GEOTECHNICAL STUDY
PROGRAM MANAGEMENT OFFICE AT IAH
GEORGE BUSH INTERCONTINENTAL AIRPORT
HOUSTON, TEXAS

SUBMITTED TO
JACOBS – GLOBAL BUILDINGS
5985 ROGERDALE
HOUSTON, TEXAS 77072

BY
HVJ ASSOCIATES, INC.
HOUSTON, TEXAS
AUGUST 10, 2015

REPORT NO. HG1213270
KEY MAP NO. 334 A

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August 10, 2015

Stephen A. Clarke, P.E.
Jacobs - Global Buildings
5985 Rogerdale Road
Houston, Texas 77072

Re: Geotechnical Investigation
Program Management Office at IAH
Houston, Texas
Owner: Houston Airport System (HAS)
HVJ Report No. HG1213270

Mr. Clarke:

Submitted herein is the report of our geotechnical investigation for the above referenced project. The study was performed in accordance with HVJ Proposal Number HG1213270 dated January 14, 2014 (Revised April 2nd, 2015) and subject to the limitations presented in this report.

It has been a pleasure to work for you on this project and we appreciate the opportunity to be of service. Please notify us if there are questions or if we may be of further assistance.

Sincerely,

HVJ ASSOCIATES, INC.
Texas Firm Registration No. F-000646

Muhammad Mustafa, PE
Branch Manager, Houston

STATE OF TEXAS
MUHAMMAD MUSTAFA
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LICENSED
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Copies submitted: 1 (Electronic) 08/10/2015

The seal appearing on this document was authorized by Muhammad Mustafa, PE 73808 on August 10, 2015. Alteration of a sealed document without proper notification to the responsible engineer is an offense under the Texas Engineering Practice Act.

- Main Text – 14 pages
- Plates – 5 pages
- Appendix A – 9 pages
- Appendix B –3 pages
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1 EXECUTIVE SUMMARY

HVJ Associates, Inc. was retained by Jacobs - Global Buildings to perform a geotechnical investigation for the construction of a Program Management Office Building and its parking lot at IAH on east side of the airport near Lee Road. Our scope of work includes performing subsurface soils investigation and providing boring logs, foundation recommendations, and pavement recommendations for the parking lot.

The subsurface stratigraphy at the project site was determined by drilling and sampling two 25-foot and three 40-foot borings at the location of the proposed PMO building and three 5 foot borings at the location of the parking lot. Laboratory tests and engineering analyses were performed to provide recommendations pertaining to design and construction of the proposed building and parking lot.

A brief summary of the findings on this investigation based on soil borings and pertinent recommendations are as follows:

1. A generalized summary of the subsurface conditions in our borings is shown below in Table 1-1 which is intended to provide a conceptual framework for considering the site and is not intended as a basis for any particular analysis. Substantial deviations from the summarized conditions should be accounted for in design and construction. Details of the subsurface stratigraphy encountered in the borings are shown on the boring logs presented in Appendix A.

Table 1-1 – Generalized Soil Profile

Stratum	Depth (below grade), Feet		Material
	From	To	
I	Surface	5 to 16	*Cohesionless Soils*: Loose to Medium Dense Sandy Silt (ML) and Sand with Silt (SP- SM).
II	5 to 16	25 to 40	*Cohesive soils:* Stiff to very Stff Fat Clay (CH), Lean Clay with Sand and Lean Clay (CL)

2. Groundwater was encountered in the borings at a depth ranging from 11 to 14 feet below grade during the drilling operations.

3. A literature review of surface faults near the project area was made from published reports. The primary objective of this review was to evaluate available information from published and open file reports. Based on our review, the project site is situated about 2.5 miles west of the Humble Salt Dome system and about 2.5 miles east of the Hardy fault. Faulting is not anticipated to impact the project site. A detailed fault study is beyond the scope of this study.

4. We have provided foundation recommendations for the proposed building in Section 6 of this report.

5. The pavement design recommendations for the proposed parking lot are presented in Section 7 of the report.

Please note that this executive summary does not fully relate our findings and opinions. These findings and opinions are only presented through our full report.

2 INTRODUCTION

2.1 General

HVJ Associates, Inc. was retained by Jacobs - Global Buildings to perform a geotechnical investigation for the construction of a Program Management Office Building and its parking lot at IAH on east side of the airport near Lee Road. Our scope of work includes performing subsurface soils investigation and providing boring logs, foundation recommendations, and pavement recommendations for the parking lot.

2.2 Scope of Work

The primary objectives of this study were to investigate subsurface conditions at the site. The objectives were accomplished by:

Drilling and sampling two 25-foot, three 40-foot, and three 5-foot borings to investigate soil stratigraphy and to obtain samples for laboratory testing.

Performing laboratory tests to determine physical characteristics of the soils.

Performing engineering analyses to develop design guidelines and recommendations for foundation and pavement design.

Subsequent sections of this report contain descriptions of the field exploration, laboratory-testing program, general subsurface conditions, and design and construction recommendations.

3 FIELD INVESTIGATION

3.1 General

The field exploration program was performed on March 13, 2015 and March 14, 2015. Subsurface conditions at the site were investigated by drilling and sampling two 25-foot, three 40-foot, and three 5-foot borings to investigate soil stratigraphy and to obtain samples for laboratory testing. The approximate boring locations are indicated on the plan of borings, Plate 2. The soil borings were drilled using truck mounted drilling equipment using dry auger and wet rotary techniques.

3.2 Sampling Method

All samples were drilled continuously to 20 feet and at 5 foot intervals thereafter. Cohesive soil samples were obtained with a three-inch thin-walled (Shelby) tube sampler in general accordance with ASTM D-1587 standard. Each sample was removed from the sampler in the field, carefully examined and then classified.

The shear strength of the cohesive soils was estimated by a hand penetrometer in the field. Suitable portions of each sample were sealed and packaged for transportation to our laboratory.

Detailed descriptions of the soils encountered in the borings are given in the boring logs presented in Appendix A. A key to the terms and symbols used for soil classification on the boring logs is also presented in Appendix A.

3.3 Water Level Measurements

Groundwater level observations were made in the open boreholes during drilling operations. Water was encountered in the borings at a depth ranging from 11 to 14 feet below the existing grade Details of the ground water levels are presented on the boring logs in Appendix A.

4 LABORATORY TESTING

Selected soil samples were tested in the laboratory to determine applicable physical and engineering properties. The field and laboratory program included moisture content, Atterberg Limits, hand penetrometer, percent passing No. 200 Sieve, unconsolidated undrained (UU) and unit weight tests.

The Atterberg Limits, moisture content and percent passing No. 200 Sieve were used to verify field classification by the Unified Soils Classification System, while the compression tests were performed to obtain the undrained shear strength of the soil.

The type and number of tests performed for this investigation are summarized below:

Table 4-1 Type and Number of Laboratory Tests

Type of Test	Number of Tests
Moisture Content (ASTM D2216)	41
Atterberg Limits (ASTM D4318)	10
Percent Passing No. 200 Sieve (ASTM D1140)	26
Hand Penetrometer	22
Unit Dry Weight (ASTM D 2166/2850)	10
Unconsolidated Undrained (UU) (ASTM D2850)	10

The laboratory test results are shown on the boring logs in Appendix A. A summary of the laboratory test results is presented in Appendix B.

5 SITE AND SUBSURFACE CONDITIONS

5.1 General Geology

There are two major surface geological formations that exist in the Houston area: the Beaumont formation and the Lissie formation. The Beaumont formation is a relatively younger formation generally found to the southeast of the Lissie formation. The Beaumont formation dips southeastward and extends beneath beach sand and waters of the Gulf of Mexico as far as the continental shelf. The project site is located in an area where the Lissie formation is typically encountered.

The upper Lissie formation is sometimes denoted as the Montgomery formation. The upper Lissie formation is heterogeneous, containing interbedded layers of clay, sand and silt. It was deposited in mid-Pleistocene times in shallow coastal river channels and flood plains.

The clay present in the formation has been preconsolidated by a process of desiccation. Numerous wetting and drying cycles have produced a network of randomly oriented and closely spaced joints, which are sometimes slickensided, that is, have a shiny appearance when exposed. The joint pattern strongly influences the engineering behavior of the soil.

The sand layers vary in compactness from loose to very dense, and in thickness from a fraction of an inch to many feet due to an irregular depositional environment. Sands are generally subrounded to subangular and vary from coarse to very fine, are poorly graded, and often contain significant amounts of silt-sized particles in the sand matrix.

5.2 Geologic Faulting

The tectonic history of the Texas Gulf Coast includes a relatively stable depositional cycle since the Cretaceous Period (about 65 million years). During this period the area has been subjected to deposition of clays, silts, and sands resulting in over 30 thousand feet of sedimentary rocks. Underlying this clastic sequence are salt formations, which have migrated upwards to produce the typical salt dome features associated with the Texas Gulf Coast. In conjunction with salt movement, dewatering and compaction of some of the deeper sediments in the basin have resulted in the development of growth faults.

A review of surface faults was made from geologic literature and available in-house records. The primary objective of this review was to evaluate available information from these reports concerning the presence of active faults in the project area. Based on our review, the project site is situated about 2.5 miles west of the Humble Fault system and about 2.5 miles east of the Hardy fault. HVJ believes that faulting is not anticipated to impact the project site. However, it should be noted that unmapped faults may exist in the project area. A detailed fault study was not within the scope of this study.

5.3 Soil Stratigraphy

Our interpretation of soil and water conditions at the project site is based on information obtained at the boring locations only. This information has been used as the basis for our conclusions and recommendations. Significant variations at areas not explored by the project borings may require reevaluation of our findings and conclusions.

A generalized summary of the subsurface conditions in our borings is shown below in Table 5-1. The generalized profile is intended to provide a conceptual framework for considering the site and is not intended as a basis of any particular analysis. Substantial deviations from the summarized conditions exist at several of the boring locations and should be accounted for in design and construction. Details of the subsurface stratigraphy encountered in the borings are shown on the boring logs presented in Appendix A.

Table 5-1 – Generalized Soil Profile

Stratum	Depth (below grade), Feet		Material
	From	To	
I	Surface	5 to 16	*Cohesionless Soils*: Loose to Medium Dense Sandy Silt (ML) and Sand with Silt (SP- SM).
II	5 to 16	25 to 40	*Cohesive soils:* Stiff to very Stff Fat Clay (CH), Lean Clay with Sand and Lean Clay (CL)

Specific types and depths of subsurface strata encountered at the site are shown on the boring logs presented in Appendix A.

5.4 Groundwater

Groundwater was encountered at the boring locations during the drilling operations. Table 5-4 shows a record of the groundwater readings obtained during drilling.

Table 5-2– Groundwater Observations

Boring No.	Groundwater Depth First Encountered (feet)	Groundwater Reading	
		Groundwater depth after 5 min. (feet)	Groundwater depth after 10 min. (feet)
B-1	14.0	8.4	8.2
B-2	14.0	8.2	8.2
B-3	11.0	8.5	8.5
B-4	12.0	8.8	8.1
B-5	14.0	9.0	9.0
CB-1	Dry	Dry	Dry
CB-2	Dry	Dry	Dry
CB-3	Dry	Dry	Dry

It should be noted that water levels determined during drilling may not accurately reflect the true groundwater conditions, and therefore should only be considered as approximate.

Groundwater levels measured in open standpipe piezometers are, on the other hand, more accurate; however, these readings will fluctuate seasonally and in response to rainfall. Other factors that might impact piezometric groundwater levels include leakage from existing sewers and/or sanitary sewers.

6 FOUNDATION RECOMMENDATIONS

6.1 General

We understand that the project will involve construction of a Program Management Office (PMO) building at IAH with associated parking lots.

6.2 Expansive Soil

One of the major design factors for lightly loaded structures in the Gulf Coast area is the shrinking and swelling potential of fine-grained soils. The shrink/swell movements can be estimated through the use of the Plasticity Index (PI). Generally, the higher the PI of a material, the greater the potential for soil movements during moisture changes. The results of the Atterberg Limits tests indicate that the soils at the site have a very low expansion potential (Effective PI = 4).

Shrink-swell movement occurs in response to soil moisture content changes beneath the slab. Moisture changes occur beneath the slab due to seasonal changes in the relative amount of rainfall and evaporation potential. These variations cause cyclic changes in soil moisture to depths of up to eight feet in the area. Also, soil moisture changes result from the construction of a slab-on-grade floor due to the presence of the slab/vapor barrier/grade beam system. The installation of the slab, vapor barrier, and grade beams reduces the natural moisture transfer from the subsurface beneath the building and generally causes the soil moisture content to increase in the soil beneath the building after construction. Another significant cause of soil moisture change is changes in vegetation, particularly trees associated with landscaping.

Potential Vertical Rise (PVR) values were estimated by the TEX 124-E method for the upper 7 feet of soils at the site, using worst condition (dry state), average condition, wet condition and the existing condition at the time of boring. The PVR represents the potential ability of a soil material

at a specific density, moisture and loading condition to swell. It indicates the potential movement of the soils that may be realized if the soils become wet from a relatively dry condition. The PVR values are provided to demonstrate the relative severity of the swell potential of the clayey soils at the site. However, this value is not intended to be used directly as a design parameter. The actual amount of swell the slab may experience depends on many variables, such as the time of year the slab is poured, which are not known at the time of this study. The soil on site at the top seven feet consisted of sands and silts. We have calculated PVR values for the site in general at the top 7 feet of soil and are presented in the table below.

Table 6-1 Potential Vertical Rise for the Soils on Site

Condition	PVR (inches)
Dry	0.20
Average	0.20
Wet	0.20
Existing	0.20

6.3 Foundation Selection

Foundations for the proposed structures must satisfy two basic design criteria. First, the bearing pressure transmitted by the foundation should not exceed the allowable bearing capacity computed with an adequate factor of safety. Second, foundation movement due to soil volume change must be within desirable limits.

The results of the Atterberg Limits tests indicate that the soils at the site have a low expansion potential (effective PI=4). Hence the soil conditions would permit the construction of the structure founded in shallow foundations, however, lateral loading is expected to act on the proposed structures, hence deep foundation like straight sided drilled shafts are recommended for the building.

6.4 Drilled Shaft Foundation Recommendations

The proposed building may be supported on straight sided drilled shafts. The ultimate compressive capacity, Q_{ult}, for a given embedded length is taken as the skin friction along the shaft wall, Q_s, and the end bearing at the tip, Q_p. Skin friction contributed at the top 10 feet from ground surface should be ignored to account for construction disturbances, and loss of adhesion between shaft wall and soil due to moisture fluctuation.

$$Q_{ult} = Q_s + Q_p = fA_{sa} + qA_E$$

Where:

A_{sa} = Embedded surface area
f = Unit skin friction
q = Unit end bearing
A_E = Cross-sectional end area

Ultimate compressive capacity curves that include skin friction and tip resistance were developed based on undrained shear strength test results using the alpha method for clays. Undrained shear strength values UU tests are used as inputs to generate ultimate capacity curves for 24, 30, 36, 42 and 48 inch diameter drilled shafts using SHAFT 6.0 program. The capacity curves for ultimate skin

and tip capacity are presented in Appendix C. These curves were generated based on a generalized profile as a conservative scenario.

In order to determine the design allowable capacity, a factor of safety must be applied to the total ultimate capacity. We recommend a factor of safety of at least 2 (two) be used to calculate allowable axial load under compression. For drilled shafts under tension, the skin friction charts should be used and should be reduced with a factor of safety equal to 3 (three). The choice of safety factor is dependent on duration of loading, confidence in soil parameters, design life of structure, the expected quality of construction control and the consequences of failure.

6.5 Drilled Shaft Construction Recommendations

Shaft construction and installation should follow City of Houston Standard Specification 02465 for drilled shaft foundation. Presented below are a few specific recommendations. Slurry displacement method should be followed for drilled shaft construction. Assessment of the need for groundwater control and installation of appropriate dewatering equipment is the contractor's responsibility. It should be noted that groundwater levels change due to seasonal changes and rainfall. In any case, the groundwater control system used must provide a relatively dry, stable bearing surface. 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 ACI 336.1-89 Section 2.3.5.2.e. ACI slurry specifications are required to assure suspension of detritus from the 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 bottom should be cleaned out with a drilling bucket in order to remove any sediments that 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. 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.

5. Concrete should conform to the requirements ACI 336.1-89 Section 2.3.5.5.

6. The casing should always remain at least five feet below the level of the concrete during placement. HVJ's analyses assume no casing will be left in place. HVJ should be informed if casing will be left in place so revised shaft capacity calculations may be provide.

7. Shaft excavations should not be made within two shaft diameters (edge to edge) of shafts that have been concreted within the last 24 hours or from open shaft excavation.

6.6 Floor Slab

The floor slab can be supported at grade. Positive drainages must be provided under the floor slab area at all times. We recommend a minimum of 12 inches of select fill to be placed underneath the slab.

6.7 Building Settlement

With the indicated bearing pressures and loads for the building, settlement is estimated to be less than one (1) inch. Differential settlement will result from variances in subsurface condition, loading conditions and construction procedures, such as cleanliness of the bearing area. Differential movement between adjacent columns is estimated to be about one-half the total settlement.

6.8 Foundation Monitoring

We recommend that any fill placed beneath the structures be monitored to determine compliance with the plasticity and compaction requirements discussed above by an accredited construction materials testing laboratory. HVJ Associates would be pleased to provide this service.

It is recommended that each foundation excavation be inspected by the Project Engineer, Architect, or Owner's Representative prior to placing concrete. The excavation should be checked to verify that a) the excavation has been constructed to the specified dimensions at the correct depth and into appropriate stratum as recommended in this report, and b) the loose cuttings and any soft-compressible materials have been removed from the bottom of the excavation. Placement of concrete should be accomplished as soon as possible to reduce changes in the state of the stress and caving of the foundation soils. No piers should be poured without the prior approval of the Project Engineer, Architect, or Owner's Representative.

6.9 Removal of Existing Foundations, Site Preparation and Select Fill

We understand that the existing foundations at the site will have to be removed and the exact information on type and depth of foundations is not available. Assessment of the type and appropriate equipment for foundation removal is the contractor's responsibility at the time of construction. The following comments are intended to represent common solutions, and may not be construed as recommendations apart from subgrade preparation and backfill recommendations. Provided below are the few general geotechnical recommendations that should be followed to preserve the strength of in-situ soils while removing the foundations.

Shallow Foundations: Foundation systems such as spread or mat foundations can be excavated using dozer or backhoe. The building area should be stripped of all deleterious materials or gravels. Stripped areas should be appropriately graded and shaped to prevent ponding of water. As noted earlier, the loose cuttings and any soft-compressible materials should be removed from the bottom of the excavation.

Pumping may occur if the site becomes wet. Structural fill required to raise the grade or backfill excavation should consist of lean or sandy clay with a Liquid Limit less than 40 and a Plasticity Index between 8 and 20. Fill material that is used should be placed in loose lifts not exceeding eight inches and should be compacted to 95 percent of the maximum dry density at a moisture content between optimum and 3% wet of optimum as determined by ASTM D 698-12.

Deep Foundations: If driven piles or straight sided shafts were used as foundation system, crane with ample capacity can be used to pull the driven piles or drilled shafts. Care should be taken to avoid the breakage of piles/shafts and in any case we recommend removing the pile/shafts

completely and backfilling the holes with flowable fill as per City of Houston Standard Specification 02322.

6.10 Vegetation

Plants consume water to live and obtain this water through their root system. Landscaping which includes plantings close enough to the foundation such that the plantings consume significant moisture from the foundation soils are a common cause of foundation problems in areas with plastic soils. To avoid these problems, we recommend that landscaping be planned such that the plants are located at least one-half their mature width away from the edge of the foundations. Therefore, small shrubs should be located at least 2 feet, large shrubs at least 5 feet, and tress at least 20 feet from the edge of the foundation. For information on the mature widths of particular plants, we suggest consulting a landscape architect.

7 PARKING LOT DESIGN RECOMMENDATIONS

7.1 General

The project includes construction of a parking lot. We have utilized our soil borings CB-1, CB-2 and CB-3 to provide recommendations for the parking lot.

7.2 Pavement Sections

Based on the subgrade soils and our experience, the following pavement sections are recommended for the extension of the pavement sections at this site.

Types of loads	Rigid Pavement Section	Flexible Pavement Section
Heavy Duty (10^6 ESALs)	7" Concrete Compacted Subgrade	8.5" Asphaltic Concrete 6" Crushed Stone Base Compacted Subgrade
Medium Loads (10^5 ESALs)	6" Concrete Compacted Subgrade	5" Asphaltic Concrete 6" Crushed Stone Base Compacted Subgrade
Light Loads (10^4 ESALs or less)	5" Concrete Compacted Subgrade	2" Asphaltic Concrete 6" Crushed Stone Base Compacted Subgrade

We recommend using sections corresponding to medium loads for the design of parking lot. The design sections should be reviewed if specific traffic loading information is available. HVJ further recommends that an appropriate drainage system should be provided to drain the surface water as quickly as possible. Providing appropriate drainage system will reduce development of future pavement distress due to softened subgrade.

7.3 Preparation of Subgrade for Parking Lot

Subgrade preparation for the proposed pavement sections should consist of clearing, stripping, proof-rolling and cement (driveways and pavements) or mechanical (sidewalks) stabilization. HVJ recommends the following procedures for subgrade preparation:

1. Demolish and remove the existing pavement and subgrade to the grade required for the proposed pavement section, driveway, or sidewalk.

2. Strip the surface soil to suitable depths. In areas where soft, compressible or loose clay soils are encountered, additional stripping may be required. Stripping should extend a minimum of two feet beyond the edge of the proposed pavement.

3. Surfaces exposed after clearing and grubbing should be proof-rolled with heavy equipment, to identify any underlying zones or pockets of soft soils and to remove such weak materials. Proof rolling should be in accordance with TxDOT Standard Specification Item 216 or equivalent Specification.

4. When required, scarify the upper six to eight inches of exposed surface as required, mix with 5% of cement at locations where clays are encountered at the surface and compact it to 95 percent of standard Proctor (ASTM D698). The cement content is only preliminary estimates based on the subsurface soils and actual percentage of cement should be confirmed by conducting appropriate lab tests on the exposed subgrade material at the time of construction.

8 MONITORING

8.1 Excavation Safety

As required under OSHA regulations, the contractor should provide a "competent person" to inspect trench and shaft excavation daily before the start of work, as needed during the shift, and after every rainstorm or other hazard increasing occurrence. When the competent person finds evidence of a hazardous condition, exposed workers should be removed from the hazardous area until the necessary precautions have been taken to ensure their safety. A competent person means one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to workers, and who has authorization to take prompt corrective measures to eliminate them.

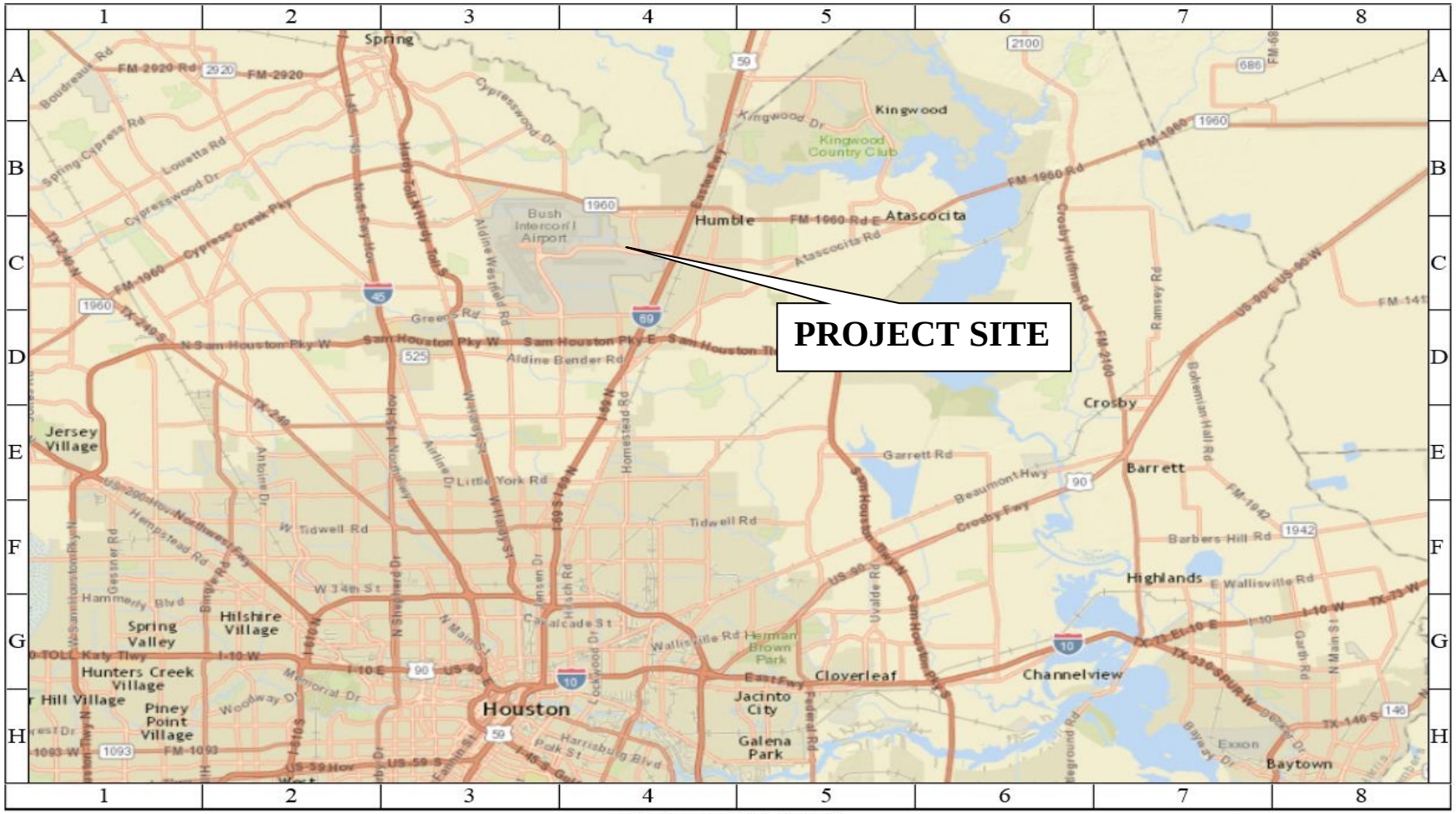
9 DESIGN REVIEW

HVJ Associates should be retained to review the final design plans and specifications for this project. During all excavation, grading and construction phases of this project, HVJ should provide the materials testing verification and observation services so our geotechnical recommendations may be interpreted and implemented correctly.

10 LIMITATIONS

This investigation was performed for the exclusive use of Jacobs for the design and for the construction of the PMO building at IAH. HVJ Associates, Inc. has endeavored to comply with generally accepted geotechnical engineering practice common in the local area. HVJ Associates, Inc. makes no warranty, express or implied. The analyses and recommendations contained in this report are based on data obtained from subsurface exploration, laboratory testing, the project information provided to us and our experience with similar soils and site condition. The methods used indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect the strata variations that usually exist between sampling locations. Should any subsurface conditions other than those described in our boring logs be encountered, HVJ Associates, Inc. should be immediately notified so that further investigation and supplemental recommendations can be provided.

PLATES



CITY OF HOUSTON
Department of Public Works and Engineering
Geographic Information & Management System (GIMS)

1 inch = 7486 feet

DISCLAIMER: THIS MAP REPRESENTS THE BEST INFORMATION AVAILABLE TO THE CITY.
THE CITY DOES NOT WARRANT ITS ACCURACY OR COMPLETENESS.
FIELD VERIFICATIONS SHOULD BE DONE AS NECESSARY.

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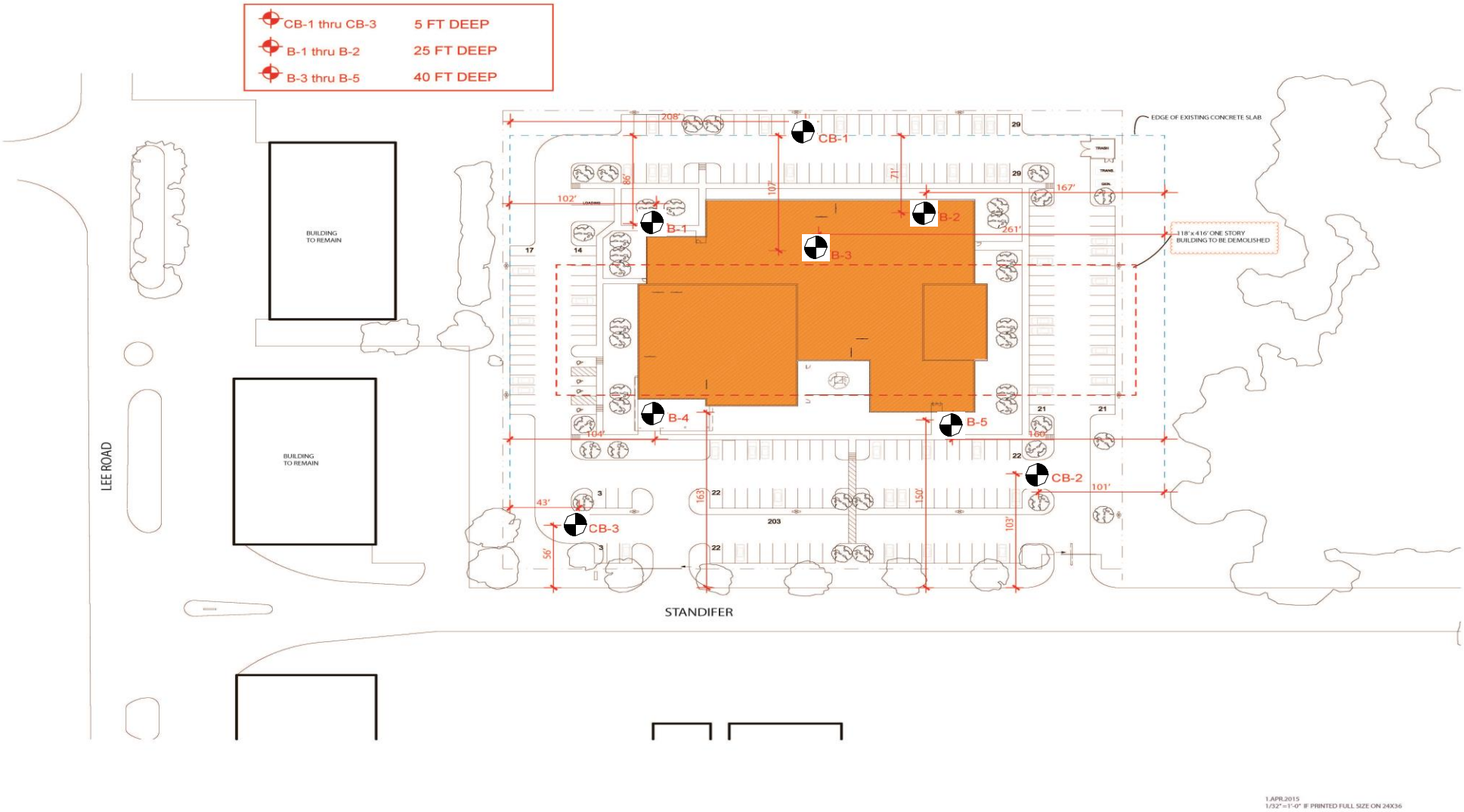
DATE: 04/19/2015	APPROVED BY: SV	PREPARED BY: KL

SITE VICINITY MAP
PROGRAM MANAGEMENT OFFICE AT IAH

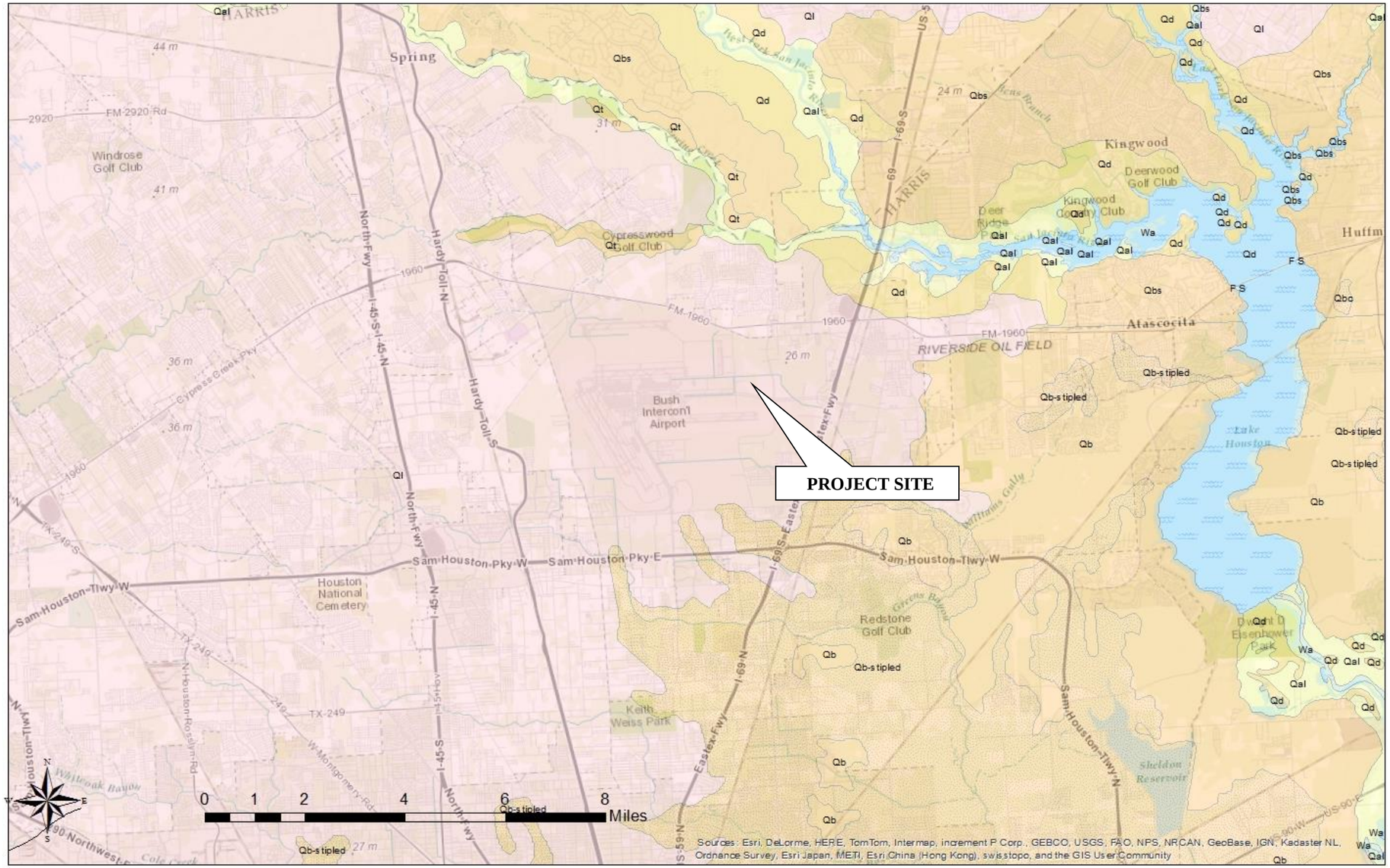
PROJECT NO.: HG1213270	DRAWING NO.: PLATE 1



LEGEND:

APPROXIMATE BORING LOCATIONS

HVJ ASSOCIATES 6120 S. Dairy Ashford Road Houston, Texas 77072-1010 281.933.7388 Ph 281.933.7293 Fax		
DATE: 08/23/2015	APPROVED BY: SV	PREPARED BY: KL
PLAN OF BORINGS PROGRAM MANAGEMENT OFFICE AT IAH		
PROJECT NO.: HG1213270	DRAWING NO.: PLATE 2	



Ql

Lissie Formation -- Upper part, clay, silt, sand, and very minor siliceous gravel of granule and small pebble size gravel more abundant northwestward, locally calcareous, concretions of calcium carbonate, iron oxide, and iron-manganese oxides common in zone of weathering; fluviatile; surface fairly flat and featureless except for numerous rounded shallow depressions and pimple mounds, bower part, clay, silt, sand, and minor amount of gravel; gravel slightly coarser than in upper part, noncalcareous, iron oxide concretions mare

Qb-stipled

Beaumont Formation -- Dominantly clay and mud of low permeability, high water-holding capacity, high compressibility, high to very high shrink-swell potential, poor drainage, level to depressed relief, low shear strength, and high plasticity; geologic units include interdistributary muds, abandoned channel-fill muds, and overbank fluvial muds

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DATE: 05/04/2015	APPROVED BY: SV	PREPARED BY: RS

GEOLOGIC MAP
PROGRAM MANAGEMENT OFFICE AT IAH

PROJECT NO.: HG1213270	DRAWING NO.: PLATE 3

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
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DATE: 05/04/2015	APPROVED BY: SV	PREPARED BY: RS

FAULT MAP
PROJECT MANAGEMENT OFFICE AT IAH

PROJECT NO.: HG1213270	DRAWING NO.: PLATE 4

APPENDIX A

BORING LOGS AND KEYS TO TERMS & SYMBOLS

LOG OF BORING B-1

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 25 FT
CAVE-IN DEPTH: 9 FT
DATE: 4/15/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 14 FT
WET ROTARY: 14 TO 25 FT

UNDRAINED SHEAR STRENGTH, TSF: ○ HAND PENETROMETER; ● UNCONFINED COMPRESSION; ■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION; △ TORVANE (0.5, 1.0, 1.5, 2.0, 2.5)

ELEVATION, FT	DEPTH, FT	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0	Pavement: 1.5" Asphaltic Concrete, 10" Cement Stabilized Sand							
		Loose to medium dense, brown, SILT WITH SAND (ML)	9	60.6		14			
	5		6						
			12	60.1					
			7			18			
	10		14						
		Medium dense, brown, SAND WITH SILT (SP-SM)	18	8.3		24			
▽	15		4						
		Very stiff, reddish brown, FAT CLAY (CH)		99.7	101	28	62	30	32
	20								
						27			
	25								

DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 14.0 FT; AFTER 10 MIN. AT 8.2 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING B-2

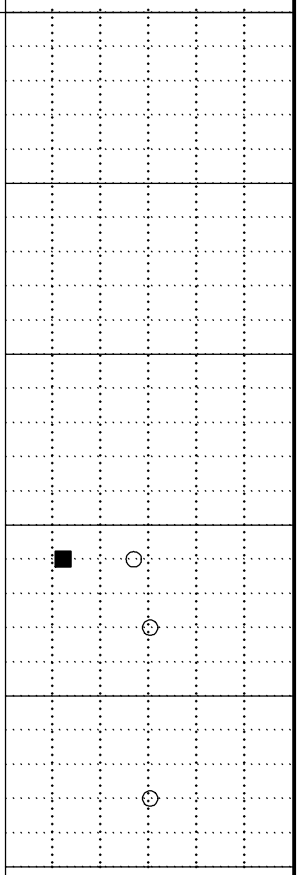
PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 25 FT
CAVE-IN DEPTH: 9 FT
DATE: 4/15/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 14 FT
WET ROTARY: 14 TO 25 FT

UNDRAINED SHEAR STRENGTH, TSF: ○ HAND PENETROMETER; ● UNCONFINED COMPRESSION; ■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION; △ TORVANE

ELEVATION, FT	DEPTH, FT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0			Pavement: 1.5" Asphaltic Concrete, 8" Cement Stabilized Sand							
				Loose, brown, SILT WITH SAND (ML)	5	68.9		15			
	5			-w/ ferrous stains 4'-10'	6						
					8	68.0					
					7			18			
	10			Firm, reddish brown, SANDY LEAN CLAY (CL)	6			34	42	21	21
				Loose, brown, CLAYEY SAND (SC)	6	12.3					
▽	15			Stiff to very stiff, reddish brown, FAT CLAY (CH), w/ silt and sand seams	9			43	63	33	30
							100	27			
	20										
								27			
	25										



DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 14.0 FT; AFTER 10 MIN. AT 8.2 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING B-3

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 40 FT
CAVE-IN DEPTH: 8.5 FT
DATE: 4/15/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 12 FT
WET ROTARY: 12 TO 40 FT

UNDRAINED SHEAR STRENGTH, TSF: ○ HAND PENETROMETER; ● UNCONFINED COMPRESSION; ■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION; △ TORVANE (0.5, 1.0, 1.5, 2.0, 2.5)

ELEVATION, FT	DEPTH, FT	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0	8" Cement Stabilized Sand							
		Loose to medium dense, brown, SILT WITH SAND (ML)	13	67.9		16			
	5		9						
			11	61.8					
		-w/ clay seams 8'-10'	5			18			
	10								
▽		Loose to medium dense, brown, SAND WITH SILT (SP-SM)	9						
			23	8.7		23			
	15	Firm to very stiff, gray and reddish brown, FAT CLAY (CH)	6			32	76	37	39
		-w/ sandstone and sand seams 16'-35'			106	23			
	20				104	24			
	25								
						22			
	30								
				95.2					
	35								
						28			
	40								

DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 11.0 FT; AFTER 10 MIN. AT 8.5 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING B-4

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 40 FT
DATE: 4/13/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 14 FT
WET ROTARY: 14 TO 40 FT

ELEVATION, FT	DEPTH, FT	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0	Pavement: 1" Asphaltic Concrete, 11" Sand		76.3		13			
		Loose to medium dense, brown, SILT WITH SAND (ML)	6						
	5		11						
			10	71.0					
		-w/ ferrous nodules 8'-10'	9						
	10	Firm, reddish brown, SANDY LEAN CLAY (CL)	5	68.8		22	42	18	24
		Medium dense, brown, CLAYEY SAND (SC)	13	14.4					
	15	Very stiff, gray and reddish brown, FAT CLAY (CH)		100.0		42	77	37	40
					99	26			
	20								
						26			
	25								
					107	22			
	30								
		Firm to stiff, brown to gray and reddish brown, SILTY CLAY WITH SAND (CL-ML)		79.8			24	19	5
	35								
					101	24			
	40								

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE
0.5 1.0 1.5 2.0 2.5

DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 12.0 FT; AFTER 10 MIN. AT 8.1 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING B-5

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 40 FT
CAVE-IN DEPTH: 9.2 FT
DATE: 4/13/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 14 FT
WET ROTARY: 14 TO 40 FT

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE
0.5 1.0 1.5 2.0 2.5

ELEVATION, FT	DEPTH, FT	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0	Pavement: 1.5" Asphaltic Concrete							
		Loose to medium dense, brown, SILT WITH SAND (ML)	6	66.9		12			
	5		7						
			13	73.5		16			
	10	-w/ ferrous nodules 10'-12'	9						
			16			20			
▽	15		20						
		Stiff to very stiff, gray and reddish brown, FAT CLAY (CH)	11	99.1		30	62	31	31
					96	30			
	20								
				100.0	94	27	57	29	28
	25								
						24			
	30								
		-w/ sand seams 33'-40'			111	21			
	35								
						22			
	40								

DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 14.0 FT; AFTER 10 MIN. AT 9.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING CB-1

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 5 FT
DATE: 4/15/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 5 FT
WET ROTARY: TO FT

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE
0.5 1.0 1.5 2.0 2.5

ELEVATION, FT	DEPTH, FT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0			Loose to medium dense, brown, SILT WITH SAND (ML)		65.7		11			
					6			13			
					11	68.7					
	5										

DEPTH TO WATER IN BORING:
FREE WATER DURING DRILLING: ---
WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING CB-2

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 5 FT
DATE: 4/15/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 5 FT
WET ROTARY: TO FT

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE
0.5 1.0 1.5 2.0 2.5

ELEVATION, FT	DEPTH, FT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0			Pavement: 2.5" Asphaltic Concrete, 7" Cement Stabilized Sand							
				Loose, brown, SILT WITH SAND (ML)	4	70.2		14			
					6			16			
	5										

DEPTH TO WATER IN BORING:
FREE WATER DURING DRILLING: ---
WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

LOG OF BORING CB-3

PROJECT: Program Management Office at IAH
LOCATION: N: N/A; E: N/A
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: N/A

PROJECT NO.: HG1213270
COMPLETION DEPTH: 5 FT
DATE: 4/15/15

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 5 FT
WET ROTARY: TO FT

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE
0.5 1.0 1.5 2.0 2.5

ELEVATION, FT	DEPTH, FT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0			Pavement: 1" Asphaltic Concrete, 8" Sand		63.7		13			
				Loose, brown, SILT WITH SAND (ML), w/ clay pockets	3						
	5			Firm, brown, LEAN CLAY WITH SAND (CL)	7	71.3		17	28	16	12

DEPTH TO WATER IN BORING:
FREE WATER DURING DRILLING: ---
WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

COH HG1213270-COH.GPJ 5/5/15

APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

Project: PMO at IAH
Location: Houston, Texas
Number: HG1213270

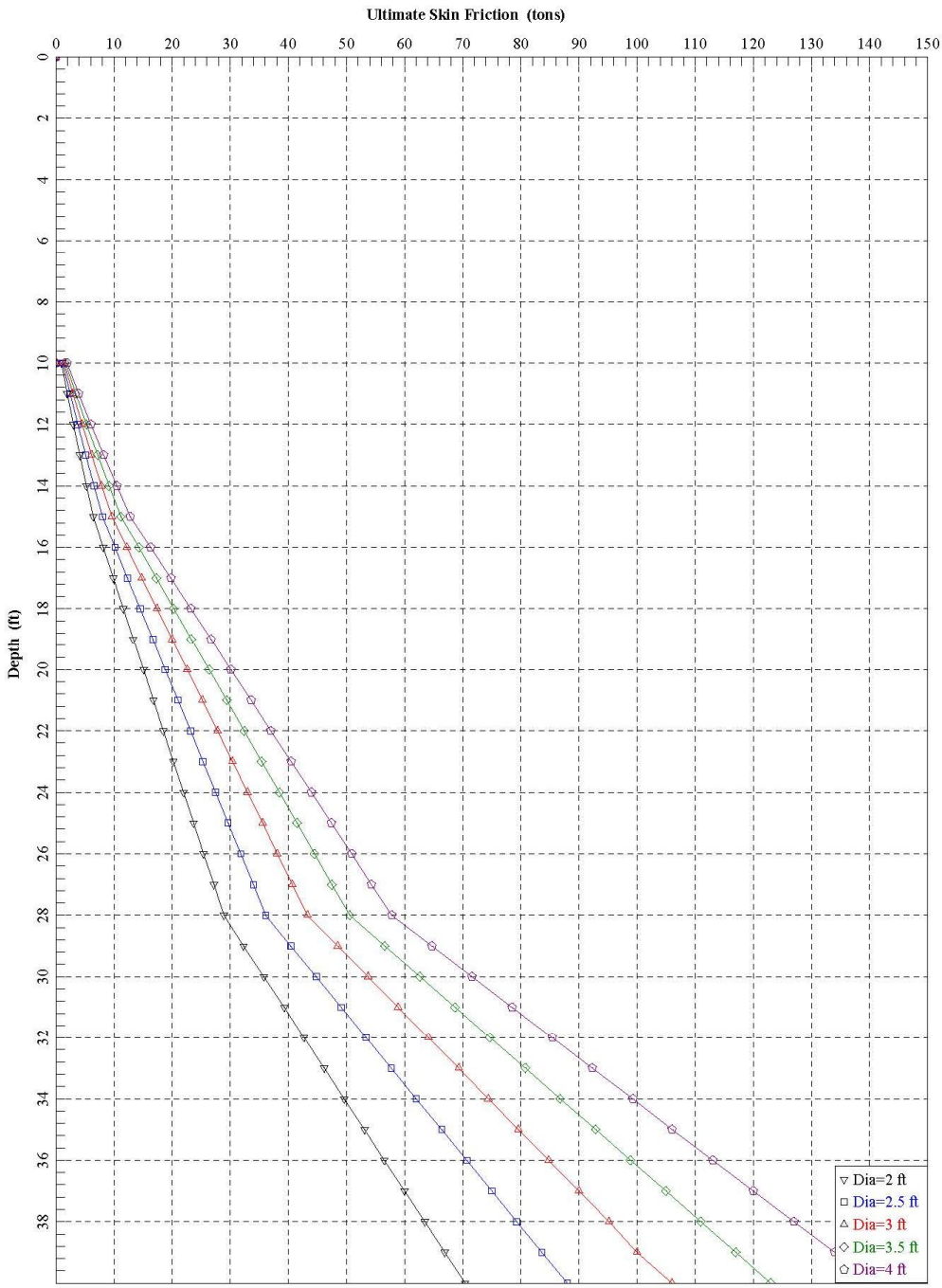
Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-1	0								
B-1	2				60.6	14			
B-1	4								
B-1	6				60.1				
B-1	8					18			
B-1	10								
B-1	12				8.3	24			
B-1	14								
B-1	16	62	30	32	99.7	28	101	1.3	1.5
B-1	18								1.5
B-1	23					27			1.5
B-2	0								
B-2	2				68.9	15			
B-2	4								
B-2	6				68				
B-2	8					18			
B-2	10	42	21	21		34			
B-2	12				12.3				
B-2	14	63	33	30		43			
B-2	16					27	100	0.6	1.3
B-2	18								1.5
B-2	23					27			1.5
B-3	0								
B-3	2				67.9	16			
B-3	4								
B-3	6				61.8				
B-3	8					18			
B-3	10								
B-3	12				8.7	23			
B-3	14	76	37	39		32			
B-3	16					23	106	1.1	1.5
B-3	18								1.5
B-3	20					24	104	0.9	1.5
B-3	29					22			1.5
B-3	34				95.2				
B-3	39					28			1.3
B-4	0.5								
B-4	1.5				76.3	13			
B-4	3								
B-4	5								
B-4	7				71				
B-4	9								
B-4	11	42	18	24	68.8	22			

Project: PMO at IAH
Location: Houston, Texas
Number: HG1213270

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-4	13								
B-4	15				14.4				
B-4	17	77	37	40	100	42			1.3
B-4	19					26	99	0.6	1.3
B-4	23					26			1.3
B-4	29					22	107	1.4	1.3
B-4	34	24	19	5	79.8				0.2
B-4	39					24	101	1	0.7
B-5	1								
B-5	3				66.9	12			
B-5	5								
B-5	7								
B-5	9				73.5	16			
B-5	11								
B-5	13					20			
B-5	15								
B-5	17	62	31	31	99.1	30			
B-5	19					30	96	1.3	1.3
B-5	24	57	29	28	100	27	94	0.9	1.3
B-5	29					24			1.5
B-5	34					21	111	2	1.5
B-5	39					22			1.5
CB-1	1				65.7	11			
CB-1	3.8					13			
CB-1	4.3				68.7				
CB-2	0.5								
CB-2	1.5								
CB-2	2.8				70.2	14			
CB-2	4.3					16			
CB-3	0.5								
CB-3	1.5				63.7	13			
CB-3	2.8								
CB-3	4.3	28	16	12	71.3	17			
Total		**10**	**10**	**10**	**26**	**41**	**10**	**10**	**22**

APPENDIX C

DRILLED SHAFT CAPACITY CURVES



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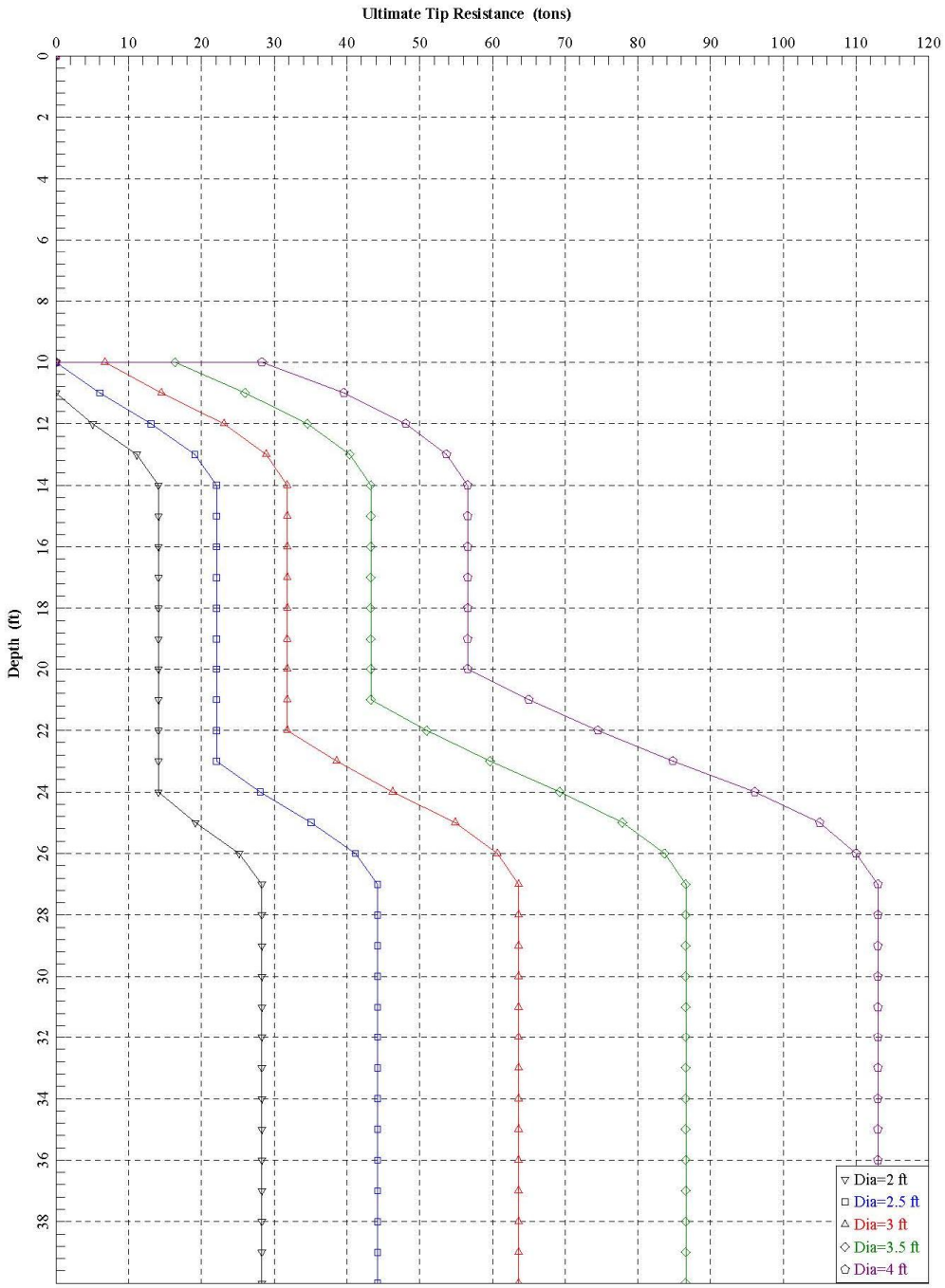
DATE: 5/4/2015	APPROVED BY: SV	PREPARED BY: FD

ULTIMATE SKIN FRICTION
PMO at IAH

PROJECT NO.: HG1213270	DRAWING NO.: PLATE C-1



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DATE: 5/4/2015	APPROVED BY: SV	PREPARED BY: FD

ULTIMATE TIP RESISTANCE
PMO at IAH

PROJECT NO.: HG1213270	DRAWING NO.: PLATE C-2