

**REPORT**  
**SUBSURFACE SOIL INVESTIGATION**  
**WIND TURBINE PILOT PROJECT**  
**YONA, GUAM**

*Prepared for*  
**TRC ENVIRONMENTAL CORPORATION**  
**708 HEARTLAND TRAIL, SUITE 3000**  
**MADISON, WISCONSIN 53717**

*By*  
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**15 July 2014**

**310.01**

## INTRODUCTION

This geotechnical report presents the results of the subsurface soil investigation performed for the Wind Turbine Pilot Project in Yona, Guam.

The proposed wind turbine will be 233 feet high, and will be located at the previous site of the 197-foot high meteorological tower.

As requested by the client, we performed a subsurface exploration at the project site, and laboratory testing assigned by the client, in order to provide the following information and recommendations:

1. General subsurface conditions at the project site (based on the test boring information obtained from the site).
2. Site geology, seismicity, and seismic site class determination.
3. Recommended design parameters for soil or rock layers encountered, including unit weight (dry density), and design unconfined compressive strength for both soil and rock.
4. Corrosivity test results of soil sample from the upper 5 feet below the existing surface.

## REGIONAL GEOLOGY

Guam is the southernmost, largest island located in the curved-shaped Mariana Islands chain. The islands sit atop the Marianas Ridge, above the deep ocean floor. Located 110 kilometers (68.3 miles) southeast of Guam is the Marianas Trench. The trench was formed approximately along the submerged surface trace of a westward dipping discontinuity in the oceanic crust, referred to



as a subduction zone. Rocks constituting the crust of the Pacific Basin are being thrust-under the Mariana Ridge; and in the process the ridge is being thrust upwards. Ridge formation has also been contributed by submarine volcanism, starting in Eocene geologic time (about 50 million years ago). Volcanism continued only through the Miocene geologic epoch (ending approximately 5 million years ago) on Guam and continues to the present in the Mariana Islands.

Geological formations on Guam are both of volcanic and organic origin, consisting predominantly of volcanic sediments and coralline limestone. The coralline limestone ranges in age from Miocene era through the present and is principally made of Mariana limestone from the Pliocene and Pleistocene age. The limestone has been deposited upon the crest and upper flanks of the volcanic ridge. Compared to the thousands of meters of the underlying volcanic rocks, the limestone represents a relatively thin surface capping layer.

Faulting and tilting of the rocks comprising the island system has occurred concurrently with volcanism and limestone deposition. All of the faults mapped on Guam are of relatively high angle, normal faults, and most have produced relatively small displacements of rocks over short distances. Greater displacements on the order of a few hundred feet have occurred on the northwest; striking Adelup Fault, dividing the northeast limestone plateau from the principally volcanic southwest portion of the island. In general, most faults occur in the volcanic rocks and do not penetrate upwards and displace the overlying limestone. Some faults do, however, occur in the limestone plateau and displace the Pleistocene era Mariana limestone. The Adelup Fault has displaced

the Mariana limestone against the Alutom volcanic formation; thus indicating that the fault has been active at least up until mid-Pleistocene time. The Adelup Fault lies in the Ordot-Asan village area, which is approximately in the middle portion of Guam Island, and is about 5 to 6 kilometers (3.1 to 3.7 miles) from the project site.

Late Pleistocene displacements are inferred on the basis of apparent small uplifts of the island, as indicated by raised reefs in the range of a few meters above present sea level. Tracy and others (1964)<sup>1</sup> indicate that "In some places on jointed headlands, the 2-meter (6.6-foot) dip is slightly displaced and in a few places minor faults with displacements of about 1.5 to 3 meters (5 to 10 feet) cut the reef margin; however, no significant movements of the island of Guam appear to have taken place since the late Pleistocene". Thus, from a seismic or earthquake risk standpoint, the island of Guam is in an active seismic belt; however, significant earthquakes are from movements of the deep seated, under-thrust faulting. One or more of the faults visible on the island, such as the Adelup Fault, have been active during the Holocene time (approximately last 11,000 years), but the displacement appears to have been small. Based on current knowledge, none of these relatively shallow seated faults has produced significant magnitude earthquake; the probability of surface displacement in the near future appears to be small.

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<sup>1</sup> Tracey, J.I., S.O. Schlanger, J.T. Stark, D.B. Doan, H.G. May (1964), "*General Geology of Guam*," USGS Professional Paper 403-A, U. S. Government Printing Office, Washington, D.C.



## SITE GEOLOGY

Based on the published information (Tracey and others, 1964), the site is underlain by only one distinct major rock unit which is the Alutom formation, a well-bedded, fine- to coarse-grained, generally gray, green, and brown tuffaceous shale, siltstone, and sandstone. Lenses of fine- to coarse-grained, tuffaceous foraminiferal limestone, pyroclastic conglomerate containing limestone fragments, interbedded with lava flows. Maximum thickness of the Alutom formation exceeds 2000 feet.

## SEISMICITY

Tracy and others (1964) have compiled a list of significant earthquakes on Guam extending back to April 1825. Between 1825 and 1936, there were 19 strongly felt or damaging earthquakes on Guam with Modified Mercalli intensities estimated in the range of VI to IX. The largest documented earthquake in Guam occurred on September 22, 1902, with an Modified Mercalli intensity of IX; Richter (1958) reports the magnitude as 8.1 and the epicenter at latitude 18 North and longitude 146 East, which is about in the vicinity of Pagan Island north of Guam. It is reported to have caused many landslides in the mountainous areas of Guam. Another significant earthquake occurred on January 25, 1849, producing Modified Mercalli intensities up to IX.

Gutenberg and Richter (1954) report earthquakes between 1904 and 1950; four of these are significant occurring in 1912, 1932, and October and

November 1936, magnitudes were in the range of 6 to 7 and focal depths were in the range of 60 to 170 kilometers (37 to 106 miles). In October of 1936, a severe earthquake with Richter magnitude of 7.7 occurred about 125 kilometers (78 miles) southwest of Guam, with no severe damage reported.

The more recent earthquake magnitudes have been in the range of 6 to 7 on the Richter scale, with epicenter depths reported as approximately 113 kilometers (70 miles), centered from several to tens of kilometers north of Guam. All of the significant earthquakes for which focal depth estimates are available indicate that the active zone is the under-thrust type associated with the subduction zone, which is believed to dip eastward at about 45 degrees beneath the island.

In more recent times from 1975 to 1983, three significant earthquakes of Richter magnitude of 5.2 to 7.1 were recorded, with epicenters located about 20 to 40 kilometers (12.5 to 25 miles) north of Guam. Several buildings suffered damage; but all were repairable.

The most recent time on August 8, 1993, a major earthquake of 8.1 Richter magnitude, with an epicenter located at about 60 kilometers (37.3 miles) south of the island of Guam, caused no reported direct loss of lives. There were two 8- to 9-story buildings that suffered severe damage. This damage was attributed to poor construction and insufficient reinforcement. During this earthquake, Sierra Wharf at the main Naval Base suffered deck collapse as a result of underlying soil liquefaction. The wharf, underlain with man-made fill placed over mostly relatively loose to medium dense silty sandy soils with coral



fragments to significant depths. Other naval wharves in the same general vicinity suffered only minor damages.

Although there were three strong-motion accelerogram instruments in place on Guam at the time of the August 1993 earthquake, no strong motions were recorded because all three instruments were not functioning. Dames & Moore (1994)<sup>2</sup> estimated the peak ground motion acceleration resulting from the August 1993 Guam earthquake to be 0.20 g.

## SUBSURFACE EXPLORATION

As requested, we drilled two test borings utilizing a truck-mounted drill rig with an 8-inch diameter hollow stem auger to drill within the upper soil layer above bedrock, and an air rotary drill rig was used to core the underlying hard volcanic rocks utilizing a 3-inch diameter Nx rock core barrel. Test Boring 1 was drilled at approximately the center of the proposed wind turbine foundation, and Test Boring 2 was drilled at a proposed anchor location. The approximate locations of the two test borings are shown on Plate 1, the site location map and the site map are shown on Figures 1 and 2.

During the subsurface exploration, our technical staff was at the site full-time logging the subsurface materials that were encountered in the test borings, obtaining the subsurface soil and rock samples for visual examination, field classification, and laboratory testing. The logs of the test borings are presented

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<sup>2</sup> Dames & Moore, "Earthquake Hazard Vulnerability Study, Guam, Mariana Islands", prepared for Government of Guam, December 1994.

on Plates 2 and 3. The Soil Classification Chart that was used for describing soils is shown on Plate 4.

The table below summarizes the test borings performed and their approximate depths, coordinates, and locations:

Test Boring No	Depth feet	Approximate Coordinates		Location
		Latitude	Longitude	
BH-1	48	13°23'21.3"	144°43'21.7"	Wind Turbine Foundation
BH-2	65	13°23'22.0"	144°43'21.6"	Anchor Location

We also conducted standard penetration tests (SPT) to obtain the standard blow counts or N-values of the underlying, undisturbed, subsurface soils in the test borings while obtaining the undisturbed subsurface soil and weak rock samples. The SPT or N-value is defined as the number of blows required to drive a standard 2-inch outside diameter, split-spoon soil sampler one foot or 12 inches into the underlying, undisturbed subsurface soil or weak rock, with a 140-pound drop weight free falling 30 inches per each blow hitting on to the soil sampler. An automatic drop hammer was used to determine the number of blows.

To obtain better undisturbed subsurface soil samples for laboratory testing, we used a larger, 3-inch outside-diameter, split barrel California Modified soil sampler, and the field blow counts later were converted into the SPT or N-values by multiplying the field blow counts with a correction factor of 0.68 to account for the larger diameter of the actual soil sampler used (based on a formula prepared by George F. Sowers in a late 1960's American Society of Civil



Engineers proceeding). The N-values obtained from the test borings are shown on the logs of the two test borings. The N-values are commonly used for empirically estimating the consistency and unconfined, compressive strength of soils.

To obtain the underlying bedrock samples, we used a 3-inch outside diameter Nx rock core barrel for rock coring in the underlying volcanic rock formation. During the rock coring, we recorded the drilling rates in minutes per foot of rock being cored, and recorded the Rock Quality Designation (RQD) of the cored rock samples. The standard penetration resistance N-values, drill rates and RQDs, are shown on the logs of the test borings at their respective depths. Photographs of the recovered rock cores are shown in Attachment B.

One bulk sample was extracted at a selected test boring location to obtain larger quantities of the near-surface soil, or the existing clayey silt within the upper 5 feet below surface in Test Boring 1. The bulk sample would be used to perform laboratory tests including laboratory compaction or moisture-density relations, and California Bearing Ratio (CBR).

## LABORATORY TESTING

The subsurface soil and rock samples gathered from the site were re-examined in our laboratory for editing the field classifications and selecting appropriate samples for testing. The tests performed included in-situ moisture content and dry density (unit weight), particle size distribution, liquid limit and

plasticity index, pH, unconfined compression test for both soil and rock, moisture-density relations (laboratory compaction), and California Bearing Ratio (CBR). The results of the laboratory tests are shown on the logs of the test borings where the tested samples were obtained, and on Plates 5 through 9. A Key to Test Data explaining the test name abbreviations is shown on Plate 4.

Corrosion Testing – Corrosion test samples were obtained in the upper 5-foot depth for testing at both test boring locations to determine the corrosivity of the soils at the site. The soils were tested in the laboratory for pH, chloride content, and sulfate. Both the chloride content and sulfate tests were performed in other laboratories; the chloride content was tested at the University of Guam laboratory, and the sulfate test samples were airfreighted and tested at the TRC Geotechnical Laboratory, the results of the tests are provided in Appendix A; the table below summarizes the test results:

Boring No.	Depth (feet)	pH	Remarks	Chloride Content (mg/l)	Remarks	Sulfate		
						Solids Content (%)	Soluble Sulfate (mg/kg as SO <sub>4</sub> )	Soluble Sulfate (%)
BH-1	0 - 5	5.4	<8.5 >4.0 Okay	19.4	<65 Okay	90	2,340	0.23
BH-2	3 – 3.5	5.8	<8.5 >4.0 Okay	12.0	<65 Okay	97	900	0.09

## SUBSURFACE CONDITIONS



The two test borings revealed similar subsurface conditions with variable depths of medium stiff to very stiff clayey silt ranged from approximately 18 feet to 40 feet thick in Test Borings 1 and 2, respectively, overlying generally hard tuff breccia of Alutom formation.

This residual soil which is reddish brown in the upper 2 to 3 feet becomes mottled reddish brown-black-yellow down to 18 feet and 40 feet from the existing ground surface. The soil samples obtained from the test borings were tested in the laboratory for moisture content, dry density (unit weight), liquid limit and plastic limit, and unconfined compressive strength. The moisture content obtained ranged from 31.1 to 92.3 percent, indicates very high which is common for volcanic soils. The dry density obtained ranged from 47 to 88 pcf (pounds per cubic foot) with an average value of 63 and 55 pcf in Test Borings 1 and 2, respectively. The unconfined compressive strength obtained from extracted undisturbed samples ranged from 1189 to 2131 psf (pounds per square foot).

The underlying tuff breccia is generally moderately hard to hard down to the bottom of the test borings. The very high drill rates that ranged from 1 to 10.53 minutes per foot obtained during coring indicates hard rock formation. The RQD (Rock Quality Designation) obtained that ranged from 7 to 73 percent, indicates very poor to fair, and core samples were generally fractured. The  $L_r$  (Recovery ratio) obtained that ranged from 63 to 100 percent, indicates good recovery. The extracted core samples were tested in the laboratory for moisture content and unconfined compressive strength, obtained moisture content of 6.0 and 11.2 percent, and the unconfined compressive strength ( $q_u$ ) values obtained



of 374 and 37.7 tsf (tons per square foot), from Test Borings 1 and 2, respectively.

No groundwater was discovered in the test borings. Permanent ground water at the site should be deep (greater than 65 feet) based on Test Boring 2. Groundwater is not anticipated to impact and has no significance on the planned development. However, seepage was encountered at approximately 53 feet below the existing ground surface within the tuff breccia in Test Boring 2. The seepage observed at Test Boring 2 is anticipated to be minor and not representative of the static groundwater level. Typically, such seepage conditions do not produce significant quantities of groundwater in this region of Guam; therefore, this seepage is not expected to impact construction.

Seismic Site Class — The depth of the underlying tuff breccia should extend to more than 100 feet below the existing ground surface; therefore, the seismic site class is “C” in accordance with the 2009 International Building Code (IBC), which is defined as very dense soil and soft rock.

Figure 1613.5(14) of the 2009 IBC indicates that the mapped spectral response acceleration (5% of critical damping) parameters for short periods ( $S_s$ ) and for 1 second ( $S_1$ ) for Guam are 1.50g and 0.60g, respectively, where g is the gravitational constant. Using the mapped spectral accelerations and the Site Coefficients in Tables 1613.5.3(1) and 1613.5.3(2) of the 2009 IBC, the maximum considered earthquake (MCE) spectral response acceleration parameters for short periods ( $S_{MS}$ ) and for 1 second ( $S_{M1}$ ) are 1.50g and 0.78g, respectively. The 2009 IBC indicates the design spectral response acceleration



parameters for short periods (SDS) and for 1 second (SD1) are two-thirds of the above values or 1.00g and 0.52g.

## DESIGN SOIL AND ROCK PARAMETERS

### Subgrade Soil Parameters

The following subgrade soil parameters may be utilized where they are required:

Test Boring No.	Depth (feet)	Soil classification	N-Value (blow/ft)	Moisture Content (%)	Dry Density (pcf)	Unconfined Compressive Strength, $q_u$ (psf)	Undrained Shear Strength, $C_u = q_u/2$ (psf)
BH-1	0-18	clayey silt (MH)	8 – 18, stiff to very stiff	61.2 (average) (31.1 - 4.8)	63 (average) (49 – 88)	1,262	631
BH-2	0-40	clayey silt (MH)	5 – 31, medium stiff to hard	76.6 (average) (51.7 - 2.3)	55 (average) (47 – 66 )	1,536 (average) (1189 – 2131 )	768

Note: psf = pounds per square foot  
pcf= pounds per cubic foot

### Subgrade Rock Parameters

The following subgrade rock parameters may be utilized where they are required:

Test Boring No.	Depth (feet)	Rock Classification	N-Value (blow/ft)	Moistue Content (%)	RQD (%)	$L_r$ (%)	Unconfined Compressive Strength (tsf)	Undrained Shear Strength, $C_u = q_u/2$ (tsf)
BH-1	18 - 48	tuff breccia	hard	6.0	38 (average) (7 - 69)	89	374	187

BH-2	40 – 65	tuff breccia	moderately hard to hard	-	43 (average) (12 - 73)	92	50 (average) (37.7 – 63.2)	25
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Note: tsf = tons per square foot  
 RQD= Rock Quality Designation  
 L<sub>r</sub>= Recovery Ratio

Undrained shear strength should be used (instead of drained shear strength) because the soils and tuff breccias are fine-grained, cohesive in nature that cannot be easily drained (or water flowing through), and Guam has a lot of rainfalls. The highly variable rock strength values between Test Borings 1 and 2 are attributed to the weathered condition of bedrock observed at BH-2.

#### Pavement Design Soil Parameters

The following subgrade CBR values for both 100 percent and 95 percent maximum dry densities may be used for pavement design.

With 100% maximum dry density	CBR = 8.4 percent
With 95% maximum dry density	CBR = 5.2 percent

The volcanic soils and weathered volcanic rocks are considered expansive based on the Atterberg limits and the swell observed during the CBR testing. The following building practices have been used to mitigate expansive soils in the region. Below pavements and shallow foundations, a 2 foot thick base of structural fill (locally sandy limestone gravel) compacted to a minimum of 95 percent of its maximum dry density is recommended. The structural fill should extend 1 foot beyond the footprint of footings and 3 feet beyond the footprint of pavements and mat foundation. The high plasticity soils in Guam have not displayed sensitivity (i.e loss of strength) during historical seismic events;



therefore, significant hazards are not present unless foundations are placed near slopes.

### Excavations

Per OSHA requirements, any excavation deeper than 5 feet should be either sloped back at a temporary 1:1 horizontal to vertical slope ratio or braced to avert any excavated side wall failure. A soil engineer or geologist should inspect the excavations during construction, unless they will be fully braced.

All stockpiled soils and rocks and any equipment should be placed or parked at least 15 feet or for a distance not less than the depth of the excavation, whichever is wider, away from the top of any excavation prior to and for the duration of each excavation and backfilling.

The contractor should be aware of potential sidewall collapse, particularly in highly plastic soils with high moisture content.

The samples obtained for this project will be kept for a period of 3 months after the date of this report; a small portion of each soil and rock type will be kept for a longer period.

The following plates are included to complete our subsurface soil investigation report prepared for the Wind Turbine Pilot Project, Yona, Guam.

Figure 1	-	Site Location Map
Figure 2	-	Site map
Plate 1	-	Test Boring Location Plan
Plates 2 and 3	-	Logs of Test Borings 1 and 2
Plate 4	-	Soil Classification Chart and Key to Test Data
Plates 5 and 6	-	Particle Size Distribution Report
Plate 7	-	Liquid and Plastic Limits Test Report
Plate 8	-	Compaction Test Report
Plate 9	-	Bearing Ratio Test Report
Appendix A	-	Chloride Content and Sulfate Test Results
Appendix B	-	Rock Core Sample Photographs

Respectfully submitted,

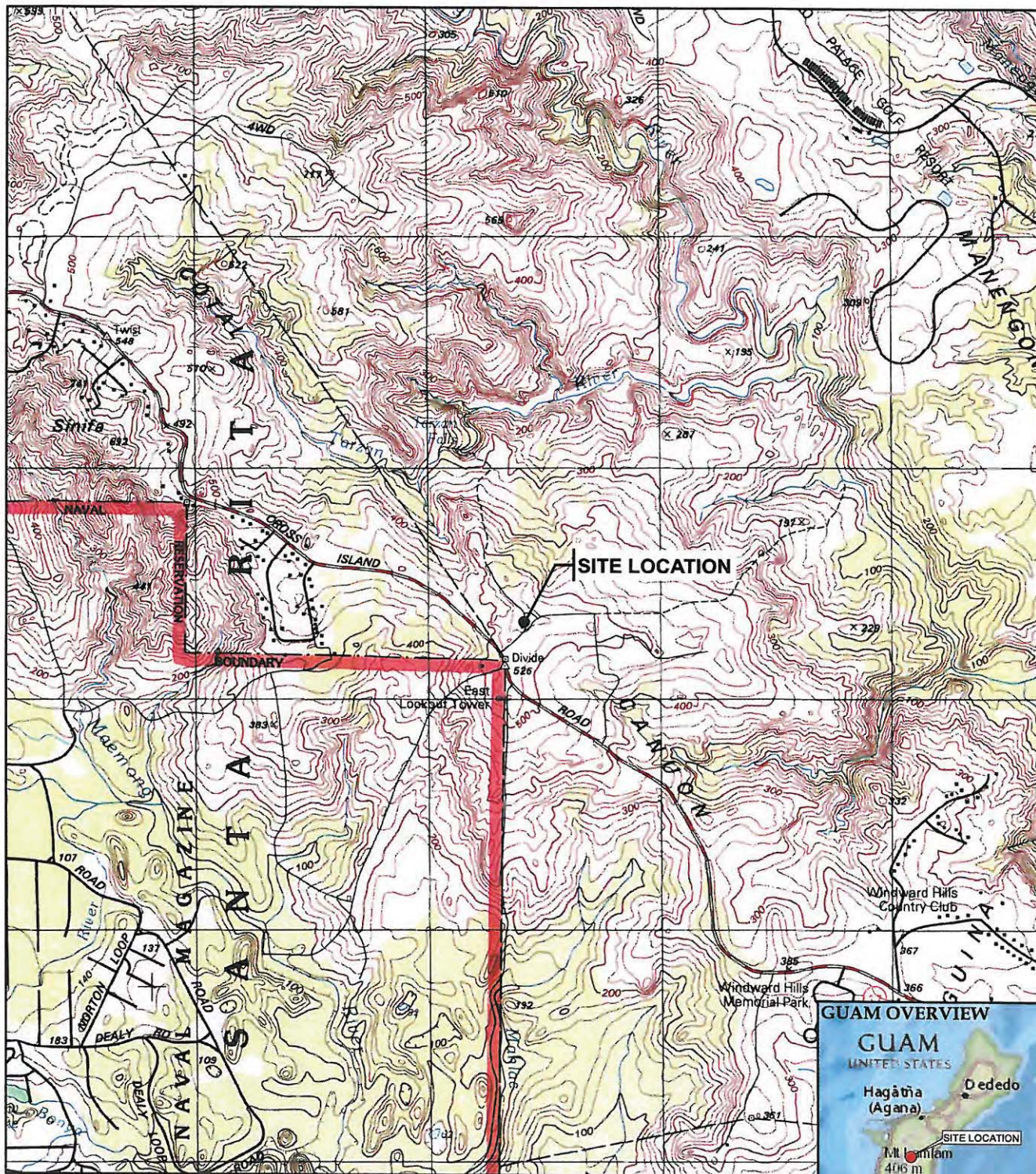
GEO-ENGINEERING & TESTING, INC.

  
Michael C. Rayo  
Project Manager

  
Ukrit Siriprusanan  
Civil Engineer - 360



TRC - GIS



BASE MAP FROM USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE SERIES: TALOFOFO, 2000.



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**SUBSURFACE SOIL INVESTIGATION  
WIND TURBINE PILOT PROJECT  
YONA, GUAM**

**SITE LOCATION MAP**

DRAWN BY:	RHODE B
APPROVED BY:	HOTSTREAM J
PROJECT NO:	182207
FILE NO.	182207-001slm.mxd
DATE:	JUNE 2014

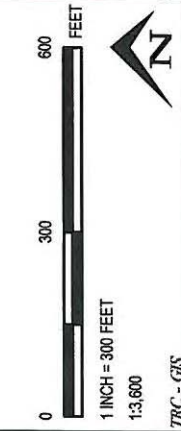


## LEGEND

-  SOIL BORING LOCATION (6/5/2014)
-  10' CONTOUR INTERVAL
-  5' CONTOUR INTERVAL

## NOTES

1. BASE MAP IMAGERY FROM ESRI/BING, "WORLD IMAGERY" WEB BASEMAP SERVICE LAYER, 2011.
2. BORINGS WERE DRILLED ON 6/5/2014 BY GEO-ENGINEERING AND TESTING, INC. FROM TAMUNING, GUAM. BORING LOCATIONS PROVIDED BY GEO-ENGINEERING AND TESTING, INC. BASED ON HANDHELD GPS COORDINATES.
3. CONTOURS ARE DERIVED FROM 10 METER DIGITAL ELEVATION MODEL FROM THE UNITED STATES GEOLOGICAL SURVEY (USGS) NATIONAL ELEVATION DATASET.
4. MAP PROJECTION AND COORDINATES SHOWN ARE IN NAD83 STATE PLANE GUAM, US SURVEY FEET. VERTICAL DATUM IS MEAN SEA LEVEL.



**TRC**

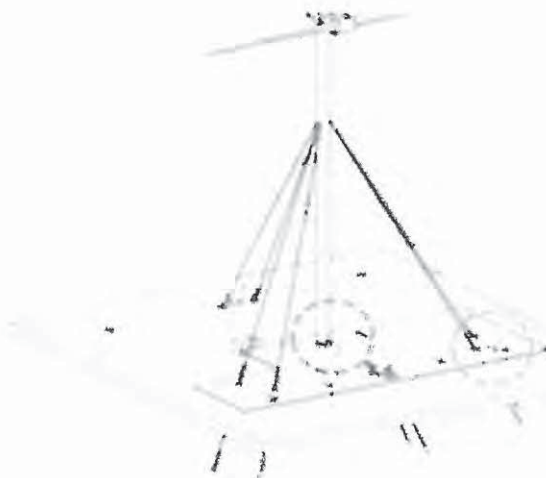
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**SUBSURFACE SOIL INVESTIGATION  
WIND TURBINE PILOT PROJECT  
YONA, GUAM**

**SITE MAP**

DRAWN BY:	RHODEB
APPROVED BY:	HOTSTREAM J
PROJ. NO.:	182207
FILE NO.:	182207-002.mxd
DATE:	JUNE 2014





Test Boring 1  
Latitude: 13°23'21.3"  
Longitude: 144°43'21.7"

Test Boring 2  
Latitude: 13°23'22.0"  
Longitude: 144°43'21.6"

**GEO-ENGINEERING & TESTING, INC.**  
Geotechnical & Material Testing Engineers

TEST BORING LOCATION PLAN  
WIND TURBINE PILOT PROJECT

PLATE



1

Job No. 310.01 Appr. U.S. Date 06/05/14

YONA

GUAM

**Notes:**

 Relatively Undisturbed Sample      SPT = Standard Penetration Test  
 Disturbed/Bulk Sample      based on 140 lb (63.5 kg) hammer  
    free falling 30 in (76 cm.)/blow

**LOG OF TEST BORING 1**DATE May 17, 2014EQUIPMENT 8" Dia. Hollow Stem AugerELEVATION --

DEPTH (FT.)	DEPTH (M.)	DESCRIPTION	GRAPHIC LOG	SAMPLE TYPE DRILL RATE (min/ft)	SPT (Blows/ft.)*	MOISTURE CONTENT, %	DRY DENSITY, lbs./cu.ft.	LABORATORY TESTS
0	0	REDDISH BROWN CLAYEY SILT (MH) - medium stiff, moist, with grass on surface		0.15		48.9		Corrosion
	1	mottled reddish brown-black-yellow clayey silt from 2'		0.15	8	84.8	49	UC(qu)=1262 psf SA LL=103; PI=29 CBR Compaction
5	2	stiff from 7'		0.48 0.22	12	75.8	55	
10	3	very stiff from 12'		0.48 0.60 0.92	18	67.9	58	LL=66; PI=12
15	4			0.57 1.35 1.75	80/8.5	31.1	88	SA
	5	mottled reddish brown-black-yellow clayey silt, very stiff to greyish brown-black tuffaceous siltstone, hard at 17'		0.93				
20	6	GREY TUFF BRECCIA - hard, fractured Nx Rock Core at 20'-25', RQD=7% (very poor) Lr=63%		1.50 1.60 2.77 2.93 7.87				
25	7			0.45 2.27 6.0 4.03 3.70		6.0		UC(qu)=374 tsf
	8	Nx Rock Core at 25'-30', RQD=25% (poor) Lr=82%		7.27 2.08 1.52 1.60 3.68				
30	9	Nx Rock Core at 30'-35', RQD=30% (poor) Lr=100%						
35	10							

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 Geotechnical & Material Testing Engineers

LOG OF TEST BORING 1

PLATE

WIND TURBINE PILOT PROJECT

2

Job No. 310.01 Date 06/05/14

YONA, GUAM



**Notes:**

☐ Relatively Undisturbed Sample      SPT = Standard Penetration Test  
☒ Disturbed/Bulk Sample      based on 140 lb (63.5 kg) hammer  
    free falling 30 in (76 cm.) / blow

**LOG OF TEST BORING 1**DATE May 17, 2014EQUIPMENT 8" Dia. Hollow Stem AugerELEVATION --

DEPTH (FT.)	DEPTH (M.)	DESCRIPTION	GRAPHIC LOG	SAMPLE TYPE DRILL RATE (min/ft)	SPT (Blows/ft.)*	MOISTURE CONTENT, %	DRY DENSITY, lbs./cu ft.	LABORATORY TESTS
35	11	Nx Rock Core at 35'-40', RQD=50% (fair) Lr=89%		7.65				
				1.20				
				2.00				
				2.00				
	12	Nx Rock Core at 40'-45', RQD=49% (poor) Lr=100%		10.53				
40				9.37				
				1.88				
	13			3.02				
				3.80				
				1.92				
45	14	Nx Rock Core at 45'-48', RQD=69% (fair) Lr=100%		7.75				
				2.07				
				2.08				
		(No free water encountered)		2.07				

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*Geotechnical & Material Testing Engineers*

LOG OF TEST BORING 1 (continued)

PLATE



WIND TURBINE PILOT PROJECT

Job No. 310.01      Date 06/05/14

YONA, GUAM

**2**  
 (cont'd)

**Notes:**

 Relatively Undisturbed Sample      SPT = Standard Penetration Test  
 Disturbed/Bulk Sample      based on 140 lb (63.5 kg) hammer  
    free falling 30 in (76 cm.)/blow

**LOG OF TEST BORING 2**DATE May 18, 2014EQUIPMENT 8" Dia. Hollow Stem AugerELEVATION --

DEPTH (FT.)	DEPTH (M.)	DESCRIPTION	GRAPHIC LOG	SAMPLE TYPE	DRILL RATE (min/ft)	SPT (Blows/ft.)*	MOISTURE CONTENT, %	DRY DENSITY, lbs./cu.ft.	LABORATORY TESTS
0	0	REDDISH BROWN CLAYEY SILT (MH) - stiff, moist, with grass on surface							
	1	very stiff at 2'							
5	2	mottled reddish brown-yellow-black, stiff from 7'							
10	3								
	4								
15	5								
	6								
20	7	very stiff from 22'							
	8								
25	9								
	10	hard from 32'							
35									

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**LOG OF TEST BORING 2**

PLATE

WIND TURBINE PILOT PROJECT



Job No. 310.01 Date 06/05/14

YONA, GUAM

**3**



**Notes:**

 Relatively Undisturbed Sample      SPT = Standard Penetration Test  
 Disturbed/Bulk Sample      based on 140 lb (63.5 kg) hammer  
    free falling 30 in (76 cm.)/blow

**LOG OF TEST BORING 2**DATE May 18, 2014EQUIPMENT 8" Dia. Hollow Stem AugerELEVATION ---

DEPTH (FT.)	DEPTH (M.)	DESCRIPTION	GRAPHIC LOG	SAMPLE TYPE	DRILL RATE (min/ft)	SPT (Blows/ft.)*	MOISTURE CONTENT, %	DRY DENSITY, lbs./cu.ft.	LABORATORY TESTS
35	11				0.20				
					0.35				
					0.77				
					1.00				
40	12				0.68				
		LIGHT BROWN WEATHERED TUFF BRECCIA - moderately hard			0.67				
					1.40				
					1.95	35			
		hard from 44'			1.72				
45	14				4.87				
		Nx Rock Core at 47'- 52', RQD=51% (fair) Lr=88%			4.78		11.2		UC(qu)=37.7 tsf
					0.58				
					1.82				
50	15				0.88				
					1.42				
		Nx Rock Core at 52'-57', RQD=35% (poor) Lr=100%			1.55				
		encountered seepage at 53', core sample wet			3.45				
					3.50				
55	17				1.48				
		Nx Rock Core at 57'-62', RQD=12% (very poor) Lr=80%			1.88		9.2		UC(qu)=63.2 tsf
					3.48				
					2.27				
60	18				2.75				
					1.63				
		Nx Rock Core at 62'-65', RQD=73% (fair) Lr=100%			3.13				
					9.82				
					2.30				
65	19				3.07				
		(No free water encountered)			1.45				

**GEO-ENGINEERING & TESTING, INC.**  
 Geotechnical & Material Testing Engineers

LOG OF TEST BORING 2 (continued)

PLATE

WIND TURBINE PILOT PROJECT

Job No. 310.01 Date 06/05/14

YONA, GUAM

**3**  
 (cont'd)

MAJOR DIVISIONS			SYMBOL		TYPICAL NAMES
COARSE GRAINED SOILS MORE THAN HALF IS LARGER THAN # 200 SIEVE	GRAVELS  MORE THAN HALF COARSE FRACTION IS LARGER THAN No. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW		WELL GRADED GRAVEL, WELL-GRADED GRAVEL WITH SAND
			GP		POORLY GRADED GRAVEL, POORLY GRADED GRAVEL WITH SAND
		GRAVELS WITH OVER 12 % FINES	GM		SILTY GRAVEL, SILTY GRAVEL WITH SAND
			GC		CLAYEY GRAVEL, CLAYEY GRAVEL WITH SAND
	SANDS  MORE THAN HALF COARSE FRACTION IS SMALLER THAN No. 4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES	SW		WELL-GRADED SAND, WELL-GRADED SAND WITH GRAVEL
			SP		POORLY GRADED SAND, POORLY GRADED SAND WITH GRAVEL
		SANDS WITH OVER 12 % FINES	SM		SILTY SAND, SILTY SAND WITH GRAVEL
			SC		CLAYEY SAND, CLAYEY SAND WITH GRAVEL
FINE GRAINED SOILS MORE THAN HALF IS SMALLER THAN # 200 SIEVE	SILTS AND CLAYS  LIQUID LIMIT LESS THAN 50		ML		SILT, SILT WITH SAND OR GRAVEL, SANDY OR GRAVELLY SILT
			CL		LEAN CLAY, LEAN CLAY WITH SAND OR GRAVEL, SANDY OR GRAVELLY LEAN CLAY
			OL		ORGANIC SILT OR CLAY, ORGANIC SILT OR CLAY WITH SAND OR GRAVEL, SANDY OR GRAVELLY ORGANIC SILT OR CLAY
	SILTS AND CLAYS  LIQUID LIMIT GREATER THAN 50		MH		ELASTIC SILT, ELASTIC SILT WITH SAND OR GRAVEL, SANDY OR GRAVELLY ELASTIC SILT
			CH		FAT CLAY, FAT CLAY WITH SAND OR GRAVEL, SANDY OR GRAVELLY FAT CLAY
			OH		ORGANIC SILT OR CLAY, ORGANIC SILT OR CLAY WITH SAND OR GRAVEL, SANDY OR GRAVELLY ORGANIC SILT OR CLAY
	HIGHLY ORGANIC SOILS		Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS

### UNIFIED SOIL CLASSIFICATION SYSTEM

#### KEY TO TEST DATA

SA	=	Sieve Analysis
LL	=	Liquid Limit
PI	=	Plasticity Index
Corrosion	=	Corrosivity Test
Compaction	=	Laboratory Compaction
CBR	=	California Bearing Ratio
UC (q <sub>u</sub> )	=	Unconfined Compression (Unconfined Compressive Strength)
N <sub>x</sub>	=	N <sub>x</sub> Rock Core
RQD	=	Rock Quality Designation
L <sub>r</sub>	=	Recovery Ratio

**GEO-ENGINEERING & TESTING, INC.**  
Geotechnical & Material Testing Engineers

#### SOIL CLASSIFICATION CHART AND KEY TO TEST DATA

PLATE

WIND TURBINE PILOT PROJECT

4

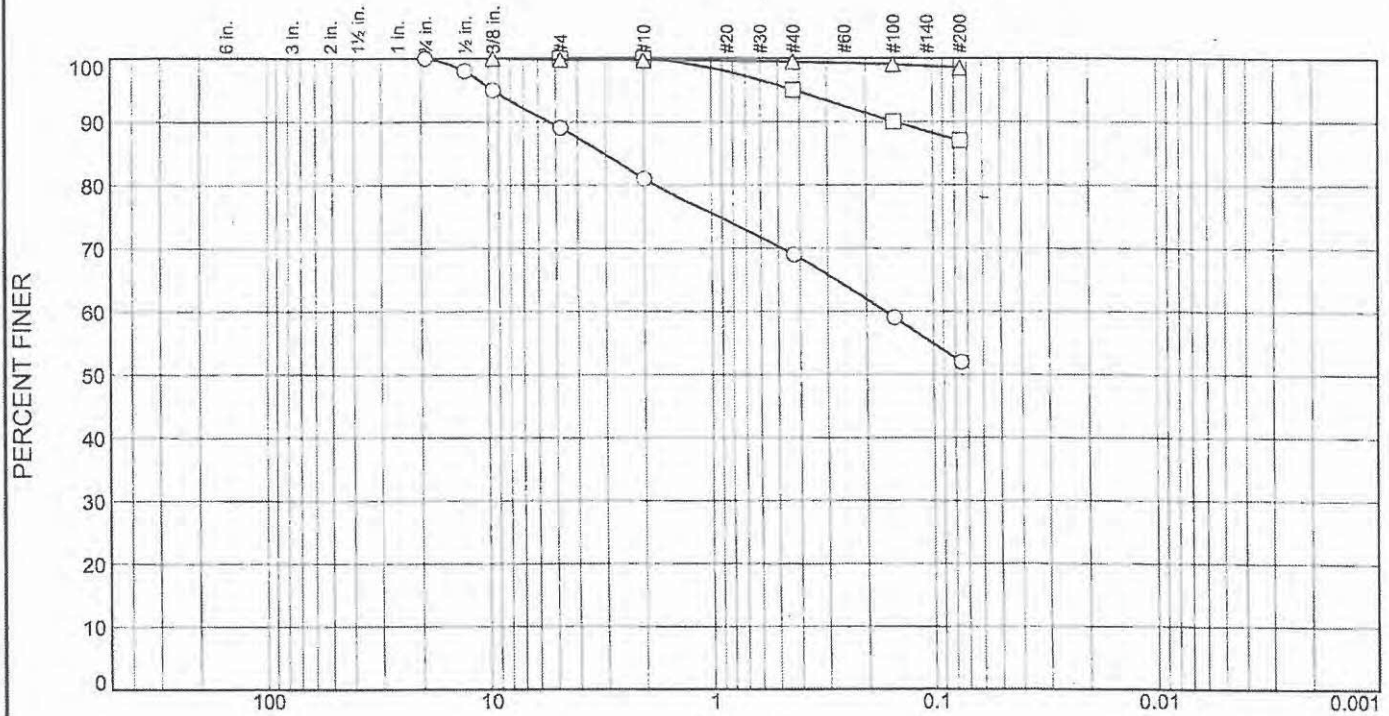
Job No. 310.01 Appr. U.S. Date: 06/05/14

YONA

GUAM



# Particle Size Distribution Report



GRAIN SIZE - mm.

	% +3"		% Gravel		% Sand			% Fines		
			Coarse	Fine	Coarse	Medium	Fine	Silt		Clay
○	0		0	11	8	12	17	52		
□	0		0	0	0	5	8	87		
△	0		0	0	0	1	1	98		
×	LL	PL	D <sub>85</sub>	D <sub>60</sub>	D <sub>50</sub>	D <sub>30</sub>	D <sub>15</sub>	D <sub>10</sub>	C <sub>c</sub>	C <sub>u</sub>
○			3.0683	0.1656						
□										
△	103	74								

Material Description	USCS	AASHTO
○ REDDISH BROWN CLAYEY SILT	MH	
□ REDDISH BROWN CLAYEY SILT	MH	
△ REDDISH BROWN CLAYEY SILT	MH	

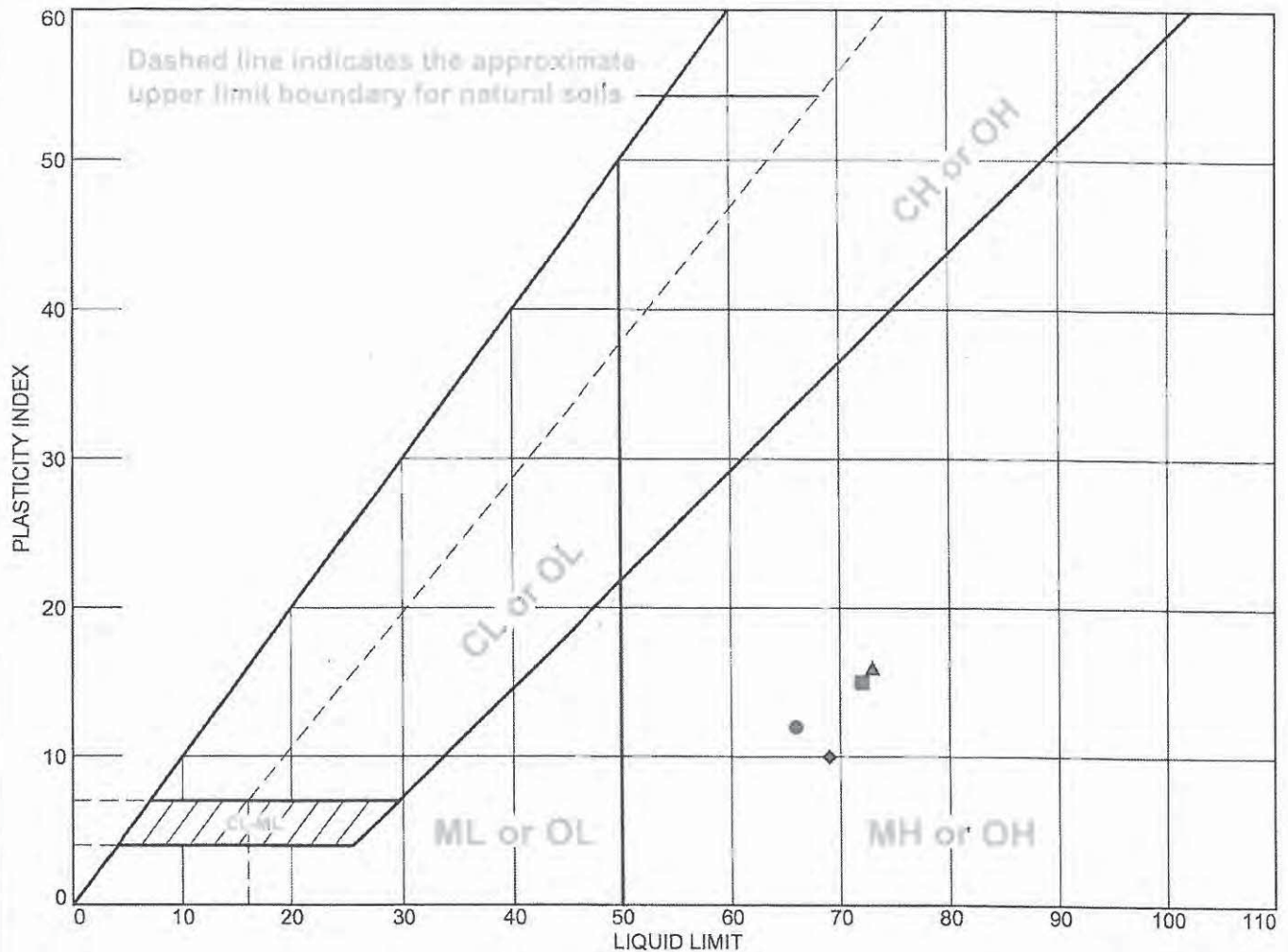
Project No. 310.01      Client: TRC Environmental Corporation  
 Project: WIND TURBINE PILOT PROJECT - YONA, GUAM  
 ○ Source of Sample: 1      Depth: 17  
 □ Source of Sample: 2      Depth: 28  
 △ Location: Boring 1 at 0'-5'      Sample Number: Bulk Sample

Remarks:

**GEO-ENGINEERING & TESTING, INC.**  
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# LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	REDDISH BROWN CLAYEY SILT	66	54	12	--	--	MH
■	REDDISH BROWN CLAYEY SILT	72	57	15	--	--	MH
▲	REDDISH BROWN CLAYEY SILT	73	57	16	--	--	MH
◆	REDDISH BROWN CLAYEY SILT	69	59	10	--	--	MH

Project No. 310.01 Client: TRC Environmental Corporation

Project: WIND TURBINE PILOT PROJECT - YONA, GUAM

- Source of Sample: 1 Depth: 12.5
- Source of Sample: 2 Depth: 12.5
- ▲ Source of Sample: 2 Depth: 23
- ◆ Source of Sample: 2 Depth: 33

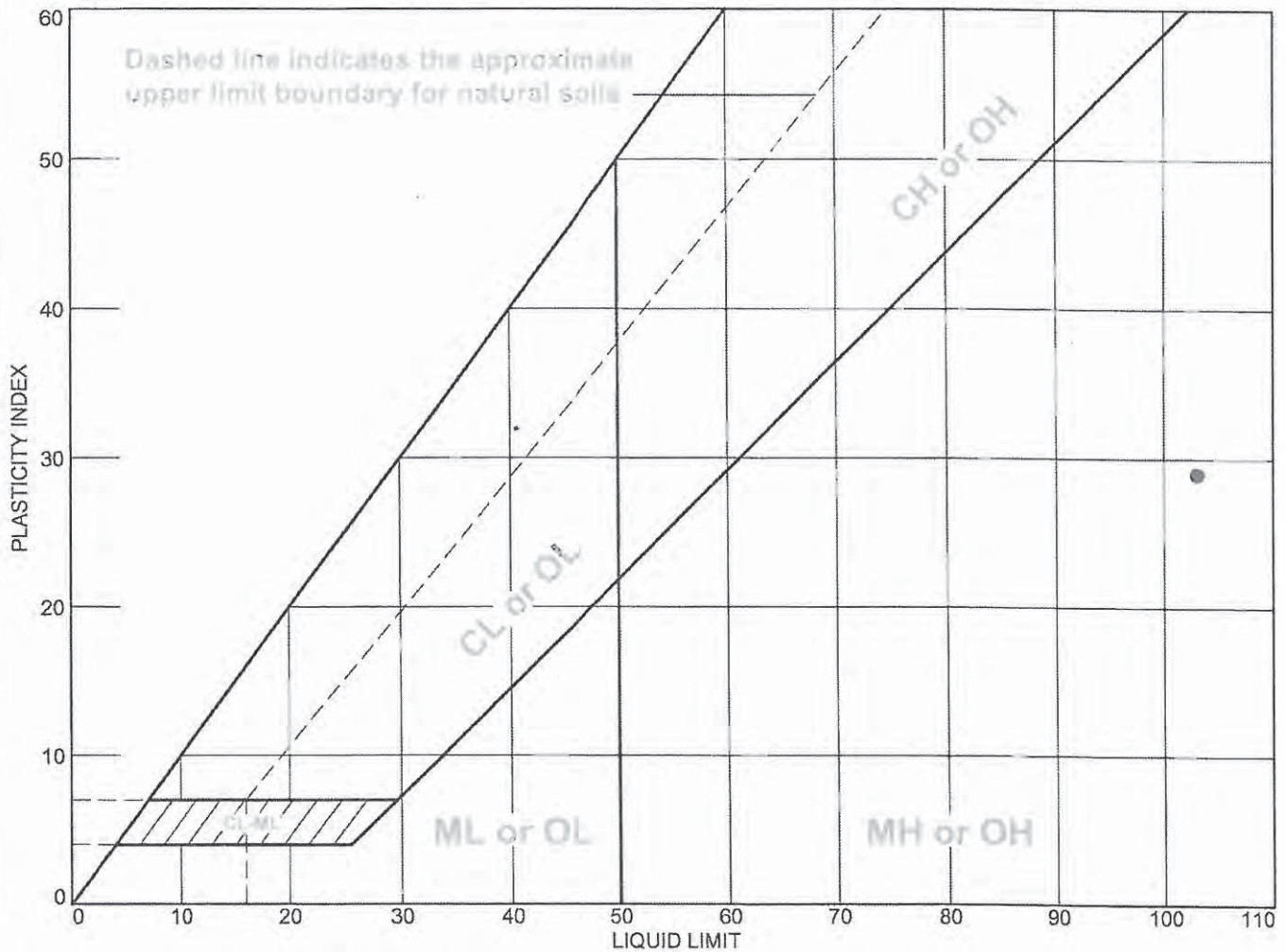
## Remarks:

- This test was performed on sample portion passing No. 40 sieve only.

**GEO-ENGINEERING & TESTING, INC.**  
Geotechnical & Materials Testing Engineers



# LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	REDDISH BROWN CLAYEY SILT	103	74	29	99	98	MH

Project No. 310.01 Client: TRC Environmental Corporation

Project: WIND TURBINE PILOT PROJECT - YONA, GUAM

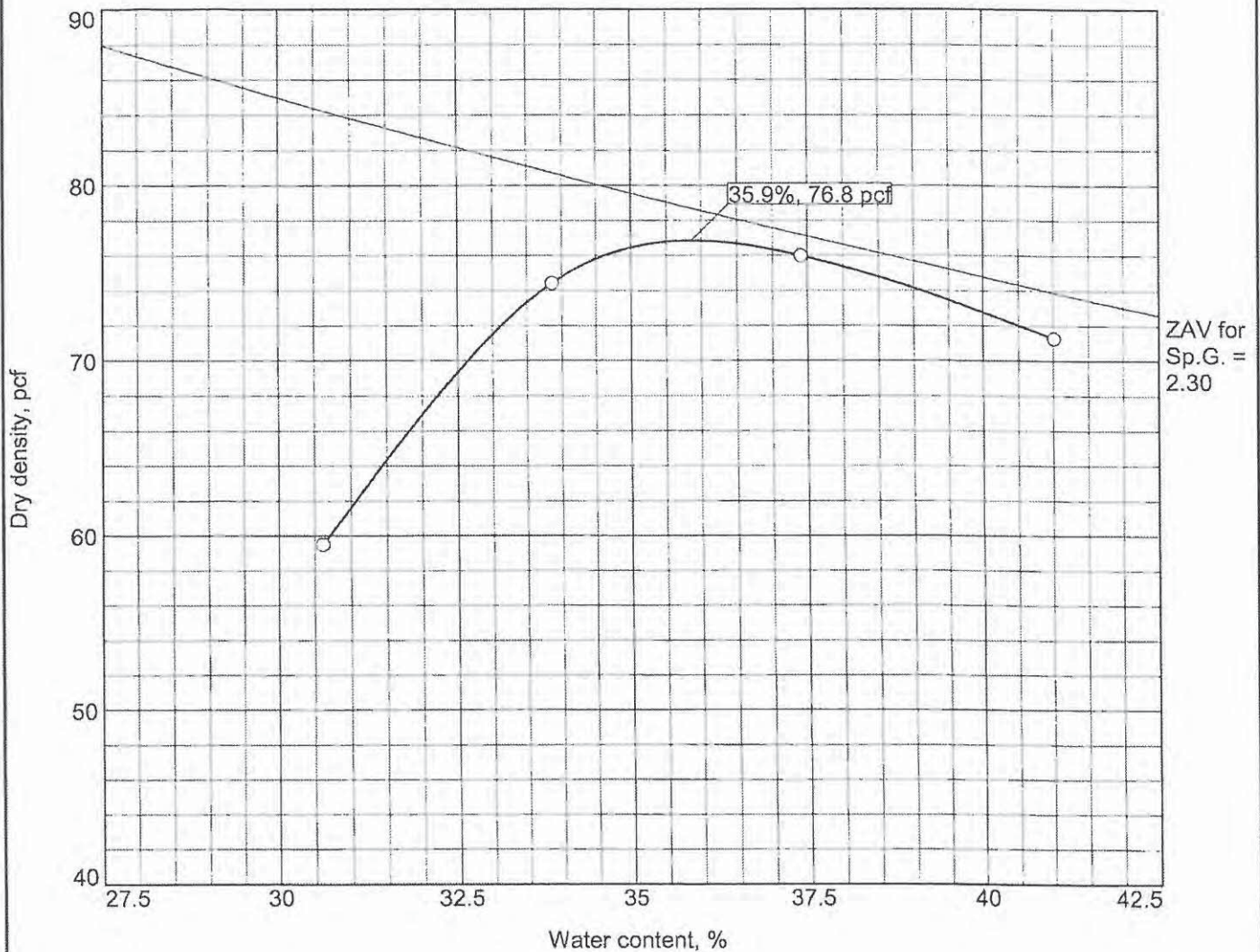
● Location: Boring 1 at 0'-5' Sample Number: Bulk Sample

## Remarks:

- This test was performed on sample portion passing No. 40 sieve only.

**GEO-ENGINEERING & TESTING, INC.**  
Geotechnical & Materials Testing Engineers

# COMPACTION TEST REPORT



Test specification: ASTM D 698-00a Method B Standard

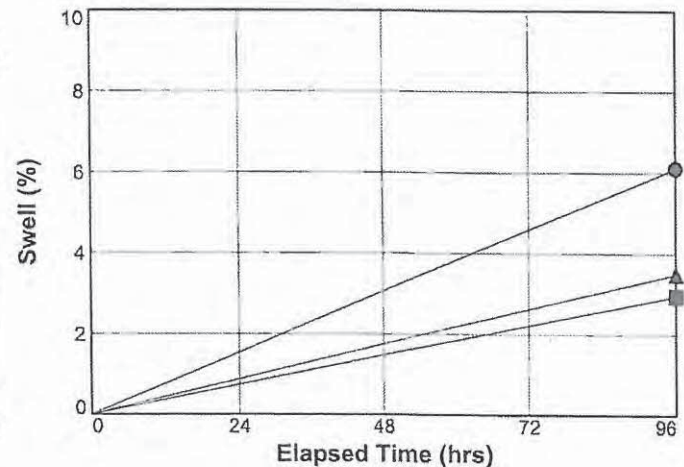
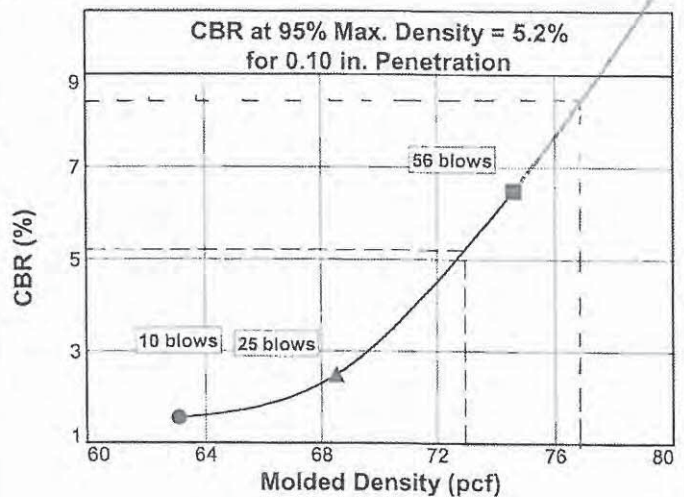
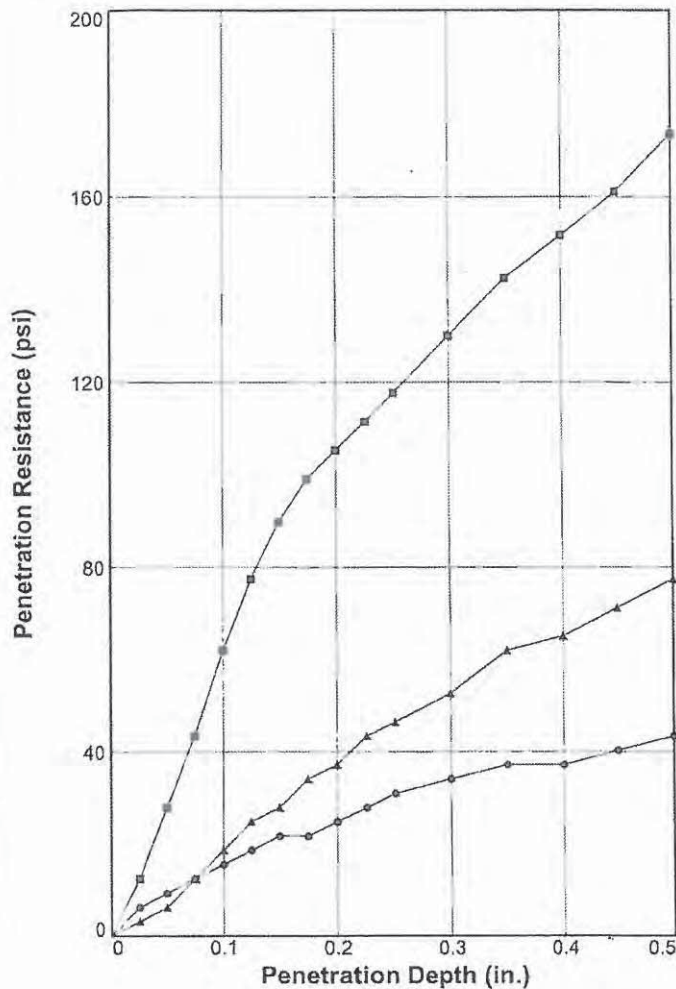
Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
	MH		48.9	2.3	103	29	0	98

TEST RESULTS		MATERIAL DESCRIPTION
Maximum dry density = 76.8 pcf  Optimum moisture = 35.9 %		REDDISH BROWN CLAYEY SILT
Project No. 310.01                      Client: TRC Environmental Corporation Project: WIND TURBINE PILOT PROJECT - YONA, GUAM  Date:  Location: Boring 1 at 0'-5'                      Sample Number: Bulk Sample		Remarks:
GEO-ENGINEERING & TESTING, INC. Geotechnical & Materials Testing Engineers		
		Plate 8



# BEARING RATIO TEST REPORT

## ASTM D 1883-07



	Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)	Max. Swell (%)
	Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.10 in.	0.20 in.			
1 ○	63.1	82.2	39.7	59.5	77.4	50.0	1.5	1.7	0.000	10	6.1
2 △	68.5	89.2	38.1	66.2	86.2	44.3	2.5	2.9	0.026	10	3.5
3 □	74.6	97.1	38.5	72.5	94.4	47.0	6.5	7.1	0.005	10	2.9
Material Description							USCS	Max. Dens. (pcf)	Optimum Moisture (%)	LL	PI
REDDISH BROWN CLAYEY SILT							MH	76.8	35.9	103	29

Project No: 310.01  
 Project: WIND TURBINE PILOT PROJECT - YONA, GUAM  
 Location: Boring 1 at 0'-5'  
 Sample Number: Bulk Sample  
 Date:

**GEO-ENGINEERING & TESTING, INC.**  
 Geotechnical & Materials Testing Engineers

Test Description/Remarks:

## **APPENDIX A**

**CHEMICAL ANALYSIS CERIFICATE  
CHLORIDE CONTENT AND SULFATE**





**UNIVERSITY OF GUAM**  
**UNIBETSEDĀT GUAHAN**



Water and Environmental Research Institute  
of the Western Pacific

**May 30, 2014**

**Marianas Drilling, Inc.**  
**136 Tun Felix Camacho St.**  
**Tamuning, Guam 96913**

**Two water samples were delivered to the WERI lab on 27 May 2014.**

**Sampling Site: Wind Turbine Pilot Project, Yona**

**Comments: Leachate; 100g soil/ 300 mL of distilled water**

<b>Sample Location ID</b>	<b>Date Collected</b>	<b>Time Collected</b>	<b>Chloride mg/L</b>	<b>WERI LAB Sample ID</b>
BH - 1, 0' - 5'	5/23/2014	4:00 PM	19.4	w2014-1953
BH - 2, 3' - 3.5'	5/23/2014	4:00 PM	12.0	w2014-1954

**Regards,**

**Jennifer O. Cruz**  
**Laboratory Manager**

TRC Environmental Corporation  
708 Heartland Trail, Suite 3000  
Madison, WI 53717

Main 608.826.3600  
Fax 608.826.3941

## Memorandum

**To:** Michael Rayo  
Geo-Engineering and Testing, Inc.

**From:** Jonathan Hotstream

**Subject:** Soluble Sulfate Testing

**Date:** June 19, 2014

**CC:** Barry Stewart - TRC

**Project No.:** 182207.0000.0002

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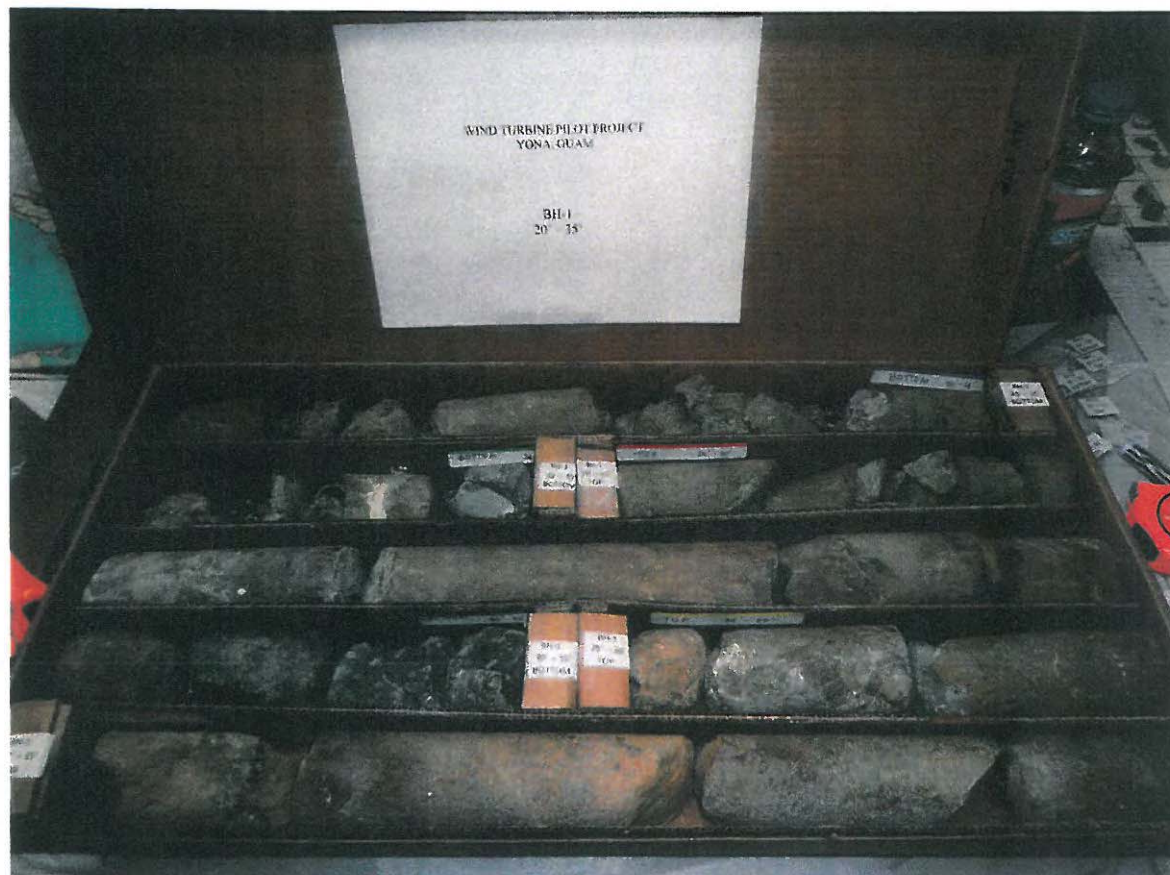
TRC performed soluble sulfate testing on the near surface samples provided by Geo-Engineering and Testing, Inc. based in Barrigada, Guam. The samples are from the geotechnical investigation performed in Yona, Guam for a proposed wind turbine. The soluble sulfate was measured by running a distilled water leach test on the soil samples, and then measuring the sulfur in the leachate. The test results are provided in the table below.

<i>Sample</i>	<i>Solids Content, %</i>	<i>Soluble Sulfate (mg/kg as SO<sub>4</sub>)</i>	<i>Soluble Sulfate %</i>
BH-1 0-5'	90	2,340	0.23
BH-2 3'-3.5'	97	900	0.09



## **APPENDIX B**

### **CORE SAMPLE PHOTOGRAPHS**





WIND TURBINE PILOT PROJECT  
YONA, GUAM

BH-1  
45' - 48'

