CITY OF HOUSTON

Sylvester Turner
Mayor

HOUSTON AIRPORT SYSTEM

Mario C. Diaz
Director of Aviation

George Bush Intercontinental ~ William P. Hobby ~ Ellington Airport

January 24, 2023

SUBJECT: **Addendum No. 3**

REFERENCE: Invitation To Bid (ITB) for the HOU ARFF Station #81 Phase 2-4 William P. Hobby Airport; Solicitation No. HHG-ARFF81-2023-006; Project No. 669

To: All Prospective Bidders:

This Addendum is issued for the following reason:

I. **Add** the following pages with the attached documents as outlined below.

1. Geotechnical Report HAS 713E (LOA 09) ARFF Station.

When issued, Addendum shall automatically become part of the solicitation documents and shall supersede any previous specification(s) and/or provision(s) in conflict with the Addendum. Addendum will be incorporated into the Agreement as applicable. It is the responsibility of the bidder(s) to ensure that it has obtained all such letter(s). By submitting a bid on this project, bidder(s) shall be deemed to have received all Addendum and to have incorporated them into their bid.

If further clarification is needed regarding this solicitation, please contact Senior Procurement Specialists, Jorge Ardines, and David Martinez via email at jorge.ardines@houstontx.gov and david.martinez@houstontx.gov.

DocuSigned by:
Cathy Vander Plaats
02232028DE99414...

Cathy Vander Plaats
Aviation Procurement Officer
Houston Airport System

DS
DE

CVP/dm

DS
AO

cc: Alfredo Oracion
Dallas Evans
Solicitation File

Attachments:

1. Geotechnical Report HAS 713E (LOA 09) ARFF Station.

GEOTECHNICAL REPORT
HAS 713E (LOA 09) ARFF STATION
Houston Hobby Airport

SUBMITTED TO

Jacobs—Buildings & Infrastructure
5985 Rogerdale Road
Houston, Texas 77072

BY

HVJ ASSOCIATES, INC.

HOUSTON, TEXAS

SEPTEMBER 29, 2020

REPORT NO. HG1710320.2.2

HVJ ASSOCIATES

HVJ ASSOCIATES

Houston
Austin
Dallas
San Antonio

6120 S. Dairy Ashford Rd.
Houston, TX 77072-1010
281.933.7388 Ph
281.933.7293 Fax
www.hvj.com

September 29, 2020

Laura Zarea, Assoc. AIA, LEED AP BD+C
Project Manager
Jacobs – Buildings & Infrastructure
5985 Rogerdale Road
Houston, Texas 77072

Re: Geotechnical Investigation
HAS 713E (LOA 09) ARFF Station
Houston Hobby Airport
Houston, Texas
Owner: Houston Airport System (HAS)
HVJ Proposal No. HG1710320.2.2

Ms. Zarea:

Submitted herein is the draft report of our geotechnical investigation for the above referenced project. The study was performed in accordance with HVJ Proposal Number HG1710320.2.2 dated August 7, 2019 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

DRAFT	**DRAFT**
Russell D. Sieg, PE Project Engineer	Prakash Dahal, EIT Staff Engineer

MH/RS/PD

This document was released for the purpose of interim review under the authority of Russell D. Sieg, PE 123606 on September 29, 2020. It is not to be used for construction, bidding or permit purposes.

- Main Text – 17 pages
- Plates – 4 pages
- Appendix A – 14 pages
- Appendix B – 5 pages
- Appendix C – 2 pages
- Appendix D – 4 pages
- Appendix E1 – 3 pages
- Appendix E2 – 3 pages
- Appendix F – 2 pages
- Appendix G – 18 pages

TABLE OF CONTENTS

PLATES

APPENDICES

1 EXECUTIVE SUMMARY

HVJ Associates, Inc. was retained by Jacobs to perform a geotechnical investigation for construction of a new Aircraft Rescue & Fire Fighting (ARFF) Station #81, which includes sleeping quarters, fire truck bays, and pavements, at Hobby Airport (HOU) located at 7990 Paul B. Koonce Dr., Houston, Texas. The purpose of this study is to provide foundation recommendations for the proposed structures, and pavement design recommendations for the proposed fire truck driveway and employee parking lot. The subsurface stratigraphy at the project site was determined by drilling and sampling 12 borings to depths of 10- to 50-feet in the project area. Based on the subsurface conditions obtained by the soil borings, the findings and recommendations of this report are summarized below:

1. <u>Building borings (B-3, B-4, B-5, B-7, B-10, B-12, B-13 & B-14):</u> Soft to very stiff cohesive soils (CH, CL and CL-ML) were generally encountered in the borings below the existing grade to their termination depths. Cohesionless soils were observed at borings B-3, B-4, B-10, B-12 and B-14. A summary of the cohesionless soil layers encountered is presented below.

Table 1-1 – Elevation and Location of Cohesionless Soils

Boring	Approx. Elevation	Material
B-3	El. 20.3 to El. 15.3	Reddish Brown & Gray Silt w/ Sand (ML)
	El. -4.7 to El. -9.7*	Medium Dense Silt w/ Sand (ML)
B-4	El. 15.9 to El. 5.94	Loose Silt (ML)
B-10	El. 31.5 to El. 16.5	Loose Silty Sand (SM)
	El. 1.5 to El. -8.5*	Brown Sandy Silt (ML)
B-12	El. -1.8 to El. -8.8*	Brown Sandy Silt (ML)
B-14	El. 18.1 to El. 3.1	Loose Silt (ML)

Note: '*'- termination depth

<u>Pavement borings (B-1, B-2, B-11 & B-15):</u> Firm to very stiff cohesive soils (CH and CL) were generally encountered in the borings below the existing grade to their termination depths.

2. Based on our groundwater observations during the drilling operations, groundwater can be expected at depths ranging from 8 to 14 feet below existing grade. 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. The readings will fluctuate seasonally and in response to rainfall.

3. We performed a Phase I fault study previously at the site and submitted a report (HVJ Report No. HE1710320.2.2 dated August 11, 2020). In our Phase I fault study report, we concluded the potential for active surface faulting to impact the proposed Subject Project Area is low since no documented fault transects the project area. Since the location of the subject faults near the Subject Project Area are fully documented in the geologic literature and by field reconnaissance, we recommended no additional investigation(s) to determine the extent of potential faulting in

the Subject Project Area. In their planned location, proposed structures are unlikely to be impacted by future fault movement.

4. Based on the subsurface soils encountered in the footprint of the proposed building, we have provided foundation recommendations for straight-sided drilled shafts or auger cast piles in Section 6 of the report. The floor slab can either be a structurally suspended slab or, based on the Potential Vertical Rise (PVR) for the onsite soils, a 6-foot thick select fill pad will be needed to reduce the PVR to approximately 1-inch for the floor slab with grade beams. Based on the existing and proposed finished floor elevations (FFE), the 6-foot thick pad could consist of approximately 1 foot of select fill surcharge above existing grade and 5 feet of soil replacement with select fill. The floor slab and grade beams bearing in select fill should be designed for an allowable bearing capacity of 2,500 psf, which includes a factor of safety of 3.

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 to perform a geotechnical investigation for construction of a new Aircraft Rescue & Fire Fighting (ARFF) Station #81, which includes sleeping quarters, fire truck bays, and pavements, at Hobby Airport (HOU) located at 7990 Paul B. Koonce Dr., Houston, Texas. A site vicinity map is provided on Plate 1.

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 12 borings to depths of 10- to 50-feet in the project area as shown in the table below. The borings were drilled to investigate soil stratigraphy and to obtain samples for laboratory testing.

Table 2-1 – Boring Location Summary

Proposed Structure	Number of Borings	Boring Depth (feet)
Building	8	50
Parking Lot	4	10

- Performing laboratory tests to determine physical characteristics of the soils.
- Performing engineering analyses to develop preliminary geotechnical and pavement recommendations for the proposed structures and pavements at the project site.

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 between May 26th and 30th, 2020. The approximate boring locations are indicated on the plan of borings, Plate 2. One of the planned borings (B-6 to 20-feet) couldn't be drilled due to the presence of the temporary modular building, which had already been constructed. Two confirmatory borings (B-8 and B-9 to 50-feet) will be drilled in the next phases of design and construction when the existing fire station buildings are demolished. The soil borings were drilled using truck-mounted and ATV drilling equipment using dry auger and wet rotary techniques. Upon completion of drilling, the boreholes were grouted with tremie method and non-shrink grout was placed at the surface.

3.2 Survey Data

The survey information of the boring locations provided to us by Jacobs is presented in the table below.

Table 3-1 – Borehole Survey Data

Boring	Drilling Depth, Feet	Structure	Coordinates, Feet		Elevation, Feet
			Northing	Easting	
B-1	10	Pavement	13,799,746.03	3,150,393.14	39.04
B-2	10	Pavement	13,799,721.83	3,150,370.46	38.78
B-3	50	Building	13,799,686.85	3,150,395.42	40.33
B-4	50	Building	13,799,622.90	3,150,459.73	40.94
B-5	50	Building	13,799,570.36	3,150,533.56	41.72
B-7	50	Building	13,799,635.64	3,150,356.03	41.77
B-10	50	Building	13,799,484.04	3,150,451.55	41.53
B-11	20	Pavement	13,799,592.73	3,150,277.94	41.53
B-12	50	Building	13,799,594.13	3,150,322.04	41.17
B-13	50	Building	13,799,554.87	3,150,358.59	41.28
B-14	50	Building	13,798,812.58	3,150,532.30	38.14
B-15	10	Pavement	13,799,463.08	3,150,362.89	40.31

Note: Boring B-6 (20-ft) could not be drilled due to presence of temporary modular building.
Borings B-8 and B-9 will be drilled in next phases after demolition of existing ARFF buildings.

Coordinates shown are referenced to Texas State Plane Coordinate System, South Central Zone, North American Datum 83. Elevations are referenced to North American Vertical Datum 1988.

3.3 Sampling Method

All the samples were obtained continuously to a depth of 20 feet and at 5-foot intervals thereafter to the termination depth of the borings. Cohesive soil samples were sampled using a 3-inch diameter thin walled tube in accordance with ASTM D1587. Each sample was extruded in the field, visually classified, and strength estimate obtained with a pocket penetrometer. Cohesionless soils were sampled with the Standard Penetration Test (SPT) sampler in accordance with ASTM D1586. Samples obtained from the Shelby tube and split-barrel sampler were visually classified. 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, which also includes a Key to the Terms and Symbols used for soil classification on the boring logs.

3.4 Groundwater Level Measurements

Groundwater level observations were made in the open boreholes during drilling operations. Details of the groundwater levels are provided in Section 5.4 and on the boring logs presented 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), unit weight, lime series, standard proctor and CBR tests. The Atterberg Limits, moisture content and percent passing

No. 200 Sieve were used to verify field classification by the modified Unified Soils Classification System (ASTM D2487), while the compression tests were performed to obtain the undrained shear strength of the soil. The standard proctor and CBR tests were performed to estimate the subgrade strength for pavement design and the lime series test was performed to calculate the percentage of lime for subgrade stabilization. The type and number of tests performed for this investigation are summarized below:

Table 4-1 –Laboratory Test Summary

Type of Test	Number of Tests
Moisture Content (ASTM D2216)	128
Atterberg Limits (ASTM D4318)	58
Percent Passing No. 200 Sieve (ASTM D1140)	64
Unit Dry Weight (ASTM D 2166/2850)	35
Unconsolidated Undrained (UU) (ASTM D2850)	35
Soil-Lime Proportion Using pH (ASTM D6276)	1
Modified Proctor (ASTM D1557)	1
Laboratory CBR (ASTM D1883)	1

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

4.1 Soil-Lime Proportion Using pH Test

The test was performed in accordance with ASTM D-6276 with the help of a pH meter. Lime series test determines the minimum percent of lime needed for a soil-lime mixture to attain a pH of 12.4. Cation exchange occurs at this pH, resulting in modification of the soil particle structure to achieve improved workability and decrease swell and plasticity. The tested samples did not achieve a pH of 12.4; however, based on the lime series test results 6% lime per dry unit weight appears to be an adequate estimate for stabilization of the onsite subgrade clays to perform satisfactorily. The lime series test result is presented in Table 4-2 below and also presented in Appendix C.

Table 4-2 – Soil-Lime Proportion Using pH Test Results

Boring	Depth, Feet	Soil Description	Estimated Lime Percentage (%)
B-1	0-2	Sandy Lean Clay	6

4.2 Standard Proctor & California Bearing Ratio Tests

One Standard Proctor and California Bearing Ratio (CBR) tests was performed on the composite sample, obtained from borings B-1, B-2, B-11 and B-15 at the project site. Based on the results of the Standard Proctor test, the maximum dry density of the composite sample was determined to be 107.4 pcf at an optimum moisture content of 14.0. A design CBR of 1.3 was estimated at 95% of the maximum dry density. The results of the Standard Proctor and CBR tests are presented in Appendix D.

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 the Beaumont formation. A geologic map is presented on Plate 3.

The Beaumont formation was deposited on land near sea level in flat river deltas and in inter-delta regions. Soil deposition occurred in fresh water streams and in flood plains (as backwater marsh and natural levees). The courses of major streams and deltaic tributaries changed frequently during the period of deposition, generating within the Beaumont clay a complex stratification of sand, silt and clay deposits. Frequently, stream courses were diverted significant distances from a given point in a backwater marsh, and the water overlying the soil would evaporate since it was cut off from a drainage path. Such water, which would be highly alkaline, would precipitate large nodules of calcium carbonate (calcareous nodules) throughout the surface of evaporation. With the coming of the Second Wisconsin Ice Age, the nearby sea withdrew, leaving the formation several hundred feet above sea level and permitting the soil to desiccate. The process of desiccation compressed the clays in the formation such that they became significantly over-consolidated to a large depth. In addition to pre-consolidating the soil, the process of desiccation, together with the later rewetting, produced a network of fissures and slickensides that are now closed but which represent potential planes of weakness in the soil.

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.

We performed a Phase I fault study previously at the site and submitted a report (HVJ Report No. HE1710320.2.2 dated August 11, 2020). In our Phase I fault study report, we conclude the potential for active surface faulting to impact the proposed Subject Project Area is low since no documented fault transects the project area. Since the location of the subject faults near the Subject Project Area are fully documented in the geologic literature and by field reconnaissance, we recommend no additional investigation(s) to determine the extent of potential faulting in the Subject Project Area. In their planned location, proposed structures are unlikely to be impacted by future fault movement.

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 re-evaluation of our findings and conclusions.

A generalized summary of the subsurface conditions in our borings is shown in the table below. 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. Details of the subsurface stratigraphy encountered in the borings are shown on the boring logs presented in Appendix A.

<u>Building borings (B-3, B-4, B-5, B-7, B-10, B-12, B-13 & B-14):</u> Soft to very stiff cohesive soils (CH, CL and CL-ML) were generally encountered in the borings below the existing grade to their

termination depths. Cohesionless soils were observed at borings B-3, B-4, B-10, B-12 and B-14. A summary of the cohesionless soil layers encountered is presented below.

Table 5-1 – Elevation and Location of Cohesionless Soils

Boring	Approx. Elevation	Material
B-3	El. 20.3 to El. 15.3	Reddish Brown & Gray Silt w/ Sand (ML)
	El. -4.7 to El. -9.7*	Medium Dense Silt w/ Sand (ML)
B-4	El. 15.9 to El. 5.94	Loose Silt (ML)
B-10	El. 31.5 to El. 16.5	Loose Silty Sand (SM)
	El. 1.5 to El. -8.5*	Brown Sandy Silt (ML)
B-12	El. -1.8 to El. -8.8*	Brown Sandy Silt (ML)
B-14	El. 18.1 to El. 3.1	Loose Silt (ML)

Note: '*'- termination depth

<u>Pavement borings (B-1, B-2, B-11 & B-15):</u> Firm to very stiff cohesive soils (CH and CL) were generally encountered in the borings below the existing grade to their termination depths.

5.4 Groundwater

Ground water levels observed during the drilling operations are presented in the table below and also on the boring logs presented in Appendix A. Groundwater was not observed in the Pavement borings terminated at 10- to 20-feet depths.

Table 5-2 – Groundwater Readings During Drilling

Boring	Depth (feet)	Groundwater Depth (El.) First Encountered (feet)
B-1	10	Dry
B-2	10	9.0 (El. 29.8)
B-3	50	8.0 (El. 32.3)
B-4	50	12.0 (El. 28.9)
B-5	50	10.0 (El. 31.7)
B-7	50	10.0 (El. 31.8)
B-10	50	10.0 (El. 31.5)
B-11	20	10.0 (El. 31.5)
B-12	50	10.0 (El. 31.2)
B-13	50	14.0 (El. 27.3)
B-14	50	10.0 (El. 28.1)
B-15	10	10.0 (El. 30.3)

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. Also, groundwater levels will fluctuate seasonally and in response to rainfall. Other factors that might impact groundwater levels include leakage from existing utility lines.

5.5 Existing Pavement Thickness

The pavement was cored at boring location B-11 and 5.5 inches of concrete was obtained.

6 BUILDING FOUNDATION RECOMMENDATIONS

6.1 General

HVJ Associates, Inc. was retained by Jacobs to perform a geotechnical investigation for construction of a new Aircraft Rescue & Fire Fighting (ARFF) Station #81 building, which will include sleeping quarters and fire truck bays. Borings B-3, B-4, B-5, B-7, B-10, B-12, B-13 and B-15 were drilled across the building footprint as shown on the plan of borings on Plate 2.

6.2 Foundation Selection

Foundations for the proposed building 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.

Due to the anticipated high gravity and lateral loads on the building, deep foundations will be suitable for the proposed structure. We have provided recommendations for straight sided drilled shafts and auger cast piles in the following sections of the report.

6.3 Straight-Sided Drilled Shaft Foundation Recommendations

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 in the top 5 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

Allowable compressive capacity curves that include skin friction and tip resistance were developed for 24, 30, 36, 42 and 48-inch diameter drilled shafts using the SHAFT 6.0 computer program. The capacity curves for allowable axial capacity under compression and allowable uplift capacity under tension are presented in Appendix E1. These curves were generated based on generalized soil conditions for the borings B-3, B-4, B-5, B-7, B-10, B-12, B-13 and B-14 drilled across the proposed building site. The safety factors used in the analysis are discussed in Section 6.5 of this report.

Drilled Shaft Construction Recommendations: Shaft construction and installation should follow City of Houston Standard Specification 02465 for drilled shaft foundations. The 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 336.1-01 Section 2.6. 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 336.1-01 Section 3.5.

6. If casing is used, 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 provided.

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.

6.4 Auger Cast Pile Foundation Recommendations

Ultimate capacity curves for Auger Cast-in-Place (ACIP) concrete piles were developed based on the results of research performed for the Texas Department of Transportation at the University of Houston. Skin friction in clay was based on an alpha value of 0.7. Skin friction in sand was based on estimating the friction between the pier and soil in accordance with the recommendation presented in Drilled Shafts: Construction Procedures and Design Methods, Publication No. FHWA-HI-88-042, August 1988.

Allowable skin friction capacity curves were developed for 18, 24, 30, and 36-inch diameter auger cast concrete piles using the SHAFT 6.0 computer program. The capacity curves for allowable axial capacity under compression and allowable uplift capacity under tension are presented in Appendix E2. These curves were generated based on generalized soil conditions for the borings B-3, B-4, B-5, B-7, B-10, B-12, B-13 and B-14 drilled across the proposed building site. The safety factors used in the analysis are discussed in the following Section 6.5 of this report.

Auger Cast Pile Construction Recommendations: Auger cast piles should be constructed in accordance with the Auger Cast-in-Place Piles (ACIP) Model Specification developed by the Deep Foundation Institute (DFI). The construction process prevents easy observation of the quality of the (ACIP) foundation during construction. Construction monitoring should be performed based on the Inspectors Guide to Augered Cast-in-Place Piles, also developed by the DFI. These documents can be obtained from DFI.

The foundation contractor's experience in ACIP installation is critically important to a successful foundation installation. We recommend that the project specifications require that the foundation contractor submit evidence of successful installation of ACIPs under similar job and subsurface conditions, including a supervisor with at least three years of ACIP installation experience.

We recommend that at least one test pile be installed at the site using the equipment and procedures planned for foundation pile construction for load testing purposes to verify design pile capacity. Axial pile load tests shall be performed in accordance with ASTM D1143. The pile shall be tested to design load and then re-loaded to failure or three times the design load, whichever occurs first. Test piles shall not become a part of the permanent foundation system.

6.5 Safety Factor

In order to determine the design allowable axial compressive capacity, a factor of safety of 2 was applied to the ultimate skin friction and 3 to the ultimate tip resistance. For the design allowable uplift capacity, a factor of safety of 3 was applied to the ultimate skin friction. 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.

The recommended safety factors presented above are appropriate for sustained loading, good confidence in soil parameters, a design life not exceeding 75 to 100 years, a failure that would result in great economic loss along with some loss of life, and quality control of construction procedures which are normal.

6.6 Lateral Capacity

Foundation elements often have to withstand significant lateral loads in addition to axial loads. Wind forces on structures are forms of lateral loading. Lateral loads or movements on a vertical pile/shaft will be countered by the mobilization of resistance in the surrounding soils as the pile/shaft deflects. The lateral load capacity of the pile/shaft, therefore, will depend on the relative stiffness of the pile/shaft and the strength of the surrounding soils. A rational analysis of a problem involving lateral loading on a pile/shaft must consider the interaction of the soil and the structure. A rational analysis of a problem involving lateral loading on a shaft must consider the interaction of the soil and the structure. Equilibrium of forces and compatibility of displacements throughout the total system are the two fundamental conditions, which are to be satisfied in the analysis.

For vertical shafts subjected to small and transient wind or traction loads, it may be assumed that they can sustain horizontal loads of up to 10 kips per foot of shaft diameter, and a transient load of 20 kips per foot of diameter. These values are allowable capacities, but do not restrict lateral deflection to a given value. Deflection associated with these loads should be within acceptable limits for the structures.

If higher lateral loads must be resisted with vertical shafts, a more detailed study should be done to provide lateral load capacity curves. Lateral load analysis was beyond the scope of this study and should be performed using computer programs such as LPILE. The input parameters for lateral load analysis are presented in Appendix F.

6.7 Group Effects

Groups of shafts/piles should have a center-to-center spacing of at least 2.5D when designing foundations using one row group of shafts/piles, and 3D for foundations using two or more rows of shafts/piles where D is the diameter of the shaft/pile. For greater spacing, the total capacity will be equal to the sum of the capacities of the individual shafts/piles in the group. The group capacity may be less than the sum of individual capacities at closer spacing. If spacing smaller is planned, HVJ should be contacted to assess group capacity.

6.8 Settlement

Movements will consist generally of elastic shortening of the pile/shaft and soil deformation at the pile/shaft tip. It is our opinion that pile/shaft head settlement will be less than 0.5 inch and differential settlement will be less than 0.25 inch.

6.9 Foundation Inspection

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 the appropriate stratum as recommended in this report, b) the footings are concentric with columns, and c) 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.

6.10 Floor Slab

The most effective means to positively eliminate damage to a foundation slab due to shrinkage and swelling soils is to isolate the interior floor slab and grade beams from the soil by means of a structurally suspended floor system. For a structural slab, a minimum crawl space of 8 inches or larger is recommended to separate the subsurface clay soils from the grade beams. Positive drainage must be provided under the floor slab in the crawl space area at all times.

A slab-on-grade floor with grade beams is both more common and cheaper than the structurally supported floor for building construction in the Houston area. It should be noted that some risks are involved when a slab-on-grade floor is utilized. Some vertical movements of the floor slab are still possible during seasonal soil moisture variations. These movements could cause cracking of interior and exterior finishes, and operating problems such as doors which do not open and close freely. However, if the below recommendations are followed, we expect these movements to be 1 inch or less and not severe enough to cause serious damage to the slab.

<u>Expansive Soil</u>: One of the major design factors for lightly loaded structures in the Houston 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 high expansion potential (Effective PI = 29). Effective PI is a weighted average of the plasticity index in the upper 7 feet of the soil stratigraphy intended to present an overall indication of swell potential.

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. Soil moisture changes also result from the construction of a slab-on-grade floor. 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 along the structure perimeter. The zone of moisture change was considered to be the top 7 feet of soil in our analysis based on our experience with Houston soils.

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 drilling. 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 generalized PVR values in the top 7 feet of soil at the proposed building are presented in the table below.

Table 6-1 – Potential Vertical Rise for the Onsite Soils

Proposed Structure	**Boring No.**	**PVR (inches)**			
		Dry	**Average**	**Wet**	**Existing**
Building	B-3, B-4, B-5, B-7, B-10, B-12, B-13 & B-14	1.8	1.2	0.7	1.8

We have estimated a PVR value of 1.2 and 1.8 inches for average and dry conditions, respectively. In order to reduce the PVR to approximately 1.0 inch for the dry condition, we recommend placing the floor slab and grade beams on a 6-foot thick pad prepared with properly compacted and moisture-conditioned select fill. With proposed ARFF building finished floor elevation (FFE) = 43.7 feet and existing ARFF building FFE of 42.3 feet, the 6-foot thick pad could consist of approximately 1 foot of select fill surcharge above existing grade and 5 feet of soil replacement with select fill. We recommend that the pad extend horizontally at least 5 feet beyond the edge of the structure. Select fill criteria are presented in the following Section 6.11 of this report.

The floor slab and grade beams bearing in select fill or lime stabilized soil should be designed for an allowable bearing capacity of 2,500 psf, which includes a factor of safety of 3. Based on the soils encountered in the area of the proposed building slab, a modulus of subgrade reaction (k-value) of 75 pounds per cubic inch is recommended for the building slab (Joint Departments of the Army and Air Force, USA, Technical Manual TM 5-809-12/AFM 88-3, Chapter 15, Table 4-1).

6.11 Site Preparation and Select Fill

The building area should be stripped of all vegetation and any other deleterious materials or gravels. Stripped areas should be appropriately graded and shaped to prevent ponding of water. Pumping may occur if the site becomes wet. Any soft or weak areas, or debris, existing foundations or pavements, and undesirable materials, if encountered, should be removed, excavated to firm subgrade, and replaced with select fill or onsite stable material.

Select fill required to raise the grade or backfill grub holes should consist of lean silty 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 D698-12.

6.12 Drainage

Drainage around the structure perimeter is an important consideration in the performance of the structure. If an area of poor drainage is allowed to exist around the structure, the soils beneath the slab in that area have greater access to water. This may cause the soils in that area to exhibit higher shrink-swell movements compared to soils away from the area of poor drainage. Over time, these cycles of shrinking and swelling may cause damage to interior and exterior finishes, operating problems such as doors which do not open freely, and possible structural damage to the slab. The owner must take care to maintain good drainage over the life of the structure to reduce the chances of shrink-swell problems with a slab-on-grade floor.

6.13 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 foundation. Therefore, small shrubs should be located at least 2 feet, large shrubs at least 5 feet, and trees 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 PAVEMENT DESIGN AND SUBGRADE RECOMMENDATION

HVJ's Pavement design report HG1710320.2.2 dated September 11, 2020 for pavement recommendations and subgrade preparation, which has been submitted separately, is also attached in Appendix G.

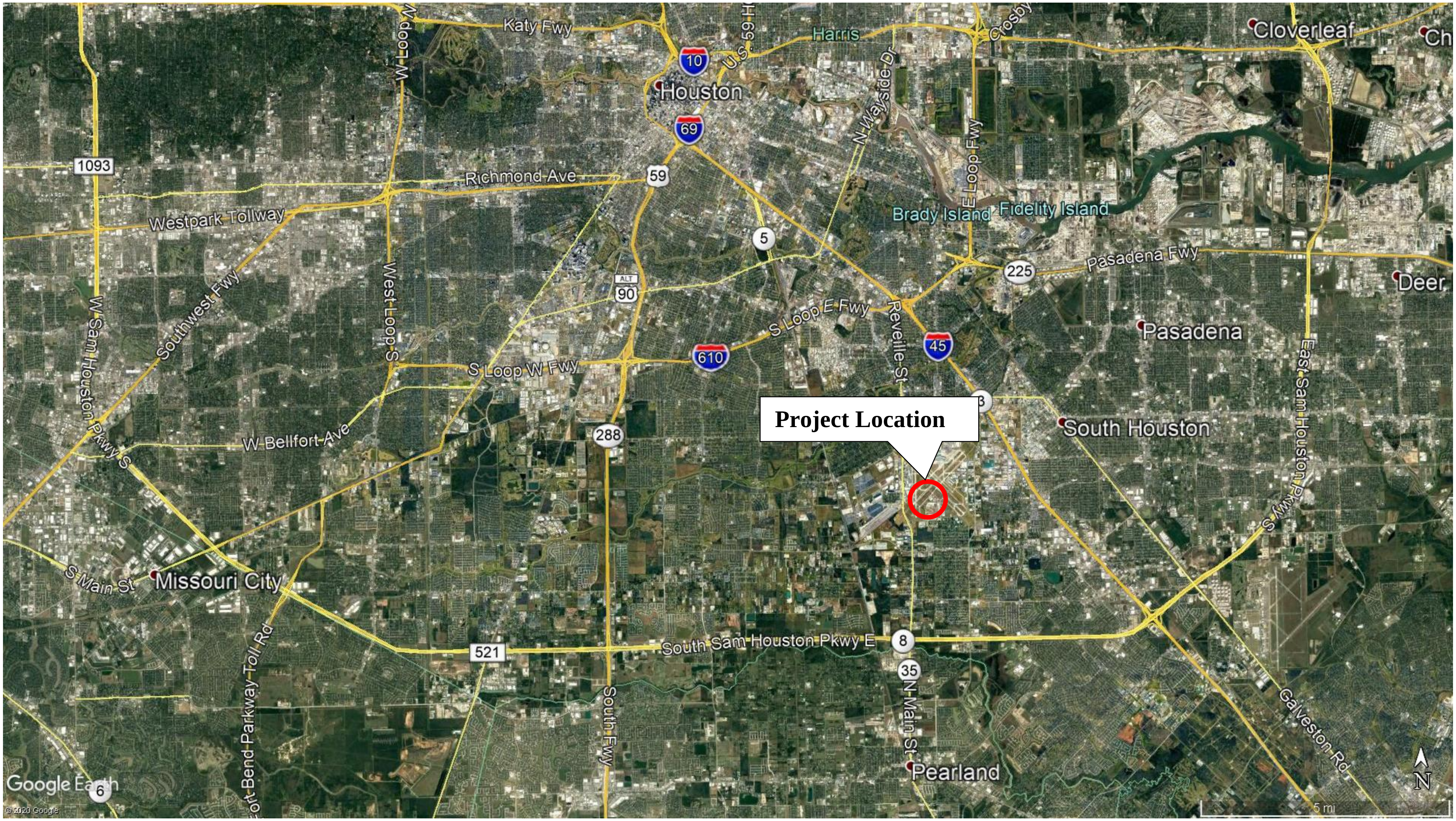
8 DESIGN REVIEW

HVJ should be retained to review the final design and construction 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 and pavement design recommendations may be interpreted and implemented correctly.

9 LIMITATIONS

This investigation was performed for the exclusive use of Jacobs and the Houston Airport System to perform a geotechnical investigation for the proposed new sleeping quarters, fire truck bays, and pavements in support of the design of the new Aircraft Rescue & fire Fighting (ARFF) Station #81 at Hobby Airport (HOU) located at 7990 Paul B. Koonce Dr., Houston, Texas.. HVJ has endeavored to comply with generally accepted geotechnical engineering practice common in the local area. HVJ 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 should be immediately notified so that further investigation and supplemental recommendations can be provided.

PLATES



6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 9/18/2020	APPROVED BY: RS	PREPARED BY: PD

SITE VICINITY MAP
HAS 715E LOA-009 ARFF STATION
WILLIAM P. HOBBY AIRPORT, HOUSTON, TEXAS

PROJECT NO.: HG1710320.2.2	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: 9/18/2020

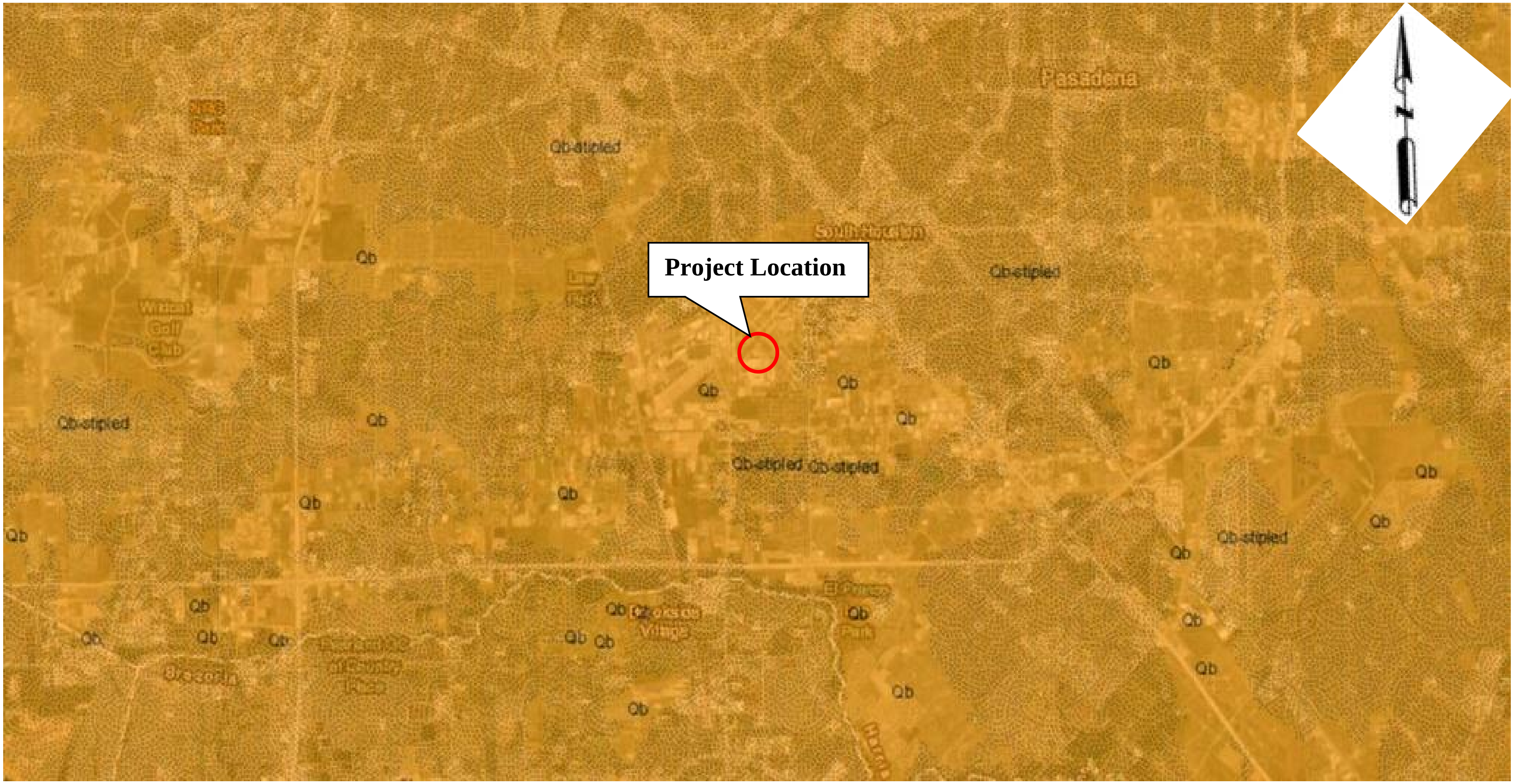
APPROVED BY: RS

PREPARED BY: PD

PLAN OF BORINGS
HAS 715E LOA-009 ARFF STATION
WILLIAM P. HOBBY AIRPORT, HOUSTON, TEXAS

PROJECT NO.: HG1710320.2.2

DRAWING NO.: PLATE 2



Source: USGS- Bureau of Economic Geology

Qb-stipled
Qb

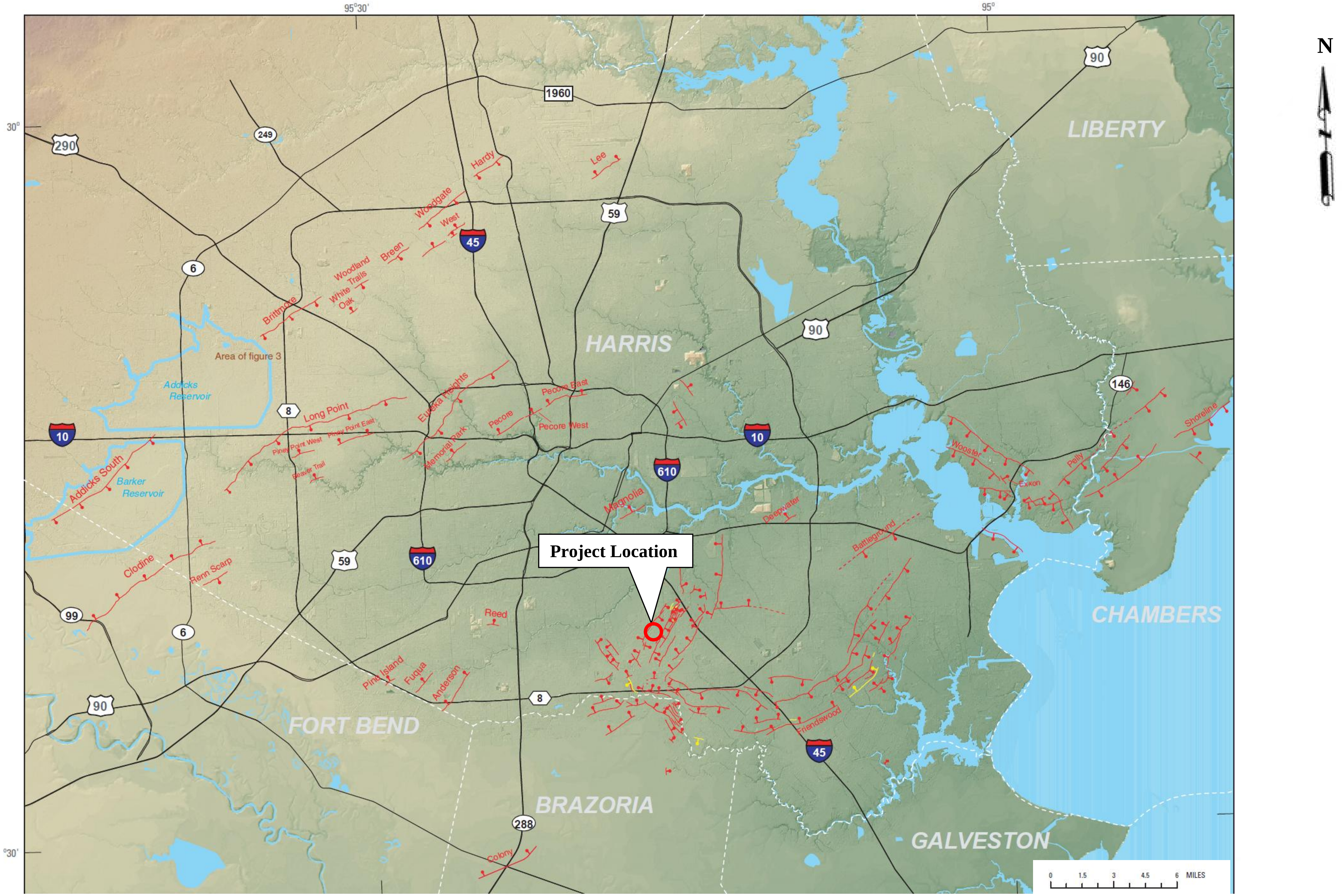
<u>Beaumont Formation</u> – Mostly clay, silt, and sand; includes mainly stream channel, point-bar, natural levee, backswamp, and to a lesser extent coastal marsh and mud flat deposits; concretions of calcium carbonate, iron oxide, and iro`n-manganese oxides in zone of weathering; surface almost featureless, characterized by relict river channels shown by meander patterns and pimple mounds on meanderbelt ridges, separated by areas of flow, relatively smooth, featureless backswamp deposits without pimple mounds; thickness ± 100 ft.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 09/18/2020
APPROVED BY: RS
PREPARED BY: PD

GEOLOGIC MAP
HAS 715E LOA-009 ARFF STATION
WILLIAM P. HOBBY AIRPORT, HOUSTON, TEXAS

PROJECT NO.: HG1710320.2.2
DRAWING NO.: PLATE 3



Source: Sachin D. Shah and Jennifer Lanning-Rush, 2005.

HVJ ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 09/18/2020	APPROVED BY: RS	PREPARED BY: PD

SITE VICINITY MAP
HAS 715E LOA-009 ARFF STATION
WILLIAM P. HOBBY AIRPORT, HOUSTON, TEXAS

PROJECT NO.: HG1710320.2.2	DRAWING NO.: PLATE 4

APPENDIX A

BORING LOGS AND KEY TO TERMS & SYMBOLS

DocuSign Envelope ID: 91090F26-2F61-4D52-8D37-B31DA376E781

LOG OF BORING B-1

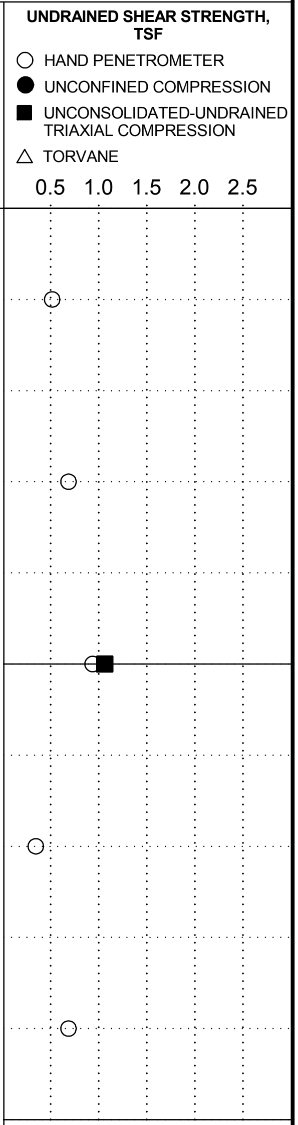
PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799746.03; E: 3150393.14
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 39.04 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 10 FT

DATE: 5/30/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: N/A TO N/A 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	Stiff, dark gray, gray and reddish brown, SANDY LEAN CLAY (CL) -w/ calcareous nodules at 0'-2'		62.4		18	37	17	20
		-w/ ferrous stains at 2'-4'				19			
35		Firm to very stiff, reddish brown and gray, LEAN CLAY (CL) -w/ calcareous nodules and ferrous stains at 4'-6'							
	5			85.7	121	21	43	19	24
30						29			
	10								



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

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

PLATE A-1

COH HG1710320.2.2.GPJ 9/24/20

LOG OF BORING B-2

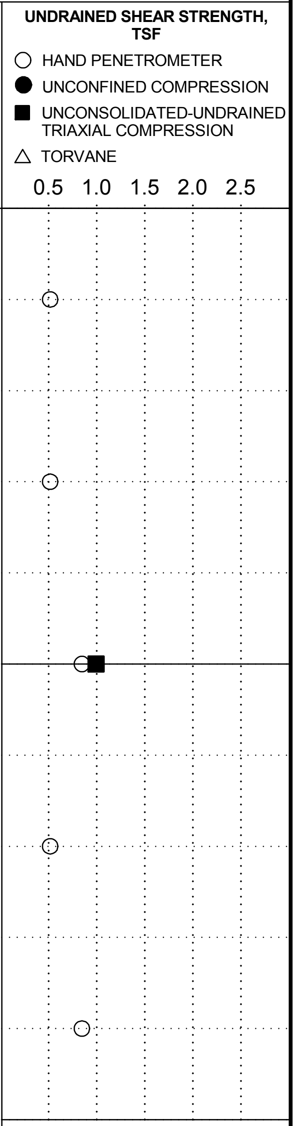
PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799721.83; E: 3150370.46
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 38.78 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 10 FT

DATE: 5/30/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: N/A TO N/A 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	Firm, dark gray and gray, SANDY LEAN CLAY (CL) -w/ calcareous nodules at 0'-4'							
						21			
				54.9		14	43	18	25
35		Stiff, reddish brown and gray, LEAN CLAY WITH SAND (CL) -w/ ferrous stains at 4'-8'							
	5				121	20			
				79.3		23	38	18	20
▽ 30						21			
	10								



DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 9.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

LOG OF BORING B-3

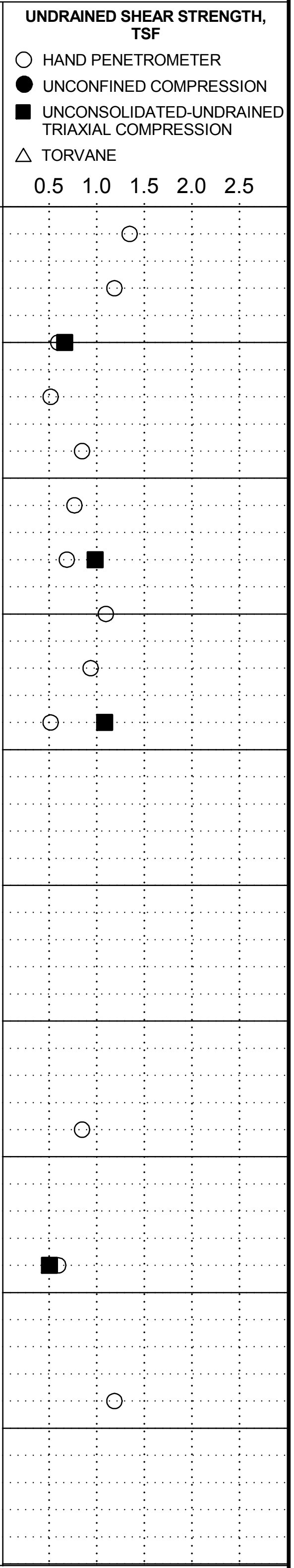
PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799686.85; E: 3150395.42
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 40.33 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

DATE: 5/30/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: 10 TO 50 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, %
Very stiff, dark gray and gray, LEAN CLAY WITH SAND (CL) -w/ roots at 0'-2' -w/ calcareous nodules at 0'-4'		71.3		16	38	19	19
Stiff, reddish brown and gray, SANDY LEAN CLAY (CL)			130	14			
-w/ ferrous stains at 6'-8' -w/ calcareous nodules at 8'-14'		69.5		14	36	19	17
			115	19			
Stiff to very stiff, reddish brown, FAT CLAY WITH SAND (CH)		81.8		25	50	25	25
			117	21			
Reddish brown and gray, SILT WITH SAND (ML)		81.9		25	25	22	3
Firm to very stiff, reddish brown, LEAN CLAY (CL) -w/ silt seams at 28'-30'	15			27			
		98.8		25	40	20	20
			114	26			
				22			
Medium dense, brown, SILT WITH SAND (ML)	12	84.5		26			



DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 8.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

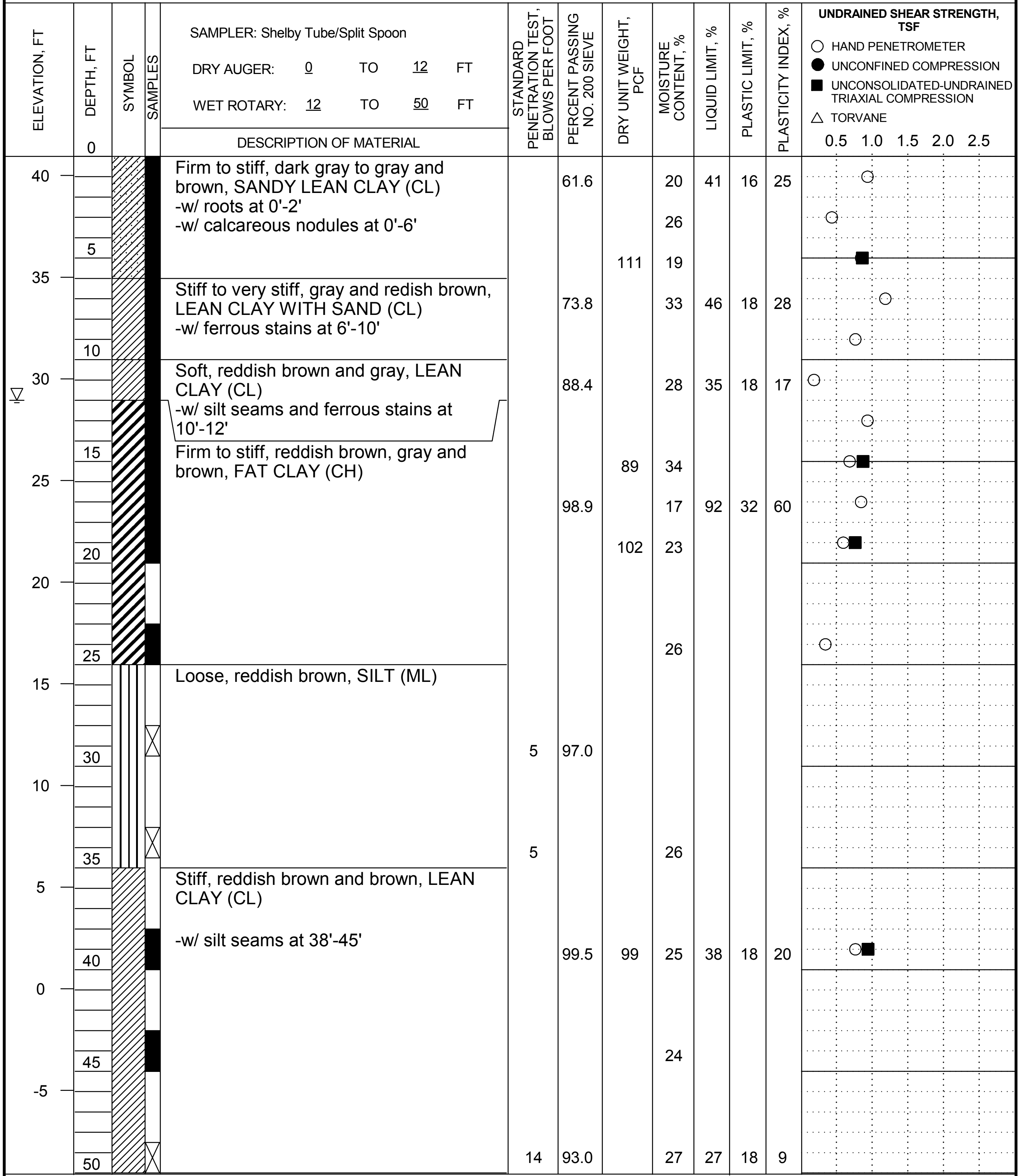
LOG OF BORING B-4

PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799622.9; E: 3150459.73
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 40.94 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

DATE: 5/29/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 12 FT
WET ROTARY: 12 TO 50 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, %
Firm to stiff, dark gray to gray and brown, SANDY LEAN CLAY (CL) -w/ roots at 0'-2' -w/ calcareous nodules at 0'-6'		61.6		20	41	16	25
				26			
			111	19			
Stiff to very stiff, gray and redish brown, LEAN CLAY WITH SAND (CL) -w/ ferrous stains at 6'-10'		73.8		33	46	18	28
Soft, reddish brown and gray, LEAN CLAY (CL) -w/ silt seams and ferrous stains at 10'-12'		88.4		28	35	18	17
Firm to stiff, reddish brown, gray and brown, FAT CLAY (CH)			89	34			
		98.9		17	92	32	60
			102	23			
				26			
Loose, reddish brown, SILT (ML)	5	97.0					
	5			26			
Stiff, reddish brown and brown, LEAN CLAY (CL) -w/ silt seams at 38'-45'		99.5	99	25	38	18	20
				24			
	14	93.0		27	27	18	9

DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 12.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

LOG OF BORING B-5

PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799570.36; E: 3150533.56
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 41.72 FT

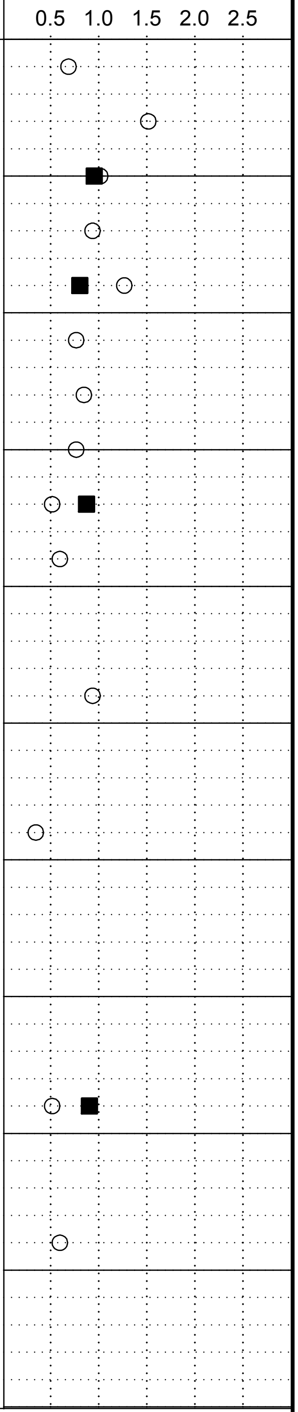
PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

DATE: 5/29/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: 10 TO 50 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, %
Stiff to very stiff, dark gray, gray and brown, SANDY LEAN CLAY (CL) -w/ calcareous nodules at 0'-2' -w/ roots at 2'-4'		65.8		12	43	18	25
Stiff to very stiff, gray and reddish brown, FAT CLAY WITH SAND (CH) -w/ calcareous nodules and ferrous stains at 4'-8' -w/ sand seams at 8'-12'		72.9	111	18	53	18	35
			112	18			
Stiff, reddish brown and gray, FAT CLAY (CH)		87.8		26	50	20	30
		99.1	88	28	86	32	54
				22			
Firm to stiff, reddish brown, LEAN CLAY (CL) -w/ sand seams at 23'-30'		88.0		14	36	19	17
				24			
Firm, reddish brown, FAT CLAY (CH)	6	100		35	68	28	40
Stiff, reddish brown and brown, LEAN CLAY (CL) -w/ sand seams at 38'-50'			102	26			
		99.4		24	30	21	9
	12	99.3		27	29	20	9

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



DEPTH TO WATER IN BORING:
∇ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

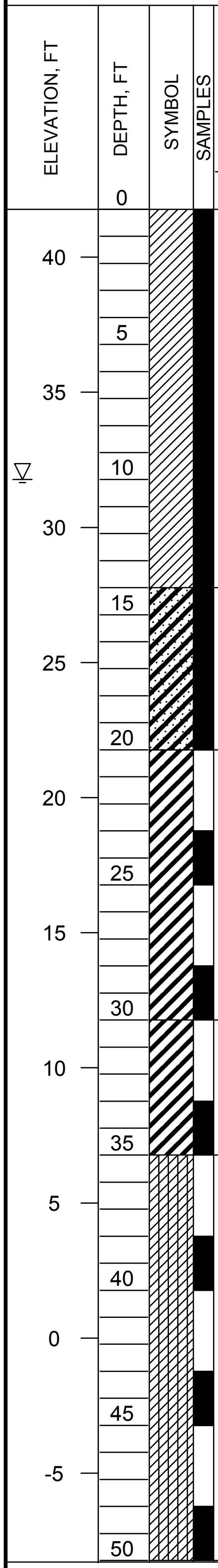
LOG OF BORING B-7

PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799635.64; E: 3150356.03
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 41.77 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

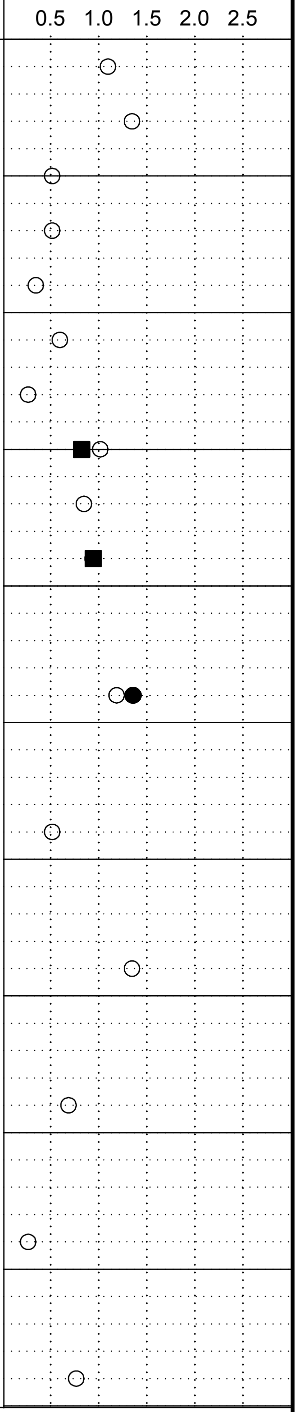
DATE: 5/28/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: 10 TO 50 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, %
Firm to very stiff, reddish brown and dark gray to gray, LEAN CLAY WITH SAND (CL) -w/ roots at 0'-2' -w/ calcareous nodules at 4'-14'				16			
		71.1		14	33	17	16
				17			
				16			
		71.0		21	28	20	8
				25			
Stiff, reddish brown, SANDY FAT CLAY (CH) -w/ silt seams at 14'-16'			105	21			
		69.0		22	83	28	55
-slickensided at 18'-20'			90	33			
Stiff to very stiff, reddish brown, FAT CLAY WITH SAND (CH) -w/ sand stone at 23'-25' -slickensided at 23'-25'		76.5	108	22	70	29	41
-w/ silt stone at 28'-30'				24			
Very stiff, reddish brown, FAT CLAY (CH) -w/ silt seams at 33'-35'		94.6		28	55	27	28
Firm to stiff, reddish brown, SILTY CLAY (CL-ML)				22			
-w/ sand seams at 43'-45'		95.1		28	30	23	7
				25			

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



DEPTH TO WATER IN BORING:
∇ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

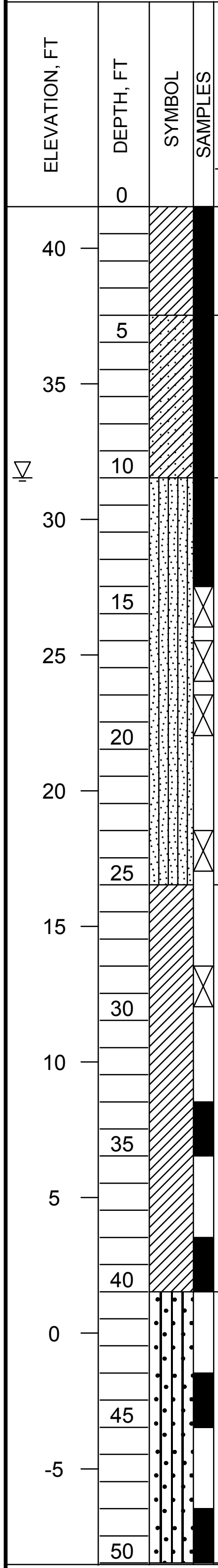
LOG OF BORING B-10

PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799484.04; E: 3150451.55
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 41.53 FT

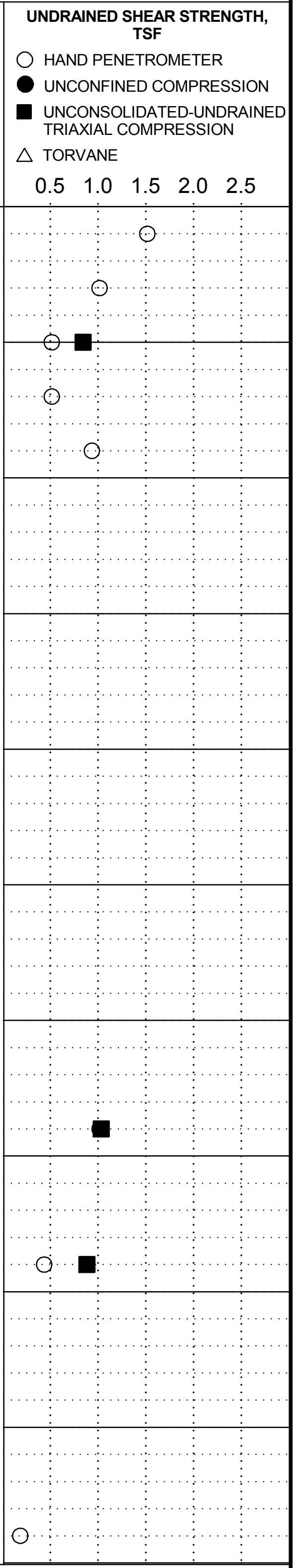
PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

DATE: 5/28/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: 10 TO 50 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, %
Very stiff, dark gray, gray and reddish brown, LEAN CLAY WITH SAND (CL)		74.0		14	42	18	24
				17			
Stiff, gray and reddish brown, SANDY LEAN CLAY (CL) -w/ calcareous nodules and ferrous stains at 4'-6'			118	17			
		55.6		19	46	17	29
Loose, brown, SILTY SAND (SM)		19.4		25			
-w/ clay seams at 12'-14'				20			
	6						
	5	13.5		25			
	5			26			
	5			25			
Firm to very stiff, reddish brown, LEAN CLAY (CL)	8	87.6		25	36	19	17
			100	30			
-w/ silt seams at 38'-40'		98.0	116	27	41	20	21
Brown, SANDY SILT (ML)		53.7		25	25	23	2
-w/ clay seams at 48'-50'				30			



DEPTH TO WATER IN BORING:
∇ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

COH HG1710320.2.2.GPJ 9/24/20

LOG OF BORING B-11

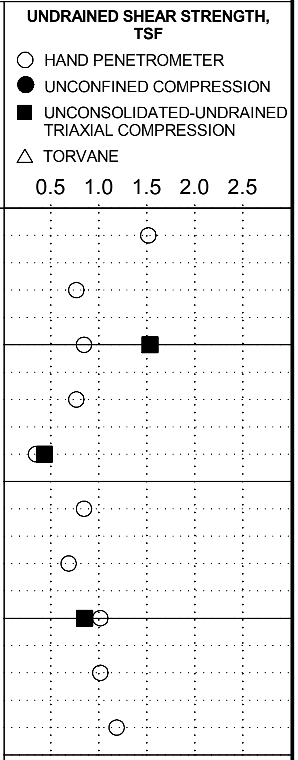
PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799592.73; E: 3150277.94
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 41.53 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 20 FT

DATE: 5/28/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 20 FT
WET ROTARY: N/A TO N/A 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: 5.5" Concrete							
40		Stiff to very stiff, dark gray to gray and reddish brown, FAT CLAY WITH SAND (CH)				20			
				73.1		22	63	19	44
	5				114	21			
35						23			
▽	10	Firm to very stiff, reddish brown, gray and brown, FAT CLAY (CH)		92.1	105	27	50	18	32
30									
		-w/ calcareous nodules at 12'-14'				31			
	15			99.5	93	30	78	28	50
25									
	20	-w/ ferrous stains at 18'-20'				25			



DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

HVJ Associates, Inc.

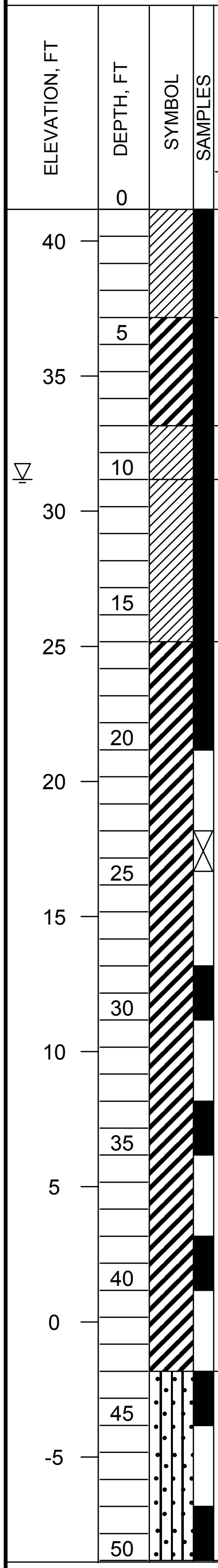
LOG OF BORING B-12

PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799594.13; E: 3150322.04
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 41.17 FT

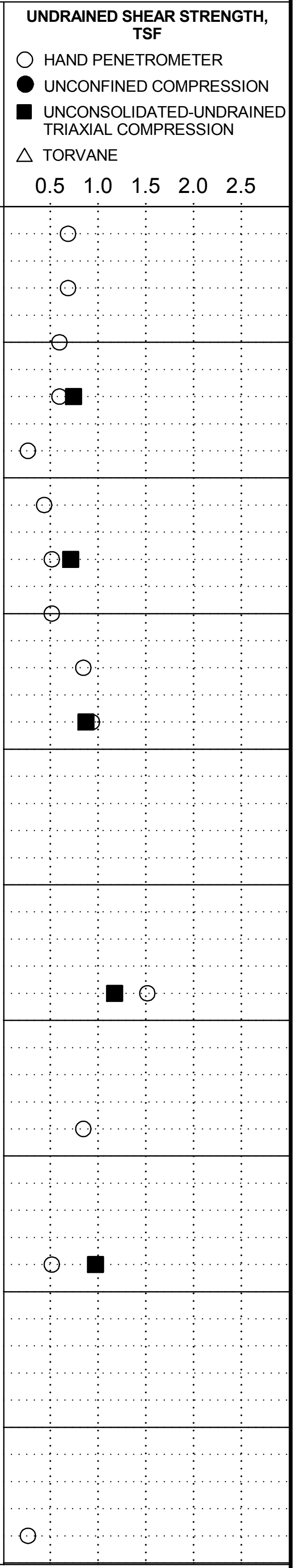
PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

DATE: 5/26/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 12 FT
WET ROTARY: 12 TO 50 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, %
Stiff, dark gray, gray and brown, LEAN CLAY WITH SAND (CL)		74.2		17	38	14	24
Stiff, dark gray and reddish brown, FAT CLAY WITH SAND (CH)		78.8		24	66	19	47
			103	23			
Firm, gray and reddish brown, LEAN CLAY WITH SAND (CL)		80.0		28	44	17	27
Firm to stiff, reddish brown, LEAN CLAY (CL) -w/ calcareous nodules at 10'-12'		98.5	102	20	44	18	26
Stiff to very stiff, reddish brown, FAT CLAY (CH)		99.0		33	86	30	56
			92	33			
-w/ silt seams at 23'-30'	10			24			
		94.0	105	26	92	31	61
				26			
		99.3	98	27	65	23	42
Brown, SANDY SILT (ML)		65.2		27			
-w/ clay seams at 48'-50'				27			



DEPTH TO WATER IN BORING:
∇ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

COH HG1710320.2.2.GPJ 9/24/20

Drilled By: Soltek Logged By: EE

LOG OF BORING B-13

PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799554.87; E: 3150358.59
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 41.28 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

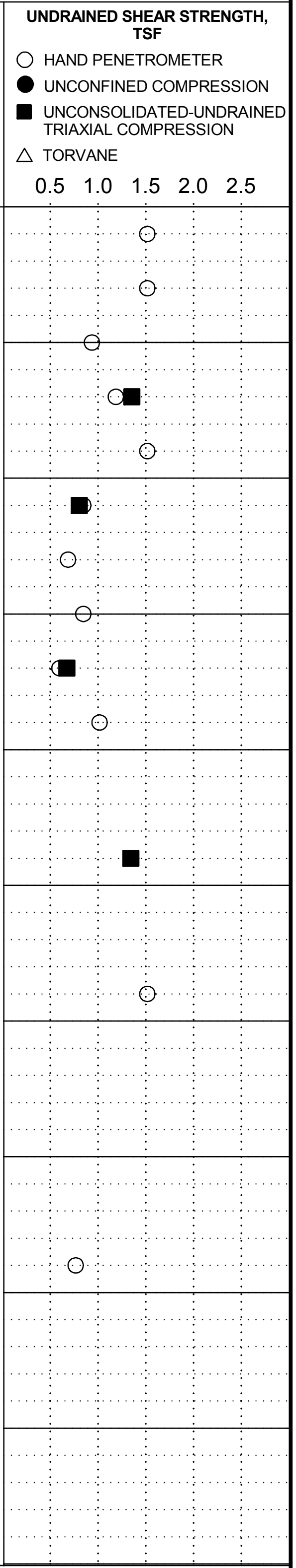
DATE: 5/26/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 14 FT
WET ROTARY: 14 TO 50 FT

DESCRIPTION OF MATERIAL

- Very stiff, dark gray and browm, LEAN CLAY WITH SAND (CL)
  - -w/ gravel at 0'-2'
  - -w/ roots at 0'-4'
- Stiff to very stiff, dark gray to gray and reddish brown, SANDY LEAN CLAY (CL)
  - -w/ calcareous nodules at 6'-10'
- Stiff, gray and reddish brown, LEAN CLAY (CL)
- Firm to very stiff, reddish brown and gray, FAT CLAY (CH)
  - -w/ silt seams at 14'-18'
  - -w/ silt seams at 28'-40'
- Firm, brown, LEAN CLAY (CL)
  - -w/ silty sand seams at 48'-50'

STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	72.8		12	37	15	22
			18			
	69.9	117	17	44	15	29
			17			
		107	23			
	90.0		27	37	18	19
	95.4	86	37	85	30	55
			26			
	86.6	102	23	52	21	31
			23			
5	98.8		31	57	23	34
			26			
	97.2		25	27	18	9
			28			



DEPTH TO WATER IN BORING:
▽ FREE WATER DURING DRILLING: 14.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

LOG OF BORING B-14

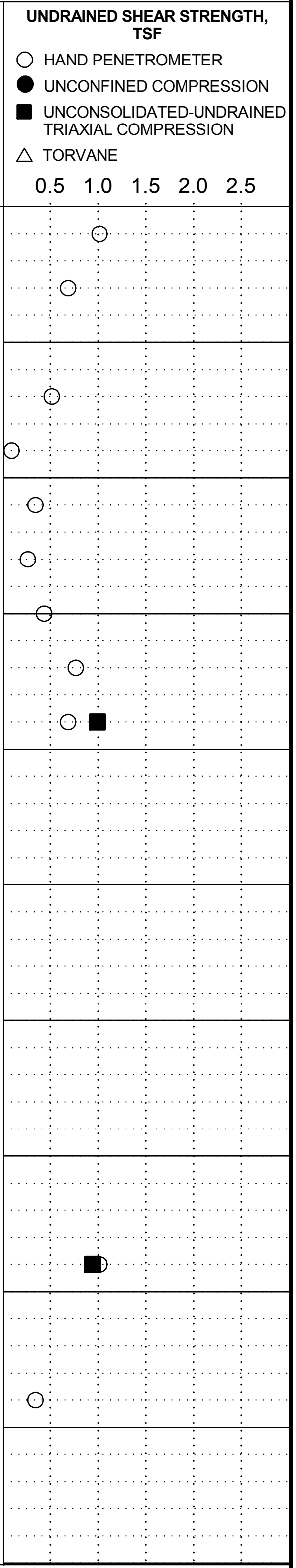
PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13798812.58; E: 3150532.3
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 38.14 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 50 FT

DATE: 5/29/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: 10 TO 50 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								
35		Stiff, brown and gray, SANDY LEAN CLAY (CL) -w/ roots and calcareous nodules at 0'-4'		67.4		13	35	18	17
	5	Very soft to stiff, gray and reddish brown, LEAN CLAY WITH SAND (CL) -w/ calcareous nodules at 4'-6'	4						
						19			
30		-w/ soft clay at 8'-10'							
∇	10			76.0		26	33	18	15
25		Firm, gray and reddish brown, LEAN CLAY (CL)		98.4		27	42	21	21
	15	Firm to stiff, reddish brown and gray, FAT CLAY (CH)				30			
				98.2		37	80	30	50
20									
	20				115	22			
		Loose, reddish brown, SILT (ML)							
15		-w/ very soft clay seams at 23'-25'							
	25					32			
10									
	30		6	91.8		29			
5									
	35	Firm to stiff, redish brown and brown, LEAN CLAY (CL)	6			36			
0									
	40				107	26			
-5									
	45			99.2		26	33	21	12
-10		-w/ silt seams at 48'-50'							
	50		4			28			



DEPTH TO WATER IN BORING:
∇ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

LOG OF BORING B-15

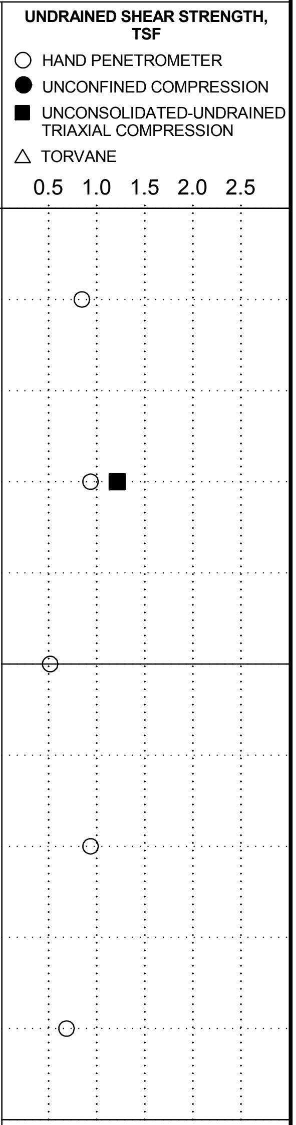
PROJECT: HAS 715E LOA-009 ARFF Station
LOCATION: N: 13799463.08; E: 3150362.89
STATION: N/A
OFFSET: N/A
SURFACE ELEVATION: 40.31 FT

PROJECT NO.: HG1710320.2.2
WBS NO.: N/A
COMPLETION DEPTH: 10 FT

DATE: 5/28/2020

SAMPLER: Shelby Tube/Split Spoon
DRY AUGER: 0 TO 10 FT
WET ROTARY: N/A TO N/A 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, %
40	0	Stiff to very stiff, dark gray, gray and reddish brown, FAT CLAY WITH SAND (CH)							
				81.0		23	67	21	46
					105	23			
	5					20			
35									
		Stiff, reddish brown and gray, SANDY LEAN CLAY (CL)							
				60.0		19	49	20	29
						20			
∇	10								



DEPTH TO WATER IN BORING:
∇ FREE WATER DURING DRILLING: 10.0 FT
▼ WATER DEPTH 24 HOURS AFTER DRILLING: ---

Drilled By: Soltek Logged By: EE

SOIL SYMBOLS

Soil Types

▨	▥	░	▓
Clay	Silt	Sand	Gravel

Modifiers

▨	▥	░	▓
Clayey	Silty	Sandy	Cemented

Construction Materials

▤	▒	▩	▒
Asphaltic Concrete	Stabilized Base	Fill or Debris	Portland Cement Concrete

SAMPLER TYPES

■	Thin Walled Shelby Tube	⧄	No Recovery	⇩	Auger
⊠	Split Barrel	▯	Core		
◧	Liner Tube	⧗	Jar Sample		

WATER LEVEL SYMBOLS

▽	Groundwater level after drilling in open borehole or piezometer
▼	Groundwater level determined during drilling operations

SOIL GRAIN SIZE

Classification	Particle Size	Particle Size or Sieve No. (U.S. Standard)
Clay	< 0.002 mm	< 0.002 mm
Silt	0.002 - 0.075 mm	0.002 mm - #200 sieve
Sand	0.075 - 4.75 mm	#200 sieve - #4 sieve
Gravel	4.75 - 75 mm	#4 sieve - 3 in.
Cobble	75 - 200 mm	3 in. - 8 in.
Boulder	> 200 mm	> 8 in.

DENSITY OF COHESIONLESS SOILS

Descriptive Term	Penetration Resistance "N" * Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

CONSISTENCY OF COHESIVE SOILS

Consistency	Undrained Shear Strength (tsf)	Penetration Resistance "N" * Blows/Foot
Very Soft	0 - 0.125	0 - 2
Soft	0.125 - 0.25	2 - 4
Firm	0.25 - 0.5	4 - 8
Stiff	0.5 - 1.0	8 - 16
Very Stiff	1.0 - 2.0	16 - 32
Hard	> 2.0	> 32

PENETRATION RESISTANCE

3/6	Blows required to penetrate each of three consecutive 6-inch increments per ASTM D-1586 *
50/4"	If more than 50 blows are required, driving is discontinued and penetration at 50 blows is noted
0/18"	Sampler penetrated full depth under weight of drill rods and hammer

* The N value is taken as the blows required to penetrate the final 12 inches

TERMS DESCRIBING SOIL STRUCTURE

Slickensided	Fracture planes appear polished or glossy, sometimes striated
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Inclusion	Small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Parting	Inclusion less than 1/4 inch thick extending through the sample
Seam	Inclusion 1/4 inch to 3 inches thick extending through the sample
Layer	Inclusion greater than 3 inches thick extending through the sample
Laminated	Soil sample composed of alternating partings of different soil type
Stratified	Soil sample composed of alternating seams or layers of different soil type
Intermixed	Soil sample composed of pockets of different soil type and laminated or stratified structure is not evident
Calcareous	Having appreciable quantities of calcium carbonate
Ferrous	Having appreciable quantities of iron
Nodule	A small mass of irregular shape

HVJ ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

KEY TO TERMS AND SYMBOLS
USED ON BORING LOGS

PROJECT NO.:	DRAWING NO.:
HG1710320.2.2	PLATE A-13

APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

Company Name: HVJ Associates, Inc.
Project: HAS 715E LOA-009 ARFF Station
Location: William P. Hobby Airport, Houston, Texas
Project Number: HG1710320.2.2

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Passing #200 Sieve	Moisture content (%)	Total Density (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-1	1	37	17	20	62.4	18			0.50
B-1	3					19			0.67
B-1	5	43	19	24	85.7	21	146	1.05	0.92
B-1	7								0.33
B-1	9					29			0.67
B-2	1					21			0.50
B-2	3	43	18	25	54.9	14			0.50
B-2	5					20	145	0.98	0.83
B-2	7	38	18	20	79.3	23			0.50
B-2	9					21			0.83
B-3	1								1.33
B-3	3	38	19	19	71.3	16			1.17
B-3	5					14	148	0.65	0.58
B-3	7								0.50
B-3	9	36	19	17	69.5	14			0.83
B-3	11								0.75
B-3	13					19	137	0.97	0.67
B-3	15	50	25	25	81.8	25			1.08
B-3	17								0.92
B-3	19					21	142	1.07	0.50
B-3	24	25	22	3	81.9	25			
B-3	29					27			
B-3	34	40	20	20	98.8	25			0.83
B-3	39					26	144	0.49	0.58
B-3	44					22			1.17
B-3	49				84.5	26			
B-4	1	41	16	25	61.6	20			0.92
B-4	3					26			0.42
B-4	5					19	132	0.85	0.83
B-4	7	46	18	28	73.8	33			1.17
B-4	9								0.75
B-4	11	35	18	17	88.4	28			0.17
B-4	13								0.92
B-4	15					34	119	0.86	0.67
B-4	17	92	32	60	98.9	17			0.83
B-4	19					23	125	0.75	0.58
B-4	24					26			0.33
B-4	29				97.0				

Company Name: HVJ Associates, Inc.
Project: HAS 715E LOA-009 ARFF Station
Location: William P. Hobby Airport, Houston, Texas
Project Number: HG1710320.2.2

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Passing #200 Sieve	Moisture content (%)	Total Density (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-4	34					26			
B-4	39	38	18	20	99.5	25	124	0.93	0.75
B-4	44					24			
B-4	49	27	18	9	93.0	27			
B-5	1	43	18	25	65.8	12			0.67
B-5	3								1.50
B-5	5	53	18	35	72.9	18	131	0.94	1.00
B-5	7								0.92
B-5	9					18	132	0.79	1.25
B-5	11								0.75
B-5	13	50	20	30	87.8	26			0.83
B-5	15								0.75
B-5	17	86	32	54	99.1	28	113	0.86	0.50
B-5	19					22			0.58
B-5	24	36	19	17	88.0	14			0.92
B-5	29					24			0.33
B-5	34	68	28	40	100.0	35			
B-5	39					26	129	0.89	0.50
B-5	44	30	21	9	99.4	24			0.58
B-5	49	29	20	9	99.3	27			
B-7	1					16			1.08
B-7	3	33	17	16	71.1	14			1.33
B-7	5					17			0.50
B-7	7					16			0.50
B-7	9	28	20	8	71.0	21			0.33
B-7	11								0.58
B-7	13					25			0.25
B-7	15					21	127	0.81	1.00
B-7	17	83	28	55	69.0	22			0.83
B-7	19					33	120	0.93	0.92
B-7	24	70	29	41	76.5	22	132	1.35	1.17
B-7	29					24			0.50
B-7	34	55	27	28	94.6	28			1.33
B-7	39					22			0.67
B-7	44	30	23	7	95.1	28			0.25
B-7	49					25			0.75
B-10	1	42	18	24	74.0	14			1.50
B-10	3					17			1.00

Company Name: HVJ Associates, Inc.
Project: HAS 715E LOA-009 ARFF Station
Location: William P. Hobby Airport, Houston, Texas
Project Number: HG1710320.2.2

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Passing #200 Sieve	Moisture content (%)	Total Density (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-10	5					17	138	0.83	0.50
B-10	7	46	17	29	55.6	19			0.50
B-10	9								0.92
B-10	11				19.4	25			
B-10	13					20			
B-10	17				13.5	25			
B-10	19					26			
B-10	24					25			
B-10	29	36	19	17	87.6	25			
B-10	34					30	130	1.02	1.00
B-10	39	41	20	21	98.0	27	147	0.87	0.42
B-10	44	25	23	2	53.7	25			
B-10	49					30			0.17
B-11	1					20			1.50
B-11	3	63	19	44	73.1	22			0.75
B-11	5					21	138	1.52	0.83
B-11	7					23			0.75
B-11	9	50	18	32	92.1	27	133	0.42	0.33
B-11	11								0.83
B-11	13					31			0.67
B-11	15	78	28	50	99.5	30	121	0.84	1.00
B-11	17								1.00
B-11	19					25			1.17
B-12	1	38	14	24	74.2	17			0.67
B-12	3								0.67
B-12	5	66	19	46	78.8	24			0.58
B-12	7					23	127	0.73	0.58
B-12	9	44	17	27	80.0	28			0.25
B-12	11								0.42
B-12	13	44	18	26	98.5	20	122	0.70	0.50
B-12	15								0.50
B-12	17	86	30	56	99.0	33			0.83
B-12	19					33	122	0.86	0.92
B-12	24					24			
B-12	29	92	31	61	94.0	26	132	1.16	1.50
B-12	34					26			0.83
B-12	39	65	23	42	99.3	27	124	0.96	0.50
B-12	44				65.2	27			

Company Name: HVJ Associates, Inc.
Project: HAS 715E LOA-009 ARFF Station
Location: William P. Hobby Airport, Houston, Texas
Project Number: HG1710320.2.2

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Passing #200 Sieve	Moisture content (%)	Total Density (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-12	49					27			0.25
B-13	1	37	15	22	72.8	12			1.50
B-13	3								1.50
B-13	5					18			0.92
B-13	7	44	15	29	69.9	17	137	1.34	1.17
B-13	9					17			1.50
B-13	11					23	132	0.79	0.83
B-13	13	37	18	19	90.0	27			0.67
B-13	15								0.83
B-13	17	85	30	55	95.4	37	118	0.66	0.58
B-13	19					26			1.00
B-13	24	52	21	31	86.6	23	125	1.33	1.33
B-13	29					23			1.50
B-13	34	57	23	34	98.8	31			
B-13	39					26			0.75
B-13	44	27	18	9	97.2	25			
B-13	49					28			
B-14	1								1.00
B-14	3	35	18	17	67.4	13			0.67
B-14	7					19			0.50
B-14	9	33	18	15	76.0	26			0.08
B-14	11								0.33
B-14	13	42	21	21	98.4	27			0.25
B-14	15					30			0.42
B-14	17	80	30	50	98.2	37			0.75
B-14	19					22	140	0.98	0.67
B-14	24					32			
B-14	29				91.8	29			
B-14	34					36			
B-14	39					26	135	0.93	1.00
B-14	44	33	21	12	99.2	26			0.33
B-14	49					28			
B-15	1	67	21	46	81.0	23			0.83
B-15	3					23	129	1.20	0.92
B-15	5					20			0.50
B-15	7	49	20	29	60.0	19			0.92
B-15	9					20			0.67
Total		**58**	**58**	**58**	**64**	**128**	**35**	**35**	**126**

APPENDIX C

LIME SERIES TEST RESULTS

HVJ
ASSOCIATES

Houston
Austin
Dallas
San Antonio

6120 S. Dairy Ashford Rd.
Houston, TX 77072-1010
281.933.7388 Ph
281.933.7293 Fax
www.hvj.com

Estimate of Soil-Lime Proportion using pH ASTM D-6276

PROJECT: **HAS 715E LOA-009 ARFF Station**

REPORT DATE : 9/20/2020

PROJECT NO: HG1710320.2.2

REPORT NO. :

LOCATION : Boring B-1 at (0'-2')

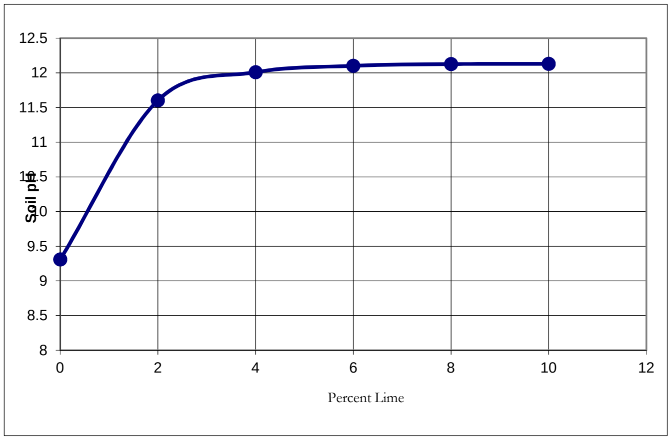
SAMPLE NO. :

TYPE OF MATERIAL: Gray & Reddish Brown Sandy Lean Clay

SAMPLED BY :

LIME CURVE
ASTM D-6276
(Soil pH vs Percent of Lime)

Percent of Lime	0	2	4	6	8	10
Soil pH	9.3	11.6	12.0	12.1	12.1	12.1



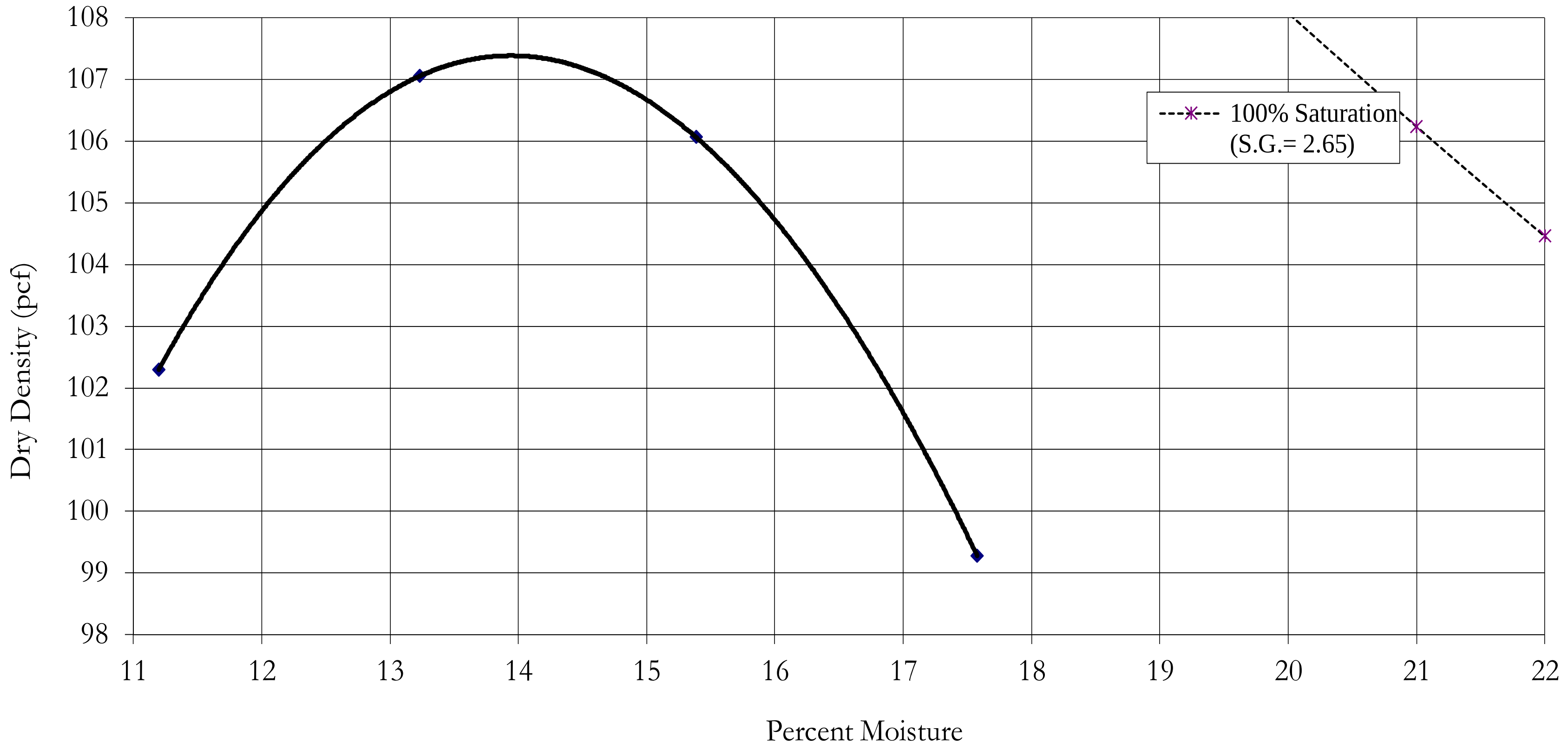
SAMPLE DESCRIPTION: GRAY & REDDISH BROWN SANDY LEAN CLAY

MIN. % LIME ESTIMATED: 6%

APPENDIX D

STANDARD PROCTOR AND CBR TEST RESULTS

METHOD OF TEST ☑ STANDARD ASTM D-698 ☐ MODIFIED ASTM D-1557



DATE TESTED: 6/9/20
TYPE OF MATERIAL : Gray and Brown Lean Clay w/ Sand
MAXIMUM DRY DENSITY : 107.4 pcf
OPT. MOISTURE CONTENT : 14%

LIQUID LIMIT : 36
PLASTICITY INDEX : 22
-200 SEIVE % : 71.3

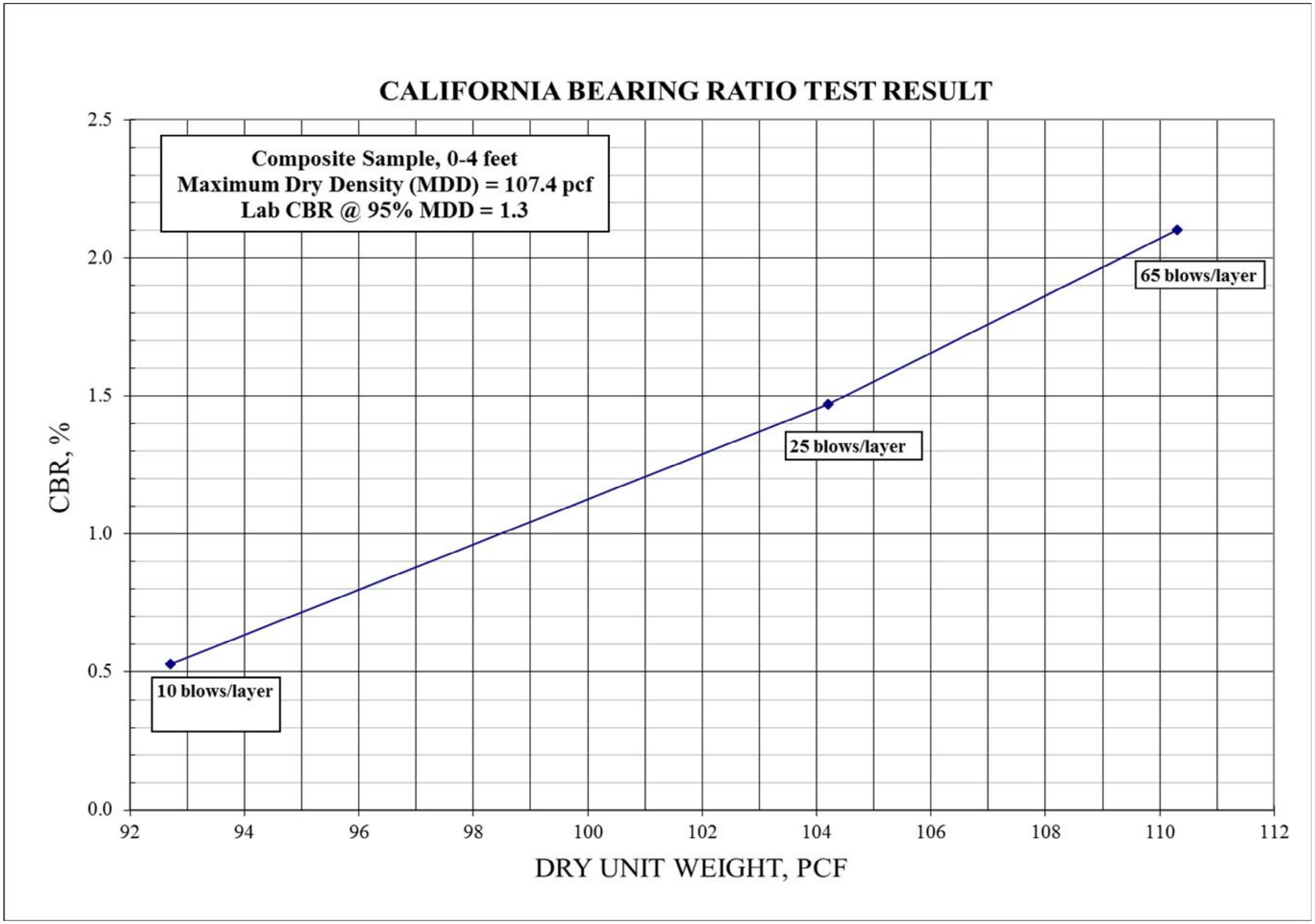
HVJ ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 08/19/2020
APPROVED BY: RS
PREPARED BY: PD

PROCTOR TEST RESULTS
HAS 715E LOA-009 ARFF STATION PROJECT

PROJECT NO.: HG1710320.2.2
DRAWING NO.: PLATE D-1



HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 08/19/2020	APPROVED BY: RS	PREPARED BY: PD

CBR TEST RESULTS
HAS 715E LOA-009 ARFF STATION PROJECT

PROJECT NO.: HG1710320.2.2	DRAWING NO.: PLATE D-2

CBR (CALIFORNIA BEARING RATIO) OF LABORATORY COMPACTED SOILS
ASTM D-1883

Project: HAS 715E LOA-009 ARFF Station Project

Sample Location: Composite, 0-4 feet

Liquid Limit: 36 **Plastic Limit:** 14 **Plasticity Index:** 22

Method of Compaction: ☒ ASTM D698
☐ ASTM D1557

Sample Condition: ☒ soaked ☐ unsoaked

No. of Blows:	**10**	**25**	**65**
Dry Density Before Soaking (pcf):	92.7	104.2	110.3
Dry Density After Soaking (pcf):	88.5	96.8	103.9
Moisture Content:			
Before Compaction (%):	14.3	15.0	12.9
Top 1-inch Layer After Soaking (%):	33.3	28.0	25.3
Swell (%):	2.9	2.6	2.3
Bearing Ratio (%): (☒ soaked ☐ unsoaked)	0.53	1.47	2.10

Surcharge: 10 lbs.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

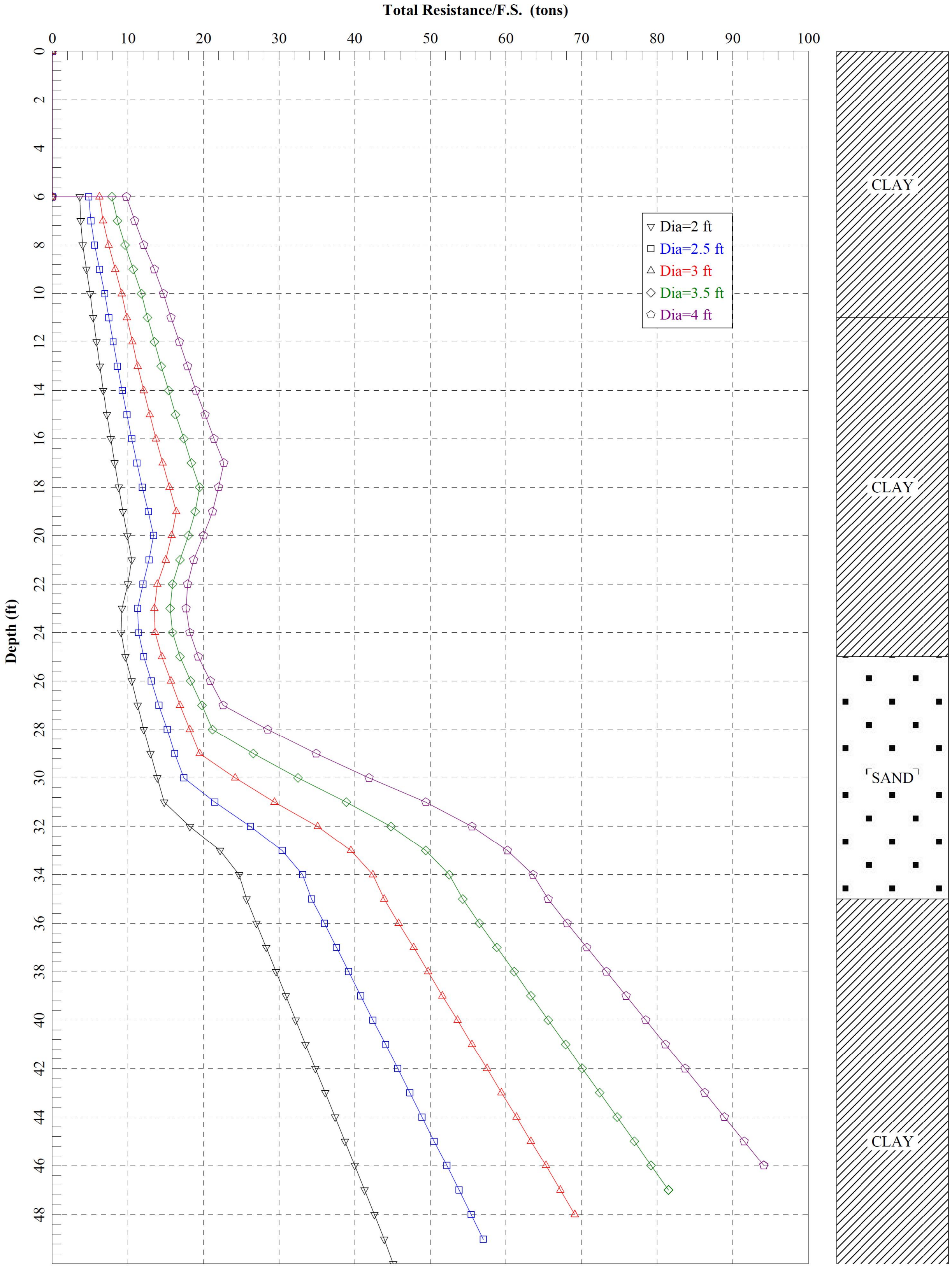
DATE: 08/19/2020	APPROVED BY: RS	PREPARED BY: PD

CBR TEST RESULTS
HAS 715E LOA-009 ARFF STATION

PROJECT NO.: HG1710320.2.2	DRAWING NO.: PLATE D-3

APPENDIX E1

DRILLED SHAFT CAPACITY CURVES



Note:

* Allowable axial compressive capacity was calculated by applying a factor of safety of 2 to the ultimate skin friction and a factor of safety of 3 to the ultimate tip resistance.

* Depth is from the existing grade level at the shaft locations.

* Skin friction contributed in the top 5 feet is ignored to account for construction disturbances.

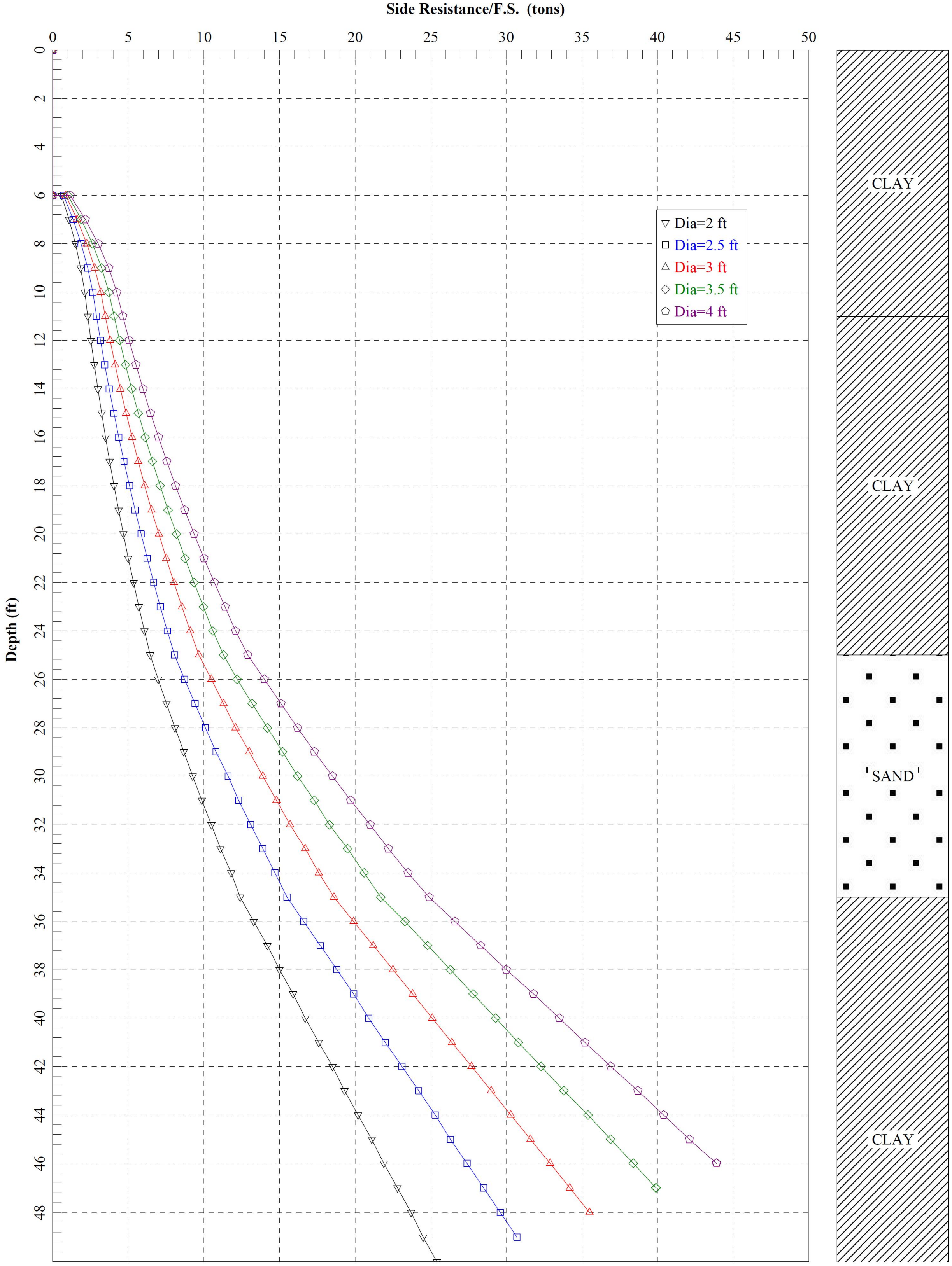
HVJ ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 9/16/2020	APPROVED BY: RS	PREPARED BY: PD

ALLOWABLE COMPRESSIVE CAPACITY
OF DRILLED SHAFTS – ARFF NO. 81

PROJECT NO.: HG1710320.2.2	DRAWING NO.: PLATE E1-1



Note:

* Allowable uplift capacity was calculated by applying a factor of safety of 3 to the ultimate skin friction.

* Depth is from the existing grade level at the shaft locations.

* Skin friction contributed in the top 5 feet is ignored to account for construction disturbances.

HVJ ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

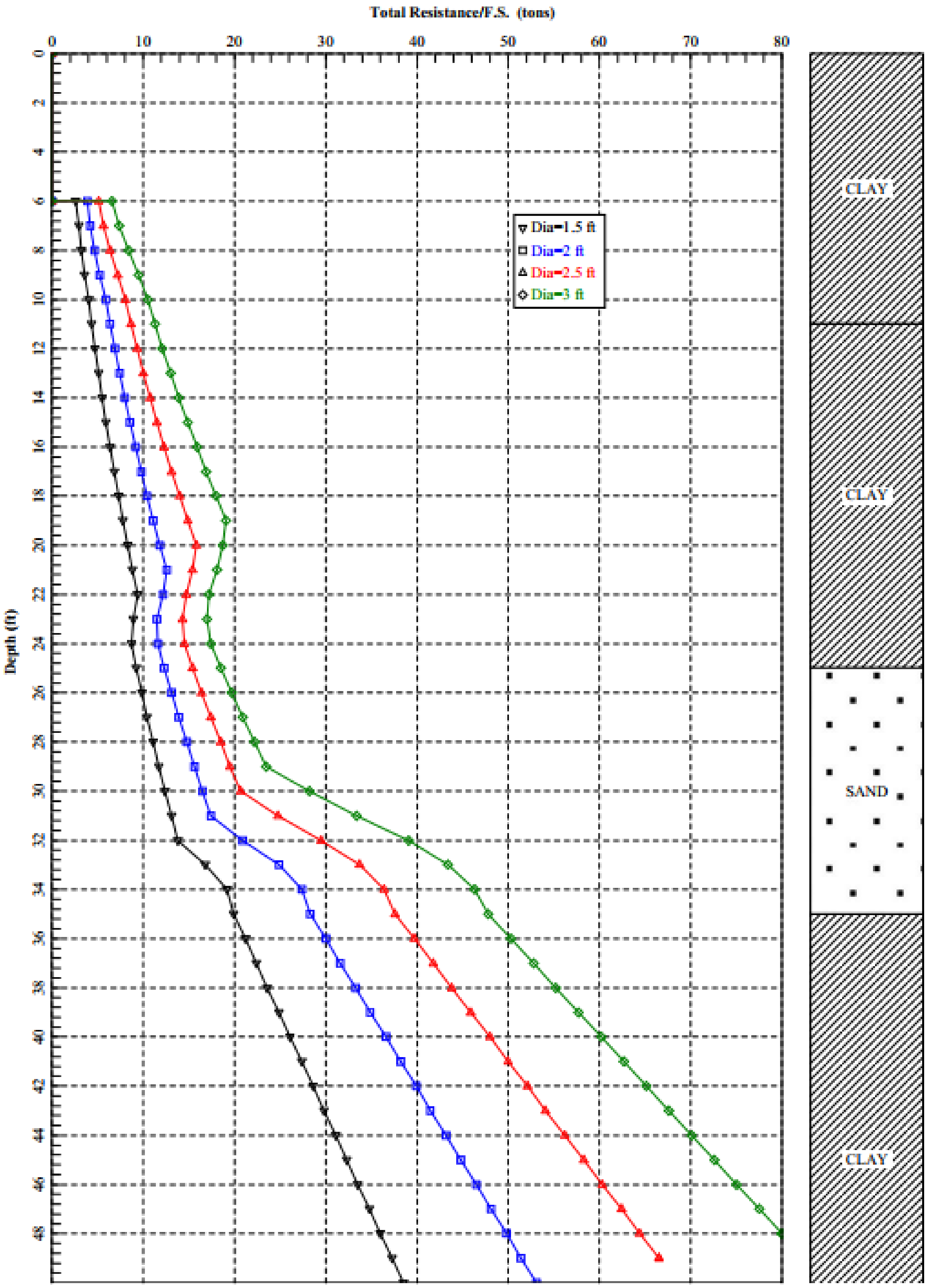
DATE: 9/16/2020	APPROVED BY: RS	PREPARED BY: PD

ALLOWABLE UPLIFT CAPACITY
OF DRILLED SHAFTS – ARFF NO. 81

PROJECT NO.: HG1710320.2.2	DRAWING NO.: PLATE E1-2

APPENDIX E2

AUGER CAST PILE CAPACITY CURVES



Note:

* Allowable axial compressive capacity was calculated by applying a factor of safety of 2 to the ultimate skin friction and a factor of safety of 3 to the ultimate tip resistance.

* Depth is from the existing grade level at the pile locations.

* Skin friction contributed in the top 5 feet is ignored to account for construction disturbances.

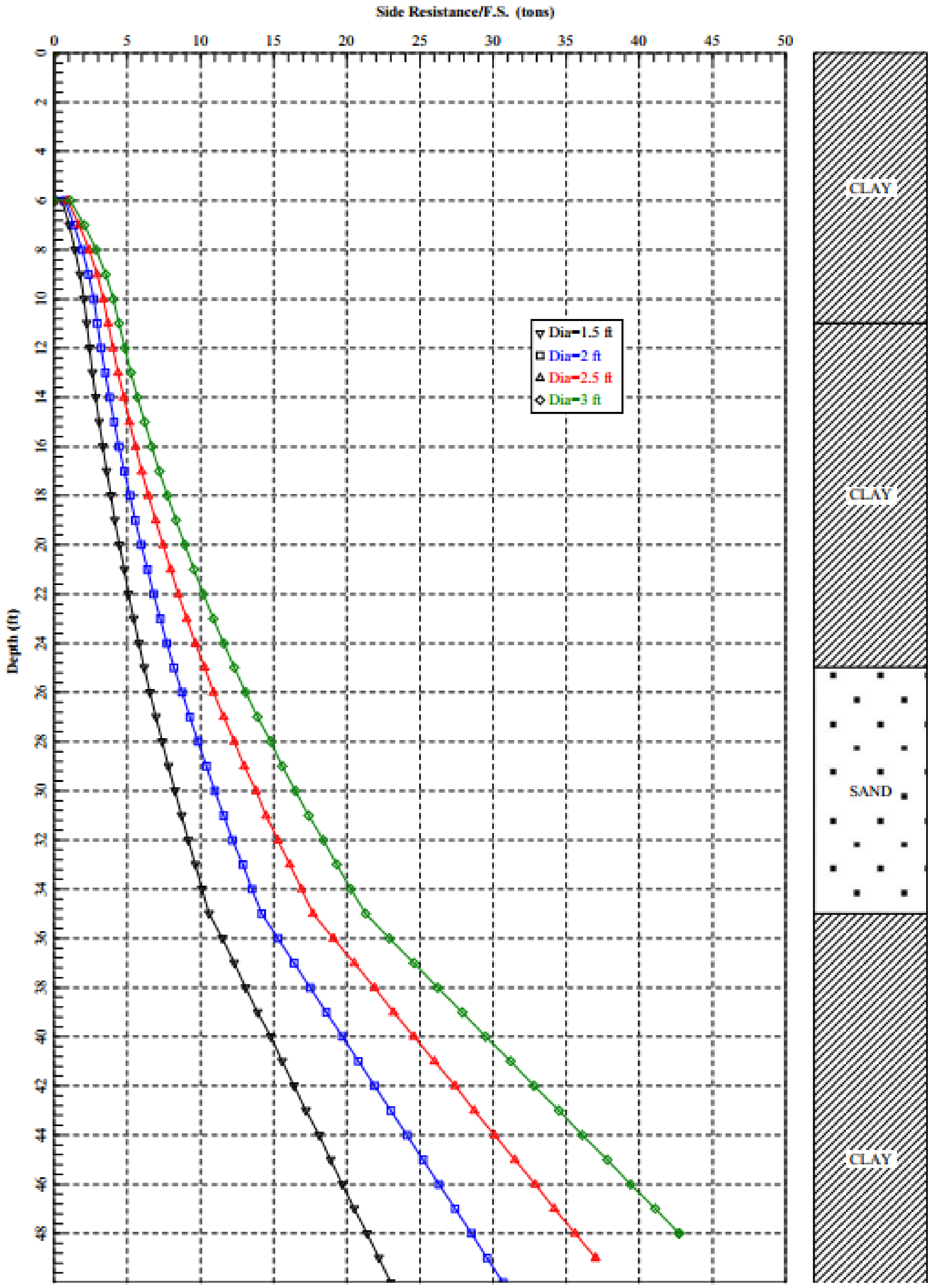
HVJ
ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 9/23/2020	APPROVED BY: RS	PREPARED BY: PD

ALLOWABLE COMPRESSIVE CAPACITY
OF DRILLED SHAFTS – ARFF NO. 81

PROJECT NO.: HG1710320.2.2	DRAWING NO.: PLATE E2-1



Note:

* Allowable uplift capacity was calculated by applying a factor of safety of 3 to the ultimate skin friction.

* Depth is from the existing grade level at the pile locations.

* Skin friction contributed in the top 5 feet is ignored to account for construction disturbances.

HVJ ASSOCIATES

6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 9/23/2020

APPROVED BY: RS

PREPARED BY: PD

ALLOWABLE UPLIFT CAPACITY
OF AUGER CAST PILES – ARFF NO. 81

PROJECT NO.: HG1710320.2.2

DRAWING NO.: PLATE E2-2

APPENDIX F

L-PILE PARAMETERS

Project Name: HAS 715E LOA-009 ARFF Station
Project Location: William P. Hobby Airport, Houston, Texas
Project Number: HG1710320.2.2

Boring No.	Groundwater Depth in feet	LPILE Parameters						
		Depth (feet)	P-Y Curve Model	Total Unit Weight (pcf)	Undrained Cohesion, Su (psf)	Friction Angle, ϕ (deg)	Static Modulus of Subgrade Reaction	Strain Factor, ε_{50}
B-3, B-4, B-5, B-7, B-10, B-12, B-13 & B-14	8	0 to 11	Mod. Stiff Clay Without Free Water	125	1000	-	100	0.01
		11 to 25	Soft Clay (Matlock)	125	-	-	500	0.02
		25 to 35	Sand (Reese)	120	-	28	20	-
		35 to 50	Mod. Stiff Clay Without Free Water	125	1500	-	500	0.007

APPENDIX G

PAVEMENT DESIGN REPORT

PAVEMENT DESIGN REPORT
AIRCRAFT RESCUE AND FIRE FIGHTING STATION (ARFF) #81
HOUSTON HOBBY AIRPORT (HOU)
HOUSTON, TEXAS

SUBMITTED TO
JACOBS
5985 Rogerdale Road
Suite 900
Houston, TX 77072

BY
HVJ ASSOCIATES, INC.
Austin, Texas
September 11, 2020

FOR
HOUSTON AIRPORT SYSTEM (HAS)
Houston, Texas

REPORT NO. HG 17 10320.2.2

HVJ ASSOCIATES

1701 Directors Boulevard, Suite 910
Austin, Texas 78744
737-222-5151
www.hvj.com

September 11, 2020

Ms. Laura Zarea, LEED AP BD+C, Project Manager
Buildings, Infrastructure & Advanced Facilities
Jacobs
5985 Rogerdale Road
Houston, Texas 77072

Re: Pavement Design Report
Aircraft Rescue and Fire Fighting (ARFF) Station #81
Hobby Airport (HOU)
Houston, Texas
Owner: Houston Airport Systems (HAS)
HVJ Report No.: HG1710320.2.2

Dear Ms. Zarea:

Submitted herein is the final report of our pavement design report for the above referenced project. The study was performed in accordance with HVJ Proposal Number HG1710320.2.2 dated August 19, 2019 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

R. F. (Frank) Carmichael III, PE
Senior Project Manager

Copies submitted: 1 (electronic)

The seal appearing on this document was authorized by R. F. Carmichael III, PE 43815 on September 11, 2020. Alteration of a sealed document without proper notification to the responsible engineer is an offense under the Texas Engineering Practice Act. It is not to be used for construction, bidding or permit purposes.

TABLE OF CONTENTS

Exhibits

1. GENERAL PROJECT INFORMATION

The project involves reconstruction of the firetruck driveway for the Aircraft Rescue and Fire Fighting (ARFF) Station #81 at Houston Hobby Airport (HOU) and the employee parking lot located on Paul B. Koonce Street and west of Randolph Street in Houston, Texas. Based on the estimated traffic data, subgrade information and other pavement thickness design inputs, HVJ designed the following section options which is presented further in this report.

- ARFF firetruck driveway:
    - PCC Over Hot Mix Asphalt Concrete (HMAC) Base
    - PCC Over Cement Treated Base (CTB)

- Employee parking:
    - PCC
    - Hot Mix Asphalt Concrete (HMAC)

The DARWin[1] computer program, based on the 1993 AASHTO Pavement Design Guide[2], was used for the pavement thickness design. The City of Houston Standard Specifications[3] were followed for the local pavement design standards. The design inputs required include design and performance constraints, traffic estimates, pavement construction material strength inputs, and insitu subgrade soil strength. The pavement evaluation and design results are summarized in following paragraphs.

2. SUBGRADE STRENGTH ESTIMATION

Based on the general soil classification for the subgrade in the project borings as shown in the Geotechnical Investigation Report[4], the site generally consists of low plasticity sandy cohesive soil and cohesionless soil within top 5 feet. The summary of geotechnical test results is shown in the table below. It was seen that the average plasticity index of the soil found in the project area was 25.6 with percentage passing sieve No. 200 to be 69.1%.

Table 2-1: Laboratory Test Results for Subgrade Soil

Boring	Plasticity Index	% Passing #200	Soil Type
B-1	20	62.4	CL
B-2	25	54.9	CL
B-3	19	71.3	CL
B-4	25	61.6	CL
B-5	25	65.8	CL
B-6	-	-	-
B-7	16	71.1	CL

---

[1] AASHTOWare DARWin 3.1 – American Association of State Highway and Transportation Officials, 1991-2009

[2] AASHTO Design of Pavement Structures, American Association of State Highway and Transportation Officials, 1993.

[3] Standard Construction Specifications, City of Houston Department of Public Works and Engineering, 2017

[4] Geotechnical Investigation, ARFF # 81 at Houston Hobby (HOU), HVJ Associates®, September 2020 (Draft)

Boring	Plasticity Index	% Passing #200	Soil Type
B-8	-	-	-
B-9	-	-	-
B-10	24	74	CL
B-11	44	73.1	CH
B-12	24	74.2	CL
B-13	22	72.8	CL
B-14	17	67.4	CL
B-15	46	81	CH

As seen in the table, the subgrade is fine grained soil with very low to no cohesion. The presence of water in such subgrade soil can cause the fine material to be washed away creating premature pumping in the concrete pavement. For such subgrade soil, it is recommended that at least 6.0" of subgrade should be stabilized with cement to prevent occurrence of pumping and to provide a working platform for the construction.

In addition to the Atterberg Limits and sieve analysis, the California Bearing Ratio (CBR) test was conducted on the subgrade soil sample obtained from the site. The laboratory report[4] showed a CBR value of 1.47. The design subgrade strength was developed using the following correlation relationship between the resilient modulus of the subgrade soil and the CBR test result.

$$Resilient\ Modulus\ (R_M) = 1500 \times CBR \quad (\textit{For CBR<10, Heukelom and Klomp, 1962})$$

Using the above relationship, the resilient modulus of the subgrade was estimated as 2,205 psi. This value was consistent with the soil type found in the project area and was used as the design subgrade resilient modulus for the pavement design. The composite modulus of subgrade reaction for the firetruck driveway was calculated using AASHTO DARWin[1] with a 4.0" of HMAC base layer and 6.0" CTB layer, with the assumed resilient modulus values of 500 ksi and 150 ksi, respectively. Both base options had loss of support of 0[2], which rendered values of 182 pci and 193 pci, respectively. Further, in the case of staff parking area, with the 6.0" of cement stabilized subgrade and a recycled crushed concrete base with assumed resilient modulus of 50 ksi and loss of support of 1[2], the composite modulus of subgrade reaction was calculated as 59 pci.

3. TRAFFIC DATA

The traffic parameters required for design include initial average daily traffic (ADT), ADT growth rate, directional and lane distribution factors, percent trucks in ADT, and average 18-kip equivalent truck factor. Based on the traffic information provided and some general assumptions, the traffic inputs were developed for the design purpose.

The types of vehicles in the average annual daily traffic (AADT) for the firetruck driveway and staff parking were provided to HVJ by Jacobs. The number of movements per day was not provided, so HVJ assumed the following daily movements, loaded weights and equivalent single axle loads (ESALs) per vehicle pass.

Vehicle Type	Gross Vehicle Weight, kips	Assumed Movements per Day, AADT	Equivalent Single Axle Loads (ESALs) per pass
Small/Fleet Vehicles (Suburban) – FHWA Class 3	7.5	6	0.002
Special Vehicles (Triage Trailer, Emergency Stairs, EMS Van Type 1) – FHWA Class 5	15.0	3	0.64
Airport Rescue and Fire Fighting (ARFF) Units (2006, 2016, 2019 Rosenbauer) – FHWA Class 6	85.0	6	22.00

After reassessing suggestions made by Jacobs and the number of parking spaces, HVJ assumed that the ARFF vehicle will have a turnover of 6 times. In case of the staff parking, the percentage trucks is assumed as 10% of ADT considering occasional emergency vehicles and fire lanes.

The heaviest vehicle (Rosenbauer) was assumed to have 65% (54.7 kips) of the load on the heaviest axle with the tandem axle and 35% (29.5 kips) load on one single axle. The rigid pavement projected slab thickness of 10 inches and terminal serviceability index of 2.5 was assumed to estimate the truck factor using the tables in the 1993 AASHTO Pavement Design Guide. The table below shows the design assumptions.

Table 3-1: Basic Traffic Data – Fire Truck Driveway

Parameter	AARF Vehicle
AARF Vehicle Gross Load	84.2 kips
Number of axles	3
Single Axle	29.5 kips
Tandem Axle	54.7 kips
Terminal Serviceability	2.5
Projected Slab thickness	10"
Truck factor	22*
ADT	6
Percentage truck ≥ Class 5	100%

* Values were referred from AASHTO Design Guide, 1993

In case of the staff parking area with occasional fire trucks being of similar gross weight category, the truck factor of 1.2 was assumed with the combined single and tandem axle.

The equivalent single axle load repetitions (ESALs) was calculated using AASHTO DARWin for the design using 0% growth factor and 50 year design life. The ESAL calculated for the design of Aircraft Rescue and Fire Fighting (ARFF) Station was 2,410,650 and that for the staff parking area was 6,312.

4. DESIGN CRITERIA AND PERFORMANCE CONSTRAINTS

A rigid pavement option was designed with the DARWin computer program for the anticipated traffic levels previously described. The confidence level used for the designs is 90%. The performance period is 50 years for the ARFF Firetruck Driveway. The initial serviceability index is set at 4.5. The terminal serviceability index is set at 2.5, which is appropriate for low traffic volume less than 3,000 average daily traffic (ADT).

HVJ recommends an HMAC base to be placed beneath the PCC surface for the Aircraft Rescue and Fire Fighting (ARFF) Driveway due to heavy truck loads. The HMAC base directly under concrete would behave as a non-erodible material that will not pump subgrade fines through the concrete joints and also behave as a moisture barrier to minimize moisture fluctuations in the subgrade that may cause shrink/swell conditions.

The initial serviceability index and the final serviceability index of the concrete pavement was assumed as 4.5 and 2.5 respectively. The 28-day modulus of elasticity of 2.6×10^6 psi was assumed for the jointed cement concrete. Reliability of 90% was used for design. The load transfer coefficient was assumed as 2.9 for a JRCP with no tied shoulder, and the drainage coefficient was assumed as 0.8. The HMAC base modulus for design was assumed at 500 ksi with depth to the bed rock at 100 ft.

5. DESIGN RESULTS

The DARWin design outputs for the Aircraft Rescue and Fire Fighting (ARFF) Station are included in Exhibit A of this report. The resulting 50-year pavement design options for Aircraft Rescue and Fire Fighting (ARFF) Driveway and the 20-year design options for the employee parking lot are as follows.

ARFF Driveway Concrete Pavement Design: 50 year service life

Site	HMAC Base Option	Cement Treated Base Option
ARFF #81	▪ 9.0" Concrete Reinforced with #4 bars at 12.5" O.C.B.W. ▪ 4.0" HMAC Base Type A or Type B ▪ 8.0" Cement Treated Subgrade (estimate 8% cement)	▪ 9.0" Concrete Reinforced with #4 bars at 12.5" O.C.B.W. ▪ 6.0" Cement Treated Base ▪ 8.0" Cement Treated Subgrade (estimate 8% cement)

Employee Parking Lot Concrete and Flexible Pavement Designs: 20 year service life

Site	HMAC Option	PCC Option
Parking Lot	▪ 3.0” DG TY C (PG70-22) ▪ 6.0” Recycled Crushed Concrete Base ▪ 8.0” Cement Treated Subgrade (est. 8% cement)	▪ 6.0” PCC* ▪ 6.0” Recycled Crushed Concrete Base ▪ 8.0” Cement Treated Subgrade (est. 8% cement)

- **Since the calculated PCC design is less than the COH minimum, HVJ recommends the minimum thickness of 6”**

Material Specifications – City of Houston Material Specifications

- Item No. 20338 – Cement Stabilized Subgrade
- Item No. 02713 – Recycled Crushed Concrete Base Course
- Item No. 02742 – Prime Coat
- Item No. 02743 – Tack Coat
- Item No. 02741 – Hot Mix Asphaltic Concrete Pavement (HMA)
- Item No. 02751 – Concrete Pavement

The concrete pavement is recommended to be Jointed Reinforced Concrete Pavement (JRCP). The reinforcement and dowel bar details will be followed as per City of Houston Concrete Pavement Details – 02751-01, and Joint Details – 02752-01. Minimum required reinforcing steel strength shall be 60,000 psi

6. PREPARATION OF SUBGRADE

The surficial soils underlying the existing pavement consist of lean clays. HVJ recommends stabilizing the top 8 inches of subgrade soil beneath the base with cement as per City of Houston specification for Cement Stabilized Subgrade - 20338. Stabilization of the subgrade will increase the modulus of subgrade reaction and provide subgrade stability for construction during inclement weather. Subgrade stabilization will enhance long-term pavement performance by reducing the tendency of the soil to displace from beneath pavement by pumping. HVJ recommends the following procedures for subgrade preparation.

1. Clear the proposed development area of existing pavement, and foreign material within the proposed area to the grade required.

2. Surfaces exposed after excavation should be proof-rolled in accordance with COH specification. If rutting develops, tire pressures should be reduced. The purpose of the proof-rolling operation is to identify any underlying zones or pockets of weak pavement/base materials.

3. For estimating purposes for cement stabilization, 8.0% cement per dry unit weight of soil may be assumed for cement stabilization as per COH – 02338. HVJ recommends the

cement percentage amount should be verified by laboratory testing prior to stabilization to confirm the appropriate percentage of cement during the time of construction.

7. LIMITATIONS

This study was performed for the exclusive use of Jacobs and Houston Airport Systems for specific application to the Aircraft Rescue and Fire Fighting (ARFF) Station #81 at Houston Hobby Airport. 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 conditions.

In the event that any changes in the nature, design, or location of the improvements are made, the conclusions and recommendations in this report should not be considered valid until the changes are reviewed and the conclusions and recommendations modified or verified in writing by HVJ Associates.

EXHIBIT A

DARWIN OUTPUTS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Rigid Structural Design Module

ARFF Fire Truck Driveway
ARFF # 81 Hobby Airport (HOU)

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	2,410,650
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	601 psi
28-day Mean Elastic Modulus of Slab	2,587,500 psi
Mean Effective k-value	182 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.9
Overall Drainage Coefficient, Cd	0.8
Calculated Design Thickness	8.76 in

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

ARFF Fire Truck Driveway
ARFF # 81 Hobby Airport (HOU)

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	2,205	500,000

Base Type	HMAC
Base Thickness	4 in
Depth to Bedrock	100 ft
Projected Slab Thickness	10 in
Loss of Support Category	0
Effective Modulus of Subgrade Reaction	182 psi/in

Simple ESAL Calculation

Performance Period (years)	50
Two-Way Traffic (ADT)	6
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	100 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	100 %
Average Initial Truck Factor (ESALs/truck)	22
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	0 %
Growth	Compound
Total Calculated Cumulative ESALs	2,410,650

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

ARFF Fire Truck Driveway
ARFF # 81 Hobby Airport (HOU)

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	2,410,650
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	601 psi
28-day Mean Elastic Modulus of Slab	2,587,500 psi
Mean Effective k-value	193 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.9
Overall Drainage Coefficient, Cd	0.8
Calculated Design Thickness	8.72 in

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

ARFF Fire Truck Driveway
ARFF # 81 Hobby Airport (HOU)

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	2,205	150,000

Base Type	Cement Treated Base
Base Thickness	6 in
Depth to Bedrock	100 ft
Projected Slab Thickness	10 in
Loss of Support Category	0
Effective Modulus of Subgrade Reaction	193 psi/in

Simple ESAL Calculation

Performance Period (years)	50
Two-Way Traffic (ADT)	6
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	100 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	100 %
Average Initial Truck Factor (ESALs/truck)	22
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	0 %
Growth	Compound
Total Calculated Cumulative ESALs	2,410,650

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

Parking Lot
ARFF # 81 Hobby Airport (HOU)

CSJ: 0918-47-240

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	6,312
Initial Serviceability	4
Terminal Serviceability	2.5
Reliability Level	90 %
Overall Standard Deviation	0.39
Roadbed Soil Resilient Modulus	2,205 psi
Stage Construction	1
Calculated Design Structural Number	2.35 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	72
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	10 %
Percent Trucks in Design Direction	100 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	10 %
Average Initial Truck Factor (ESALs/truck)	1.2
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	0 %
Growth	Compound
Total Calculated Cumulative ESALs	6,312

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Hot Mix Asphalt Concrete	0.44	1	3	12	1.32
2	Recycled Crushed Concrete Base	0.14	1	6	12	0.84
3	Cement Stabilized Subgrade	0.06	1	8	12	0.48
Total	-	-	-	17.00	-	2.64

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

Parking Lot
ARFF # 81 Hobby Airport (HOU)

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	6,312
Initial Serviceability	4
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	601 psi
28-day Mean Elastic Modulus of Slab	2,587,500 psi
Mean Effective k-value	59 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.9
Overall Drainage Coefficient, Cd	0.8
Calculated Design Thickness	3.20 in

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

Parking Lot
ARFF # 81 Hobby Airport (HOU)

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	2,205	50,000

Base Type	Recycled Crushed Concrete Base
Base Thickness	6 in
Depth to Bedrock	100 ft
Projected Slab Thickness	4 in
Loss of Support Category	1
Effective Modulus of Subgrade Reaction	59 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	72
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	10 %
Percent Trucks in Design Direction	100 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	10 %
Average Initial Truck Factor (ESALs/truck)	1.2
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	0 %
Growth	Compound
Total Calculated Cumulative ESALs	6,312