Double Hydro. Test: 20.1% Dispersion |
| 5 | | | P=4.50 | 111 | 2.935 | 2 | 0 | 17 | | | | | |
| | | -very stiff below 8 | P=3.75 | 112 | | | | 16 | | | | | |
| 10 | CH | **FAT CLAY (CH)**, very stiff, high plasticity, reddish-brown & tan, moist -slickensided @ 10'-12' | P=2.25 | 96 | 1.13 | 8* | 0 | 30 | | | | | 6' - 8': Sample failed along vertical shear plane. * Sample failed along slickensides. |
| | | | P=4.25 | | | | | 22 | 52 | 20 | 32 | 99 | |
| | | | P=3.00 | | | | | 23 | | | | | |
| 15 | CL | **LEAN CLAY (CL)**, firm, medium plasticity, reddish brown & light gray, w/ silty sand seams & ferrous nodules, moist | P=1.25 | 101 | 0.405 | 15 | 15 | 23 | | | | | 16' - 18': Sample bulged at failure. |
| | | | P=1.00 | | | | | 23 | | | | | |
| 20 | | Boring terminated at 20 ft. | | | | | | | | | | | |

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit (20, 40, 60, 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Ground water was measured at a depth of 10.4' & the borehole was open to a depth of 10.6' 6.5 hours after completion of drilling.

Sample Key: ☒ SPT ▨ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
$C_u$ - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
Driller: Geo Tech Services, LLC
The borehole was dry during drilling.

Logger: G. Love, TWEI

# SYMBOLS AND TERMS USED ON BORING LOGS

**Most Common Unified Soil Classifications System Symbols**

- CH Fat Clay
- CH Fat Clay w/ Sand
- CH Sandy Fat Clay
- CL Lean Clay
- CL Lean Clay w/ Sand
- CL Sandy Lean Clay
- CL-ML Silty Clay
- CL-ML Silty Clay w/ Sand
- CL-ML Sandy Silty Clay
- ML Silt
- ML Silt w/ Sand
- ML Sandy Silt
- SC Clayey Sand
- SC-SM Silty, Clayey Sand
- SM Silty Sand
- SP-SM Poorly Graded Sand w/ Silt
- SP Poorly Graded Sand
- MH Elastic Silt
- MH Elastic Silt w/ Sand
- GP Poorly Graded Gravel

**Miscellaneous Materials**

- Asphalt and/or Base
- Concrete
- Fill

| Sampler Symbols | Meaning |
|---|---|
| | Thin-walled tube sample |
| | Standard Penetration Test (SPT) |
| | Auger sample |
| | Sampling attempt with no recovery |
| | TxDOT Cone Penetrometer Test |

**Field Test Data**

| | |
|---|---|
| P = 2.50 | Pocket penetrometer reading in tons per square foot |
| N = 12 | The sum of blows required to penetrate the final 12-in. of the Standard Penetration Test |
| T = 800 | Torvane measurement in pounds per square foot |
| WOR | Weight of rod |
| WOH | Weight of hammer |
| | Observed free water level during drilling |
| | Observed static water level after drilling |

**Laboratory Test Data**

| | |
|---|---|
| $W_c$ (%) | Moisture content in percent |
| Density (pcf) | Dry unit weight in pounds per cubic foot |
| Qu (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 |
| * | Slickensided failure |
| ** | Did not fail @ 15% strain |

| Degree of Plasticity | Plasticity Index |
|---|---|
| None | 0-4 |
| Slight | 5-10 |
| Medium | 11-20 |
| High | 21-40 |
| Very High | > 40 |

**Moisture Condition**
ASTM D 2488

| | |
|---|---|
| **Dry** | Absence of moisture, dusty, dry to the touch |
| **Moist** | Damp but no visible water |
| **Wet** | Visible free water |

**RELATIVE DENSITY OF COHESIONLESS & SEMI-COHESIVE SOILS**

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

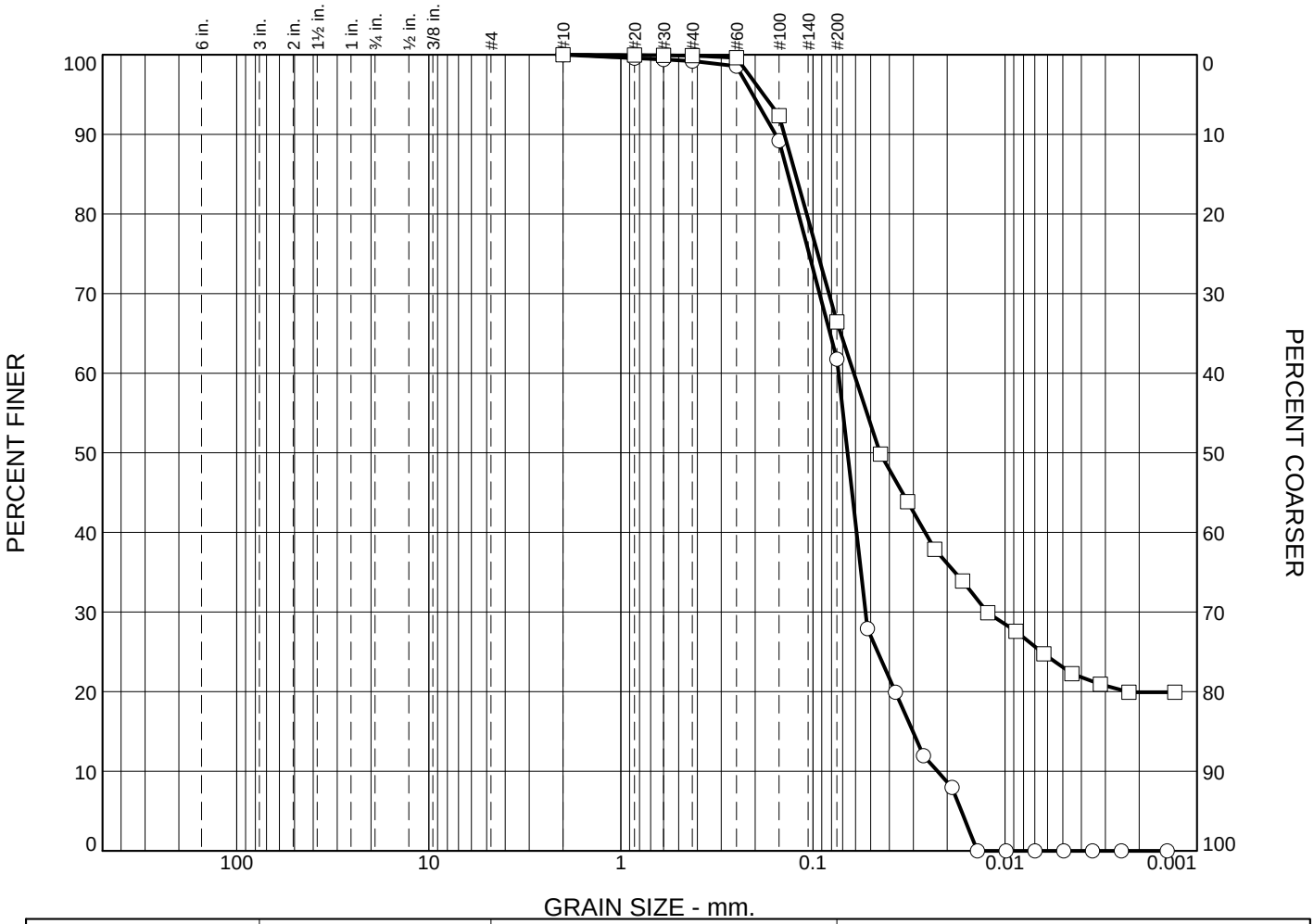
| Typical Unconfined Compressive Strength (tsf) | Typical Undrained Shear Strength (tsf) | Consistency | Typical SPT "N" Value Range** |
|---|---|---|---|
| $q_u < 0.25$ | $S_u < 0.125$ | Very soft | $\leq 2$ |
| $0.25 \leq q_u < 0.50$ | $0.125 \leq S_u < 0.25$ | Soft | 3-4 |
| $0.50 \leq q_u < 1.00$ | $0.25 \leq S_u < 0.50$ | Firm | 5-8 |
| $1.00 \leq q_u < 2.00$ | $0.50 \leq S_u < 1.00$ | Stiff | 9-15 |
| $2.00 \leq q_u \leq 4.00$ | $1.00 \leq S_u \leq 2.00$ | Very Stiff | 16-30 |
| $q_u > 4.00$ | $S_u > 2.00$ | Hard | $\geq 31$ |

** 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.

# APPENDIX G

# SELECTED PARTICLE SIZE ANALYSIS OF SOILS, PINHOLE DISPERSION, DOUBLE HYDROMETER, CRUMB, CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION W/PORE PRESSURE MEASUREMENTS, CONSOLIDATION AND PROCTOR TEST RESULTS

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 37.4 | 61.8 | 0.0 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 33.5 | 46.5 | 19.9 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | A-1 | | 0-2. | SANDY LEAN CLAY w/o Sodium Hexametaphosphate | CL |
| □ | A-1 | | 0-2.1 | SANDY LEAN CLAY w/ Sodium Hexametaphosphate | CL |
| | | | | | |
| | | | | | |
| | | | | | |

**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

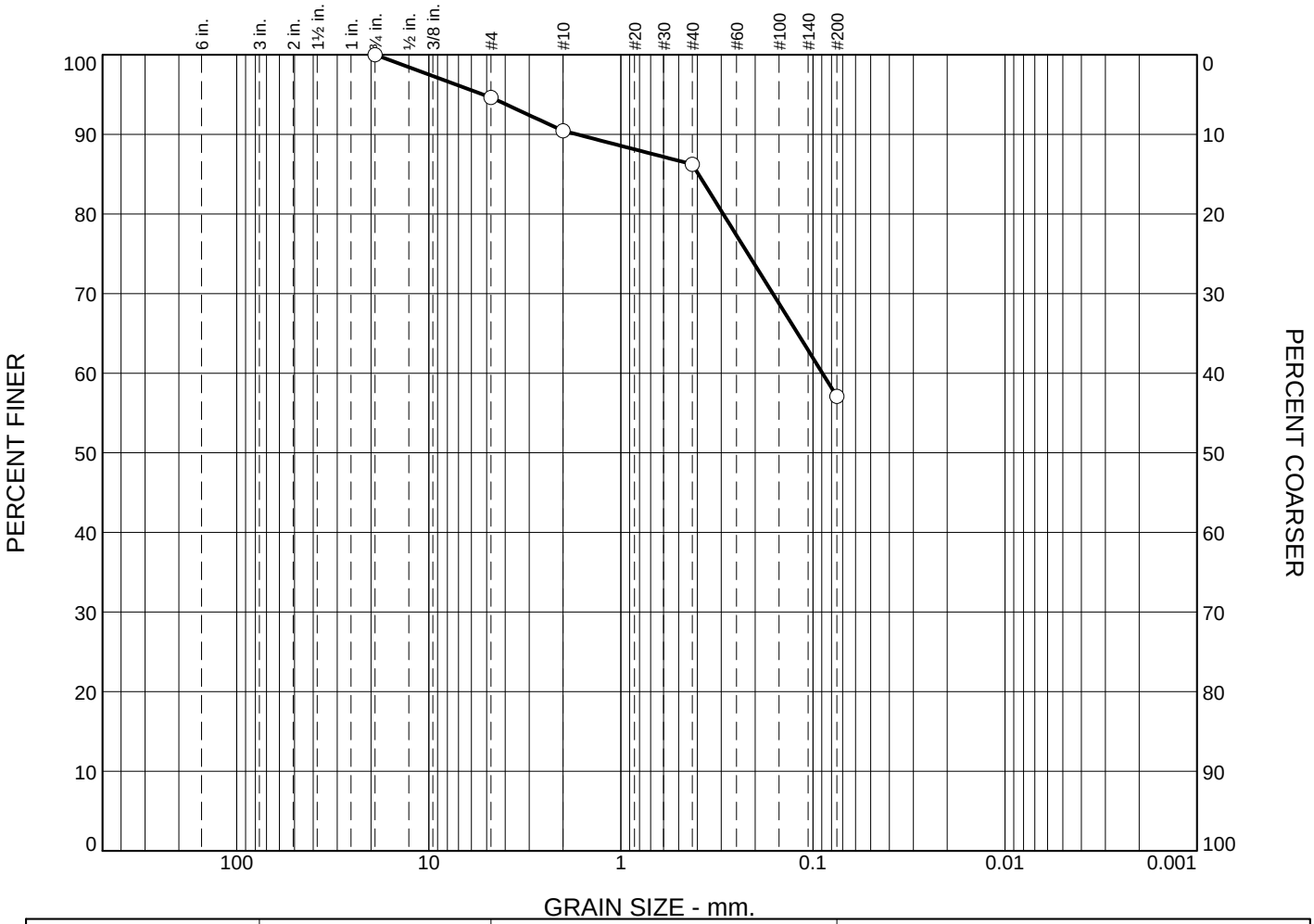
**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180

**Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 5.4 | 4.2 | 4.2 | 29.1 | 57.1 | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | A-1 | | 2-4 | Gray SANDY LEAN CLAY; calcareous nodules | CL |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

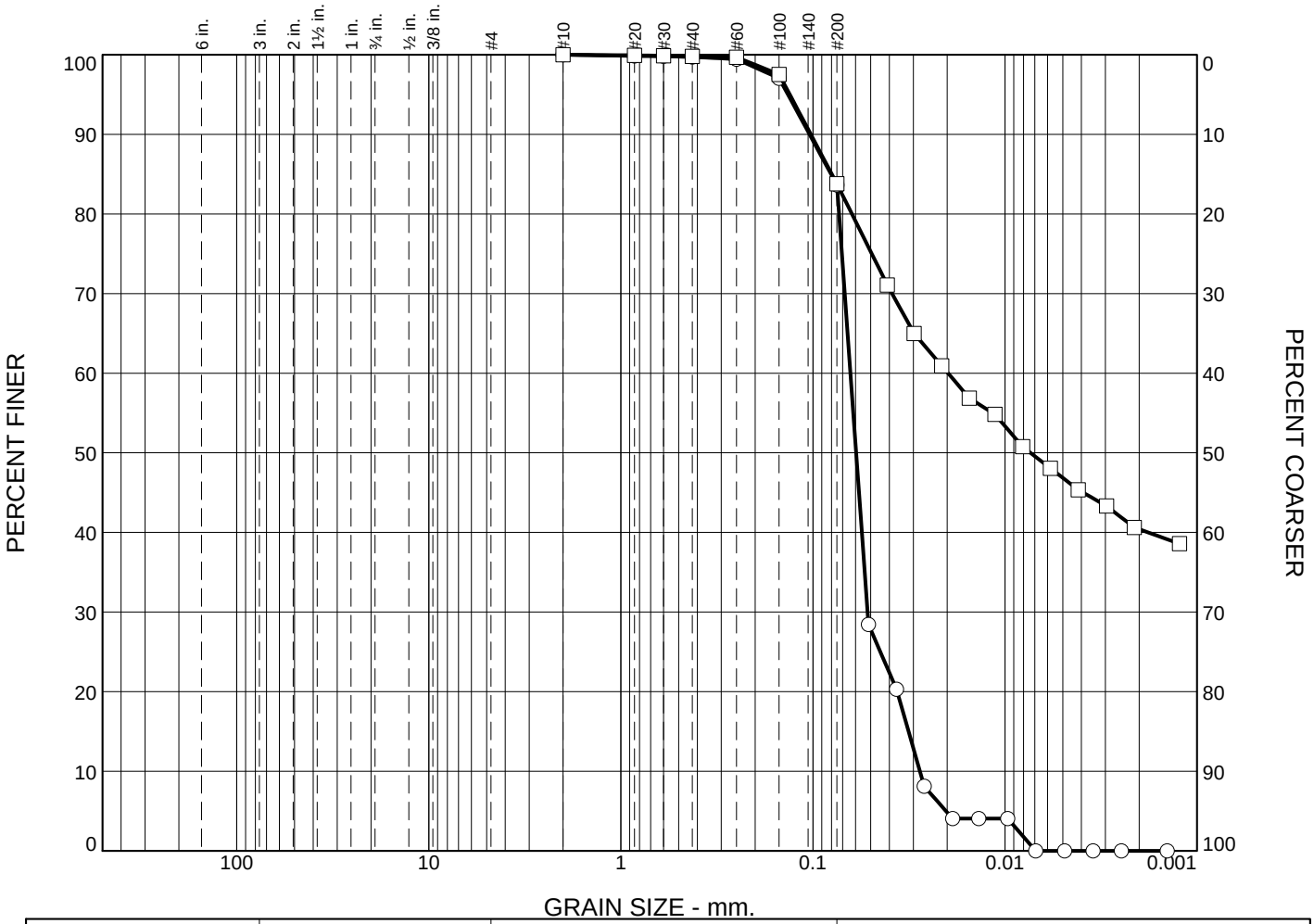
**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180

**Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 16.1 | 83.6 | 0.0 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 16.0 | 43.4 | 40.4 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | BB-1 | | 0-2. | FAT CLAY WITH SAND w/o Sodium Hexametaphosphate | CH |
| □ | BB-1 | | 0-2.1 | FAT CLAY WITH SAND w/ Sodium Hexametaphosphate | CH |
| | | | | | |
| | | | | | |
| | | | | | |

**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

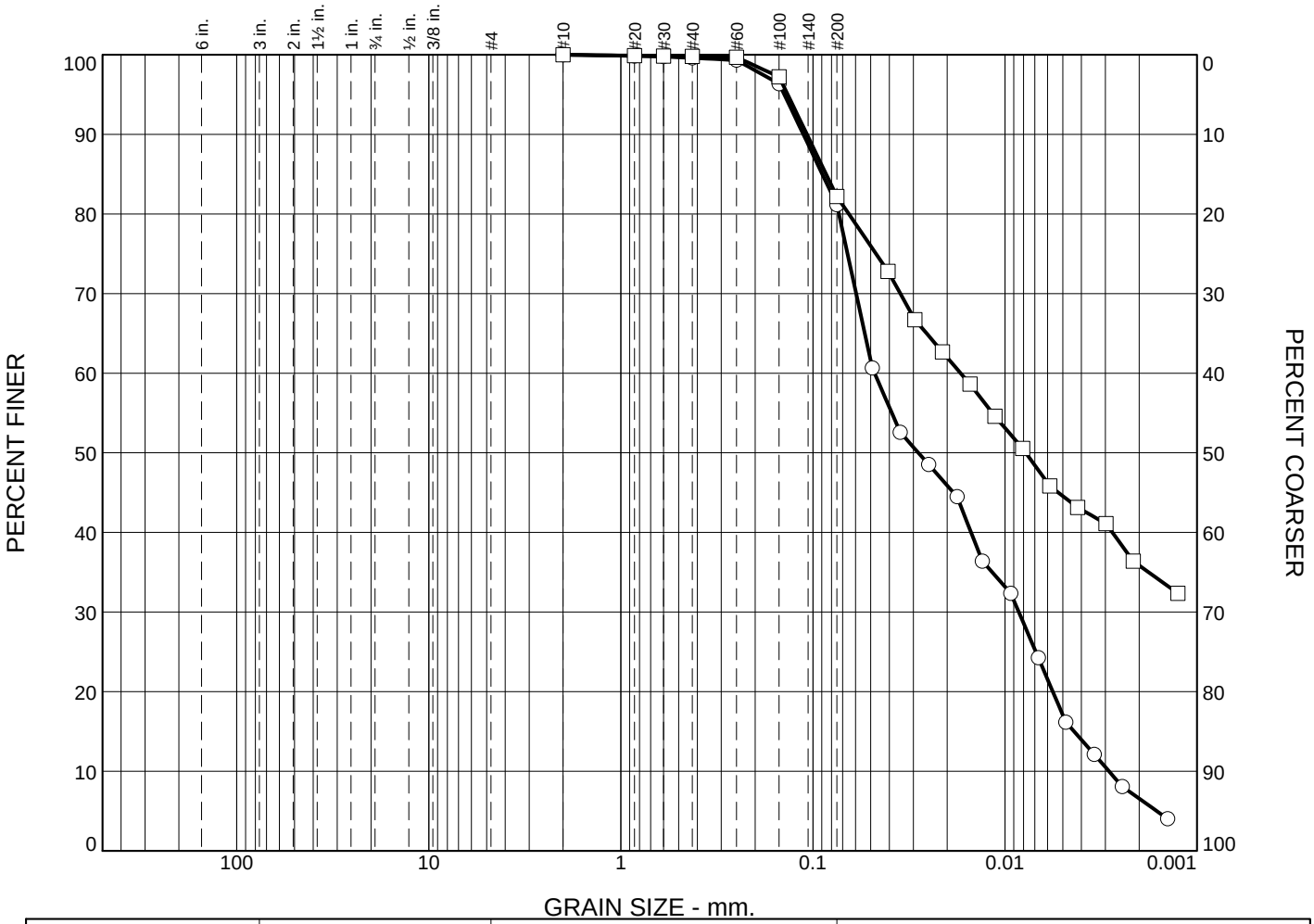
**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180

**Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 18.4 | 74.6 | 6.6 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 17.6 | 46.4 | 35.8 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | BB-2 | | 2-4. | FAT CLAY WITH SAND w/o Sodium Hexametaphosphate | CH |
| □ | BB-2 | | 2.4.1 | FAT CLAY WITH SAND w/ Sodium Hexametaphosphate | CH |
| | | | | | |
| | | | | | |
| | | | | | |

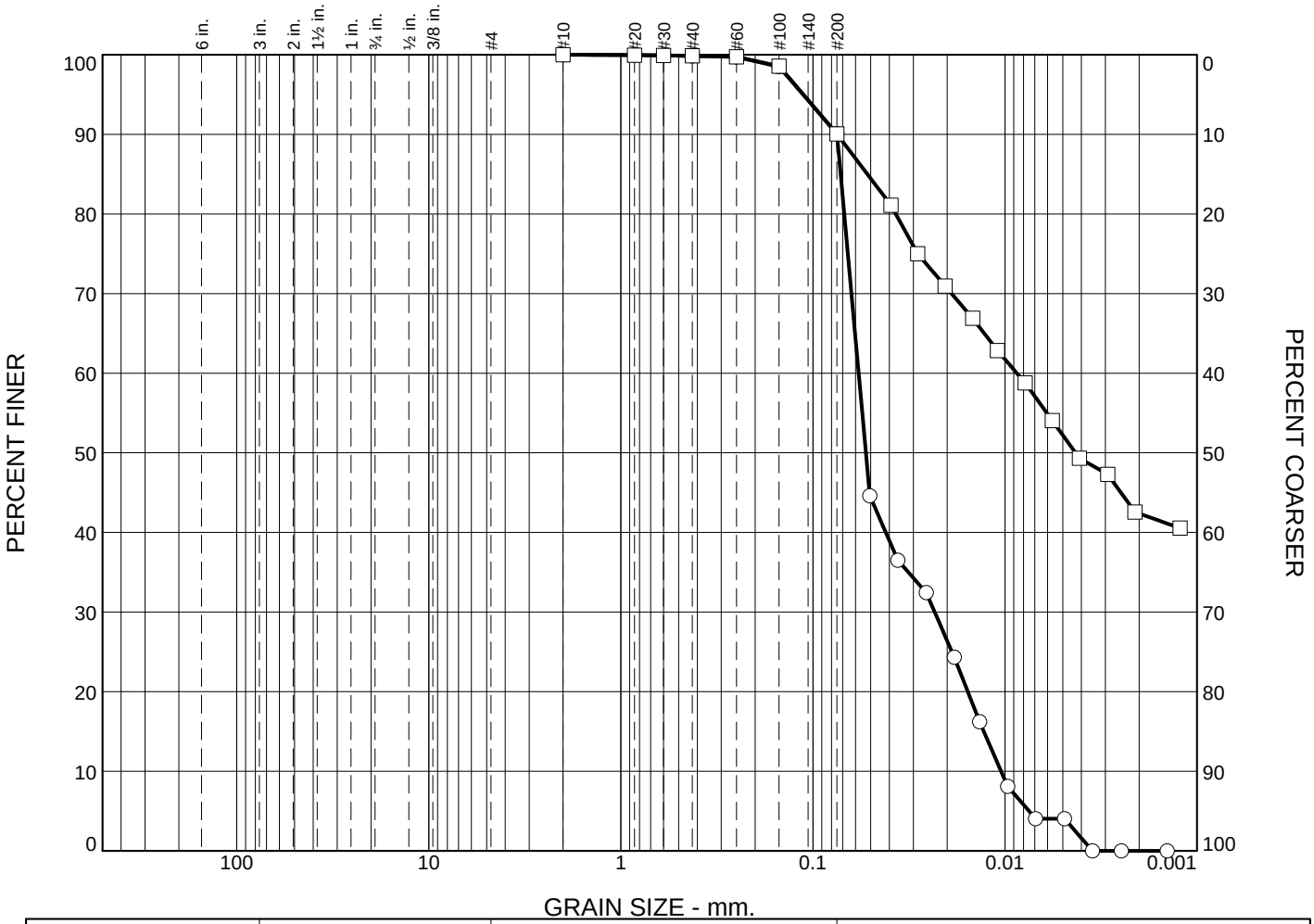
**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180 **Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 9.7 | 90.1 | 0.0 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 9.9 | 47.6 | 42.4 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | C-2 | | 2-4. | FAT CLAY w/o Sodium Hexametaphosphate | CH |
| □ | C-2 | | 2.4.1 | FAT CLAY w/ Sodium Hexametaphosphate | CH |
| | | | | | |
| | | | | | |
| | | | | | |

**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

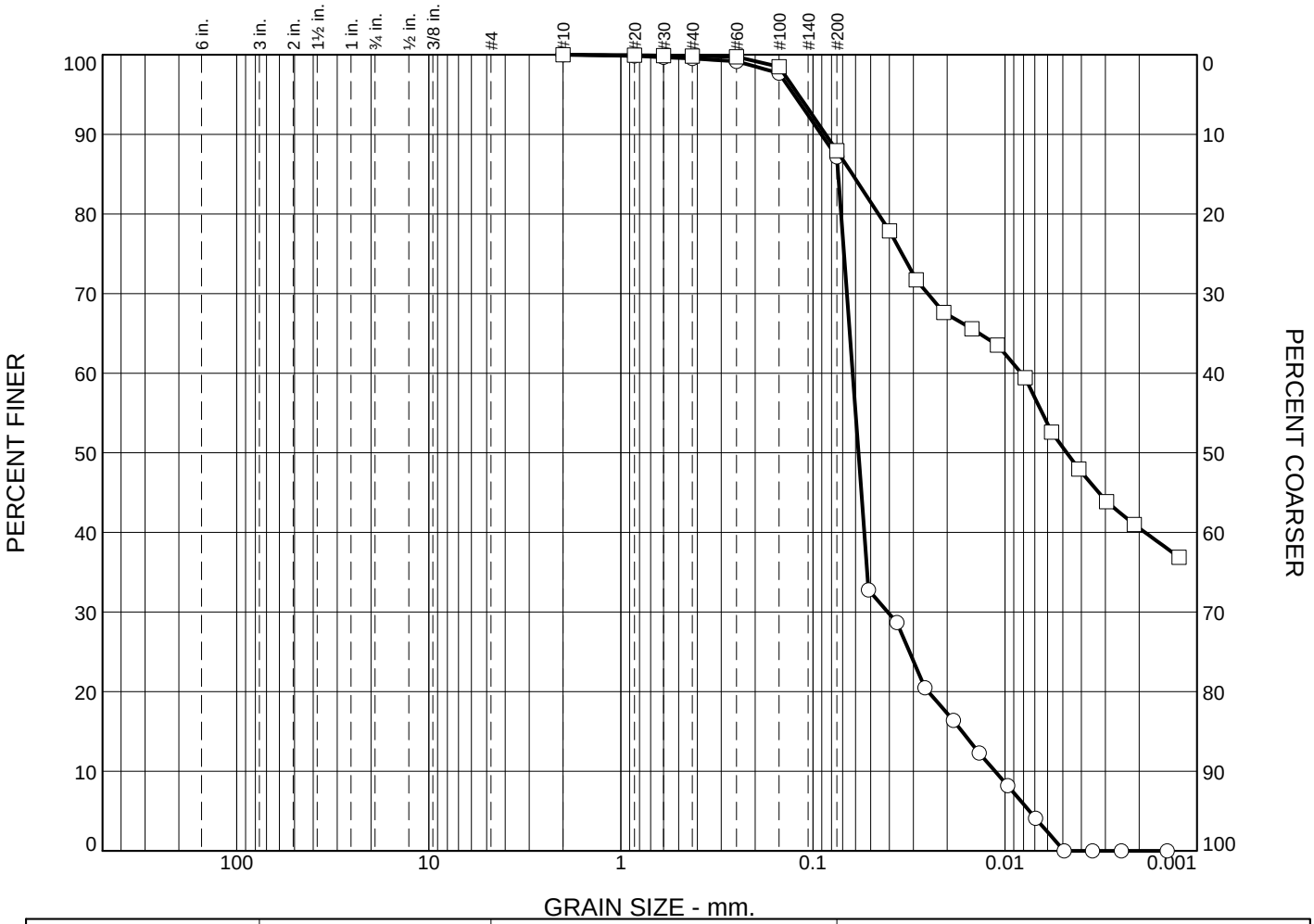
**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180

**Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 12.3 | 87.2 | 0.0 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 11.9 | 47.4 | 40.5 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | C-3 | | 0-2. | FAT CLAY w/o Sodium Hexametaphosphate | CH |
| □ | C-3 | | 0-2.1 | FAT CLAY w/ Sodium Hexametaphosphate | CH |
| | | | | | |
| | | | | | |
| | | | | | |

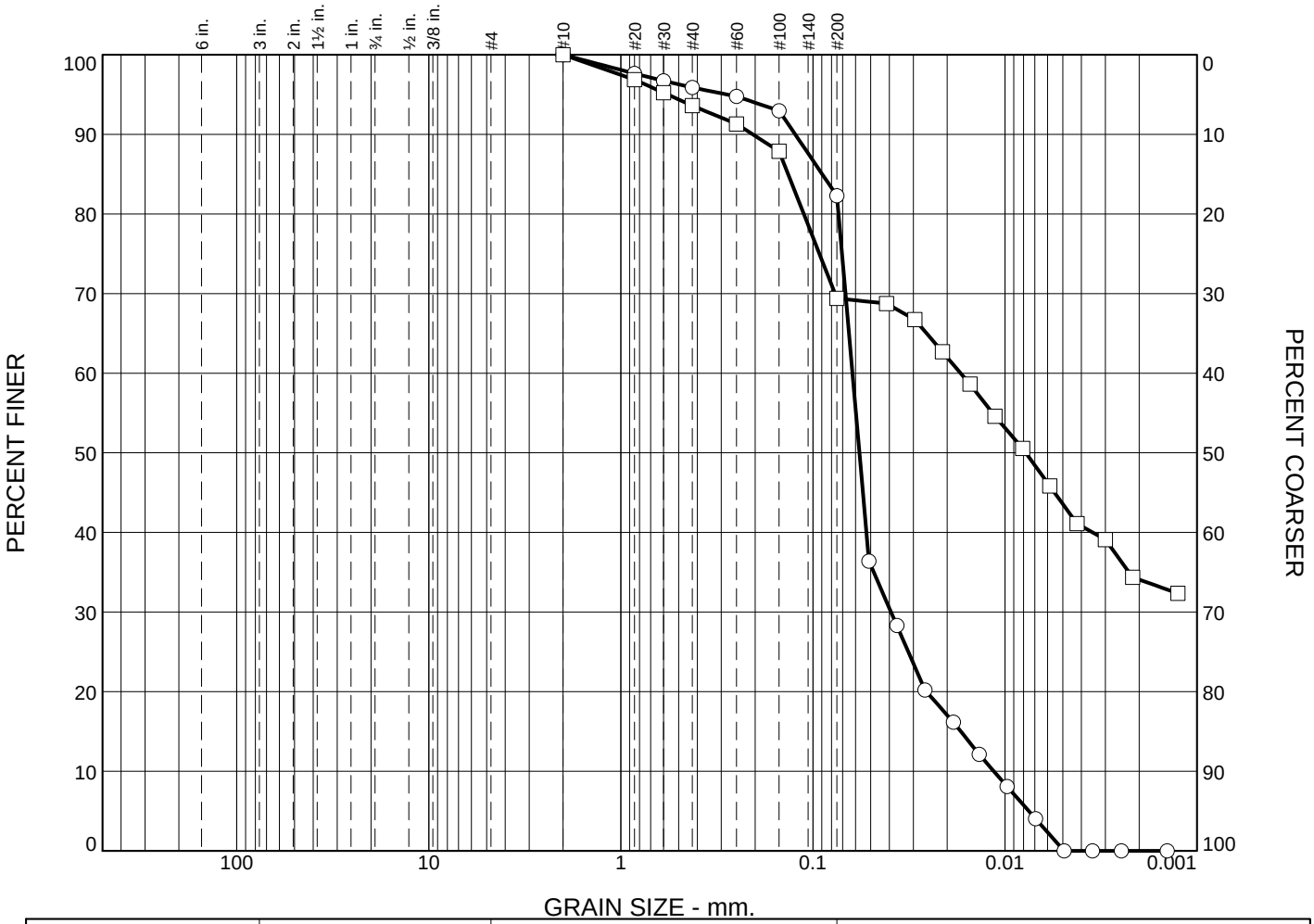
**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180 **Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 4.1 | 13.6 | 82.3 | 0.0 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 6.4 | 24.2 | 35.3 | 34.1 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | D-1 | | 2-4. | FAT CLAY WITH SAND w/o Sodium Hexametaphosphate | CH |
| □ | D-1 | | 2-4.1 | FAT CLAY WITH SAND w/ Sodium Hexametaphosphate | CH |
| | | | | | |
| | | | | | |
| | | | | | |

**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

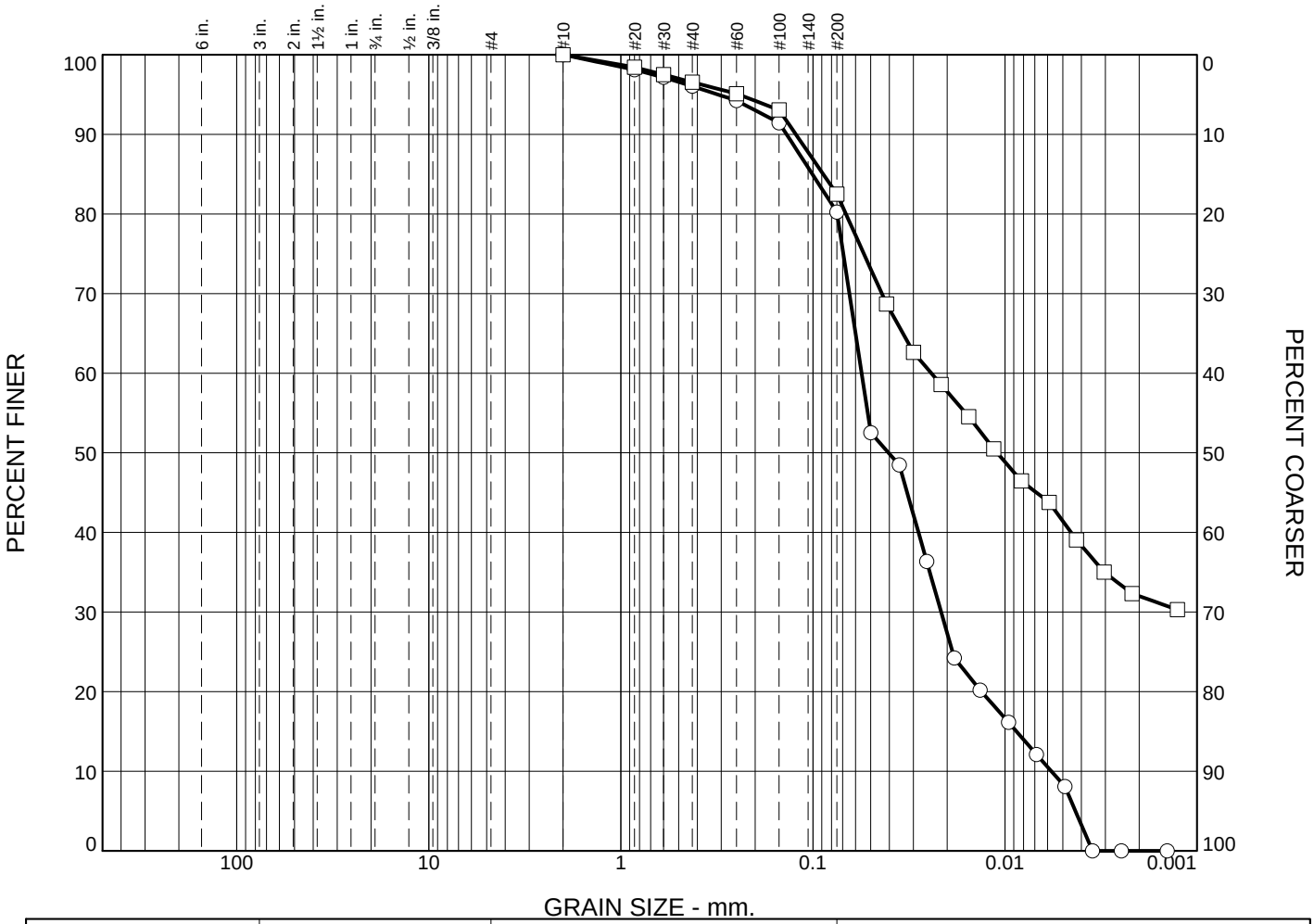
**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180

**Figure**

# Particle Size Analysis - ASTM D 422




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 15.8 | 80.2 | 0.0 |
| □ | 0.0 | 0.0 | 0.0 | 0.0 | 3.5 | 14.0 | 50.5 | 32.0 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## SOIL DATA

| SYMBOL | SOURCE | SAMPLE NO. | DEPTH (ft.) | Material Description | USCS |
|---|---|---|---|---|---|
| ○ | D-3 | | 4-6. | FAT CLAY WITH SAND w/o Sodium Hexametaphosphate | CH |
| □ | D-3 | | 4-6.1 | FAT CLAY WITH SAND w/ Sodium Hexametaphosphate | CH |
| | | | | | |
| | | | | | |
| | | | | | |

**Tolunay-Wong Engineers, Inc.**
**Houston, Texas**

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd. Houston, Texas

**Project No.:** 11.13.180

**Figure**

Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | A-1 (0' - 2') |
| Soil Description | 4.50 tsf; Hard gray SANDY LEAN CLAY (CL) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | II | Weight, g | 72.08 |
| Wet Weight + Tare, g | 128.21 | Length, in. | 1.505 |
| Dry Weight + Tare, g | 119.91 | Diameter, in. | 1.371 |
| Weight of Water, g | 8.3 | Unit Wet Weight, pcf | 123.6 |
| Tare Weight, g | 30.31 | Unit Dry Weight, pcf | 113.1 |
| Weight of Dry Soil, g | 88.4 | Compaction, % | Undisturbed |
| Water Content, % | 9.3 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow | | Flow Rate, ml/s | Turbidity from Side | | | | | | Completely Clear from Top | Tare weight of cell=115.58<br>Tare weight+samp=187.66 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ml | sec | | Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | | |
| 8:36 | 2” | 10 | 25 | 0.50 | | | | | | X | | Trial#1 |
| 8:36:30 | 2” | 10 | 26 | | | | | | | X | | Trial#2 |
| 8:37:05 | 2” | 10 | 25 | 0.50 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 8:38 | 2” | 120 | 300 | 0.40 | | | | | | X | | Start of test |
| 8:44 | 2” | 120 | 300 | 0.40 | | | | | | X | | |
| | | | | | | | | | | | | |
| 8:52 | 7” | 180 | 300 | 0.60 | | | | | X | | | Particals Falling |
| | | | | | | | | | | | | |
| 8:58 | 15” | 945 | 300 | 3.15 | | | | | X | | | Particals Falling |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
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| | | | | | |
|---|---|---|---|---|---|
| Pinhole Diameter after Test | | 1.5 mm | Test Method | x A ☐ B ☐ C | |
| Test Results | | ND3 (Slightly Dispersive) | | | |
| Tested By | RAL | Computed By | T.B | Checked By | EEH |
| Date | 10/18/11 | Date | 10/19/11 | Date | 10/19/11 |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | A-1 (2' - 4') |
| Soil Description | 4.5 tsf; Hard light gray SANDY LEAN CLAY (CL) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | RL-4 | Weight, g | 76.54 |
| Wet Weight + Tare, g | 126.17 | Length, in. | 1.450 |
| Dry Weight + Tare, g | 120.47 | Diameter, in. | 1.371 |
| Weight of Water, g | 5.7 | Unit Wet Weight, pcf | 136.2 |
| Tare Weight, g | 30.68 | Unit Dry Weight, pcf | 128.1 |
| Weight of Dry Soil, g | 89.79 | Compaction, % | Undisturbed |
| Water Content, % | 6.3 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow ml | Flow sec | Flow Rate, ml/s | Turbidity from Side: Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | Completely Clear from Top | Tare weight of cell= Tare weight+samp= |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12:24 | 2” | 10 | 25 | 0.40 | | | | | X | | | Trial#1 |
| 12:25 | 2” | 10 | 24 | 0.38 | | | | | | X | | Trial#2 |
| 12:26 | 2” | 10 | 24 | 0.38 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 12:28 | 2” | 120 | 300 | 0.40 | | | | | | X | | Start of test |
| 12:39 | 2” | 120 | 300 | 0.40 | | | | | X | | | |
| | | | | | | | | | | | | |
| 12:46 | 7” | 214 | 300 | 0.71 | | | | | X | | | |
| | | | | | | | | | | | | |
| 12:53 | 15” | 303 | 300 | 1.01 | | | | | X | | | |
| | | | | | | | | | | | | |
| 13:03 | 40” | 936 | 300 | 3.12 | | | | | X | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Pinhole Diameter after Test | 1.0 mm | Test Method | x A ☐ B ☐ C | | |
| Test Results | ND2 (Nondispersive) | | | | |
| Tested By | RAL | Computed By | EEH | Checked By | |
| Date | 9/30/11 | Date | 10/3/11 | Date | |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | BB-1 (0-2') |
| Soil Description | 3.75 tsf; Very stiff gray & brown FAT CLAY w/ SAND (CH) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | OT-1 | Weight, g | 76.81 |
| Wet Weight + Tare, g | 106.79 | Length, in. | 1.569 |
| Dry Weight + Tare, g | 94.00 | Diameter, in. | 1.371 |
| Weight of Water, g | 12.79 | Unit Wet Weight, pcf | 126.3 |
| Tare Weight, g | 30.76 | Unit Dry Weight, pcf | 105.1 |
| Weight of Dry Soil, g | 63.24 | Compaction, % | Undisturbed |
| Water Content, % | 20.2 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow ml | Flow sec | Flow Rate, ml/s | Turbidity from Side: Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | Completely Clear from Top | Tare weight of cell=115.54gr Tare weight+samp= |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3:30 | 2" | 10 | 24 | 0.42 | | | | | | X | | Trial#1 |
| 3:30:30 | 2" | 10 | 24 | 0.42 | | | | | | X | | Trial#2 |
| 3:31:10 | 2" | 10 | 24 | 0.42 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 3:33 | 2" | 122 | 300 | 0.41 | | | | | | X | | Start of test |
| 3:39 | 2" | 120 | 300 | 0.40 | | | | | | X | | |
| | | | | | | | | | | | | |
| 3:46 | 7" | 372 | 300 | 1.24 | | | | | | X | | |
| | | | | | | | | | | | | |
| 3:52 | 15" | 483 | 300 | 1.61 | | | | | | X | | |
| | | | | | | | | | | | | |
| 4:00 | 40" | 882 | 300 | 2.94 | | | | | | X | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Pinhole Diameter after Test | 1.0mm | Test Method | x A ☐ B ☐ C | | |
| Test Results | ND1 (Nondispersive) | | | | |
| Tested By | RAL | Computed By | RAL | Checked By | T.B |
| Date | 10/10/11 | Date | 10/10/11 | Date | 10/11/11 |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | BB-2 (2' - 4') |
| Soil Description | 4.5 tsf; Hard gray & tan FAT CLAY w/ SAND (CH) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | M | Weight, g | 76.27 |
| Wet Weight + Tare, g | 113.47 | Length, in. | 1.527 |
| Dry Weight + Tare, g | 101.85 | Diameter, in. | 1.371 |
| Weight of Water, g | 11.62 | Unit Wet Weight, pcf | 128.9 |
| Tare Weight, g | 30.64 | Unit Dry Weight, pcf | 110.8 |
| Weight of Dry Soil, g | 71.21 | Compaction, % | Undisturbed |
| Water Content, % | 16.3 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow ml | Flow sec | Flow Rate, ml/s | Turbidity from Side: Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | Completely Clear from Top | Tare weight of cell=115.54gr Tare weight+samp=191.90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10:00 | 2” | 10 | 24 | 0.41 | | | | | | X | | Trial#1 |
| 10:00:30 | 2” | 10 | 24 | 0.41 | | | | | | X | | Trial#2 |
| 10:01:05 | 2” | 10 | 24 | 0.43 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 10:04 | 2” | 126 | 300 | 0.42 | | | | | | X | | Start of test |
| 10:07 | 2” | 129 | 300 | 0.43 | | | | | | X | | |
| | | | | | | | | | | | | |
| 10:12 | 7” | 387 | 300 | 1.29 | | | | | | X | | |
| | | | | | | | | | | | | |
| 10:18 | 15” | 717 | 300 | 2.39 | | | | | | X | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
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| | | | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Pinhole Diameter after Test | 1.5mm | Test Method | x A ☐ B ☐ C | | |
| Test Results | ND3 (Slightly dispersive) | | | | |
| Tested By | RAL | Computed By | RAL | Checked By | T.B |
| Date | 10/10/11 | Date | 10/10/11 | Date | 10/11/11 |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | C-2 (2'- 4') |
| Soil Description | 4.5 tsf; Very stiff-hard gray & brown FAT CLAY (CH) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | P-2 | Weight, g | 76.76 |
| Wet Weight + Tare, g | 132.94 | Length, in. | 1.599 |
| Dry Weight + Tare, g | 118.32 | Diameter, in. | 1.371 |
| Weight of Water, g | 14.62 | Unit Wet Weight, pcf | 123.9 |
| Tare Weight, g | 31.06 | Unit Dry Weight, pcf | 106.1 |
| Weight of Dry Soil, g | 87.26 | Compaction, % | Undisturbed |
| Water Content, % | 16.8 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow | | Flow Rate, ml/s | Turbidity from Side | | | | | | Completely Clear from Top | Tare weight of cell=115.54gr Tare weight+samp=192.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ml | sec | | Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | | |
| 9:15 | 2” | 10 | 25 | 0.50 | | | | | X | | | Trial#1 |
| 9:15:30 | 2” | 10 | 24 | 0.42 | | | | | | X | | Trial#2 |
| 9:16 | 2” | 10 | 24 | 0.42 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 9:17 | 2” | 138 | 300 | 0.46 | | | | | | X | | Start of test |
| 9:23 | 2” | 135 | 300 | 0.45 | | | | | | X | | |
| | | | | | | | | | | | | |
| 9:25 | 7” | 390 | 300 | 1.30 | | | | | | X | | |
| | | | | | | | | | | | | |
| 9:31 | 15” | 483 | 300 | 1.61 | | | | | | X | | |
| | | | | | | | | | | | | |
| 9:42 | 40” | 727 | 300 | 3.09 | | | | | | X | | |
| | | | | | | | | | | | | |
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| | | | | | |
|---|---|---|---|---|---|
| Pinhole Diameter after Test | | 1.0mm | Test Method | x A ☐ B ☐ C | |
| Test Results | | ND2 (Non dispersive) | | | |
| Tested By | RAL | Computed By | RAL | Checked By | T.B |
| Date | 10/10/11 | Date | 10/10/11 | Date | 10/11/11 |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | C-3 (0' - 2') |
| Soil Description | 2.00 tsf; Stiff dark gray FAT CLAY (CH) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | 10 | Weight, g | 76.83 |
| Wet Weight + Tare, g | 133.97 | Length, in. | 1.570 |
| Dry Weight + Tare, g | 113.41 | Diameter, in. | 1.371 |
| Weight of Water, g | 20.56 | Unit Wet Weight, pcf | 126.3 |
| Tare Weight, g | 31.18 | Unit Dry Weight, pcf | 101.0 |
| Weight of Dry Soil, g | 82.23 | Compaction, % | Undisturbed |
| Water Content, % | 25.0 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow ml | Flow sec | Flow Rate, ml/s | Turbidity from Side: Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | Completely Clear from Top | Tare weight of cell=115.54gr Tare weight+samp=192.37 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11:40 | 2” | 10 | 25 | 0.50 | | | | | | X | | Trial#1 |
| 11:40:30 | 2” | 10 | 24 | 0.42 | | | | | | X | | Trial#2 |
| 11:41:15 | 2” | 10 | 24 | 0.42 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 11:43 | 2” | 120 | 300 | 0.40 | | | | | | X | | Start of test |
| 11:49 | 2” | 123 | 300 | 0.41 | | | | | | X | | |
| | | | | | | | | | | | | |
| 11:56 | 7” | 390 | 300 | 1.30 | | | | | | X | | |
| | | | | | | | | | | | | |
| 12:02 | 15” | 495 | 300 | 1.65 | | | | | | X | | |
| | | | | | | | | | | | | |
| 12:10 | 40” | 885 | 300 | 2.95 | | | | | | X | | |
| | | | | | | | | | | | | |
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|---|---|---|---|---|---|
| Pinhole Diameter after Test | 1.0mm | Test Method | x A ☐ B ☐ C | | |
| Test Results | ND1 (Non dispersive) | | | | |
| Tested By | RAL | Computed By | RAL | Checked By | T.B |
| Date | 10/10/11 | Date | 10/10/11 | Date | 10/11/11 |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | D-1 (2' - 4') |
| Soil Description | 4.50 tsf; Hard gray & tan FAT CLAY w/ SAND (CH) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | Geo 2 | Weight, g | 77.89 |
| Wet Weight + Tare, g | 122.42 | Length, in. | 1.499 |
| Dry Weight + Tare, g | 112.04 | Diameter, in. | 1.371 |
| Weight of Water, g | 10.38 | Unit Wet Weight, pcf | 134.1 |
| Tare Weight, g | 30.80 | Unit Dry Weight, pcf | 118.9 |
| Weight of Dry Soil, g | 81.24 | Compaction, % | Undisturbed |
| Water Content, % | 12.8 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow | | Flow Rate, ml/s | Turbidity from Side | | | | | | Completely Clear from Top | Tare weight of cell= Tare weight+samp= |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ml | sec | | Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | | |
| 12:30 | 2” | 10 | 25 | 0.50 | | | | | | X | | Trial#1 |
| 12:30:30 | 2” | 10 | 24 | 0.50 | | | | | | X | | Trial#2 |
| 12:31:10 | 2” | 10 | 24 | 0.50 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 12:33 | 2” | 119 | 300 | 0.40 | | | | | | X | | Start of test |
| 12:39 | 2” | 120 | 300 | 0.40 | | | | | | X | | |
| | | | | | | | | | | | | |
| 12:47 | 7” | 390 | 300 | 1.30 | | | | | | X | | |
| | | | | | | | | | | | | |
| 12:55 | 15” | 528 | 300 | 1.76 | | | | | | X | | |
| | | | | | | | | | | | | |
| 13:08 | 40” | 933 | 300 | 3.11 | | | | | | X | | |
| | | | | | | | | | | | | |
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|---|---|---|---|---|---|
| Pinhole Diameter after Test | | 1 mm | Test Method | x A | ☐ B ☐ C |
| Test Results | | ND2 (Non dispersive) | | | |
| Tested By | RAL | Computed By | RAL | Checked By | T.B |
| Date | 10/10/11 | Date | 10/10/11 | Date | 10/11/11 |

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Tolunay-Wong Engineers, Inc.

10710 S. Sam Houston Pkwy. W, Suite 100 Houston, TX 77031

# Pinhole Dispersion Test

ASTM D4647

| | |
|---|---|
| Project No. | 11.13.180 |
| Project Name | Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas |
| Sample ID | D-3 (4' - 6') |
| Soil Description | 4.50 tsf; Hard tan & gray FAT CLAY w/ SAND (CH) |

| Water Content | | Specimen Data | |
|---|---|---|---|
| Tare No. | 5548 | Weight, g | 68.91 |
| Wet Weight + Tare, g | 135.62 | Length, in. | 1.499 |
| Dry Weight + Tare, g | 122.30 | Diameter, in. | 1.371 |
| Weight of Water, g | 13.32 | Unit Wet Weight, pcf | 118.6 |
| Tare Weight, g | 30.92 | Unit Dry Weight, pcf | 103.5 |
| Weight of Dry Soil, g | 91.38 | Compaction, % | Undisturbed |
| Water Content, % | 14.6 | Distilled Water Used: | X Yes ☐ No |

| Clock Time | Head | Flow | | Flow Rate, ml/s | Turbidity from Side | | | | | | Completely Clear from Top | Tare weight of cell=115.54gr Tare weight+samp=184.45 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ml | sec | | Very Dark | Dark | Moderately Dark | Slightly Dark | Barely Visible | Completely Clear | | |
| 5:30 | 2” | 10 | 23 | 0.43 | | | | | | X | | Trial#1 |
| 5:30:29 | 2” | 10 | 24 | 0.42 | | | | | | X | | Trial#2 |
| 5:31:15 | 2” | 10 | 23 | 0.43 | | | | | | X | | Trial#3 |
| | | | | | | | | | | | | |
| 5:33 | 2” | 180 | 300 | 0.60 | | | | | | X | | Start of test |
| 5:39 | 2” | 189 | 300 | 0.63 | | | | | X | | | |
| | | | | | | | | | | | | |
| 5:44 | 7” | 414 | 300 | 1.38 | | | | | X | | | |
| | | | | | | | | | | | | |
| 5:50 | 15” | 870 | 300 | 2.90 | | | | X | | | | |
| | | | | | | | | | | | | |
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| | | | | | |
|---|---|---|---|---|---|
| Pinhole Diameter after Test | 1.5 mm | Test Method | x A ☐ B ☐ C | | |
| Test Results | ND3 (Slightly dispersive) | | | | |
| Tested By | RAL | Computed By | RAL | Checked By | T.B |
| Date | 10/10/11 | Date | 10/10/11 | Date | 10/11/11 |

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# Project: Buffalo Speedway Extension From West Airport Boulevard to Willowbend Boulevard, Houston, Texas

**TWEI Project No: 11.13.180**

## Double Hydrometer Test Result

Boring A-1 (0'-2')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{0.0 \times 100}{22.99}$$

= 0.0% Dispersion

Boring A-1 (2'- 4')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{0.0 \times 100}{27.03}$$

= 0.0% Dispersion

# Project: Buffalo Speedway Extension From West Airport Boulevard to Willowbend Boulevard, Houston, Texas

**TWEI Project No: 11.13.180**

## Double Hydrometer Test Result

Boring BB-1 (0'-2')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{0.0 \times 100}{46.75}$$

= 0.0% Dispersion

Boring BB-2 (2'- 4')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{17.05 \times 100}{44.45}$$

= 38.4% Dispersion

# Project: Buffalo Speedway Extension From West Airport Boulevard to Willowbend Boulevard, Houston, Texas

**TWEI Project No: 11.13.180**

## Double Hydrometer Test Result

Boring C-2 (2'-4')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{4.1 \times 100}{52.0}$$

= 7.9% Dispersion

Boring C-3 (0'- 2')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{0.21 \times 100}{50.59}$$

= 0.4% Dispersion

# Project: Buffalo Speedway Extension From West Airport Boulevard to Willowbend Boulevard, Houston, Texas

**TWEI Project No: 11.13.180**

## Double Hydrometer Test Result

Boring D-1 (2'-4')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{0.08 \times 100}{43.45}$$

= 0.2% Dispersion

Boring D-3 (4'- 6')

$$\% \text{ Dispersion} = \frac{\% \text{ Passing 5-µm in Test Method D4221} \times 100}{\% \text{ Passing 5-µm in Test Method D422}}$$

$$= \frac{8.3 \times 100}{41.31}$$

= 20.1% Dispersion

**Project Name: Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas**

**Project No. _11.13.180_____**

**ASTM D 6572-06**

**Determining Dispersive Characteristics of Clayey Soils by the Crumb Test**

1)

Boring No.: __A-1__ Depth _0'-2'_____ Disturbed ___ Undisturbed __X__

Soil description: __Gray SANDY LEAN CLAY (CL) _____ _____

Natural moisture content ____9.0_____

Natural irregularly shaped crumb __X _ Remolded crumb cube _____

**Moisture content:**

Natural moisture __X_ Air-dried ___ Distilled water added to remold specimen ___

Curing time __24__ minutes Water used: Distilled __X_ or Distilled demineralized___

Initial water temperature __20_°C Time at beginning of test __9:00___ **am** or pm

2)

Boring No.: ___A-1_____ Depth ____2'-4'_____ Disturbed ___ Undisturbed ___

Soil description: _____Light gray SANDY LEAN CLAY (CL)_____

Natural moisture content ____6.0_____

Natural irregularly shaped crumb ____X____ Remolded crumb cube _____

**Moisture content:**

Natural moisture _X__ Air-dried ___ Distilled water added to remold specimen ___

Curing time _____ minutes Water used: Distilled _X__ or Distilled demineralized___

Initial water temperature __23.3_°C Time at beginning of test __10:00____ am or pm

**A cube of remolded soil approximately 15 mm (5/8 in) on each side (pair of <u>dice sized</u>) or a natural soil crumb of approximately similar volume is placed on the bottom of a white porcelain dish containing 250 mL of <u>distilled water</u>.**

| Specimen Number | Dish Number | 2 minutes | | 1 hour | | 6 - 24 hours | |
|---|---|---|---|---|---|---|---|
| | | Grade | °C | Grade | °C | Grade | °C |
| A-1 (0-2) | | 1 | 20.4 | 1 | 20 | 1 | 21 |
| A-1 (2-4) | | 2 | 23.4 | 2 | 23.6 | 2 | 23.3 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**12. Interpretation of Results**
12.1 Use the following criteria to classify crumb test results:
**12.1.1 *Grade 1*—Nondispersive.**
**12.1.2 *Grade 2*—Intermediate**.
12.1.3 *Grade 3*—Dispersive.
12.1.4 *Grade 4*—Highly Dispersive.
12.2 If the dispersive grade changed during the test, the 1-h reading is normally used for the overall test evaluation. However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 and 6-h readings, use the 6-h reading.

Method **A** or B

Tested By: _LGC___ Date: _10/19/11__Checked By: _EEH/t.b___ Date: _10/20/11___

**Project Name: Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas**

**Project No. __11.13.180_____**

**ASTM D 6572-06**

**Determining Dispersive Characteristics of Clayey Soils by the Crumb Test**

1)

Boring No.: _BB-1__ Depth __0'-2'_____ Disturbed ___ Undisturbed __X__

Soil description: __ Gray & brown FAT CLAY w/ SAND (CH)_____ _____

Natural moisture content __20.0_____

Natural irregularly shaped crumb __x_ _ Remolded crumb cube _____

**Moisture content:**

Natural moisture __x__ Air-dried ___ Distilled water added to remold specimen _x__

Curing time _____ minutes Water used: Distilled _x___ or Distilled demineralized___

Initial water temperature __74_$^{o}$F Time at beginning of test _____ am or pm

2)

Boring No.: __BB-2____ Depth _2'-4'_____ Disturbed ___ Undisturbed _x__

Soil description: _Gray & tan Fat CLAY w/ SAND (CH) _____

Natural moisture content ___16.0_____

Natural irregularly shaped crumb ___X__ Remolded crumb cube _____

**Moisture content:**

Natural moisture _X__ Air-dried ___ Distilled water added to remold specimen _X__

Curing time _____ minutes Water used: Distilled _X__ or Distilled demineralized___

Initial water temperature _74_$^{o}$F Time at beginning of test _____ am or pm

**A cube of remolded soil approximately 15 mm (5/8 in) on each side (pair of <u>dice sized</u>) or a natural soil crumb of approximately similar volume is placed on the bottom of a white porcelain dish containing 250 mL of <u>distilled water</u>.**

| Specimen Number | Dish Number | 2 minutes | | 1 hour | | 6 - 24 hours | |
|---|---|---|---|---|---|---|---|
| | | Grade | °C | Grade | °C | Grade | °C |
| BB-1 | 0-2 | 1 | 74.3 | 1 | 74.0 | 1 | 74.1 |
| BB-2 | 2-4 | 2 | 74.2 | 3 | 73.1 | 3 | 73.4 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**12. Interpretation of Results**

12.1 Use the following criteria to classify crumb test results:

**12.1.1 *Grade 1*—Nondispersive.**

12.1.2 *Grade 2*—Intermediate.

**12.1.3 *Grade 3*—Dispersive.**

12.1.4 *Grade 4*—Highly Dispersive.

12.2 If the dispersive grade changed during the test, the 1-h reading is normally used for the overall test evaluation. However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 and 6-h readings, use the 6-h reading.

Method A or B

Tested By: __RAL___ Date: __10/10/11__Checked By: __T.B_____ Date: __10/11/11___

**Project Name: Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas**

**Project No. __11.13.180_____**

**ASTM D 6572-06**

**Determining Dispersive Characteristics of Clayey Soils by the Crumb Test**

1)

Boring No.: _C-2__ Depth __2'-4'____ Disturbed ___ Undisturbed __X__

Soil description: __ Gray & brown FAT CLAY (CH)_____ _____

Natural moisture content __17.0_____

Natural irregularly shaped crumb __x_ _ Remolded crumb cube _____

**Moisture content:**

Natural moisture __x__ Air-dried ___ Distilled water added to remold specimen _x__

Curing time _____ minutes Water used: Distilled _x___ or Distilled demineralized___

Initial water temperature __74_$^{o}$F Time at beginning of test _____ am or pm

2)

Boring No.: __C-3____ Depth _0'-2'_____ Disturbed ___ Undisturbed _x__

Soil description: _Dark gray FAT CLAY (CH)_____

Natural moisture content __25.0_____

Natural irregularly shaped crumb ___X__ Remolded crumb cube _____

**Moisture content:**

Natural moisture _X__ Air-dried ___ Distilled water added to remold specimen _X__

Curing time _____ minutes Water used: Distilled _X__ or Distilled demineralized___

Initial water temperature _74_$^{o}$F Time at beginning of test _____ am or pm

**A cube of remolded soil approximately 15 mm (5/8 in) on each side (pair of <u>dice sized</u>) or a natural soil crumb of approximately similar volume is placed on the bottom of a white porcelain dish containing 250 mL of <u>distilled water</u>.**

| Specimen Number | Dish Number | 2 minutes | | 1 hour | | 6 - 24 hours | |
|---|---|---|---|---|---|---|---|
| | | Grade | °C | Grade | °C | Grade | °C |
| C-2 | 2-4 | 1 | 73.1 | 1 | 74.2 | 1 | 73.4 |
| C-3 | 0-2 | 1 | 72.5 | 1 | 73.4 | 1 | 73.3 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**12. Interpretation of Results**
12.1 Use the following criteria to classify crumb test results:
**12.1.1 *Grade 1*—Nondispersive.**
12.1.2 *Grade 2*—Intermediate.
12.1.3 *Grade 3*—Dispersive.
12.1.4 *Grade 4*—Highly Dispersive.
12.2 If the dispersive grade changed during the test, the 1-h reading is normally used for the overall test evaluation. However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 and 6-h readings, use the 6-h reading.

Method A or B

Tested By: __RAL___ Date: __10/10/11__Checked By: __T.B_____ Date: __10/11/11___

**Project Name: Buffalo Speedway Extension From W. Airport Blvd. to Willowbend Blvd., Houston, Texas**

**Project No. __11.13.180_____**

**ASTM D 6572-06**

**Determining Dispersive Characteristics of Clayey Soils by the Crumb Test**

1)

Boring No.: _D-1__ Depth __2'-4'____ Disturbed ___ Undisturbed __X__

Soil description: __Gray & tan FAT CLAY w/ SAND (CH) _____ _____

Natural moisture content __13.0_____

Natural irregularly shaped crumb __x_ _ Remolded crumb cube _____

**Moisture content:**

Natural moisture __x__ Air-dried ___ Distilled water added to remold specimen _x__

Curing time _____ minutes Water used: Distilled _x___ or Distilled demineralized___

Initial water temperature __74_$^{o}$F Time at beginning of test _____ am or pm

2)

Boring No.: __D-3____ Depth _4'-6'_____ Disturbed ___ Undisturbed _x__

Soil description: _ Gray & tan FAT CLAY w/ SAND (CH)_____

Natural moisture content __15.0_____

Natural irregularly shaped crumb ___X__ Remolded crumb cube _____

**Moisture content:**

Natural moisture _X__ Air-dried ___ Distilled water added to remold specimen _X__

Curing time _____ minutes Water used: Distilled _X__ or Distilled demineralized___

Initial water temperature _74_$^{o}$F Time at beginning of test _____ am or pm

**A cube of remolded soil approximately 15 mm (5/8 in) on each side (pair of <u>dice sized</u>) or a natural soil crumb of approximately similar volume is placed on the bottom of a white porcelain dish containing 250 mL of <u>distilled water</u>.**

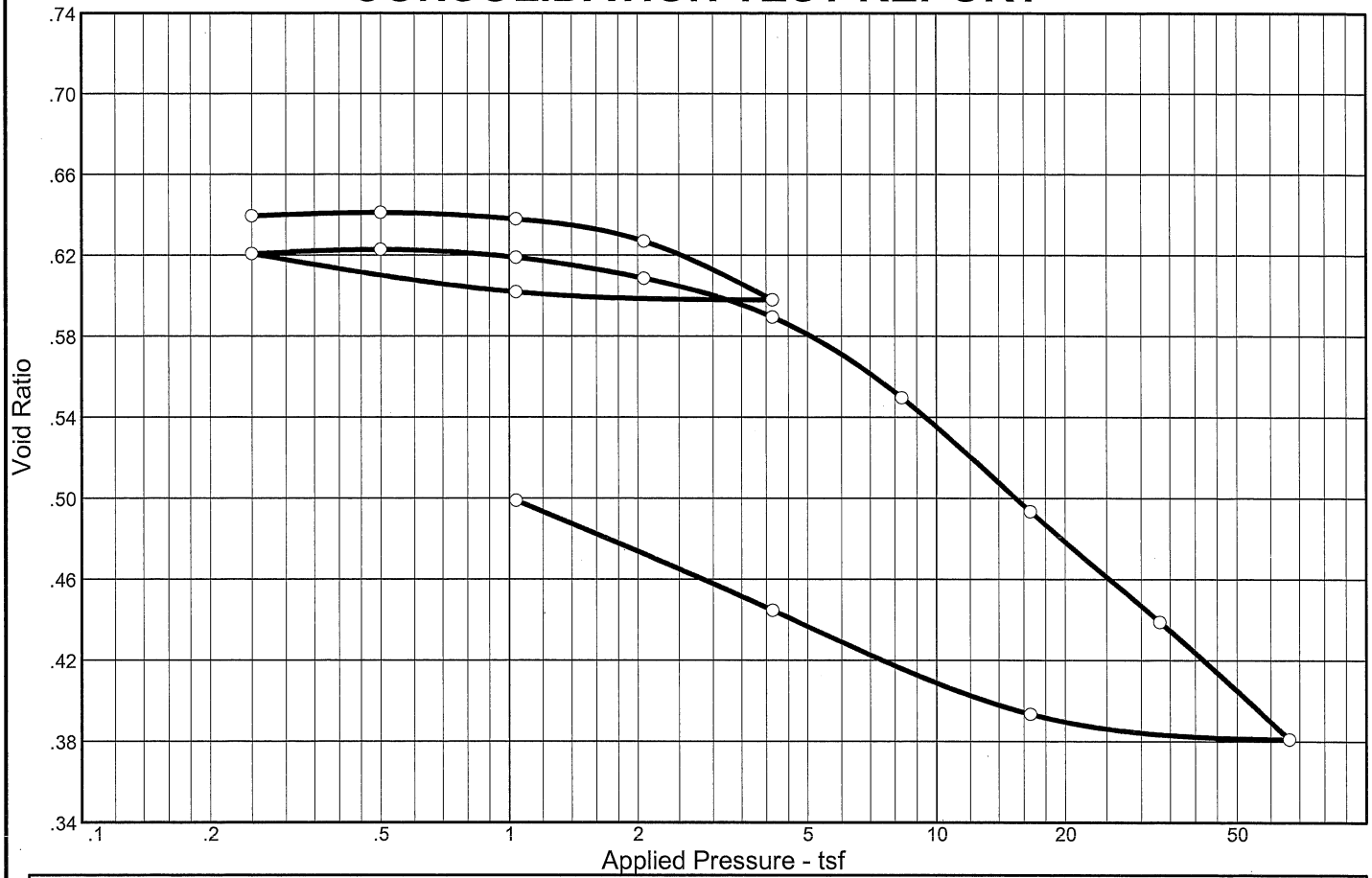
| Specimen Number | Dish Number | 2 minutes | | 1 hour | | 6 - 24 hours | |
|---|---|---|---|---|---|---|---|
| | | Grade | °C | Grade | °C | Grade | °C |
| D-1 | 2-4 | 1 | 74.0 | 1 | 72.6 | 1 | 73.2 |
| D-3 | 4-6 | 2 | 74.3 | 3 | 74.0 | 3 | 74.0 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**12. Interpretation of Results**
12.1 Use the following criteria to classify crumb test results:
**12.1.1 *Grade 1*—Nondispersive.**
12.1.2 *Grade 2*—Intermediate.
**12.1.3 *Grade 3*—Dispersive.**
12.1.4 *Grade 4*—Highly Dispersive.
12.2 If the dispersive grade changed during the test, the 1-h reading is normally used for the overall test evaluation. However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 and 6-h readings, use the 6-h reading.

Method A or B

Tested By: __RAL___ Date: __10/10/11__Checked By: __T.B_____ Date: __10/11/11___

# CONSOLIDATION TEST REPORT




Coefficients of Consolidation and Secondary Consolidation

| No. | Load (tsf) | $C_v$ (ft.2/day) | $C_\alpha$ | No. | Load (tsf) | $C_v$ (ft.2/day) | $C_\alpha$ | No. | Load (tsf) | $C_v$ (ft.2/day) | $C_\alpha$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.25 | 5.394 | | 11 | 4.14 | 0.028 | | | | | |
| 2 | 0.50 | 5.069 | | 12 | 8.30 | 0.010 | | | | | |
| 3 | 1.04 | 0.165 | | 13 | 16.60 | 0.006 | | | | | |
| 4 | 2.07 | 0.115 | | 14 | 33.20 | 0.006 | | | | | |
| 5 | 4.14 | 0.042 | | 15 | 66.40 | 0.005 | | | | | |
| 6 | 1.04 | 0.026 | | 16 | 16.60 | 0.010 | | | | | |
| 7 | 0.25 | 0.006 | | 17 | 4.14 | 0.002 | | | | | |
| 8 | 0.50 | 0.088 | | 18 | 1.04 | 0.001 | | | | | |
| 9 | 1.04 | 0.062 | | | | | | | | | |
| 10 | 2.07 | 0.050 | | | | | | | | | |

| Natural | | Dry Dens. (pcf) | LL | PI | Sp. Gr. | Overburden (tsf) | $P_c$ (tsf) | $C_c$ | Initial Void Ratio |
|---|---|---|---|---|---|---|---|---|---|
| Saturation | Moisture | | | | | | | | |
| 94.9 % | 22.4 % | 102.9 | 51 | 31 | 2.7 | 0.68 | 3.94 | 0.19 | 0.637 |

| MATERIAL DESCRIPTION | USCS | AASHTO |
|---|---|---|
| Light gray and reddish-brown FAT CLAY | CH | |

**Project No.** 11.13.180 **Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas

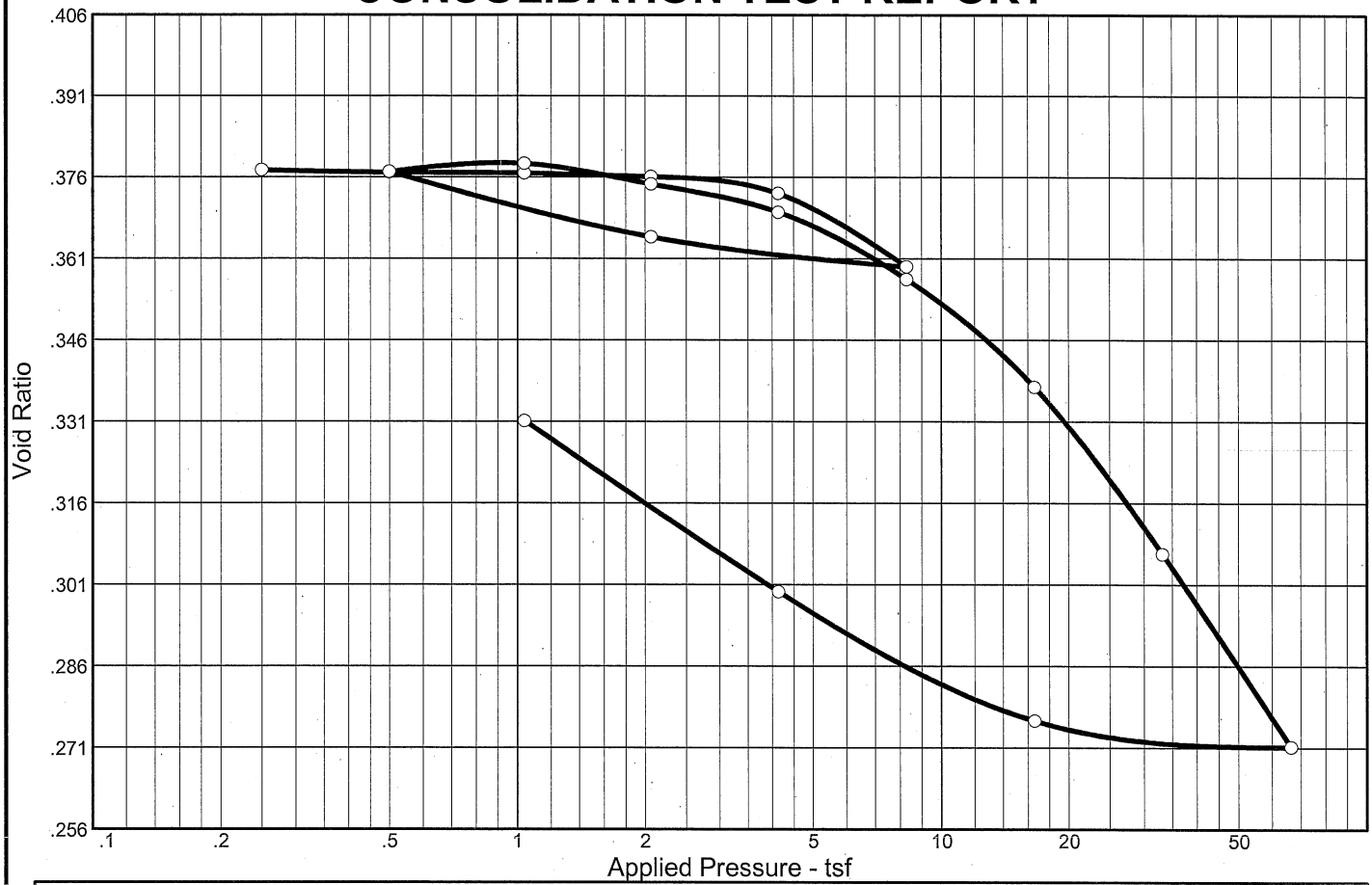
**Source:** B-2 **Elev./Depth:** 14'-16'

**Remarks:**
Test method: ASTM D 2435
Specific gravity: Assumed

**Tolunay-Wong Engineers, Inc.**

**Houston, Texas**

# CONSOLIDATION TEST REPORT




Coefficients of Consolidation and Secondary Consolidation

| No. | Load (tsf) | $C_v$ (ft.$^2$/day) | $C_\alpha$ | No. | Load (tsf) | $C_v$ (ft.$^2$/day) | $C_\alpha$ | No. | Load (tsf) | $C_v$ (ft.$^2$/day) | $C_\alpha$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.25 | 2.298 | | 11 | 4.14 | 0.210 | | | | | |
| 2 | 0.50 | 1.569 | | 12 | 8.30 | 0.066 | | | | | |
| 3 | 1.04 | 0.218 | | 13 | 16.60 | 0.026 | | | | | |
| 4 | 2.07 | 0.158 | | 14 | 33.20 | 0.021 | | | | | |
| 5 | 4.14 | 0.077 | | 15 | 66.40 | 0.017 | | | | | |
| 6 | 8.30 | 0.041 | | 16 | 16.60 | 0.115 | | | | | |
| 7 | 2.07 | 0.015 | | 17 | 4.14 | 0.006 | | | | | |
| 8 | 0.50 | 0.014 | | 18 | 1.04 | 0.002 | | | | | |
| 9 | 1.04 | 0.002 | | | | | | | | | |
| 10 | 2.07 | 0.034 | | | | | | | | | |

| Natural | | Dry Dens. (pcf) | LL | PI | Sp. Gr. | Overburden (tsf) | $P_c$ (tsf) | $C_c$ | Initial Void Ratio |
|---|---|---|---|---|---|---|---|---|---|
| Saturation | Moisture | | | | | | | | |
| 73.2 % | 10.2 % | 122.5 | 41 | 23 | 2.70 | 1.92 | 10.13 | 0.12 | 0.376 |

| MATERIAL DESCRIPTION | USCS | AASHTO |
|---|---|---|
| Tan and light gray LEAN CLAY with SAND | CL | |

**Project No.** 11.13.180 **Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas

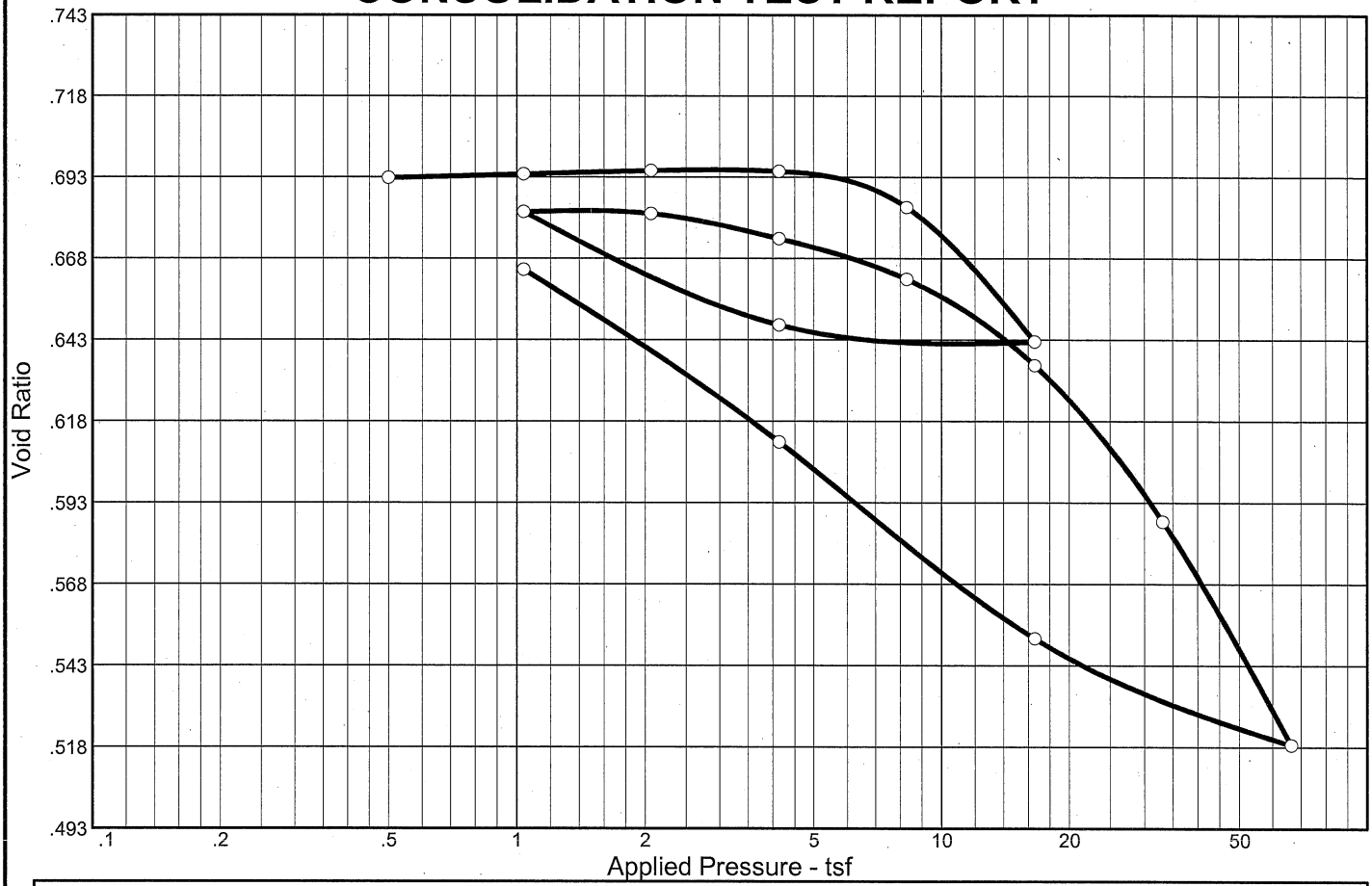
**Source:** B-9 **Elev./Depth:** 43'-45'

**Remarks:**
Test method: ASTM D 2435
Specific gravity: Assumed

**Tolunay-Wong Engineers, Inc.**

**Houston, Texas**

# CONSOLIDATION TEST REPORT




Coefficients of Consolidation and Secondary Consolidation

| No. | Load (tsf) | $C_v$ (ft.2/day) | $C_\alpha$ | No. | Load (tsf) | $C_v$ (ft.2/day) | $C_\alpha$ | No. | Load (tsf) | $C_v$ (ft.2/day) | $C_\alpha$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.50 | 0.859 | | 11 | 8.30 | 0.060 | | | | | |
| 2 | 1.04 | 1.725 | | 12 | 16.60 | 0.030 | | | | | |
| 3 | 2.07 | 2.165 | | 13 | 33.20 | 0.010 | | | | | |
| 4 | 4.14 | 0.559 | | 14 | 66.40 | 0.010 | | | | | |
| 5 | 8.30 | 0.056 | | 15 | 16.60 | 0.009 | | | | | |
| 6 | 16.60 | 0.020 | | 16 | 4.14 | 0.004 | | | | | |
| 7 | 4.14 | 0.015 | | 17 | 1.04 | 0.002 | | | | | |
| 8 | 1.04 | 0.005 | | | | | | | | | |
| 9 | 2.07 | 0.042 | | | | | | | | | |
| 10 | 4.14 | 0.048 | | | | | | | | | |

| Natural | | Dry Dens. (pcf) | LL | PI | Sp. Gr. | Overburden (tsf) | $P_c$ (tsf) | $C_c$ | Initial Void Ratio |
|---|---|---|---|---|---|---|---|---|---|
| Saturation | Moisture | | | | | | | | |
| 94.9 % | 24.3 % | 99.7 | 64 | 44 | 2.70 | 2.82 | 14.13 | 0.23 | 0.691 |

| MATERIAL DESCRIPTION | USCS | AASHTO |
|---|---|---|
| Reddish-brown FAT CLAY | CH | |

**Project No.** 11.13.180 **Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas

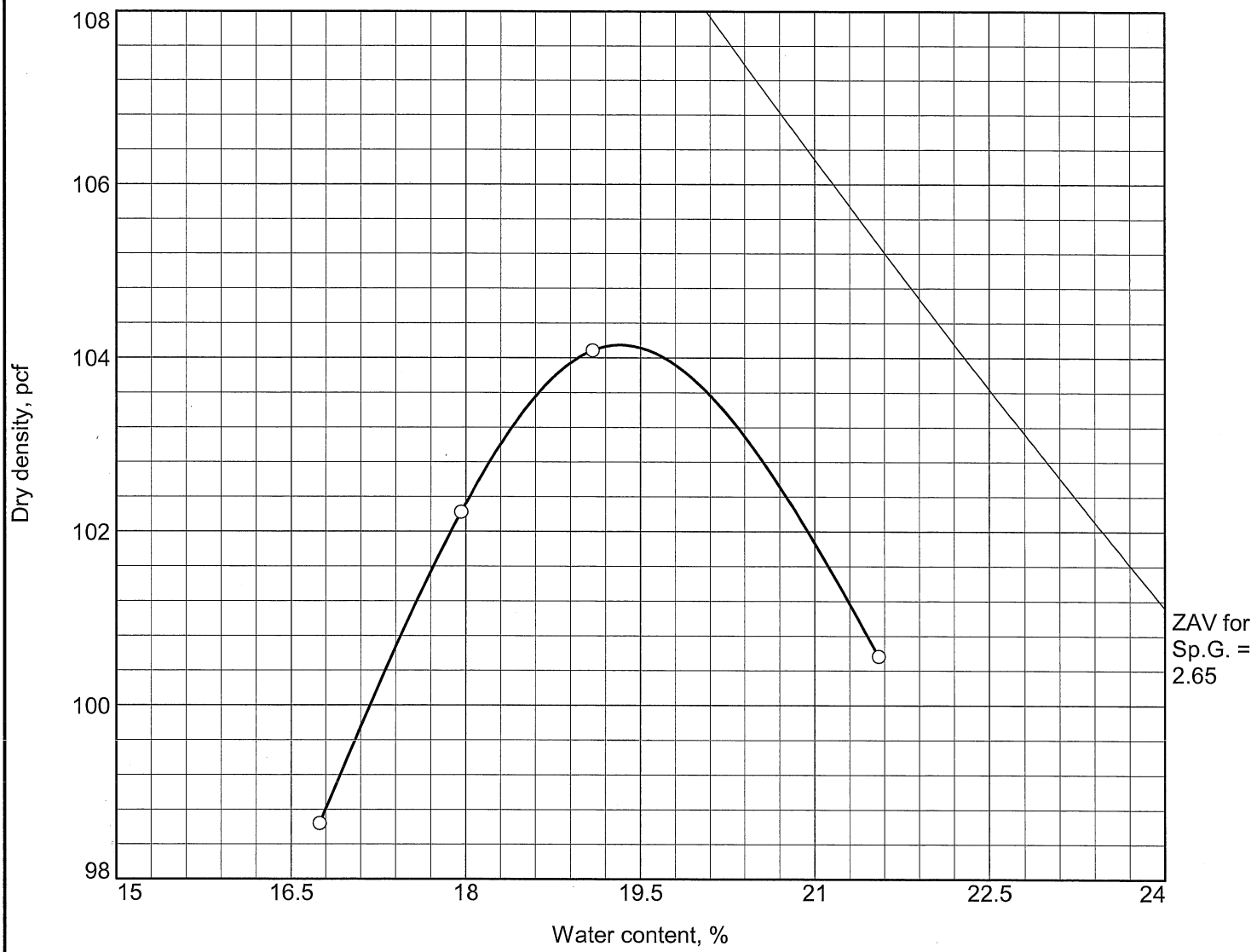
**Source:** B-9 **Elev./Depth:** 78'-80'

**Remarks:**
Test method: ASTM D 2435
Specific gravity: Assumed

**Tolunay-Wong Engineers, Inc.**

**Houston, Texas**

# Moisture-Density Relationship




Test specification: ASTM D 698-07 Method A Standard

| Elev/ Depth | Classification | | Nat. Moist. | Sp.G. | LL | PI | % > #4 | % < No.200 |
|---|---|---|---|---|---|---|---|---|
| | USCS | AASHTO | | | | | | |
| 1'-2' | CH | A-7-6(24) | | 2.65 | 51 | 30 | 1.4 | 78.0 |

| TEST RESULTS | MATERIAL DESCRIPTION |
|---|---|
| Maximum dry density = 104.1 pcf<br>Optimum moisture = 19.3 % | Gray & tan FAT CLAY w/ Sand |

**Project No.** 11.13.180 **Client:** CLR, Inc., Waller, Texas
**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.
Houston, Texas **Date:** 9/29/11
○ **Source of Sample:** B-5 **Depth:** 1'-2'

**Remarks:**
Preparation Met:Wet
Sp.G.-Assumed

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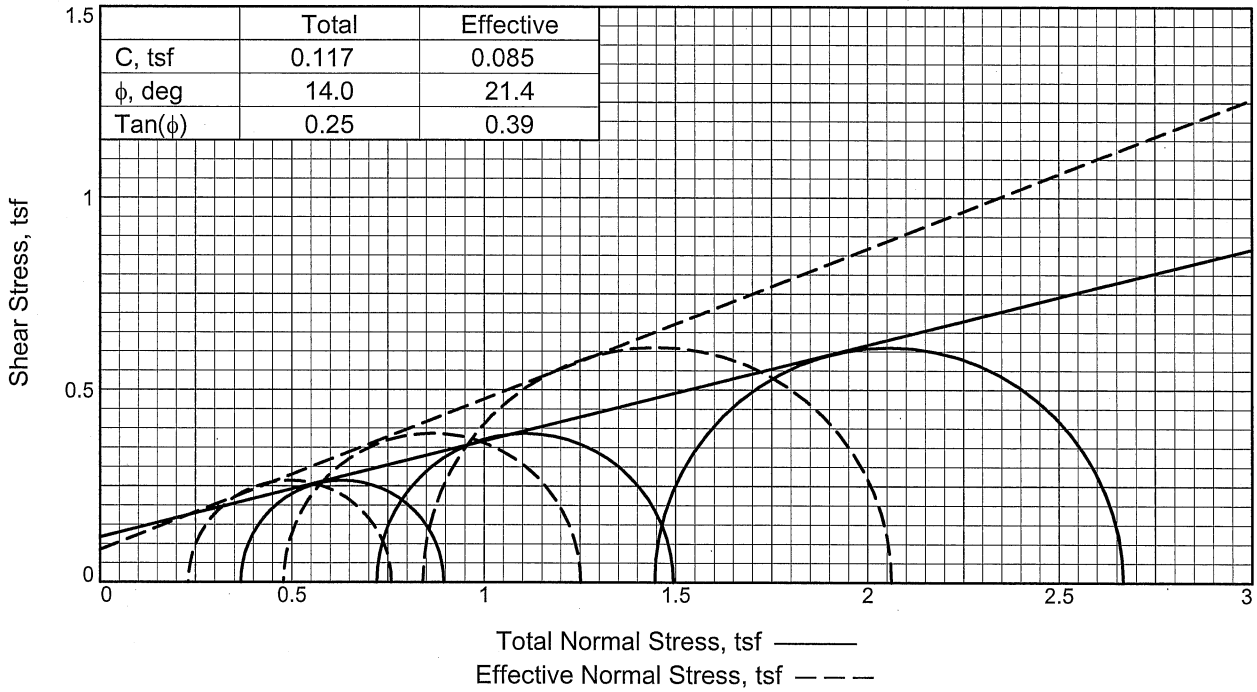
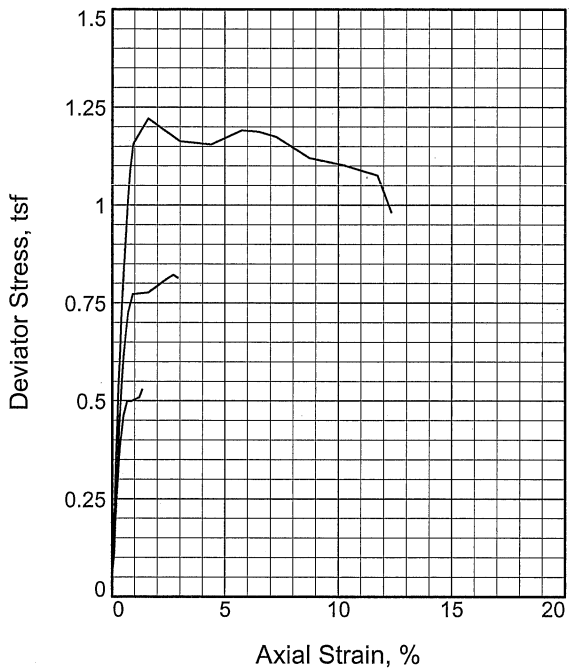
**Houston, Texas**

**Tested By:** D.O




| | Total | Effective |
|---|---|---|
| C, tsf | 0.117 | 0.085 |
| $\phi$, deg | 14.0 | 21.4 |
| Tan($\phi$) | 0.25 | 0.39 |




| Sample No. | | 1 | 2 | 3 |
|---|---|---|---|---|
| Initial | Water Content, % | 28.5 | 28.5 | 28.5 |
| | Dry Density, pcf | 93.0 | 93.0 | 93.0 |
| | Saturation, % | 92.7 | 92.7 | 92.7 |
| | Void Ratio | 0.8455 | 0.8455 | 0.8455 |
| | Diameter, in. | 2.03 | 2.03 | 2.03 |
| | Height, in. | 3.91 | 3.91 | 3.91 |
| At Test | Water Content, % | 31.7 | 31.7 | 31.7 |
| | Dry Density, pcf | 91.7 | 91.7 | 91.7 |
| | Saturation, % | 100.0 | 100.0 | 100.0 |
| | Void Ratio | 0.8713 | 0.8713 | 0.8713 |
| | Diameter, in. | 2.05 | 2.06 | 2.09 |
| | Height, in. | 3.86 | 3.82 | 3.72 |
| Strain rate, %/min. | | 0.01 | 0.0033 | 0.0033 |
| Eff. Cell Pressure, psi | | 5.10 | 10.02 | 20.08 |
| Fail. Stress, tsf | | 0.53 | 0.77 | 1.22 |
| Excess Pore Pr., tsf | | 0.14 | 0.24 | 0.60 |
| Strain, % | | 1.3 | 0.9 | 1.6 |
| Ult. Stress, tsf | | 0.53 | 0.81 | 0.98 |
| Excess Pore Pr., tsf | | 0.14 | 0.19 | 0.34 |
| Strain, % | | 1.3 | 2.9 | 12.3 |
| $\bar{\sigma}_1$ Failure, tsf | | 0.76 | 1.25 | 2.06 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.23 | 0.48 | 0.84 |

**Type of Test:**
CU with Pore Pressures

**Sample Type:** Undisturbed

**Description:** Reddish-brown FAT CLAY (CH), w/ calcareous nodules

**LL=** 74 **PL=** 22 **PI=** 52

**Assumed Specific Gravity=** 2.75

**Remarks:** -200 (%) = 99
Test Method: ASTM D 4767
Pocket Pen: 2.75 tsf
Failure Type: Slickenside

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.

**Source of Sample:** B-3 **Depth:** 14'-16'

**Proj. No.:** 11.13.180 **Date Sampled:** 9/15/2011

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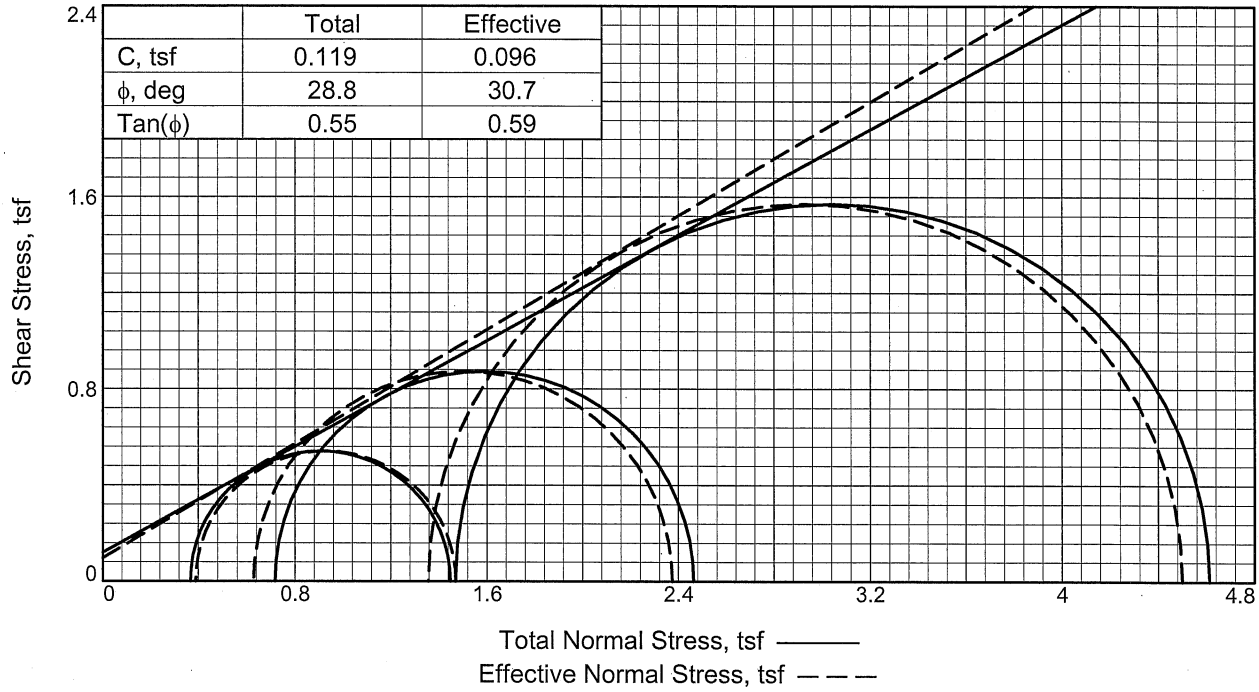
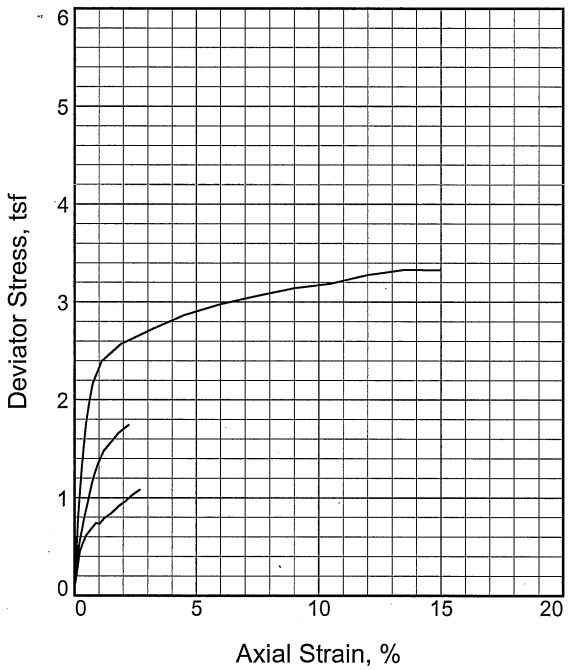
Houston, Texas




| | Total | Effective |
|---|---|---|
| C, tsf | 0.119 | 0.096 |
| ϕ, deg | 28.8 | 30.7 |
| Tan(ϕ) | 0.55 | 0.59 |




| Sample No. | | 1 | 2 | 3 |
|---|---|---|---|---|
| Initial | Water Content, % | 19.1 | 19.1 | 19.1 |
| | Dry Density, pcf | 104.9 | 104.9 | 104.9 |
| | Saturation, % | 82.3 | 82.3 | 82.3 |
| | Void Ratio | 0.6372 | 0.6372 | 0.6372 |
| | Diameter, in. | 2.04 | 2.04 | 2.04 |
| | Height, in. | 4.12 | 4.12 | 4.12 |
| At Test | Water Content, % | 19.9 | 19.9 | 19.9 |
| | Dry Density, pcf | 110.9 | 110.9 | 110.9 |
| | Saturation, % | 100.0 | 100.0 | 100.0 |
| | Void Ratio | 0.5480 | 0.5480 | 0.5480 |
| | Diameter, in. | 1.98 | 2.00 | 2.02 |
| | Height, in. | 4.10 | 4.03 | 3.96 |
| Strain rate, %/min. | | 0.03 | 0.02 | 0.03 |
| Eff. Cell Pressure, psi | | 5.10 | 9.96 | 20.43 |
| Fail. Stress, tsf | | 1.08 | 1.75 | 3.14 |
| Excess Pore Pr., tsf | | -0.02 | 0.09 | 0.11 |
| Strain, % | | 2.7 | 2.2 | 9.0 |
| Ult. Stress, tsf | | 1.08 | 1.75 | 3.34 |
| Excess Pore Pr., tsf | | -0.02 | 0.09 | -0.02 |
| Strain, % | | 2.7 | 2.2 | 15.0 |
| $\bar{\sigma}_1$ Failure, tsf | | 1.47 | 2.37 | 4.50 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.39 | 0.63 | 1.36 |

**Type of Test:**
CU with Pore Pressures

**Sample Type:** Undisturbed

**Description:** Light gray and tan SANDY LEAN CLAY (CL); ferrous nodules

**LL=** 35 **PL=** 18 **PI=** 17

**Assumed Specific Gravity=** 2.75

**Remarks:** -200 (%) = 62
Test Method: ASTM D 4767
Pocket Pen: 2.00 tsf
Failure Type: Bulge

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.

**Source of Sample:** A-1 **Depth:** 8'-10'

**Proj. No.:** 11.13.180 **Date Sampled:** 9/22/2011

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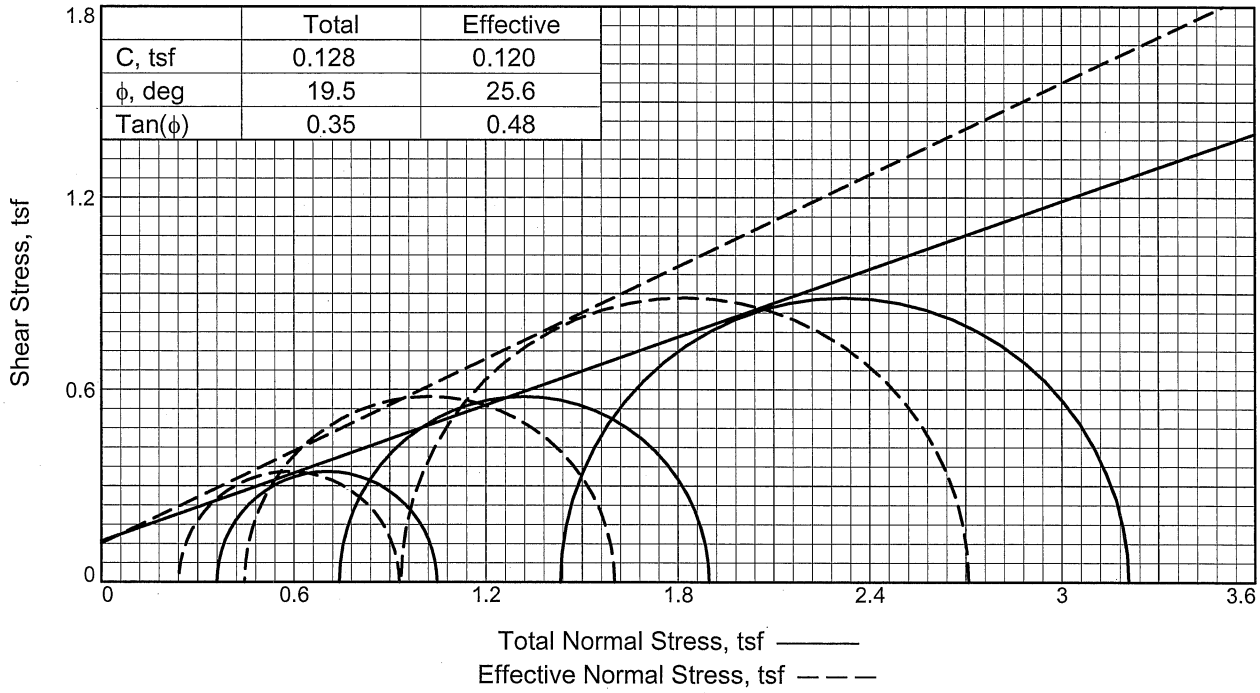
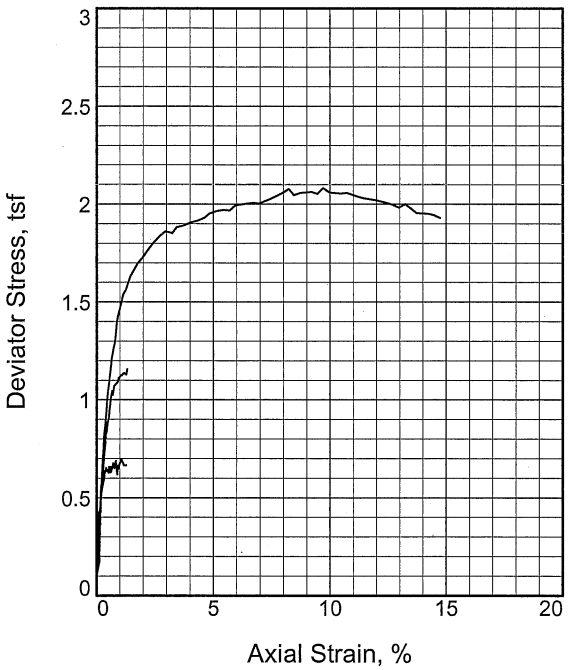
Houston, Texas




| | Total | Effective |
|---|---|---|
| C, tsf | 0.128 | 0.120 |
| $\phi$, deg | 19.5 | 25.6 |
| Tan($\phi$) | 0.35 | 0.48 |




| Sample No. | | 1 | 2 | 3 |
|---|---|---|---|---|
| Initial | Water Content, % | 22.6 | 22.6 | 22.6 |
| | Dry Density, pcf | 103.4 | 103.4 | 103.4 |
| | Saturation, % | 96.9 | 96.9 | 96.9 |
| | Void Ratio | 0.6300 | 0.6300 | 0.6300 |
| | Diameter, in. | 2.01 | 2.01 | 2.01 |
| | Height, in. | 4.14 | 4.14 | 4.14 |
| At Test | Water Content, % | 20.8 | 20.8 | 20.8 |
| | Dry Density, pcf | 107.8 | 107.8 | 107.8 |
| | Saturation, % | 100.0 | 100.0 | 100.0 |
| | Void Ratio | 0.5629 | 0.5629 | 0.5629 |
| | Diameter, in. | 1.96 | 1.97 | 1.98 |
| | Height, in. | 4.14 | 4.10 | 4.07 |
| Strain rate, %/min. | | 0.03 | 0.01 | 0.01 |
| Eff. Cell Pressure, psi | | 5.00 | 10.30 | 19.90 |
| Fail. Stress, tsf | | 0.69 | 1.16 | 1.77 |
| Excess Pore Pr., tsf | | 0.12 | 0.30 | 0.50 |
| Strain, % | | 0.8 | 1.3 | 2.2 |
| Ult. Stress, tsf | | 0.66 | 1.16 | 1.93 |
| Excess Pore Pr., tsf | | 0.11 | 0.30 | -0.14 |
| Strain, % | | 1.3 | 1.3 | 14.7 |
| $\bar{\sigma}_1$ Failure, tsf | | 0.93 | 1.60 | 2.71 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.24 | 0.45 | 0.94 |

**Type of Test:**
CU with Pore Pressures

**Sample Type:** Undisturbed

**Description:** Reddish-brown FAT CLAY (CH); calcareous nodules

**LL=** 62 **PL=** 22 **PI=** 40

**Assumed Specific Gravity=** 2.70

**Remarks:** -200 (%) = 96
Test method: ASTM D 4767
Pocket Pen: 4.00 tsf
Failure type: Slickensided

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.

**Source of Sample:** BB-2 **Depth:** 8'-10'

**Proj. No.:** 11.13.180 **Date Sampled:** 9/20/2011

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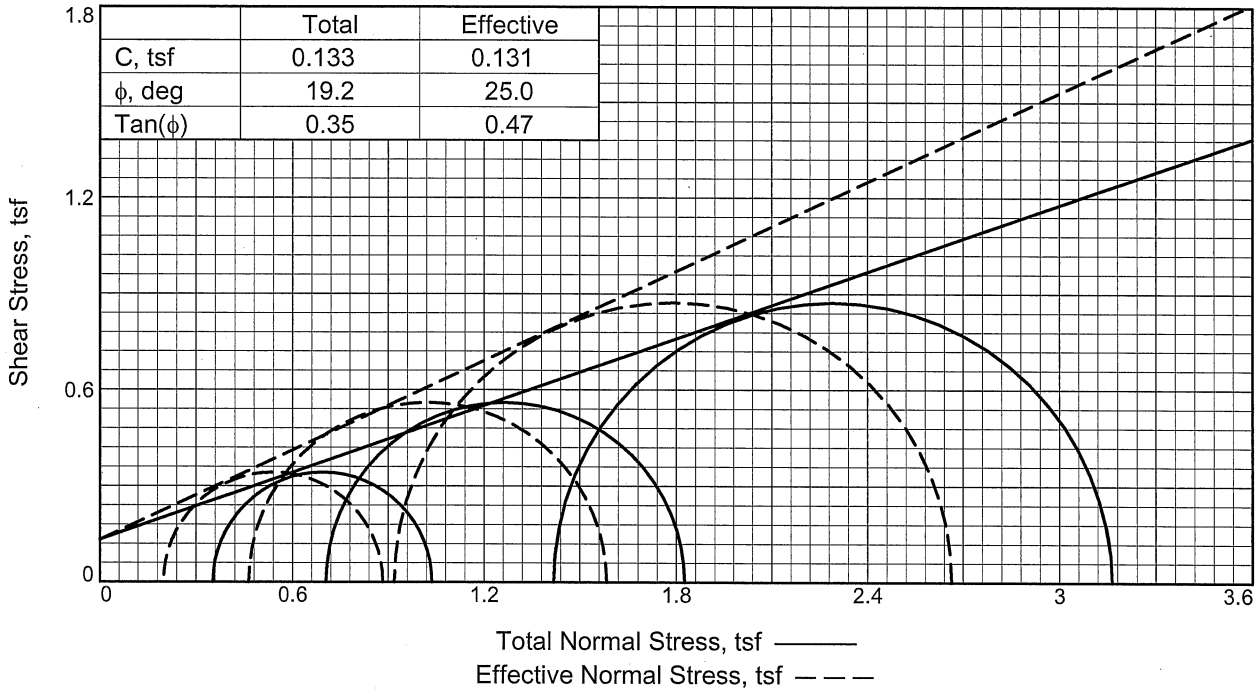
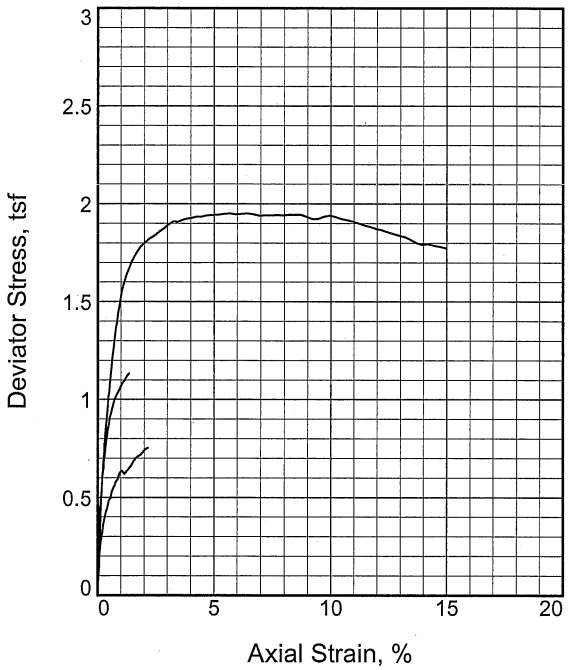
Houston, Texas




| | Total | Effective |
|---|---|---|
| C, tsf | 0.133 | 0.131 |
| $\phi$, deg | 19.2 | 25.0 |
| Tan($\phi$) | 0.35 | 0.47 |




| Sample No. | | 1 | 2 | 3 |
|---|---|---|---|---|
| Initial | Water Content, % | 23.2 | 23.2 | 23.2 |
| | Dry Density, pcf | 104.0 | 104.0 | 104.0 |
| | Saturation, % | 98.0 | 98.0 | 98.0 |
| | Void Ratio | 0.6504 | 0.6504 | 0.6504 |
| | Diameter, in. | 2.83 | 2.83 | 2.83 |
| | Height, in. | 5.57 | 5.57 | 5.57 |
| At Test | Water Content, % | 21.0 | 21.0 | 21.0 |
| | Dry Density, pcf | 108.9 | 108.9 | 108.9 |
| | Saturation, % | 100.0 | 100.0 | 100.0 |
| | Void Ratio | 0.5763 | 0.5763 | 0.5763 |
| | Diameter, in. | 2.76 | 2.78 | 2.79 |
| | Height, in. | 5.61 | 5.51 | 5.47 |
| Strain rate, %/min. | | 0.01 | 0.0067 | 0.0047 |
| Eff. Cell Pressure, psi | | 4.90 | 9.80 | 19.70 |
| Fail. Stress, tsf | | 0.68 | 1.12 | 1.74 |
| Excess Pore Pr., tsf | | 0.15 | 0.24 | 0.50 |
| Strain, % | | 1.5 | 1.3 | 1.6 |
| Ult. Stress, tsf | | 0.75 | 1.13 | 1.77 |
| Excess Pore Pr., tsf | | 0.13 | 0.23 | -0.05 |
| Strain, % | | 2.2 | 1.4 | 15.0 |
| $\bar{\sigma}_1$ Failure, tsf | | 0.88 | 1.58 | 2.66 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.20 | 0.46 | 0.92 |

**Type of Test:**
CU with Pore Pressures

**Sample Type:** Undisturbed

**Description:** Reddish-brown FAT CLAY; calcareous nodules

**LL=** 63 **PL=** 22 **PI=** 41

**Assumed Specific Gravity=** 2.75

**Remarks:**
Test method: ASTM D 4767
Failure type: Slickensided

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.

**Source of Sample:** C-2 **Depth:** 10'-12'

**Proj. No.:** 11.13.180 **Date Sampled:** 11/30/11

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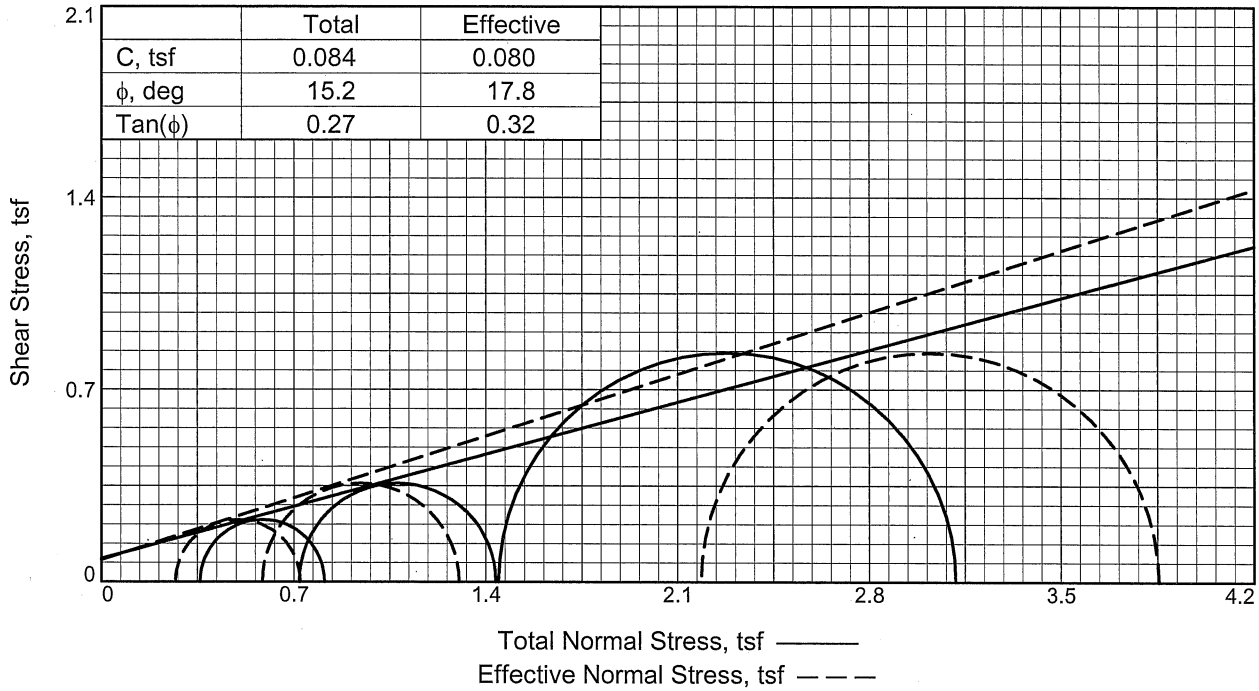
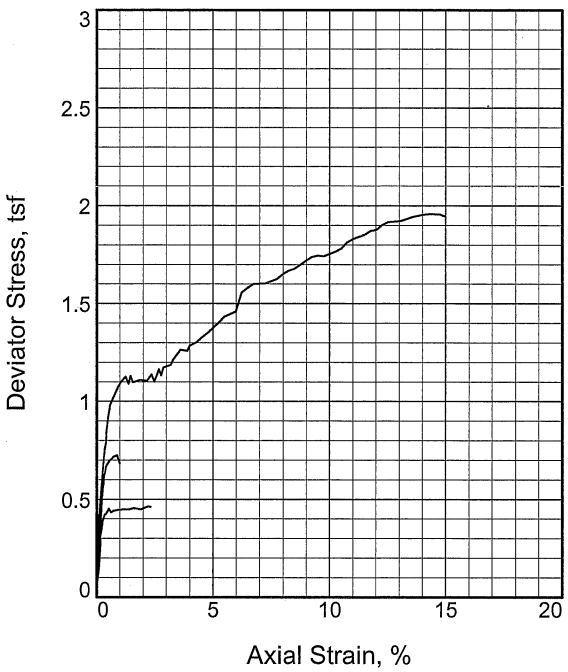
Tolunay-Wong Engineers, Inc.
Houston, Texas

| | Total | Effective |
|---|---|---|
| C, tsf | 0.084 | 0.080 |
| $\phi$, deg | 15.2 | 17.8 |
| Tan($\phi$) | 0.27 | 0.32 |




| Sample No. | | 1 | 2 | 3 |
|---|---|---|---|---|
| Initial | Water Content, % | 24.6 | 24.6 | 24.6 |
| | Dry Density, pcf | 101.4 | 101.4 | 101.4 |
| | Saturation, % | 97.7 | 97.7 | 97.7 |
| | Void Ratio | 0.6931 | 0.6931 | 0.6931 |
| | Diameter, in. | 2.01 | 2.01 | 2.01 |
| | Height, in. | 4.15 | 4.15 | 4.15 |
| At Test | Water Content, % | 23.6 | 23.6 | 23.6 |
| | Dry Density, pcf | 104.0 | 104.0 | 104.0 |
| | Saturation, % | 100.0 | 100.0 | 100.0 |
| | Void Ratio | 0.6503 | 0.6503 | 0.6503 |
| | Diameter, in. | 1.98 | 2.00 | 2.01 |
| | Height, in. | 4.15 | 4.06 | 4.03 |
| Strain rate, %/min. | | 0.05 | 0.0050 | 0.0050 |
| Eff. Cell Pressure, psi | | 5.00 | 10.00 | 20.10 |
| Fail. Stress, tsf | | 0.45 | 0.72 | 1.67 |
| Excess Pore Pr., tsf | | 0.09 | 0.13 | -0.74 |
| Strain, % | | 0.5 | 0.7 | 8.2 |
| Ult. Stress, tsf | | 0.46 | 0.72 | 1.96 |
| Excess Pore Pr., tsf | | 0.07 | 0.13 | -1.14 |
| Strain, % | | 2.2 | 0.9 | 14.3 |
| $\bar{\sigma}_1$ Failure, tsf | | 0.72 | 1.30 | 3.85 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.27 | 0.59 | 2.19 |

**Type of Test:**
CU with Pore Pressures

**Sample Type:** Undisturbed

**Description:** Reddish-brown FAT CLAY (CH)

**LL=** 60 **PL=** 22 **PI=** 38

**Assumed Specific Gravity=** 2.75

**Remarks:** -200 (%) = 93
Test method: ASTM D 4767
Pocket Pen., tsf = 3.00
Failure type: Multiple shear

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.

**Source of Sample:** C-3 **Depth:** 10'-12'

**Proj. No.:** 11.13.180 **Date Sampled:** 9/20/2011

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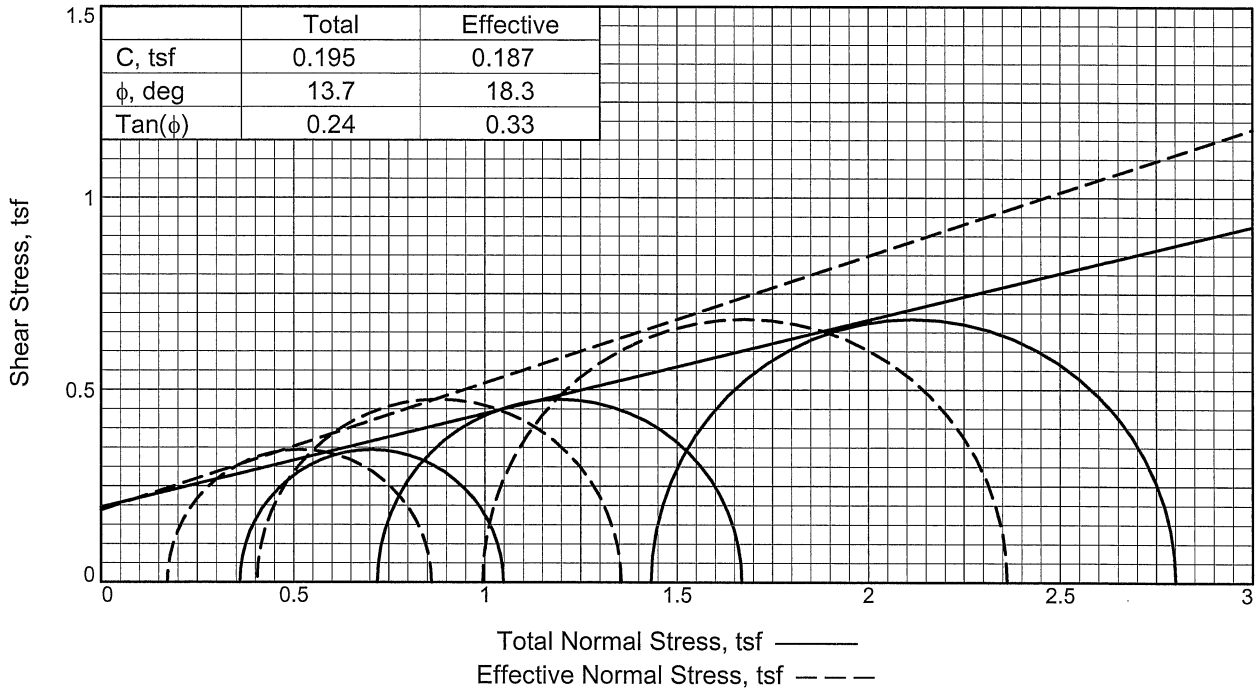
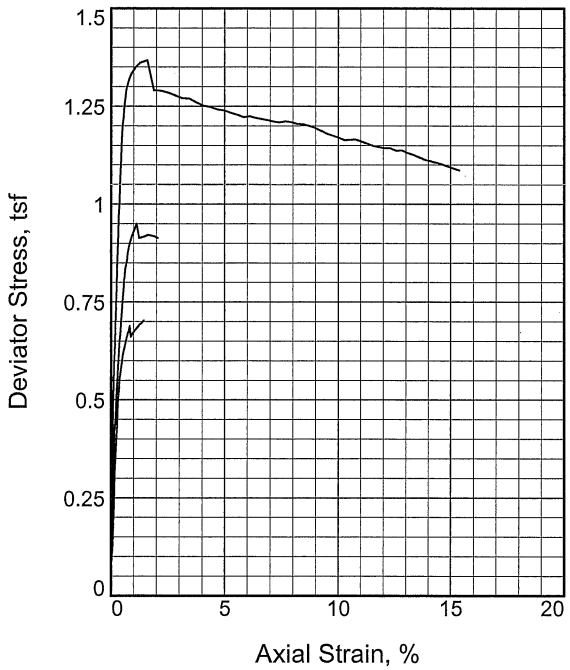
Tolunay-Wong Engineers, Inc.
Houston, Texas




| | Total | Effective |
|---|---|---|
| C, tsf | 0.195 | 0.187 |
| $\phi$, deg | 13.7 | 18.3 |
| Tan($\phi$) | 0.24 | 0.33 |




| Sample No. | | 1 | 2 | 3 |
|---|---|---|---|---|
| Initial | Water Content, % | 25.6 | 25.6 | 25.6 |
| | Dry Density, pcf | 99.5 | 99.5 | 99.5 |
| | Saturation, % | 99.5 | 99.5 | 99.7 |
| | Void Ratio | 0.6947 | 0.6947 | 0.6938 |
| | Diameter, in. | 2.00 | 2.00 | 2.00 |
| | Height, in. | 4.13 | 4.13 | 4.14 |
| At Test | Water Content, % | 24.3 | 24.3 | 24.3 |
| | Dry Density, pcf | 101.8 | 101.8 | 101.8 |
| | Saturation, % | 100.0 | 100.0 | 100.0 |
| | Void Ratio | 0.6549 | 0.6549 | 0.6549 |
| | Diameter, in. | 1.98 | 1.99 | 2.00 |
| | Height, in. | 4.14 | 4.10 | 4.03 |
| Strain rate, %/min. | | 0.03 | 0.0051 | 0.0050 |
| Eff. Cell Pressure, psi | | 5.00 | 10.00 | 19.90 |
| Fail. Stress, tsf | | 0.69 | 0.95 | 1.37 |
| Excess Pore Pr., tsf | | 0.19 | 0.32 | 0.44 |
| Strain, % | | 0.8 | 1.1 | 1.6 |
| Ult. Stress, tsf | | 0.70 | 0.95 | 1.37 |
| Excess Pore Pr., tsf | | 0.17 | 0.32 | 0.44 |
| Strain, % | | 1.5 | 1.1 | 1.6 |
| $\bar{\sigma}_1$ Failure, tsf | | 0.86 | 1.35 | 2.36 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.17 | 0.40 | 0.99 |

**Type of Test:**
CU with Pore Pressures

**Sample Type:** Undisturbed

**Description:** Reddish-brown and gray FAT CLAY (CH)

**LL=** 61 **PL=** 22 **PI=** 39

**Assumed Specific Gravity=** 2.70

**Remarks:** -200 (%) = 94
Test method: ASTM D 4767
Pocket Pen., tsf = 2.75
Failure type: Slickensided

**Client:** CLR, Inc., Waller, Texas

**Project:** Buffalo Speedway Ext. From W. Airport Blvd. to Willowbend Blvd.

**Source of Sample:** D-2 **Depth:** 10'-12'

**Proj. No.:** 11.13.180 **Date Sampled:** 9/20/2011

TRIAXIAL SHEAR TEST REPORT
Tolunay-Wong Engineers, Inc.
Houston, Texas

# APPENDIX H

# ANALYTICAL TEST RESULTS BY ALS ENVIRONMENTAL

ALS Environmental

06-Oct-2011

Eric Haynes
Tolunay-Wong Engineers, Inc.
10710 S. Sam Houston Pkwy W.
Suite 100
Houston, TX 77031

Tel: (713) 722-7064
Fax: (713) 722-0319

Re: Buffalo Speedway

Work Order: **1109928**

Dear Eric,

ALS Environmental received 3 samples on 29-Sep-2011 02:40 PM for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested. Results are expressed as "as received" unless otherwise noted.

QC sample results for this data met EPA or laboratory specifications except as noted in the Case Narrative or as noted with qualifiers in the QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained by ALS Environmental. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 9.

If you have any questions regarding this report, please feel free to call me.

Sincerely,

Ed B. Fry

Electronically approved by: Yvan K. Ty

Ed B. Fry
Project Manager

ACCREDITED IN ACCORDANCE WITH nelac

Certificate No: TX: T104704231-11-5

# ALS Environmental

Date: 06-Oct-11

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Work Order:** **1109928**

## Work Order Sample Summary

| Lab Samp ID | Client Sample ID | Matrix | Tag Number | Collection Date | Date Received | Hold |
|---|---|---|---|---|---|---|
| 1109928-01 | B-3 (2-4') | Soil | | 9/29/2011 | 9/29/2011 14:40 | |
| 1109928-02 | B-4 (6-8') | Soil | | 9/29/2011 | 9/29/2011 14:40 | |
| 1109928-03 | B-6 (4-6') | Soil | | 9/29/2011 | 9/29/2011 14:40 | |

# ALS Environmental

**Date:** *06-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Sample ID:** B-3 (2-4')
**Collection Date:** 9/29/2011

**Work Order:** 1109928
**Lab ID:** 1109928-01
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/5/2011** | Analyst: **RPM** |
| **Sulfate** | **262** | | **49.5** | **mg/Kg** | 10 | 10/6/2011 12:26 AM |
| *Surr: Selenate (surr)* | *97.5* | | *85-115* | *%REC* | 10 | 10/6/2011 12:26 AM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

# ALS Environmental

**Date:** *06-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Sample ID:** B-4 (6-8')
**Collection Date:** 9/29/2011

**Work Order:** 1109928
**Lab ID:** 1109928-02
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/5/2011** | Analyst: **RPM** |
| **Sulfate** | **227** | | **49.8** | **mg/Kg** | 10 | 10/6/2011 12:47 AM |
| *Surr: Selenate (surr)* | *95.4* | | *85-115* | *%REC* | 10 | 10/6/2011 12:47 AM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

# ALS Environmental

**Date:** *06-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Sample ID:** B-6 (4-6')
**Collection Date:** 9/29/2011

**Work Order:** 1109928
**Lab ID:** 1109928-03
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/5/2011** | Analyst: **RPM** |
| **Sulfate** | **112** | | **49.9** | **mg/Kg** | 10 | 10/6/2011 01:09 AM |
| *Surr: Selenate (surr)* | *90.2* | | *85-115* | *%REC* | 10 | 10/6/2011 01:09 AM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

ALS Environmental

Date: 06-Oct-11

**Client:** Tolunay-Wong Engineers, Inc.
**Work Order:** 1109928
**Project:** Buffalo Speedway

# QC BATCH REPORT

Batch ID: **55900** Instrument ID **ICS3K2** Method: **E300**

**MBLK** Sample ID: **WBLKS1-100511-55900** Units: **mg/Kg** Analysis Date: **10/5/2011 12:13 PM**

Client ID: Run ID: **ICS3K2_111005A** SeqNo: **2549343** Prep Date: **10/5/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | U | 5.0 | | | | | | | | |
| *Surr: Selenate (surr)* | *45.03* | 1.0 | *50* | 0 | *90.1* | *85-115* | 0 | | | |

**LCS** Sample ID: **WLCSS1-100511-55900** Units: **mg/Kg** Analysis Date: **10/5/2011 12:35 PM**

Client ID: Run ID: **ICS3K2_111005A** SeqNo: **2549344** Prep Date: **10/5/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 182.2 | 5.0 | 200 | 0 | 91.1 | 90-110 | 0 | | | |
| *Surr: Selenate (surr)* | *49.58* | 1.0 | *50* | 0 | *99.2* | *85-115* | 0 | | | |

**LCSD** Sample ID: **WLCSDS1-100511-55900** Units: **mg/Kg** Analysis Date: **10/5/2011 12:56 PM**

Client ID: Run ID: **ICS3K2_111005A** SeqNo: **2549345** Prep Date: **10/5/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 182.2 | 5.0 | 200 | 0 | 91.1 | 90-110 | 182.2 | 0.022 | 20 | |
| *Surr: Selenate (surr)* | *49.68* | 1.0 | *50* | 0 | *99.4* | *85-115* | 49.58 | *0.201* | *20* | |

**MS** Sample ID: **1110115-01AMS** Units: **mg/Kg** Analysis Date: **10/5/2011 06:42 PM**

Client ID: Run ID: **ICS3K2_111005A** SeqNo: **2549359** Prep Date: **10/5/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 909.3 | 4.9 | 98.6 | 817.5 | 93.1 | 75-125 | 0 | | | O |
| *Surr: Selenate (surr)* | *48.74* | 0.99 | *49.3* | 0 | *98.9* | *80-120* | 0 | | | |

**MSD** Sample ID: **1110115-01AMSD** Units: **mg/Kg** Analysis Date: **10/5/2011 07:04 PM**

Client ID: Run ID: **ICS3K2_111005A** SeqNo: **2549360** Prep Date: **10/5/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 900.6 | 4.9 | 98.58 | 817.5 | 84.3 | 75-125 | 909.3 | 0.96 | 20 | O |
| *Surr: Selenate (surr)* | *48.01* | 0.99 | *49.29* | 0 | *97.4* | *80-120* | 48.74 | *1.51* | *20* | |

**The following samples were analyzed in this batch:** 1109928-01A 1109928-02A 1109928-03A

**Note:** See Qualifiers Page for a list of Qualifiers and their explanation.

## ALS Environmental

Date: 06-Oct-11

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**WorkOrder:** **1109928**

# QUALIFIERS, ACRONYMS, UNITS

| Qualifier | Description |
|---|---|
| * | Value exceeds Regulatory Limit |
| a | Not accredited |
| B | Analyte detected in the associated Method Blank above the Reporting Limit |
| E | Value above quantitation range |
| H | Analyzed outside of Holding Time |
| J | Analyte detected below quantitation limit |
| M | Manually integrated, see raw data for justification |
| n | Not offered for accreditation |
| ND | Not Detected at the Reporting Limit |
| O | Sample amount is > 4 times amount spiked |
| P | Dual Column results percent difference > 40% |
| R | RPD above laboratory control limit |
| S | Spike Recovery outside laboratory control limits |
| U | Analyzed but not detected above the MDL |

| Acronym | Description |
|---|---|
| DCS | Detectability Check Study |
| DUP | Method Duplicate |
| LCS | Laboratory Control Sample |
| LCSD | Laboratory Control Sample Duplicate |
| MBLK | Method Blank |
| MDL | Method Detection Limit |
| MQL | Method Quantitation Limit |
| MS | Matrix Spike |
| MSD | Matrix Spike Duplicate |
| PDS | Post Digestion Spike |
| PQL | Practical Quantitation Limit |
| SD | Serial Dilution |
| SDL | Sample Detection Limit |
| TRRP | Texas Risk Reduction Program |

| Units Reported | Description |
|---|---|
| mg/Kg | Milligrams per Kilogram |

1109928

TW-HOU: Tolunay-Wong Engineers, Inc.

Project: Buffalo Speedway

# Tolunay-Wong Engineers, Inc.
## Chain of Custody Record

| | | | |
|---|---|---|---|
| TO: | ALS Group USA | Sampled By: | Eric Haynes |
| attention: Ed Fry | | Project Name: | Buffalo Speedway |
| | | Date: | September 29, 2011 |
| | | TWEI Project No.: | 11.13.180 |
| Phone: | 281-530-5656 | Contact: | Eric Haynes/Mohammed Islam |

Due Date: 7 Day turn around

| Identification / Sample No. | # CNTS | Date Sampled | Time | Type | Matrix | Sulfate | Notes |
|---|---|---|---|---|---|---|---|
| B-3 (2-4') | | 9/29/2011 | | Grab | Soil | X | |
| B-4 (6-8') | | 9/29/2011 | | Grab | Soil | X | |
| B-6 (4-6') | | 9/29/2011 | | Grab | Soil | X | |

| Relinquished By | Date | Time | Received By | Date | Time |
|---|---|---|---|---|---|
| Eric Haynes Sr. | 9/29/11 | | [illegible] | 9-29-11 | 11:45 |
| [illegible] | 9-29-11 | 1452 | [illegible] | 9/29/11 | 14:52 |

10710 S Sam Houston Parkway W, Suite 100 - Houston, Texas 77031

(713) 722-7064 Office
(281) 722-0309 Fax

Matrix: S= Soil, W= Water, SL= Sludge,
Type GR= Grab, SP= Split, CO= Composite, J= Jar, T= Tube

COCPw (Rev.B) 2/2010

ALS Environmental

## Sample Receipt Checklist

Client Name: **TW-HOU**

Date/Time Received: **29-Sep-11 14:40**

Work Order: **1109928**

Received by: **PS**

Checklist completed by Robert D. Harris (eSignature) 29-Sep-11 (Date)

Reviewed by: Yuan L. Ty (eSignature) 30-Sep-11 (Date)

Matrices: soils
Carrier name: ALS.HS

| | | | |
|---|---|---|---|
| Shipping container/cooler in good condition? | Yes ✔ | No | Not Present |
| Custody seals intact on shipping container/cooler? | Yes | No | Not Present ✔ |
| Custody seals intact on sample bottles? | Yes | No | Not Present ✔ |
| Chain of custody present? | Yes ✔ | No | |
| Chain of custody signed when relinquished and received? | Yes ✔ | No | |
| Chain of custody agrees with sample labels? | Yes ✔ | No | |
| Samples in proper container/bottle? | Yes ✔ | No | |
| Sample containers intact? | Yes ✔ | No | |
| Sufficient sample volume for indicated test? | Yes ✔ | No | |
| All samples received within holding time? | Yes ✔ | No | |
| Container/Temp Blank temperature in compliance? | Yes ✔ | No | |
| Temperature(s)/Thermometer(s): | 3.9c | 002 | |
| Cooler(s)/Kit(s): | | | |
| Water - VOA vials have zero headspace? | Yes | No | No VOA vials submitted ✔ |
| Water - pH acceptable upon receipt? | Yes | No | N/A ✔ |
| pH adjusted? | Yes | No | N/A ✔ |
| pH adjusted by: | - | | |

Login Notes:

Client Contacted:

Date Contacted:

Person Contacted:

Contacted By:

Regarding:

Comments:

CorrectiveAction:

12-Oct-2011

Eric Haynes
Tolunay-Wong Engineers, Inc.
10710 S. Sam Houston Pkwy W.
Suite 100
Houston, TX 77031

Tel: (713) 722-7064
Fax: (713) 722-0319

Re: Buffalo Speedway Work Order: **1110145**

Dear Eric,

ALS Environmental received 4 samples on 05-Oct-2011 02:20 PM for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested. Results are expressed as "as received" unless otherwise noted.

QC sample results for this data met EPA or laboratory specifications except as noted in the Case Narrative or as noted with qualifiers in the QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained by ALS Environmental. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 11.

If you have any questions regarding this report, please feel free to call me.

Sincerely,

Ed B. Fry

Electronically approved by: Mary K. Knowles

Ed B. Fry
Project Manager

Certificate No: TX: T104704231-11-5

# ALS Environmental

Date: 12-Oct-11

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Work Order:** **1110145**

## Work Order Sample Summary

| Lab Samp ID | Client Sample ID | Matrix | Tag Number | Collection Date | Date Received | Hold |
|---|---|---|---|---|---|---|
| 1110145-01 | B-5 (6-7') | Soil | | 10/5/2011 | 10/5/2011 14:20 | ☐ |
| 1110145-02 | B-7 (8-10') | Soil | | 10/5/2011 | 10/5/2011 14:20 | ☐ |
| 1110145-03 | B-8 (4-6') | Soil | | 10/5/2011 | 10/5/2011 14:20 | ☐ |
| 1110145-04 | B-9 (2-4') | Soil | | 10/5/2011 | 10/5/2011 14:20 | ☐ |

# ALS Environmental

**Date:** *12-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Sample ID:** B-5 (6-7')
**Collection Date:** 10/5/2011

**Work Order:** 1110145
**Lab ID:** 1110145-01
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/10/2011** | Analyst: **RPM** |
| **Sulfate** | **42.1** | | **4.90** | **mg/Kg** | 1 | 10/11/2011 07:37 PM |
| *Surr: Selenate (surr)* | *99.7* | | *85-115* | *%REC* | 1 | 10/11/2011 07:37 PM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

# ALS Environmental

**Date:** *12-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Work Order:** 1110145
**Sample ID:** B-7 (8-10')
**Lab ID:** 1110145-02
**Collection Date:** 10/5/2011
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/10/2011** | Analyst: **RPM** |
| **Sulfate** | **8.50** | | **4.97** | **mg/Kg** | 1 | 10/11/2011 08:41 PM |
| *Surr: Selenate (surr)* | *97.0* | | *85-115* | *%REC* | 1 | 10/11/2011 08:41 PM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

# ALS Environmental

**Date:** *12-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Work Order:** 1110145
**Sample ID:** B-8 (4-6')
**Lab ID:** 1110145-03
**Collection Date:** 10/5/2011
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/10/2011** | Analyst: **RPM** |
| Sulfate | ND | | 4.94 | mg/Kg | 1 | 10/11/2011 09:02 PM |
| *Surr: Selenate (surr)* | *103* | | *85-115* | *%REC* | 1 | 10/11/2011 09:02 PM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

# ALS Environmental

**Date:** *12-Oct-11*

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**Work Order:** 1110145
**Sample ID:** B-9 (2-4')
**Lab ID:** 1110145-04
**Collection Date:** 10/5/2011
**Matrix:** SOIL

| Analyses | Result | Qual | Report Limit | Units | Dilution Factor | Date Analyzed |
|---|---|---|---|---|---|---|
| **ANIONS - EPA 300.0 (1993)** | | | **E300** | | Prep Date: **10/10/2011** | Analyst: **RPM** |
| Sulfate | ND | | 5.00 | mg/Kg | 1 | 10/11/2011 09:23 PM |
| *Surr: Selenate (surr)* | *96.2* | | *85-115* | *%REC* | 1 | 10/11/2011 09:23 PM |

**Note:** See Qualifiers Page for a list of qualifiers and their explanation.

ALS Environmental

Date: 12-Oct-11

**Client:** Tolunay-Wong Engineers, Inc.
**Work Order:** 1110145
**Project:** Buffalo Speedway

# QC BATCH REPORT

Batch ID: **56053** Instrument ID **ICS3000** Method: **E300**

**MBLK** Sample ID: **WBLKS2-101011-56053** Units: **mg/Kg** Analysis Date: **10/11/2011 05:11 PM**

Client ID: Run ID: **ICS3000_111011A** SeqNo: **2555715** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | ND | 5.0 | | | | | | | | |
| *Surr: Selenate (surr)* | *48.35* | 1.0 | *50* | 0 | *96.7* | *85-115* | 0 | | | |

**LCS** Sample ID: **WLCSS2-101011-56053** Units: **mg/Kg** Analysis Date: **10/11/2011 05:32 PM**

Client ID: Run ID: **ICS3000_111011A** SeqNo: **2555717** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 207 | 5.0 | 200 | 0 | 103 | 90-110 | 0 | | | |
| *Surr: Selenate (surr)* | *50.27* | 1.0 | *50* | 0 | *101* | *85-115* | 0 | | | |

**LCSD** Sample ID: **WLCSDS2-101011-56053** Units: **mg/Kg** Analysis Date: **10/11/2011 05:53 PM**

Client ID: Run ID: **ICS3000_111011A** SeqNo: **2555719** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 208.4 | 5.0 | 200 | 0 | 104 | 90-110 | 207 | 0.655 | 20 | |
| *Surr: Selenate (surr)* | *50.48* | 1.0 | *50* | 0 | *101* | *85-115* | 50.27 | *0.417* | *20* | |

**MS** Sample ID: **1110145-01AMS** Units: **mg/Kg** Analysis Date: **10/11/2011 07:58 PM**

Client ID: **B-5 (6-7')** Run ID: **ICS3000_111011A** SeqNo: **2555722** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 143 | 4.9 | 97.88 | 42.09 | 103 | 75-125 | 0 | | | |
| *Surr: Selenate (surr)* | *48.07* | 0.98 | *48.94* | 0 | *98.2* | *80-120* | 0 | | | |

**MS** Sample ID: **1110174-16AMS** Units: **mg/Kg** Analysis Date: **10/12/2011 04:46 AM**

Client ID: Run ID: **ICS3000_111011A** SeqNo: **2555758** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 154.8 | 4.9 | 98.85 | 48.67 | 107 | 75-125 | 0 | | | |
| *Surr: Selenate (surr)* | *49.17* | 0.99 | *49.43* | 0 | *99.5* | *80-120* | 0 | | | |

**MSD** Sample ID: **1110145-01AMSD** Units: **mg/Kg** Analysis Date: **10/11/2011 08:19 PM**

Client ID: **B-5 (6-7')** Run ID: **ICS3000_111011A** SeqNo: **2555724** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 142.2 | 4.9 | 97.85 | 42.09 | 102 | 75-125 | 143 | 0.574 | 20 | |
| *Surr: Selenate (surr)* | *48.15* | 0.98 | *48.92* | 0 | *98.4* | *80-120* | 48.07 | *0.164* | *20* | |

**Note:** See Qualifiers Page for a list of Qualifiers and their explanation.

**Client:** Tolunay-Wong Engineers, Inc.
**Work Order:** 1110145
**Project:** Buffalo Speedway

# QC BATCH REPORT

Batch ID: **56053** Instrument ID **ICS3000** Method: **E300**

**MSD** Sample ID: **1110174-16AMSD** Units: **mg/Kg** Analysis Date: **10/12/2011 05:07 AM**

Client ID: Run ID: **ICS3000_111011A** SeqNo: **2555759** Prep Date: **10/10/2011** DF: **1**

| Analyte | Result | PQL | SPK Val | SPK Ref Value | %REC | Control Limit | RPD Ref Value | %RPD | RPD Limit | Qual |
|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | 153.8 | 4.9 | 98.77 | 48.67 | 106 | 75-125 | 154.8 | 0.662 | 20 | |
| *Surr: Selenate (surr)* | *49.21* | 0.99 | *49.39* | 0 | *99.6* | *80-120* | 49.17 | *0.0817* | *20* | |

**The following samples were analyzed in this batch:**

| | | |
|---|---|---|
| 1110145-01A | 1110145-02A | 1110145-03A |
| 1110145-04A | | |

**Note:** See Qualifiers Page for a list of Qualifiers and their explanation.

# ALS Environmental

Date: 12-Oct-11

**Client:** Tolunay-Wong Engineers, Inc.
**Project:** Buffalo Speedway
**WorkOrder:** **1110145**

## QUALIFIERS, ACRONYMS, UNITS

| Qualifier | Description |
|---|---|
| * | Value exceeds Regulatory Limit |
| a | Not accredited |
| B | Analyte detected in the associated Method Blank above the Reporting Limit |
| E | Value above quantitation range |
| H | Analyzed outside of Holding Time |
| J | Analyte detected below quantitation limit |
| M | Manually integrated, see raw data for justification |
| n | Not offered for accreditation |
| ND | Not Detected at the Reporting Limit |
| O | Sample amount is > 4 times amount spiked |
| P | Dual Column results percent difference > 40% |
| R | RPD above laboratory control limit |
| S | Spike Recovery outside laboratory control limits |
| U | Analyzed but not detected above the MDL |

| Acronym | Description |
|---|---|
| DCS | Detectability Check Study |
| DUP | Method Duplicate |
| LCS | Laboratory Control Sample |
| LCSD | Laboratory Control Sample Duplicate |
| MBLK | Method Blank |
| MDL | Method Detection Limit |
| MQL | Method Quantitation Limit |
| MS | Matrix Spike |
| MSD | Matrix Spike Duplicate |
| PDS | Post Digestion Spike |
| PQL | Practical Quantitation Limit |
| SD | Serial Dilution |
| SDL | Sample Detection Limit |
| TRRP | Texas Risk Reduction Program |

| Units Reported | Description |
|---|---|
| mg/Kg | Milligrams per Kilogram |

1110145

TW-HOU: Tolunay-Wong Engineers, Inc.

Project: Buffalo Speedway

# Tolunay-Wong Engineers, Inc.
## Chain of Custody Record

| | | | |
|---|---|---|---|
| TO: | ALS Group USA | Sampled By: | Eric Haynes |
| attention: Ed Fry | | Project Name: | Buffalo Speedway |
| | | | |
| | | Date: | October 5, 2011 |
| | | TWEI Project No.: | 11.13.180 |
| Phone: | 281-530-5656 | Contact: | Eric Haynes/Mohammed Islam |

| Due Date |
|---|
| 5 Day turn around |

| Identification / Sample No. | # CNTS | Date Sampled | Time | Type | Matrix | Sulfate | Notes |
|---|---|---|---|---|---|---|---|
| B-5 (6-7') | | 10/5/2011 | | Grab | Soil | X | |
| B-7 (8-10') | | 10/5/2011 | | Grab | Soil | X | |
| B-8 (4-6') | | 10/5/2011 | | Grab | Soil | X | |
| B-9 (2-4') | | 10/5/2011 | | Grab | Soil | x | |

| Relinquished By | Date | Time | Received By | Date | Time |
|---|---|---|---|---|---|
| Eric Haynes Sr. | 10/5/11 | 2:20 | [illegible] | 10/5/11 | 2:20 |
| [illegible] | 10/5/11 | 2:28 | [illegible] | 10/5/11 | 1428 |

10710 S Sam Houston Parkway W, Suite 100 - Houston, Texas 77031

(713) 722-7064 Office

(281) 722-0309 Fax

Matrix: S= Soil, W= Water, SL= Sludge,

Type GR= Grab, SP= Split, CO= Composite, J= Jar, T= Tube

COCPw (Rev.B) 2/2010

ALS Environmental

## Sample Receipt Checklist

Client Name: **TW-HOU** Date/Time Received: **05-Oct-11 14:20**

Work Order: **1110145** Received by: **ECD**

Checklist completed by Robert D. Harris (eSignature) 05-Oct-11 (Date) Reviewed by: Ed B. Fry (eSignature) 06-Oct-11 (Date)

Matrices: soil
Carrier name: ALS.HS

| | | | |
|---|---|---|---|
| Shipping container/cooler in good condition? | Yes ☑ | No ☐ | Not Present ☐ |
| Custody seals intact on shipping container/cooler? | Yes ☐ | No ☐ | Not Present ☑ |
| Custody seals intact on sample bottles? | Yes ☐ | No ☐ | Not Present ☑ |
| Chain of custody present? | Yes ☑ | No ☐ | |
| Chain of custody signed when relinquished and received? | Yes ☑ | No ☐ | |
| Chain of custody agrees with sample labels? | Yes ☑ | No ☐ | |
| Samples in proper container/bottle? | Yes ☑ | No ☐ | |
| Sample containers intact? | Yes ☑ | No ☐ | |
| Sufficient sample volume for indicated test? | Yes ☑ | No ☐ | |
| All samples received within holding time? | Yes ☑ | No ☐ | |
| Container/Temp Blank temperature in compliance? | Yes ☑ | No ☐ | |
| Temperature(s)/Thermometer(s): | Ambient | N/A | |
| Cooler(s)/Kit(s): | | | |
| Water - VOA vials have zero headspace? | Yes ☐ | No ☐ | No VOA vials submitted ☑ |
| Water - pH acceptable upon receipt? | Yes ☐ | No ☐ | N/A ☑ |
| pH adjusted? | Yes ☐ | No ☐ | N/A ☑ |
| pH adjusted by: | _ | | |

Login Notes:

Client Contacted: Date Contacted: Person Contacted:

Contacted By: Regarding:

Comments:

CorrectiveAction:

# APPENDIX I

# BEARING CAPACITY, OVERTURNING AND SLIDING CALCULATIONS FOR 18-FT HIGH MSE RETAINING WALL AT NORTH OF BRIDGE OVERPASS

Tolunay-Wong Engineers, Inc.

# AASHTO 2002 ASD DESIGN METHOD
# Buffalo Speedway Extension, Houston, Tx

MSEW(3.0): Update # 14.4

## PROJECT IDENTIFICATION

Title: Buffalo Speedway Extension, Houston, Tx
Project Number: 11.13.180
Client: CLR, Inc.
Designer: Mohammed Islam
Station Number: 182+00.00

**Description:**

18 ft High MSE Retaining Wall at North of Overpass Bridge

**Company's information:**

Name: Tolunay-Wong Engineers, Inc.
Street: 10710 S. Sam Houston Pkwy W., Suite 100

Houston, TX 77031
Telephone #: 713-722-7064
Fax #: 713-777-1424
E-Mail:

**Original file path and name:** T:\Geotechnical\Projects\2011\11.13.180\MSWE\18ft H Ret..... .....n (On-site Soil).BEN

**Original date and time of creating this file:** 12/20/2011

**PROGRAM MODE:** ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.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## SOIL DATA

REINFORCED SOIL

| | |
|---|---|
| Unit weight, $\gamma$ | 125.0 lb/ft $^3$ |
| Design value of internal angle of friction, $\phi$ | 38.0 ° |

RETAINED SOIL

| | |
|---|---|
| Unit weight, $\gamma$ | 125.0 lb/ft $^3$ |
| Design value of internal angle of friction, $\phi$ | 30.0 ° |

FOUNDATION SOIL (Considered as an equivalent uniform soil)

| | |
|---|---|
| Equivalent unit weight, $\gamma_{equiv.}$ | 125.0 lb/ft $^3$ |
| Equivalent internal angle of friction, $\phi_{equiv.}$ | 0.0 ° |
| Equivalent cohesion, $c_{equiv.}$ | 1350.0 lb/ft $^2$ |

Water table does not affect bearing capacity

## LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3334 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

## BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N $\gamma$= 0.00

## SEISMICITY

Not Applicable


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## INPUT DATA: Metal strips (Analysis)

| D A T A | Metal strip type #1 | Metal strip type #2 | Metal strip type #3 | Metal strip type #4 | Metal strip type #5 |
|---|---|---|---|---|---|
| Yield strength of steel, Fy [kips/in ²] | 65.3 | N/A | N/A | N/A | N/A |
| Gross width of strip, b [in] | 2.0 | N/A | N/A | N/A | N/A |
| Vertical spacing, Sv [ft] | Varies | N/A | N/A | N/A | N/A |
| Design cross section area, Ac [in ²] | 0.20 | N/A | N/A | N/A | N/A |

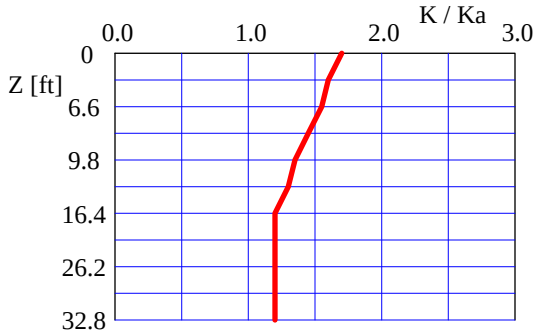
Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

| | | | | | |
|---|---|---|---|---|---|
| Friction angle along reinforcement-soil interface, | ρ | | | | |
| @ the top | 63.43 | N/A | N/A | N/A | N/A |
| @ 19.7 ft or below | 45.00 | N/A | N/A | N/A | N/A |
| Pullout resistance factor, F* | | | | | |
| @ the top | 2.00 | N/A | N/A | N/A | N/A |
| @ 19.7 ft or below | 1.00 | N/A | N/A | N/A | N/A |
| Scale-effect correction factor, α | 1.00 | N/A | N/A | N/A | N/A |

Note: Z for calculating K/Ka and F* is measured from roadway surface (FHWA-NHI-10-024).

### Variation of Lateral Earth Pressure Coefficient With Depth

| Z | K / Ka |
|---|---|
| 0 ft | 1.70 |
| 3.3 ft | 1.60 |
| 6.6 ft | 1.55 |
| 9.8 ft | 1.45 |
| 13.1 ft | 1.35 |
| 16.4 ft | 1.30 |
| 19.7 ft | 1.20 |





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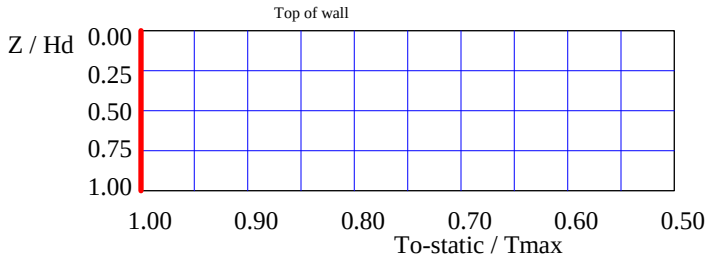
## INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is $\gamma_f$ = 152.78 lb/ft $^3$

| Z / Hd | To-static / Tmax |
|---|---|
| 0.00 | 1.00 |
| 0.25 | 1.00 |
| 0.50 | 1.00 |
| 0.75 | 1.00 |
| 1.00 | 1.00 |




| D A T A (for connection only) | Type #1 | Type #2 | Type #3 | Type #4 | Type #5 |
|---|---|---|---|---|---|
| Product Name | --- | N/A | N/A | N/A | N/A |
| Strength reduction at the connection, CRu = Fyc / Fy | 1.00 | N/A | N/A | N/A | N/A |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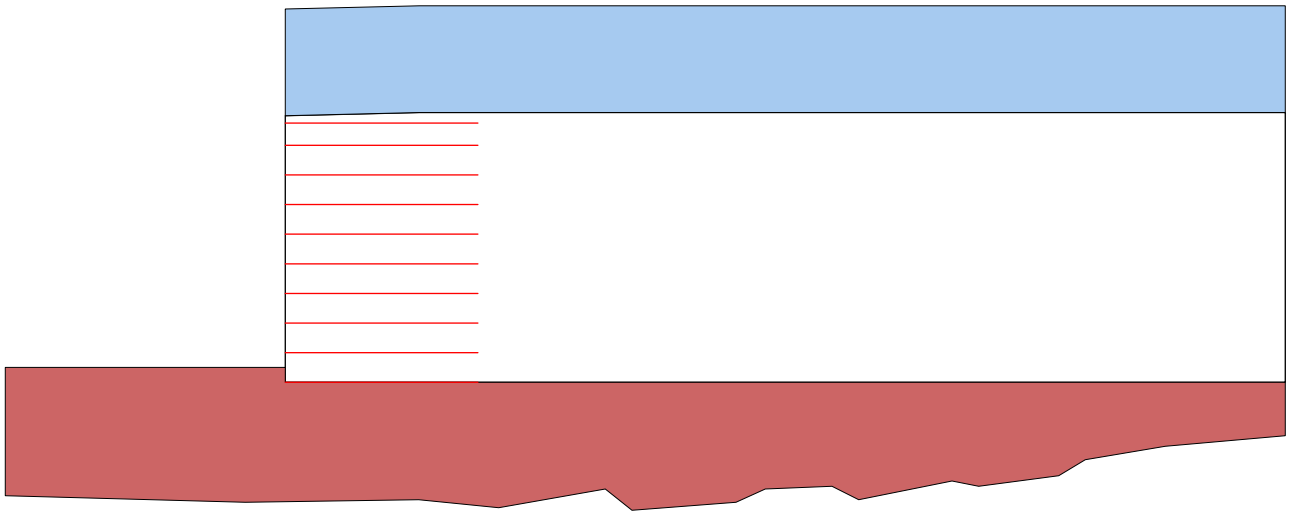
## INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

| | | | |
|---|---|---|---|
| Design height, Hd | 18.00 | [ft] | { Embedded depth is E = 1.00 ft, and height above top of finished bottom grade is H = 17.00 ft } |
| Batter, ω | 0.0 | [deg] | |
| Backslope, β | 1.3 | [deg] | |
| Backslope rise | 0.2 | [ft] | Broken back equivalent angle, I = 0.33° (see Fig. 25 in DEMO 82) |

U N I F O R M  S U R C H A R G E

Uniformly distributed dead load is 240.0 [lb/ft ²]

## ANALYZED REINFORCEMENT LAYOUT:



## SCALE:

0 2 4 6 8 10 [ft]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## ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.05, Meyerhof stress = 3378 lb/ft².
Foundation Interface: Direct sliding, Fs = 2.098, Eccentricity, e/L = 0.1284, Fs-overturning = 3.86

| METAL STRIP | | | | CONNECTION | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Elevation [ft] | Length [ft] | Type # | Fs-overall [pullout resistance] | Fs-overall [connection break] | Fs-overall [metal strip strength] | Metal strip strength Fs | Pullout resistance Fs | Direct sliding Fs | Eccentricity e/L | Product name |
| 1 | 0.00 | 13.00 | 1 | N/A | 5.91 | 5.91 | 5.908 | 5.255 | 3.048 | 0.1284 | --- |
| 2 | 2.00 | 13.00 | 1 | N/A | 3.12 | 3.12 | 3.115 | 2.477 | 3.390 | 0.1032 | --- |
| 3 | 4.00 | 13.00 | 1 | N/A | 3.41 | 3.41 | 3.409 | 2.353 | 3.819 | 0.0806 | --- |
| 4 | 6.00 | 13.00 | 1 | N/A | 3.77 | 3.77 | 3.766 | 2.180 | 4.376 | 0.0607 | --- |
| 5 | 8.00 | 13.00 | 1 | N/A | 4.21 | 4.21 | 4.206 | 1.956 | 5.126 | 0.0433 | --- |
| 6 | 10.00 | 13.00 | 1 | N/A | 4.84 | 4.84 | 4.840 | 1.853 | 6.199 | 0.0284 | --- |
| 7 | 12.00 | 13.00 | 1 | N/A | 5.85 | 5.85 | 5.848 | 1.910 | 7.871 | 0.0161 | --- |
| 8 | 14.00 | 13.00 | 1 | N/A | 7.61 | 7.61 | 7.606 | 1.984 | 10.895 | 0.0061 | --- |
| 9 | 16.00 | 13.00 | 1 | N/A | 12.27 | 12.27 | 12.273 | 2.275 | 18.495 | -0.0018 | --- |
| 10 | 17.50 | 13.00 | 1 | N/A | 26.05 | 26.05 | 26.050 | 3.190 | 48.237 | -0.0073 | --- |


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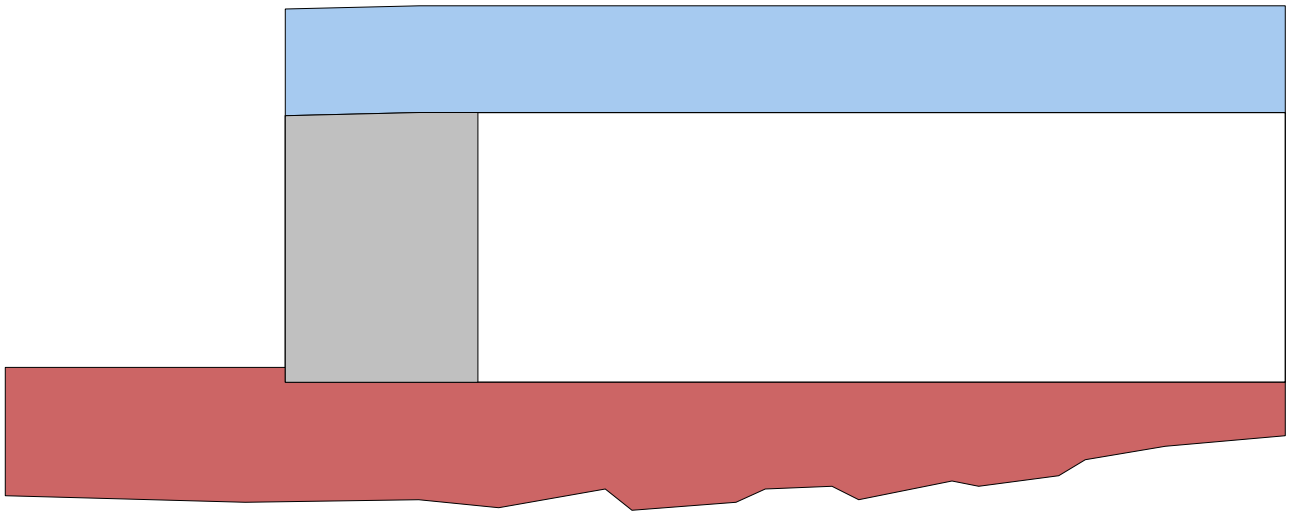
## BEARING CAPACITY for GIVEN LAYOUT

| | STATIC | SEISMIC | UNITS |
|---|---|---|---|
| (Water table does not affect bearing capacity) | | | |
| Ultimate bearing capacity, q-ult | 6941 | N/A | [lb/ft ²] |
| Meyerhof stress, $\sigma_V$ | 3378.1 | N/A | [lb/ft ²] |
| Eccentricity, e | 1.67 | N/A | [ft] |
| Eccentricity, e/L | 0.128 | N/A | |
| Fs calculated | 2.05 | N/A | |
| Base length | 13.00 | N/A | [ft] |



SCALE:

0 2 4 6 8 10 [ft]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## DIRECT SLIDING for GIVEN LAYOUT (for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 2.098

| # | Metal strip Elevation [ft] | Metal strip Length [ft] | Fs Static | Fs Seismic | Metal strip Type # | Product name |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 13.00 | 3.048 | N/A | 1 | --- |
| 2 | 2.00 | 13.00 | 3.390 | N/A | 1 | --- |
| 3 | 4.00 | 13.00 | 3.819 | N/A | 1 | --- |
| 4 | 6.00 | 13.00 | 4.376 | N/A | 1 | --- |
| 5 | 8.00 | 13.00 | 5.126 | N/A | 1 | --- |
| 6 | 10.00 | 13.00 | 6.199 | N/A | 1 | --- |
| 7 | 12.00 | 13.00 | 7.871 | N/A | 1 | --- |
| 8 | 14.00 | 13.00 | 10.895 | N/A | 1 | --- |
| 9 | 16.00 | 13.00 | 18.495 | N/A | 1 | --- |
| 10 | 17.50 | 13.00 | 48.237 | N/A | 1 | --- |

## ECCENTRICITY for GIVEN LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.1284; Overturning: Fs-static = 3.86

| # | Metal strip Elevation [ft] | Metal strip Length [ft] | e / L Static | e / L Seismic | Metal strip Type # | Product name |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 13.00 | 0.1284 | N/A | 1 | --- |
| 2 | 2.00 | 13.00 | 0.1032 | N/A | 1 | --- |
| 3 | 4.00 | 13.00 | 0.0806 | N/A | 1 | --- |
| 4 | 6.00 | 13.00 | 0.0607 | N/A | 1 | --- |
| 5 | 8.00 | 13.00 | 0.0433 | N/A | 1 | --- |
| 6 | 10.00 | 13.00 | 0.0284 | N/A | 1 | --- |
| 7 | 12.00 | 13.00 | 0.0161 | N/A | 1 | --- |
| 8 | 14.00 | 13.00 | 0.0061 | N/A | 1 | --- |
| 9 | 16.00 | 13.00 | -0.0018 | N/A | 1 | --- |
| 10 | 17.50 | 13.00 | -0.0073 | N/A | 1 | --- |


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**RESULTS for STRENGTH** **[ Note: Actual Fs-overall = (Yield stress) / (Actual stress)** For Simplified Method
Live Load included in calculating Tmax

| # | Metal strip Elevation [ft] | Coverage ratio, Rc=b/Sh | Horizontal spacing, Sh [ft] | Long-term strength Fy·Ac·Rc/b [lb/ft] | Tmax [lb/ft] | Tmd [lb/ft] | Specified minimum Fs-overall static | Actual calculated Fs-overall static | Specified minimum Fs-overall seismic | Actual calculated Fs-overall seismic |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.055 | 3.000 | 4350 | 736.26 | N/A | N/A | 5.908 | N/A | N/A |
| 2 | 2.00 | 0.055 | 3.000 | 4350 | 1396.40 | N/A | N/A | 3.115 | N/A | N/A |
| 3 | 4.00 | 0.055 | 3.000 | 4350 | 1276.13 | N/A | N/A | 3.409 | N/A | N/A |
| 4 | 6.00 | 0.055 | 3.000 | 4350 | 1155.19 | N/A | N/A | 3.766 | N/A | N/A |
| 5 | 8.00 | 0.055 | 3.000 | 4350 | 1034.25 | N/A | N/A | 4.206 | N/A | N/A |
| 6 | 10.00 | 0.055 | 3.000 | 4350 | 898.80 | N/A | N/A | 4.840 | N/A | N/A |
| 7 | 12.00 | 0.055 | 3.000 | 4350 | 743.87 | N/A | N/A | 5.848 | N/A | N/A |
| 8 | 14.00 | 0.055 | 3.000 | 4350 | 571.91 | N/A | N/A | 7.606 | N/A | N/A |
| 9 | 16.00 | 0.055 | 3.000 | 4350 | 354.44 | N/A | N/A | 12.273 | N/A | N/A |
| 10 | 17.50 | 0.055 | 3.000 | 4350 | 166.98 | N/A | N/A | 26.050 | N/A | N/A |

**RESULTS for PULLOUT** Live Load included in calculating Tmax

| # | Metal strip Elevation [ft] | Coverage Ratio Rc=b/Sh | Tmax [lb/ft] | Tmd [lb/ft] | Le [ft] | La [ft] | Avail.Static Pullout, Pr [lb/ft] | Specified Static Fs | Actual Static Fs | Avail.Seism. Pullout, Pr [lb/ft] | Specified Seismic Fs | Actual Seismic Fs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.055 | 736.3 | N/A | 13.00 | 0.00 | 3869.3 | N/A | 5.255 | N/A | N/A | N/A |
| 2 | 2.00 | 0.055 | 1396.4 | N/A | 11.80 | 1.20 | 3459.1 | N/A | 2.477 | N/A | N/A | N/A |
| 3 | 4.00 | 0.055 | 1276.1 | N/A | 10.60 | 2.40 | 3002.6 | N/A | 2.353 | N/A | N/A | N/A |
| 4 | 6.00 | 0.055 | 1155.2 | N/A | 9.40 | 3.60 | 2517.8 | N/A | 2.180 | N/A | N/A | N/A |
| 5 | 8.00 | 0.055 | 1034.2 | N/A | 8.20 | 4.80 | 2023.3 | N/A | 1.956 | N/A | N/A | N/A |
| 6 | 10.00 | 0.055 | 898.8 | N/A | 7.56 | 5.44 | 1665.0 | N/A | 1.853 | N/A | N/A | N/A |
| 7 | 12.00 | 0.055 | 743.9 | N/A | 7.56 | 5.44 | 1420.8 | N/A | 1.910 | N/A | N/A | N/A |
| 8 | 14.00 | 0.055 | 571.9 | N/A | 7.56 | 5.44 | 1134.6 | N/A | 1.984 | N/A | N/A | N/A |
| 9 | 16.00 | 0.055 | 354.4 | N/A | 7.56 | 5.44 | 806.4 | N/A | 2.275 | N/A | N/A | N/A |
| 10 | 17.50 | 0.055 | 167.0 | N/A | 7.56 | 5.44 | 532.6 | N/A | 3.190 | N/A | N/A | N/A |


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## RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

| # | Metal strip Elevation [ft] | Coverage ratio Rc=b/Sh | Horizontal spacing, Sh [ft] | Connection force, To [lb/ft] | Reduction factor for connection break, CRu | Long-term connection strength,Tac (break criterion) [lb/ft] | Metal strip long-term strength, [lb/ft] | Fs-overall connection break | | Fs-overall Metal strip strength | | Product name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Specified | Actual | Specified | Actual | |
| 1 | 0.00 | 0.055 | 3.000 | 736 | 1.00 | 4350 | 4350 | N/A | 5.91 | N/A | 5.91 | --- |
| 2 | 2.00 | 0.055 | 3.000 | 1396 | 1.00 | 4350 | 4350 | N/A | 3.12 | N/A | 3.12 | --- |
| 3 | 4.00 | 0.055 | 3.000 | 1276 | 1.00 | 4350 | 4350 | N/A | 3.41 | N/A | 3.41 | --- |
| 4 | 6.00 | 0.055 | 3.000 | 1155 | 1.00 | 4350 | 4350 | N/A | 3.77 | N/A | 3.77 | --- |
| 5 | 8.00 | 0.055 | 3.000 | 1034 | 1.00 | 4350 | 4350 | N/A | 4.21 | N/A | 4.21 | --- |
| 6 | 10.00 | 0.055 | 3.000 | 899 | 1.00 | 4350 | 4350 | N/A | 4.84 | N/A | 4.84 | --- |
| 7 | 12.00 | 0.055 | 3.000 | 744 | 1.00 | 4350 | 4350 | N/A | 5.85 | N/A | 5.85 | --- |
| 8 | 14.00 | 0.055 | 3.000 | 572 | 1.00 | 4350 | 4350 | N/A | 7.61 | N/A | 7.61 | --- |
| 9 | 16.00 | 0.055 | 3.000 | 354 | 1.00 | 4350 | 4350 | N/A | 12.27 | N/A | 12.27 | --- |
| 10 | 17.50 | 0.055 | 3.000 | 167 | 1.00 | 4350 | 4350 | N/A | 26.05 | N/A | 26.05 | --- |


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# APPENDIX J

# BEARING CAPACITY, OVERTURNING AND SLIDING CALCULATIONS FOR 18.5-FT HIGH MSE RETAINING WALL AT SOUTH OF BRIDGE OVERPASS

Tolunay-Wong Engineers, Inc.

# AASHTO 2002 ASD DESIGN METHOD
# Buffalo Speedway Extension, Houston, Tx

MSEW(3.0): Update # 14.4

## PROJECT IDENTIFICATION

Title: Buffalo Speedway Extension, Houston, Tx
Project Number: 11.13.180
Client: CLR, Inc.
Designer: Mohammed Islam
Station Number: 182+00.00

**Description:**

18.5 ft High MSE Retaining Wall at South of Overpass Bridge

**Company's information:**

Name: Tolunay-Wong Engineers, Inc.
Street: 10710 S. Sam Houston Pkwy W., Suite 100

Houston, TX 77031
Telephone #: 713-722-7064
Fax #: 713-777-1424
E-Mail:

**Original file path and name:** T:\Geotechnical\Projects\2011\11.13.180\MSWE\18.5ft H R.....
.....n (On-site Soil).BEN

**Original date and time of creating this file:** 12/20/2011

**PROGRAM MODE:** ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.


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## SOIL DATA

REINFORCED SOIL

| | |
|---|---|
| Unit weight, $\gamma$ | 125.0 lb/ft $^3$ |
| Design value of internal angle of friction, $\phi$ | 38.0 ° |

RETAINED SOIL

| | |
|---|---|
| Unit weight, $\gamma$ | 125.0 lb/ft $^3$ |
| Design value of internal angle of friction, $\phi$ | 30.0 ° |

FOUNDATION SOIL (Considered as an equivalent uniform soil)

| | |
|---|---|
| Equivalent unit weight, $\gamma_{equiv.}$ | 125.0 lb/ft $^3$ |
| Equivalent internal angle of friction, $\phi_{equiv.}$ | 0.0 ° |
| Equivalent cohesion, $c_{equiv.}$ | 1000.0 lb/ft $^2$ |

Water table does not affect bearing capacity

## LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

## BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N $\gamma$= 0.00

## SEISMICITY

Not Applicable


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## INPUT DATA: Metal strips (Analysis)

| D A T A | Metal strip type #1 | Metal strip type #2 | Metal strip type #3 | Metal strip type #4 | Metal strip type #5 |
|---|---|---|---|---|---|
| Yield strength of steel, Fy [kips/in ²] | 65.3 | N/A | N/A | N/A | N/A |
| Gross width of strip, b [in] | 2.0 | N/A | N/A | N/A | N/A |
| Vertical spacing, Sv [ft] | Varies | N/A | N/A | N/A | N/A |
| Design cross section area, Ac [in ²] | 0.20 | N/A | N/A | N/A | N/A |

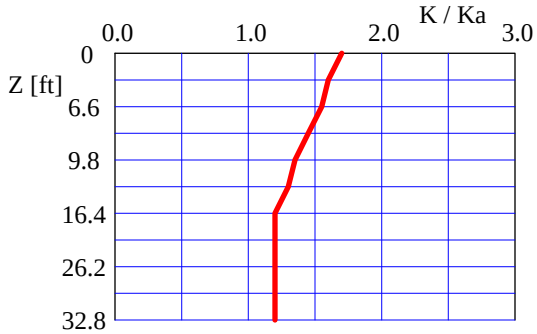
Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

| | | | | | |
|---|---|---|---|---|---|
| Friction angle along reinforcement-soil interface, | ρ | | | | |
| @ the top | 63.43 | N/A | N/A | N/A | N/A |
| @ 19.7 ft or below | 45.00 | N/A | N/A | N/A | N/A |
| Pullout resistance factor, F* | | | | | |
| @ the top | 2.00 | N/A | N/A | N/A | N/A |
| @ 19.7 ft or below | 1.00 | N/A | N/A | N/A | N/A |
| Scale-effect correction factor, α | 1.00 | N/A | N/A | N/A | N/A |

Note: Z for calculating K/Ka and F* is measured from roadway surface (FHWA-NHI-10-024).

### Variation of Lateral Earth Pressure Coefficient With Depth

| Z | K / Ka |
|---|---|
| 0 ft | 1.70 |
| 3.3 ft | 1.60 |
| 6.6 ft | 1.55 |
| 9.8 ft | 1.45 |
| 13.1 ft | 1.35 |
| 16.4 ft | 1.30 |
| 19.7 ft | 1.20 |





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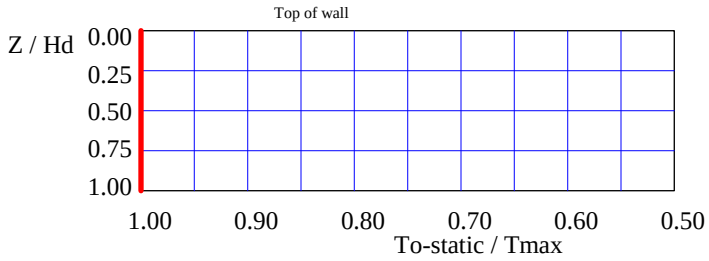
## INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is $\gamma_f$ = 152.78 lb/ft $^3$

| Z / Hd | To-static / Tmax |
|---|---|
| 0.00 | 1.00 |
| 0.25 | 1.00 |
| 0.50 | 1.00 |
| 0.75 | 1.00 |
| 1.00 | 1.00 |




| D A T A (for connection only) | Type #1 | Type #2 | Type #3 | Type #4 | Type #5 |
|---|---|---|---|---|---|
| Product Name | --- | N/A | N/A | N/A | N/A |
| Strength reduction at the connection, CRu = Fyc / Fy | 1.00 | N/A | N/A | N/A | N/A |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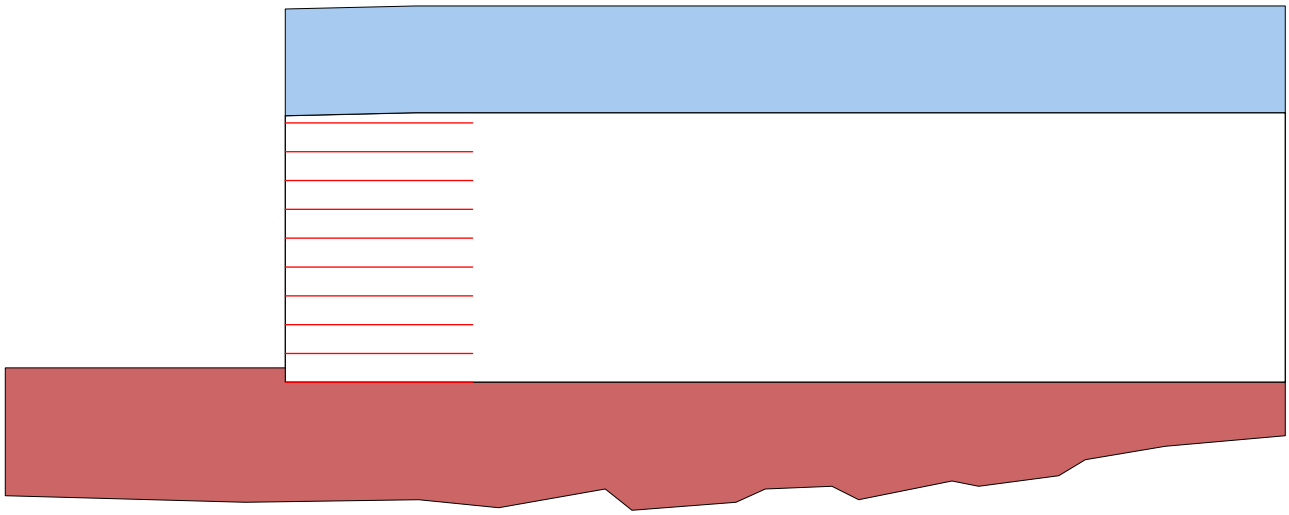
## INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

| | | | |
|---|---|---|---|
| Design height, Hd | 18.50 | [ft] | { Embedded depth is E = 1.00 ft, and height above top of finished bottom grade is H = 17.50 ft } |
| Batter, ω | 0.0 | [deg] | |
| Backslope, β | 1.3 | [deg] | |
| Backslope rise | 0.2 | [ft] | Broken back equivalent angle, I = 0.33° (see Fig. 25 in DEMO 82) |

U N I F O R M  S U R C H A R G E

Uniformly distributed dead load is 240.0 [lb/ft ²]

## ANALYZED REINFORCEMENT LAYOUT:



## SCALE:

0 2 4 6 8 10 [ft]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## ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 1.46, Meyerhof stress = 3526 lb/ft².
Foundation Interface: Direct sliding, Fs = 1.479, Eccentricity, e/L = 0.1351, Fs-overturning = 3.67

| METAL STRIP | | | | CONNECTION | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Elevation [ft] | Length [ft] | Type # | Fs-overall [pullout resistance] | Fs-overall [connection break] | Fs-overall [metal strip strength] | Metal strip strength Fs | Pullout resistance Fs | Direct sliding Fs | Eccentricity e/L | Product name |
| 1 | 0.00 | 13.00 | 1 | N/A | 5.83 | 5.83 | 5.830 | 5.190 | 2.974 | 0.1351 | --- |
| 2 | 2.00 | 13.00 | 1 | N/A | 3.06 | 3.06 | 3.058 | 2.446 | 3.298 | 0.1093 | --- |
| 3 | 4.00 | 13.00 | 1 | N/A | 3.33 | 3.33 | 3.326 | 2.321 | 3.702 | 0.0861 | --- |
| 4 | 6.00 | 13.00 | 1 | N/A | 3.67 | 3.67 | 3.668 | 2.157 | 4.222 | 0.0654 | --- |
| 5 | 8.00 | 13.00 | 1 | N/A | 4.08 | 4.08 | 4.081 | 1.943 | 4.915 | 0.0474 | --- |
| 6 | 10.00 | 13.00 | 1 | N/A | 4.66 | 4.66 | 4.656 | 1.803 | 5.890 | 0.0319 | --- |
| 7 | 12.00 | 13.00 | 1 | N/A | 5.55 | 5.55 | 5.546 | 1.856 | 7.370 | 0.0190 | --- |
| 8 | 14.00 | 13.00 | 1 | N/A | 7.06 | 7.06 | 7.065 | 1.926 | 9.927 | 0.0084 | --- |
| 9 | 16.00 | 13.00 | 1 | N/A | 9.91 | 9.91 | 9.914 | 1.993 | 15.649 | 0.0000 | --- |
| 10 | 18.00 | 13.00 | 1 | N/A | 20.79 | 20.79 | 20.794 | 2.495 | 48.237 | -0.0073 | --- |


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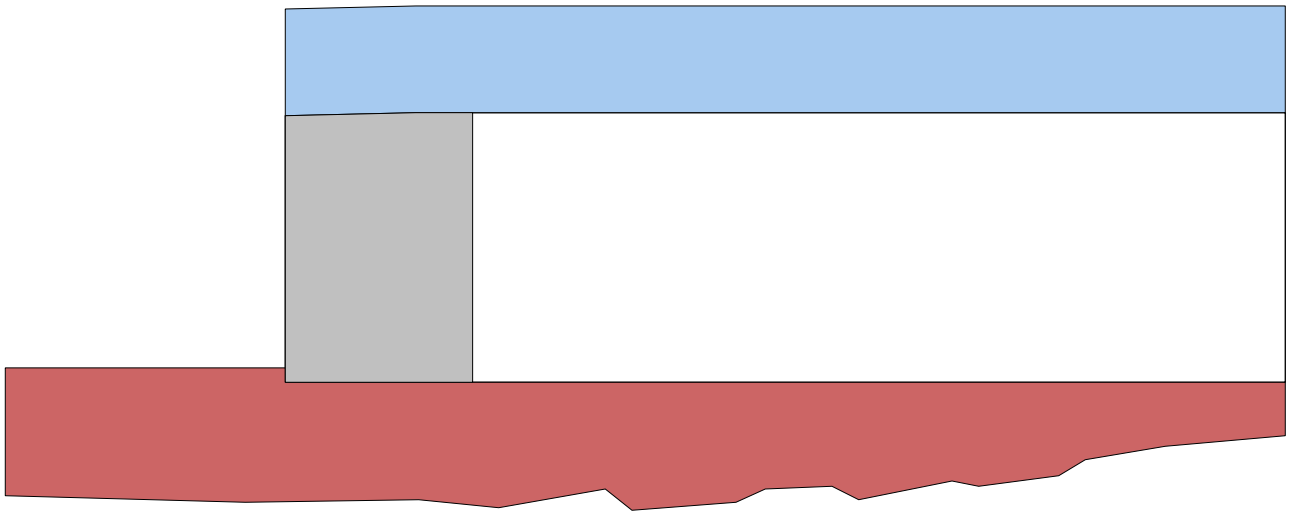
## BEARING CAPACITY for GIVEN LAYOUT

| | STATIC | SEISMIC | UNITS |
|---|---|---|---|
| (Water table does not affect bearing capacity) | | | |
| Ultimate bearing capacity, q-ult | 5142 | N/A | [lb/ft ²] |
| Meyerhof stress, $\sigma_V$ | 3526.1 | N/A | [lb/ft ²] |
| Eccentricity, e | 1.76 | N/A | [ft] |
| Eccentricity, e/L | 0.135 | N/A | |
| Fs calculated | 1.46 | N/A | |
| Base length | 13.00 | N/A | [ft] |



SCALE:

0 2 4 6 8 10 [ft]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## DIRECT SLIDING for GIVEN LAYOUT (for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 1.479

| # | Metal strip Elevation [ft] | Metal strip Length [ft] | Fs Static | Fs Seismic | Metal strip Type # | Product name |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 13.00 | 2.974 | N/A | 1 | --- |
| 2 | 2.00 | 13.00 | 3.298 | N/A | 1 | --- |
| 3 | 4.00 | 13.00 | 3.702 | N/A | 1 | --- |
| 4 | 6.00 | 13.00 | 4.222 | N/A | 1 | --- |
| 5 | 8.00 | 13.00 | 4.915 | N/A | 1 | --- |
| 6 | 10.00 | 13.00 | 5.890 | N/A | 1 | --- |
| 7 | 12.00 | 13.00 | 7.370 | N/A | 1 | --- |
| 8 | 14.00 | 13.00 | 9.927 | N/A | 1 | --- |
| 9 | 16.00 | 13.00 | 15.649 | N/A | 1 | --- |
| 10 | 18.00 | 13.00 | 48.237 | N/A | 1 | --- |

## ECCENTRICITY for GIVEN LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.1351; Overturning: Fs-static = 3.67

| # | Metal strip Elevation [ft] | Metal strip Length [ft] | e / L Static | e / L Seismic | Metal strip Type # | Product name |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 13.00 | 0.1351 | N/A | 1 | --- |
| 2 | 2.00 | 13.00 | 0.1093 | N/A | 1 | --- |
| 3 | 4.00 | 13.00 | 0.0861 | N/A | 1 | --- |
| 4 | 6.00 | 13.00 | 0.0654 | N/A | 1 | --- |
| 5 | 8.00 | 13.00 | 0.0474 | N/A | 1 | --- |
| 6 | 10.00 | 13.00 | 0.0319 | N/A | 1 | --- |
| 7 | 12.00 | 13.00 | 0.0190 | N/A | 1 | --- |
| 8 | 14.00 | 13.00 | 0.0084 | N/A | 1 | --- |
| 9 | 16.00 | 13.00 | 0.0000 | N/A | 1 | --- |
| 10 | 18.00 | 13.00 | -0.0073 | N/A | 1 | --- |


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**RESULTS for STRENGTH** **[ Note: Actual Fs-overall = (Yield stress) / (Actual stress)** For Simplified Method
Live Load included in calculating Tmax

| # | Metal strip Elevation [ft] | Coverage ratio, Rc=b/Sh | Horizontal spacing, Sh [ft] | Long-term strength Fy·Ac·Rc/b [lb/ft] | Tmax [lb/ft] | Tmd [lb/ft] | Specified minimum Fs-overall static | Actual calculated Fs-overall static | Specified minimum Fs-overall seismic | Actual calculated Fs-overall seismic |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.055 | 3.000 | 4350 | 746.07 | N/A | N/A | 5.830 | N/A | N/A |
| 2 | 2.00 | 0.055 | 3.000 | 4350 | 1422.42 | N/A | N/A | 3.058 | N/A | N/A |
| 3 | 4.00 | 0.055 | 3.000 | 4350 | 1307.70 | N/A | N/A | 3.326 | N/A | N/A |
| 4 | 6.00 | 0.055 | 3.000 | 4350 | 1185.98 | N/A | N/A | 3.668 | N/A | N/A |
| 5 | 8.00 | 0.055 | 3.000 | 4350 | 1066.02 | N/A | N/A | 4.081 | N/A | N/A |
| 6 | 10.00 | 0.055 | 3.000 | 4350 | 934.21 | N/A | N/A | 4.656 | N/A | N/A |
| 7 | 12.00 | 0.055 | 3.000 | 4350 | 784.26 | N/A | N/A | 5.546 | N/A | N/A |
| 8 | 14.00 | 0.055 | 3.000 | 4350 | 615.74 | N/A | N/A | 7.065 | N/A | N/A |
| 9 | 16.00 | 0.055 | 3.000 | 4350 | 438.77 | N/A | N/A | 9.914 | N/A | N/A |
| 10 | 18.00 | 0.055 | 3.000 | 4350 | 209.19 | N/A | N/A | 20.794 | N/A | N/A |

**RESULTS for PULLOUT** Live Load included in calculating Tmax

| # | Metal strip Elevation [ft] | Coverage Ratio Rc=b/Sh | Tmax [lb/ft] | Tmd [lb/ft] | Le [ft] | La [ft] | Avail.Static Pullout, Pr [lb/ft] | Specified Static Fs | Actual Static Fs | Avail.Seism. Pullout, Pr [lb/ft] | Specified Seismic Fs | Actual Seismic Fs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.055 | 746.1 | N/A | 13.00 | 0.00 | 3872.0 | N/A | 5.190 | N/A | N/A | N/A |
| 2 | 2.00 | 0.055 | 1422.4 | N/A | 11.80 | 1.20 | 3479.9 | N/A | 2.446 | N/A | N/A | N/A |
| 3 | 4.00 | 0.055 | 1307.7 | N/A | 10.60 | 2.40 | 3034.8 | N/A | 2.321 | N/A | N/A | N/A |
| 4 | 6.00 | 0.055 | 1186.0 | N/A | 9.40 | 3.60 | 2558.2 | N/A | 2.157 | N/A | N/A | N/A |
| 5 | 8.00 | 0.055 | 1066.0 | N/A | 8.20 | 4.80 | 2071.6 | N/A | 1.943 | N/A | N/A | N/A |
| 6 | 10.00 | 0.055 | 934.2 | N/A | 7.41 | 5.59 | 1684.7 | N/A | 1.803 | N/A | N/A | N/A |
| 7 | 12.00 | 0.055 | 784.3 | N/A | 7.41 | 5.59 | 1455.7 | N/A | 1.856 | N/A | N/A | N/A |
| 8 | 14.00 | 0.055 | 615.7 | N/A | 7.41 | 5.59 | 1185.6 | N/A | 1.926 | N/A | N/A | N/A |
| 9 | 16.00 | 0.055 | 438.8 | N/A | 7.41 | 5.59 | 874.4 | N/A | 1.993 | N/A | N/A | N/A |
| 10 | 18.00 | 0.055 | 209.2 | N/A | 7.41 | 5.59 | 522.0 | N/A | 2.495 | N/A | N/A | N/A |


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## RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

| # | Metal strip Elevation [ft] | Coverage ratio Rc=b/Sh | Horizontal spacing, Sh [ft] | Connection force, To [lb/ft] | Reduction factor for connection break, CRu | Long-term connection strength,Tac (break criterion) [lb/ft] | Metal strip long-term strength, [lb/ft] | Fs-overall connection break | | Fs-overall Metal strip strength | | Product name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Specified | Actual | Specified | Actual | |
| 1 | 0.00 | 0.055 | 3.000 | 746 | 1.00 | 4350 | 4350 | N/A | 5.83 | N/A | 5.83 | --- |
| 2 | 2.00 | 0.055 | 3.000 | 1422 | 1.00 | 4350 | 4350 | N/A | 3.06 | N/A | 3.06 | --- |
| 3 | 4.00 | 0.055 | 3.000 | 1308 | 1.00 | 4350 | 4350 | N/A | 3.33 | N/A | 3.33 | --- |
| 4 | 6.00 | 0.055 | 3.000 | 1186 | 1.00 | 4350 | 4350 | N/A | 3.67 | N/A | 3.67 | --- |
| 5 | 8.00 | 0.055 | 3.000 | 1066 | 1.00 | 4350 | 4350 | N/A | 4.08 | N/A | 4.08 | --- |
| 6 | 10.00 | 0.055 | 3.000 | 934 | 1.00 | 4350 | 4350 | N/A | 4.66 | N/A | 4.66 | --- |
| 7 | 12.00 | 0.055 | 3.000 | 784 | 1.00 | 4350 | 4350 | N/A | 5.55 | N/A | 5.55 | --- |
| 8 | 14.00 | 0.055 | 3.000 | 616 | 1.00 | 4350 | 4350 | N/A | 7.06 | N/A | 7.06 | --- |
| 9 | 16.00 | 0.055 | 3.000 | 439 | 1.00 | 4350 | 4350 | N/A | 9.91 | N/A | 9.91 | --- |
| 10 | 18.00 | 0.055 | 3.000 | 209 | 1.00 | 4350 | 4350 | N/A | 20.79 | N/A | 20.79 | --- |


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# APPENDIX K

# CALCULATION FOR SOIL PARAMETRES OF WEATHERING SOILS

**TWEI Project No.:** **11.13.180** **Appendix K**

**Project:** **Buffalo Speedway Extension, Channel "B"**
**Houston, Texas**

**Boring:** **BB-2, 8'-10'** CU w/ pp Test Results

Effective Stress Parameters for Long Term Condition

Depth of water = 19.9 ft PI = 40 $\gamma_T$ = 127 pcf

$\gamma_w$ = 62.4 pcf

| Depth | Peak Shear Strength (psf) | Peak Cohesion (psf) | Density, pcf | Effective Stress (psf) | $\phi'$ (degree) | Correction Factor | Mob. Shear Strength, (psf) | $\phi'$ (degree) | Reduced Cohesion, psf |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 301 | 240 | 127 | 127.0 | 25.6 | 0.54 | 162 | 26 | 102 |
| 1.5 | 331 | 240 | 127 | 190.5 | 25.6 | 0.54 | 179 | 26 | 88 |
| 2 | 362 | 240 | 127 | 254.0 | 25.6 | 0.54 | 195 | 26 | 74 |
| 3 | 423 | 240 | 127 | 381.0 | 25.6 | 0.54 | 228 | 26 | 46 |
| 4 | 483 | 240 | 127 | 508.0 | 25.6 | 0.54 | 261 | 26 | 18 |
| 4.5 | 514 | 240 | 127 | 571.5 | 25.6 | 0.54 | 277 | 26 | 4 |
| 5 | 544 | 240 | 127 | 635.0 | 25.6 | 0.54 | 294 | 26 | 0 |
| 6 | 605 | 240 | 127 | 762.0 | 25.6 | 0.54 | 327 | 26 | 0 |
| 7 | 666 | 240 | 127 | 889.0 | 25.6 | 0.54 | 360 | 26 | 0 |

**TWEI Project No.:** **11.13.180** **Appendix K**

**Project:** **Buffalo Speedway Extension, Channel "C"**
**Houston, Texas**

**Boring:** **C-1, 0'-2'** Using Charts from TWEI CU w/ pp Test Results Data Base

Effective Stress Parameters for Long Term Condition

Depth of water = 20 ft PI = 25 $\gamma_T$ = 125 pcf

$\gamma_w$ = 62.4 pcf

| Depth | Peak Shear Strength (psf) | Peak Cohesion (psf) | Density, pcf | Effective Stress (psf) | $\phi'$ (degree) | Correction Factor | Mob. Shear Strength, (psf) | $\phi'$ (degree) | Reduced Cohesion, psf |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 306 | 240 | 125 | 125.0 | 28 | 0.75 | 230 | 28 | 163 |
| 1.5 | 340 | 240 | 125 | 187.5 | 28 | 0.75 | 255 | 28 | 155 |
| 2 | 373 | 240 | 125 | 250.0 | 28 | 0.75 | 280 | 28 | 147 |
| 3 | 439 | 240 | 125 | 375.0 | 28 | 0.75 | 330 | 28 | 130 |
| 4 | 506 | 240 | 125 | 500.0 | 28 | 0.75 | 379 | 28 | 114 |
| 4.5 | 539 | 240 | 125 | 562.5 | 28 | 0.75 | 404 | 28 | 105 |
| 5 | 572 | 240 | 125 | 625.0 | 28 | 0.75 | 429 | 28 | 97 |
| 6 | 639 | 240 | 125 | 750.0 | 28 | 0.75 | 479 | 28 | 80 |
| 7 | 705 | 240 | 125 | 875.0 | 28 | 0.75 | 529 | 28 | 64 |

**TWEI Project No.:** **11.13.180** **Appendix K**

**Project:** **Buffalo Speedway Extension, Channel "C"**
**Houston, Texas**

**Boring:** **C-2, 10'-12'** CU w/ pp Test Results

Effective Stress Parameters for Long Term Condition

Depth of water = 20 ft PI = 41 $\gamma_T$ = 128 pcf

$\gamma_w$ = 62.4 pcf

| Depth | Peak Shear Strength (psf) | Peak Cohesion (psf) | Density, pcf | Effective Stress (psf) | $\phi'$ (degree) | Correction Factor | Mob. Shear Strength, (psf) | $\phi'$ (degree) | Reduced Cohesion, psf |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 322 | 262 | 128 | 128.0 | 25 | 0.54 | 174 | 25 | 114 |
| 1.5 | 352 | 262 | 128 | 192.0 | 25 | 0.54 | 190 | 25 | 100 |
| 2 | 381 | 262 | 128 | 256.0 | 25 | 0.54 | 206 | 25 | 87 |
| 3 | 441 | 262 | 128 | 384.0 | 25 | 0.54 | 238 | 25 | 59 |
| 4 | 501 | 262 | 128 | 512.0 | 25 | 0.54 | 270 | 25 | 32 |
| 4.5 | 531 | 262 | 128 | 576.0 | 25 | 0.54 | 287 | 25 | 18 |
| 5 | 560 | 262 | 128 | 640.0 | 25 | 0.54 | 303 | 25 | 4 |
| 6 | 620 | 262 | 128 | 768.0 | 25 | 0.54 | 335 | 25 | 0 |
| 7 | 680 | 262 | 128 | 896.0 | 25 | 0.54 | 367 | 25 | 0 |

**TWEI Project No.:** **11.13.180**

**Appendix K**

**Project:** **Buffalo Speedway Extension, Channel "C"**
**Houston, Texas**

**Boring:** **C-3, 10'-12'** CU w/ pp Test Results

Effective Stress Parameters for Long Term Condition

Depth of water = 20 ft PI = 38 $\gamma_T$ = 126 pcf

$\gamma_w$ = 62.4 pcf

| Depth | Peak Shear Strength (psf) | Peak Cohesion (psf) | Density, pcf | Effective Stress (psf) | $\phi'$ (degree) | Correction Factor | Mob. Shear Strength, (psf) | $\phi'$ (degree) | Reduced Cohesion, psf |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 200 | 160 | 126 | 126.0 | 17.8 | 0.56 | 112 | 18 | 72 |
| 1.5 | 221 | 160 | 126 | 189.0 | 17.8 | 0.56 | 124 | 18 | 63 |
| 2 | 241 | 160 | 126 | 252.0 | 17.8 | 0.56 | 135 | 18 | 54 |
| 2.5 | 261 | 160 | 126 | 315.0 | 17.8 | 0.56 | 146 | 18 | 45 |
| 3 | 281 | 160 | 126 | 378.0 | 17.8 | 0.56 | 158 | 18 | 36 |
| 4 | 322 | 160 | 126 | 504.0 | 17.8 | 0.56 | 180 | 18 | 18 |
| 4.5 | 342 | 160 | 126 | 567.0 | 17.8 | 0.56 | 192 | 18 | 10 |
| 5 | 362 | 160 | 126 | 630.0 | 17.8 | 0.56 | 203 | 18 | 1 |
| 6 | 403 | 160 | 126 | 756.0 | 17.8 | 0.56 | 226 | 18 | 0 |
| 7 | 443 | 160 | 126 | 882.0 | 17.8 | 0.56 | 248 | 18 | 0 |

**TWEI Project No.:** **11.13.180**

**Appendix K**

**Project:** **Buffalo Speedway Extension, Channel "D"**
**Houston, Texas**

**Boring:** **D-2, 10'-12'** CU w/ pp Test Results

Effective Stress Parameters for Long Term Condition

Depth of water = 12.1 ft PI = 39 $\gamma_T$ = 125 pcf

$\gamma_w$ = 62.4 pcf

| Depth | Peak Shear Strength (psf) | Peak Cohesion (psf) | Density, pcf | Effective Stress (psf) | $\phi'$ (degree) | Correction Factor | Mob. Shear Strength, (psf) | $\phi'$ (degree) | Reduced Cohesion, psf |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 415 | 374 | 125 | 125.0 | 18.3 | 0.54 | 224 | 18 | 183 |
| 1.5 | 436 | 374 | 125 | 187.5 | 18.3 | 0.54 | 235 | 18 | 173 |
| 2 | 457 | 374 | 125 | 250.0 | 18.3 | 0.54 | 247 | 18 | 164 |
| 3 | 498 | 374 | 125 | 375.0 | 18.3 | 0.54 | 269 | 18 | 145 |
| 4 | 539 | 374 | 125 | 500.0 | 18.3 | 0.54 | 291 | 18 | 126 |
| 4.5 | 560 | 374 | 125 | 562.5 | 18.3 | 0.54 | 302 | 18 | 116 |
| 5 | 581 | 374 | 125 | 625.0 | 18.3 | 0.54 | 314 | 18 | 107 |
| 6 | 622 | 374 | 125 | 750.0 | 18.3 | 0.54 | 336 | 18 | 88 |
| 7 | 663 | 374 | 125 | 875.0 | 18.3 | 0.54 | 358 | 18 | 69 |

# Check List For Geotechnical Reports

**HCFCD Geotechnical Guidelines are in Appendix-D, Policy Criteria & Procedure Manual (PCPM), Dec 2010**

http://www.hcfcd.org/downloads/manuals/HCFCD_PCPM_Dec2010.pdf

1 **Project Description:** Properly described scope of work with Key Map numbers

**Detention Basin / Channel: (Unit No.)**

- [x] Basin Area (Acres) /Length of Channel (feet)
- [x] Depth (Feet)

**Bridge over a Channel**

- [ ] Length of Channel (Feet)
- [ ] Depth in Feet
- [ ] Layout and Cross Section Drawings to be attached
- [x] Key Map Number
- [x] Site Vicinity Map

2 **Field Exploration (Section 3.1, Appendix-D, PCPM)**

- [x] - Number of Borings
- [x] - Depth of Borings (=>1.75 * Depth of Basin/Channel)
- [x] - Continuous Sampling to 20' depth
- [x] - Surveying Data Available
- [x] - Boring Logs in gINT Format
- [x] - Groundwater Level Data

3 **Laboratory Testing (Section 4, Appendix-D, PCPM)**

- [x] - Minimum Series of Testing for each significant layer
- [x] - Crumb and Pin hole tests on cohesive soils within Channel/Basin Side slopes
- [x] - Triaxial Consolidated Undrained Compression Test (ASTM D4767)
- [x] - Soil Classification per ASTM D2487 Flow Chart

4 **Slope Stability Analysis**

- [x] -Explain the basis for selection of Input Parameters
- [x] -Attach backup calculations
- [x] -Surcharge in End of Construction and Long Term Cases
- [x] -Use Weathered Parameters for Soils with PI > 20
- [ ] -Input and Output sheets from Slope Stability Analysis

5 **Bridges Over Existing HCFCD Channels**

- [ ] Slope Stability to Evaluate Impact of Bridge Construction Done

6 **Attachments**

- [x] -Boring Logs in gINT Format
- [x] -X-Y Cordinates (NAD 83)
- [x] -Surface Elevation at Boring Locations (NAVD88, 2001 Adj)
- [x] -Soil Profile with proper identification of Strata used in engineering analyses
- [x] -Test Data Sheets for Pin Hole Testing
- [x] -Triaxial CU Test results w/Stress-Strain Curves, Stress Paths, strain rate, maximum strain etc.
- [x] -CU Test results should identify sample depth, Boring Number, soil class and indicated LL, PL, PI
- [x] -Layout and Cross Section Drawings to be attached