Preliminary Geotechnical Engineering Report

Heritage Wind Project
Orleans County, New York
January 31, 2020
Terracon Project No. J5195205

Prepared for:
Apex Clean Energy Management, LLC
Charlottesville, VA

Prepared by:
Terracon Consultants-NY, Inc.
Rochester, New York

January 31, 2020

Apex Clean Energy Management, LLC
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Attn: Mr. Tracy Butler
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Re: Preliminary Geotechnical Engineering Report
Heritage Wind Project
Town of Barre
Orleans County, New York
Terracon Project No. J5195205

Dear Mr. Butler:

We have completed the Preliminary Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. PJ5185205 dated October 29, 2019. This report presents the findings of the subsurface exploration and provides preliminary geotechnical recommendations concerning earthwork and the design and construction of foundations and slabs for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants-NY, Inc.

Zeru Kiffle, EIT
Staff Engineer

Michele A. Fiorillo, P.E.
Geotechnical Department Manager

Reviewed by: Mathew B. Fielding, P.E.* - Terracon Subject Expert Matter on Wind Projects
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REPORT TOPICS

Note: This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the ***GeoReport*** logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

ATTACHMENTS

Note: Refer to each individual Attachment for a listing of contents.

Preliminary Geotechnical Engineering Report

Heritage Wind Project

Town of Barre

Orleans County, New York

Terracon Project No. J5195205

January 31, 2020

INTRODUCTION

This report presents the results of our limited subsurface exploration and preliminary geotechnical engineering services performed for the proposed wind turbine project located in the Town of Barre in Orleans County, New York. The purpose of these services is to provide information and preliminary geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Earthwork and Structural Fill
- Preliminary foundation recommendations
- Access roadways

Our scope of services for the project consisted of:

- Soil borings for turbine generator and substations at 7 locations (T-3, T-7, T-11, T-18, T-26, T-30, and Substation) to depths ranging from 20.5 to 51.5 feet
- Test pits at 5 locations (TP-1 through TP-5) to a depth of 4 to 5 feet approximately.
- Temporary groundwater monitoring wells at 7 locations
- Laboratory testing of soil samples
- Field electrical resistivity testing at 5 locations
- Thermal resistivity tests at 5 locations
- Corrosivity suite testing at 7 locations
- Preliminary geotechnical engineering analysis and preparation of this report

Maps showing the site and boring locations are shown in **Appendix A**, Exhibit- A001 and A002, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs included in **Appendix A**, and/or as separate graphs in **Appendix B**. Results of the field electrical resistivity tests are provided in **Appendix C**. The seismic test results are provided in **Appendix D**.

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project is in the Town of Barre in Orleans County, New York. The approximate centroid of the facility (the Facility) site is located at: ▪ Latitude N43.1510° ▪ Longitude: W78.2018° For additional information and clarification regarding the site location and layout, please see **Appendix A**, Exhibit- A001 and A002.
Existing Improvements	The new electric generating Facility will be located on leased private land that is generally rural in nature.
Current Ground Cover	Current ground cover within the Facility consists of light to heavy vegetation and agricultural fields.
Existing Topography (from USGS Topo Maps)	Based on the USGS Topographic Maps, the proposed turbine and substation sites appear to be relatively level, with ground surface elevations at various turbine and substation sites ranging from about 645 feet to 670 feet.

REGIONAL GEOLOGY, HYDROGEOLOGY, AND SEISMOLOGY

Information regarding geology, tectonic setting, and seismology was obtained from existing published sources, including the Soil Survey of Orleans County, the USDA Natural Resource Conservation Service's SSURGO (Soil Survey Geographic Database), statewide bedrock geology and surficial geology mapping, 2014 New York State Hazard Map (USGS, 2014b), New York State DOT Geotechnical Design Manual, and SGS Earthquake Hazards Program (USGS, 2017).

Area Geology and Hydrogeology

The Facility is located within the Erie-Ontario Lowlands physiographic province of New York. This province consists of the relatively low, flat areas to the south of Lake Ontario and Lake Erie. It rises to the Portage Escarpment in the south where it borders the Allegheny Plateau Province. The final event that deposited glacial material was the Wisconsin glaciation. As the glacial moved southwestward, it scoured and picked up older glacial deposits, bedrock, and soil and finally deposited unconsolidated material as the glacial melted and receded. The soil deposits within this province generally consist of both glacially-derived deposits, such as glacial till (i.e. terminal moraines and ground moraine), granular deposits (i.e. kame, glacial outwash, and beach ridges)

and glacio-lacustrine deposits (i.e. varved silts, clay, and fine sand deposits). Subsurface condition encountered in the borings are consistent with the geologic map information.

The topography of Orleans County generally consists of flat to undulating or gently rolling areas. The elevation increases gradually southward with relief that is generally more uneven within the southern portion of the county. Elevations within the Facility area range from about 600 feet to 680 feet above mean sea level (AMSL).

Drainage of Orleans County flows into Lake Ontario through several small streams. Oak Orchard Creek, which is located just south of the Facility, and its tributary control the largest drainage area.

Surficial Soils

In Orleans County soils generally formed in glacial till, outwash, glaciolacustrine materials, recent alluvium, and organic material. Of the various types of glacial deposits, the most common that occurs, and influences soil formation is glacial till, which is most extensive in the county and is generally encountered within the Facility area.

Bedrock

Our review of geological maps and SSURGO data indicate bedrock may be encountered generally within 4 to 8 feet of surface along the northern portion of the Facility and this is consistent with our observation during field exploration. Bedrock in the study area is expected to consist of sedimentary bedrock of upper Silurian age. The bedrock units are expected to dip gently to the south, which causes the oldest units to be exposed in the north and progressively younger units exposed to the south. The predominant bedrock lithology within the Facility is mapped as:

- Limestone and Dolostone of the Lockport Group (central and northern portion of the Facility)
- Dolostone with interbedded Shale of the Camillus, Syracuse and Vernon Formations (southern portion of the Facility).

Seismicity

New York State generally is not as seismically active as states that have areas located near tectonic plate boundaries. The probability of the State being struck by a major earthquake is small. Based on the 2014 New York State Hazard Map, the Facility is in an area of low seismic hazard,

with a peak ground acceleration[1] value less than 10 percent of the acceleration force of gravity (g), with a 2 percent probability of exceedance in 50 years (USGS, 2014).

The following section addresses seismic considerations pertaining to New York State (NYS). Historical information for NYS as well as generally accepted seismic interpretations are presented. This section is not intended to be an in-depth discussion or prediction of earthquake frequency, probable intensity, or seismic risk. However, adequate consideration should be given to the possible influence of seismic activity for the structural design of the structural components.

Tectonic

The northeast United States lies within the relatively tectonically stable and geologically old North American plate. In describing the seismic characteristics of NYS it is noted that the majority of the State is relatively inactive. However, areas which are located along the Buffalo-Attica Region (Western New York) and the St. Lawrence River Valley are moderately active. Our review of published literature indicates the following know faults in proximity to the Facility:

- The Clarendon-Linden Fault System is a major fault located in Western New York. The fault system trends northward from Allegany County, New York toward Lake Ontario, extending west of Picton, and continuing toward Wellington, Ontario. The fault system has no more than 100 meters (328 feet) of total displacement across its breadth, exposed at the surface north of Attica, New York. Investigations performed by several authors (Hutchinson, Pomeroy[2]) suggest the fault system may extend across Lake Ontario. The fault zone is a member of a family of Late Proterozoic-Cambrian normal faults that formed during the rifting episode that initiated the Iapetus Ocean and other members of this fault family have been inferred to be the sources of damaging earthquakes[3]

Earthquakes

The recorded history of earthquakes in NYS is geologically short, dating from the 1633 St. Lawrence Valley Earthquake in Canada which was also felt in New York State. Mapping of all earthquakes that occurred in NYS from 1900 to present time, as well as the "2014 USGS Seismic Hazard Map", are available online at the United States Geological Survey (USGS) website[4]. Our

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[1] Peak ground acceleration (PGA) is the largest increase in velocity recorded by a particular station during an earthquake. %PGA is a common earthquake measurement that indicate the probability of an earthquake of each given level of severity (10% chance in 50 years) and the strength of ground movement (severity) expressed in terms of percent of the acceleration force of gravity (%g)

[2] Hutchinson, D.R.; Pomeroy, P.W.; Wold,R.J. " Investigation of the possible continuation of the Clarendon-Linden Fault under lake Ontario. Geological Society of America, Abstracts with programs, volume 9, number 7, 1977, page 1031.

[3] NYSDOT Geotechnical Design Manual, Chapter 9, Seismic Design, page 9-40

[4] *Seismicity and Hazard by Region – New York at URL https://www.usgs.gov/natural-hazards/earthquake-hazards/science/information-region-new-york?qt-science_center_objects=0#qt-science_center_objects*

review of the seismic hazard map indicates the areas with higher probability of earthquake occurrences are located along the northern (St. Lawrence River Valley), western (Buffalo-Attica regions) and southern (New York City region) portions of New York State, with the lowest probability in the central portions of the State. The Facility is located within an area of medium low probability of earthquake occurrence.

In terms of specific activities, at least two high-intensity earthquakes have occurred in modern times in the St. Lawrence River Valley and Buffalo-Attica regions. The first of these occurring in 1929 and centered near Attica, New York. The second, which was considered as the most damaging earthquake in New York State, occurred in the St. Lawrence River Valley on September 5, 1944. The Cornwall-Massena Earthquake was registered as a magnitude 5.6 on the Richter Scale (VIII on the Modified Mercalli Scale or MMI), and resulted in significant damage in Massena, Cornwall, and surrounding areas. The epicenter was localized near Massena Center. Many chimneys in this area required rebuilding, and several structures were unsafe for occupancy until repaired. Residents of St. Lawrence County reported many water wells went dry. This severe earthquake was felt from Canada south to Maryland and from Maine west to Indiana. Many smaller earthquakes have been detected in this region before and since the 1944 event.

The most recent high-intensity earthquake recorded in New York State was the April 20, 2002 earthquake with epicenter located at approximately 15 miles southwest (44.512N;73.697W) of Plattsburgh, New York in northeastern Adirondack Mountains. The epicenter of the main shock was about 8 km north of the town of Au Sable Forks and the focal depth of the main shock was about 11 km from the surface. Hence, the earthquake on April 20, 2002 is formally called Au Sable Forks Earthquake. The earthquake's magnitude was 5.3 on the Richter Scale, and was felt from Cleveland, Ohio to Maine and from Ontario and Quebec to Maryland. Some damage to roads, bridges, chimneys and water mains in Clinton and Essex Counties were observed. Many people reported cracked walls and foundations, small items knocked from shelves and some broken windows. The earthquake caused substantial damage above 10 million dollars and Federal Disaster Area status was granted to the affected Clinton and Essex Counties.

PROJECT DESCRIPTION

Item	Description
Information Provided	Request for Proposal (RFP) dated September 23, 2019 and Google Earth files showing the layout of the proposed WTGs and associated substation. HER_Lay_034.kmz HER_LAY-035.kmz (revised sent by email after project was awarded)
Site Layout	The Facility site is planned to be within southern part of Orleans County in New York. See the attached Exhibit A001 for general project areas.
Project Description	The proposed Facility site has an approximate nameplate capacity of 185-megawatt located on leased private land that is generally rural. The area

Item	Description
	of land within which all Facility components will ultimately be located is approximately 35,300 acres.
Proposed Structures	The project includes: ■ 33 wind turbines ■ 57 miles of associated 34.5 kV line ■ Meteorological towers ■ Point of connection (POI) substation to interconnect with National Grid's existing Lockport-Mortimer 115 kV transmission line. ■ Medium voltage underground cables ■ Underground communication systems ■ Collection Substation ■ POI switchyard ■ Operations and maintenance (O&M) building ■ Roadways
Anticipated Maximum Loads	Assumed Extreme Loads: ■ Shear (Top of the Foundation): 300 kips ■ Overturning Moment (Bottom of the Foundation): 116,000 kip-ft ■ Total Dead Load (turbine, backfill, and foundation): 8,100 kips Assumed Normal Operating Loads: ■ Shear (Top of the Foundation): 250 kips ■ Overturning Moment (Bottom of the Foundation): 95,000 kip-ft ■ Total Dead Load (turbine, backfill, and foundation): 8,200 kips Assumed Substation Transformers: Axial Load 30 kips Assumed O&M Building: 1 to 2 klf
Expected Foundations	Mat foundations for WTGs, shallow foundations such as spread footing and slabs for ancillary structures, and deep foundations to support transmission line towers.
Below-Grade Structures	Not anticipated for turbines, potential below-grade structure for substation control building.
Grading/Slopes	Unknown at this time. We anticipate less than two (2) feet of site grading will be required to achieve the final site elevations.

GEOTECHNICAL CHARACTERIZATION

Subsurface Profile

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of

the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of site preparation and foundation options. Conditions encountered at each exploration point are indicated on the individual logs. The individual logs can be found in the **Appendix A**, Exhibit A007 through A014 and the GeoModel can be found in the **Appendix A**, Exhibit A006 of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel.

Model Layer	Layer Name	General Description
1	**Surficial**	Topsoil
2	**Native Soil**	Mixtures of silt, sand and clay (SM; ML, CL-ML; SW-SM); red brown to gray; medium stiff to hard or medium dense to very dense
3	**Native Layer-2**	Silt, Sand and Gravel (SM; ML); brown to gray; loose to very dense
4	**Bedrock**	Dolostone: gray to gray-black; fine-grained, slightly fractured, close fracture spacing, slightly weathered, medium strong.

Note the dimensions of the sampling equipment may preclude sampling particles larger than 2-inch in dimension. Rock fragments and split-spoon sampler refusal was encountered at some locations within the depths explored, indicating the presence of possible cobbles and boulders.

Bedrock was encountered at T-7, T-11, T-18, T-26, T-30 and Substation. From each location (with the exception of T-18), core samples of 5 to 15 feet length were obtained. Recoveries of the core samples ranged from 82 to 100 percent and RQDs from 15 to 100 percent (average 75 percent), indicating very poor to excellent rock quality. Bedrock was encountered as follows:

Boring	Bedrock Type	Top of Bedrock		Rock Core Information		
		Approximate Depth (ft)	Approximate Elevation (ft)[1]	Depth (ft)	Recovery (%)	RQD
T-7	**Dolostone**	**30**	616	30-35	82	82
T-11	**Dolostone**	**9**	650	9-14 14-19 19-24	100 95 92	95 72 84
T-18	**Dolostone**	**30**	616	Not Applicable	Not Applicable	Not Applicable
T-26	**Dolostone**	**15**	650	15.5-20.5 20.5-25.5 25.5-30.5	100 93 97	100 78 78
T-30	**Dolostone**	**5.5**	665.5	5.5-10.5	97	72

Boring	Bedrock Type	Top of Bedrock		Rock Core Information		
		Approximate Depth (ft)	Approximate Elevation (ft)[1]	Depth (ft)	Recovery (%)	RQD
				10.5-15.5 15.5-20.5	97 95	15 84
Substation	**Dolostone**	**42.5**	627.5	42.5-46.5 46.5-5105	85 85	75 62

1. This is estimated from Google Earth and is not a surveyed number

Groundwater Conditions

We monitored the boreholes for the presence and level of groundwater at completion of drilling. Also, temporary water wells were installed at 7 locations for delayed readings. The groundwater levels in each boring can be found on the boring logs in **Appendix A,** Exhibit A007 through A014.

Boring No.	Groundwater level 1st Observation (at completion of sampling/prior to coring) (ft.)	Groundwater level at 2nd observation (after coring) (ft)	Groundwater level at 3nd observation (ft)
T-3	25.5 ft at completion of soil sampling	N/A	1 ft on 12/13/2019
T-7	26 ft prior to coring	0 ft after coring	0.5 ft on 12/13/2019
T-11	5 ft prior to coring	0 ft after coring	0.5 ft on 12/13/2019
T-18	5.5 ft at completion of sampling	N/A	1 ft on 12/13/2019
T-26	None encountered at completion of soil sampling	N/A	1.5 ft on 12/13/2019
T-30	None encountered at completion of soil sampling	N/A	5 ft on 12/13/2019
Substation	None encountered at completion of sampling	N/A	0 ft on 12/13/2019

In addition to boreholes, the test pits were visually observed for groundwater conditions. One of the test pits, TP-5, was observed to fill-up three times in the course of excavation.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings and test pits were performed. Dense glacial till, high fine content soils, and sedimentary rock were generally encountered in the borings and test pits and would be considered relatively impermeable. Therefore, perched groundwater conditions

could be encountered in excavations where soil/rock conditions are encountered, particularly after rainfall events or irrigation. Groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Test Borings

The preliminary subsurface investigations by Terracon included subsurface soil and bedrock sampling and geotechnical laboratory testing at boring locations located within proximity to the proposed turbine sites and substation. Borings were located across the site to provide preliminary information of the overall Facility required during the permitting process.

Borings were performed as follows:

Number of Borings	Boring Depth [1]	Location
7 (T-3, T-7, T-11, T-18, T-26, T-30 and Substation)	20 to 51.5 feet	Turbine locations and substation

1. Below ground surface.

Boring Layout and Elevations: Terracon personnel provided the exploration layout. Coordinates were obtained with a recreational-grade GPS unit (estimated horizontal accuracy of about ±15 feet), and approximate elevations were obtained by interpolation from the USGS topographic maps. If elevations and a more precise exploration layout are desired, we recommend explorations be surveyed following completion of fieldwork.

Subsurface Exploration Procedures: We advanced the borings with an ATV-mounted rotary drill rig using continuous hollow stem flight augers. Soil sampling was performed using split-spoon sampling procedures. In the split-spoon sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon is driven into the ground by a 140-pound automatic hammer falling 30 inches. The number of blows required to advance the sampling spoon the middle 12 inches of a normal 24-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. We observed and recorded groundwater levels during drilling and sampling. For safety purposes, all borings were backfilled with auger cuttings after their completion.

When auger refusal was encountered upon bedrock, rock cores were generally obtained using NQ size core bits. Water was circulated between the barrels and across the bit face to cool the core bit and to flush away cuttings. The recovery length and the Rock Quality Designation (RQD) for the recovered sample were recorded. The percent recovery is the ratio of the length of rock recovered over the length of coring. The RQD is the ratio of the sum of the length of recovered rock core 4 inches or greater in length, over the length of core run. The RQD is useful is providing a qualitative and quantitative evaluation of the engineering quality of bedrock.
The sampling depths, penetration distances, and other sampling information were recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and further classification by a Geologist and/or a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs include visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Field Electrical Resistivity Testing

Field electrical resistivity testing (ER) was completed at the Facility in general accordance with ASTM G57 by the Wenner Four Probe Method at locations provided by High Bridge Wind. Five test locations were selected, and two perpendicular ER lines were performed at each test location, one running north-south and the other running east-west. Tests were performed at “a”-spacings of about:

- 2, 5, 10, 20, 50, and 75 feet at the WGT areas, and
- 1, 2, 4, 8, 10, 15, 25, 50, 75, 100, 150, 200, 200, 300, and 400 at the substation area.

The electrical resistivity reports are included in **Appendix C**, Exhibit C001 to C011 of this preliminary report.

Geophysical Program

Terracon used a seismic refraction system consisting of a Seismic Source DAQLink III seismograph and 24 geophones to derive subsurface seismic velocity information. Linear arrays of 24 geophones were placed near four turbine locations (T-3, T-11, T-18, and T-30). The test locations were selected to provide a wide spatial coverage of the project area. The following types of seismic data were recorded:

- *Refraction microtremors* produced by ambient seismic noise were recorded. The data was processed using a wavefield-transformation data-processing technique and an interactive Rayleigh-wave dispersion-modeling tool. The refraction microtremor exploits aspects of Spectral Analysis of Surface Waves (SASW) and Multi-Channel Analysis of

Surface Waves (MASW) to derive a shear wave (s-wave) profile and an average shear-wave velocity along the array for a corresponding depth.

- *First-arrival travel times of compressive waves (p-waves)* produced by a p-wave source were recorded. Using only the first-arrival travel times and survey geometry, the data was forward modeled using a non-linear optimization technique called adaptive simulated annealing. This algorithm determines the compressive wave velocity model for a corresponding depth and resolution with the minimum travel-time error without searching through every possible model.
- *MASW* was performed by collecting surface waves created by a seismic source consisting of a sledge hammer and a metal plate. The data was then processed using dispersion analysis software (SurfSeis, engineered by the Kansas Geological Survey) that extracts the fundamental-mode dispersion curve(s). The curves are inverted and modeled to yield a 1D shear-wave velocity profile along the array for a corresponding depth. Using a roll-along setup and subsets of geophones, 1D profiles are created along an array and then combined to yield a 2D profile.

Seismic testing uses shear and compressive wave arrival times and dispersion to detect changes in the subsurface of the area being investigated. Changes in the travel time and dispersion generally indicate material property changes such as but not limited to density and wave speed, which in some cases can be used to derive qualitative and quantitative soil and rock properties.

Final outputs consist of 1D s-wave and p-wave profiles are included in **Appendix D**, Exhibit D001 to D005. Subsurface conditions interpreted from geophysical testing are subject to possible anomalies creating variations from actual conditions. The boring logs should also be reviewed in conjunction with the interpreted subsurface conditions.

Laboratory Testing

Disturbed SPT samples were obtained and sealed in the field to prevent moisture loss. Bulk samples were also obtained from the auger cuttings at selected locations and sealed in the field in 5-gallons plastic buckets. Samples were then transported to our laboratory for examination and testing.

Samples obtained during the field exploration were visually classified in the laboratory in general accordance with the Unified Soil Classification System (USCS). The USCS is described in the **Supporting Information** section of this report. The results of standard soil classification (index) laboratory tests are presented on the boring logs or as separate documents in **Appendix B.**

Rock classification was conducted using locally accepted practices for engineering purposes; petrographic analysis may reveal other rock types. Rock core samples typically provide an improved specimen for this classification. Boring log rock classification was determined using the Description of Rock Properties.

In addition to the standard soil index testing, other laboratory work including the tests noted below was performed to aid the engineer in making appropriate design recommendations for the project. The results for these tests can be found in **Appendix B.**

- ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D422 Standard Test Method for Particle-Size Analysis of Soils
- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
- ASTM D7012 Unconfined Compressive Strength of Rock Cores
- Chemical testing (pH, sulfides, sulfates, chlorides, and oxidation-reduction potential)

Thermal Resistivity Testing

The test included field (in-situ) and lab thermal resistivity testing at five site locations (TP-1, TP-2, TP-3, TP-4, and TP-5). In-situ thermal resistivity and ambient temperature measurements were conducted at depths of 2, 3, and 4-feet at each location along the cable routes. The field thermal resistivity values were measured at the given soil moisture on that day. Depending on weather and environmental conditions; i.e. drying due to cable heat or other heat source, seasonal drying (drought), artificial draining, water demand of crops, drying due to frost (ice lenses), etc., the soil may be drier at certain times of the year. Therefore, the design thermal resistivity for the native soils should be based on the driest expected conditions. In-situ thermal test were conducted in accordance with the IEEE Standard 442-2017 using thermal probes and the Geotherm TPA-2000; run off a portable power source.

Lab thermal resistivity included the measurement of moisture content, density and thermal dry-out characterization (thermal resistivity as a function of moisture content). The bulk samples were re-constituted to the 'in-situ' moisture content and 92% of the corrected Proctor density. A series of thermal resistivity measurements were made in stages with moisture content ranging from 'natural' to totally dry condition. The tests were conducted in accordance with IEEE Standard 442-2017. Test results are attached in **Appendix B**, Exhibit B017 to B020. The thermal resistivity test results presented are for the samples obtained at the location(s) referenced in Geotherm's report and at the reported dry density and moisture content.

Corrosion Testing

Soil samples from seven boring locations were tested for corrosivity potential. These samples were being tested for pH, water soluble sulfate, sulfides, chlorides, total salts, Red-Ox potential,

and electrical resistivity. Corrosion testing results are included in **Appendix B**, Exhibit B015 to B016, and summarized below.

Corrosivity Test Results Summary								
Test Boring[1]	**USCS**	**Sulfides (mg/Kg)**	**pH**	**Water Soluble Sulfates (mg/kg)**	**Soluble Chlorides (mg/kg)**	**Red-Ox (mV)**	**Total Salts (mg/Kg)**	**Electrical Resistivity (Ω-cm)**
T-3	(SC-SM)	Nil	8.32	151	23	+679	518	9,118
T-7	(SM)	Nil	8.49	62	77	+680	544	7,954
T-11	(GM)	Nil	8.40	87	50	+681	574	5,578
T-18	(ML)	Nil	7.60	74	48	+679	446	8,730
T-26	(SM)	Nil	7.76	66	48	+680	447	8,779
T-30	(SM)	Nil	8.33	131	55	+682	895	3,298
Substation	(ML)	Nil	8.37	104	90	+681	673	5,820

1. Samples tested generally obtained at depths ranging from 2 to 4 feet below ground surface

These test results are provided to assist in determining the type and degree of corrosion protection that may be required. Although we are providing general guidance below, we recommend a certified corrosion engineer determine the need for corrosion protection and design appropriate protective measures, if required.

SHRINK/SWELL POTENTIAL

The soils observed in the test borings generally consists of non-plastic silt with varying amounts of sand and gravel. It is our opinion the on-site soils should have minimal shrink/swell potential. As a result, we do not anticipate that specific construction procedures associated with potential expansive clays are required for this project. Therefore, further assessment was not conducted.

POTENTIAL FOR FROST ACTION

Design and construction of the proposed foundations, roadways, and work pads should anticipate surficial topsoil and organic subsoil overlying generally poor draining and frost-susceptible glacial till over bedrock. Foundations and associated buried interconnect are typically placed at suitable depths below the frost line, assumed 4 feet below ground surface. Therefore, further assessment was not conducted.

LANDSLIDE

Most of the Facility soil consists of dense glacial till that stands up well to landslide tendency[5]. Review of USGS topographic maps and available aerial photographs suggests much of the Facility area consists of relatively flat and gently rolling areas. Obvious indications of steep, unstable slopes or cliffs were not noted. However, localized erosion undercutting may exist leading to slope instability.

We have reviewed local geological data regarding soil types and seismic considerations (i.e. review of soil survey information; seismicity of the site; geologic map of New York State; USGS for fault zones), the NYSDOT GDM Chapter 16, "Landslide Analysis and Mitigation", the 2014 New York State Hazard Mitigation Plan[5], and the "Landslide Inventory Map of New York"[6]. Based upon the results of our review, and the existing and anticipated site topography, it is our opinion the Facility is in an area of low landslide incidence.

KARST

The project area is underlain by limestone and dolostone bedrock with interbedded shale layers. The borings advanced within the bedrock did not encounter indications of voids or solution features. The shear-wave profiles obtained from the geophysical survey completed at four locations (T-3, T-11, T-18, and T-30) across the site were also examined for changes in seismic wave velocities to indicate potential for karst features within the bedrock. Potential karst anomalies, generally identified by low velocity zones, were not identified at any of the 1-D and 2-D profiles completed for this project. As a result, we do not anticipate that specific construction procedures associated with karst geology are required for this project. Therefore, further assessment was not conducted.

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[5] *http://www.dhses.ny.gov/recovery/mitigation/documents/2014-shmp/Section-3-14-Landslide.pdf*
[6] *Landslide Inventory Map of New York, 1989; Fickies, RH, Brabb, EE; New York State Museum Circular 52, Albany, NY.*

GEOTECHNICAL OVERVIEW

The subsurface conditions encountered in the test borings were generally consistent with the mapped surficial and bedrock geology at those locations. Based upon the subsurface conditions encountered at the test borings, the glacial till deposits and/or bedrock encountered at the Facility are structurally suitable for support of wind turbine foundations, support buildings, and access roads. A detailed subsurface geotechnical investigation must be completed prior to final design and construction to assess localized subsurface conditions at the proposed structure locations.

Based on the explorations completed for this preliminary exploration, and based upon the assumption that the base of the WTG will be placed at a minimum depth of 8 feet below ground surface, WTG foundations are expected to bear on the following material:

- Medium dense to dense native glacial till soil at five locations (T-3, T-7, T-11, T-18, T-26).
- Bedrock at the remaining WTG location (T-30).

Rock excavation using hydraulic rams or blasting will likely be required on some of the WTG (wind turbine generator) locations to remove sound and weathered rock to achieve design elevations. Consideration should be given to use pre-stressed rock anchor foundations where sound bedrock is within 8 feet below finish grade to provide additional resistance to uplift and overturning and to decrease the footprint of the foundation.

As discussed in **Exploration and Testing Procedures**, soil samples were obtained at boring locations using a standard 2-inch outer diameter split barrel sampling spoon, and rock coring was performed also using an approximately 2-inch outer diameter core bit. The WTG foundations are anticipated to have widths greater than 60 feet. It should be noted that variations in the depths/elevations and the quality of the soils and rock should be anticipated across the large footprint of the new WTG foundations. This could result in encountering material (soil, rock, weathered rock) in localized areas which may be shallower or deeper, than the material indicated in the borings, which could result in a non-uniform foundation bearing material (i.e. part of the foundation bearing on rock and part on highly weathered rock or soil).

While foundations founded on rock would have a higher bearing capacity, to take in account for possible variations of bearing material across the foundation footprint and minimize differential settlements, we recommend foundations to be designed for the same bearing capacity calculated for the medium dense to very dense soils. We anticipate using this approach will simplify the WTG foundation design effort and may also result in lower construction costs. Preliminary recommendations for WTG foundations and rock anchors are provided in the **Wind Turbine Foundation** section.

During Terracon's preliminary subsurface investigation, groundwater was encountered at the test boring locations at shallow depths. As discussed in **Geotechnical Characterization**, fine-grained soil layers, dense glacial till, and sedimentary rock were encountered in the borings at shallow depths and would be considered relatively impermeable. Therefore, perched groundwater conditions should be expected in excavations where dense soil/rock conditions are encountered, particularly after rainfall events or irrigation. Construction dewatering will likely be required for surface water control and for excavations that encounter perched groundwater conditions, groundwater or seepage. Open sump pumping method is a common and economical method of dewatering and is anticipated to be sufficient based on relatively low permeability soils anticipated.

The soils observed in the test borings generally consist of non-plastic to low-plastic soil. It is our opinion these soils may be sensitive to moisture and difficult to compact when above the optimum moisture content. As such, re-using the on-site fine-grained soils may be difficult during seasonally wet periods, as discussed in the **Earthwork** section.

We recommend the excavated subgrades be evaluated after excavation to proposed grade. We recommend Terracon be retained to evaluate the bearing material for foundation subgrade soils. Variation in the top of rock elevation can occur abruptly in short horizontal distances.

Construction on steep slopes (i.e., more than 15 percent) should be avoided by siting access roads and wind turbines in a linear fashion along the ridgelines as opposed to traversing the hillsides in multiple locations. With proper subgrade preparation, the near surface soils appear suitable for support of gravel-covered roadway sections; however, as with all gravel-covered roadways, on-going maintenance throughout the life of the project will be required to maintain roadway performance.

Specific to the Facility area, the anticipated Seismic Site Class definition for consideration under the New York State Building Code for the proposed turbine locations will likely be C or D, indicating dense soil/soft rock. The actual Seismic Site Class at each turbine location will be determined after the supplemental geotechnical investigation is performed for final design.

The **General Comments** section provides an understanding of the report limitations.

EARTHWORK

Stripping, excavation, grading, and subgrade preparation should be performed in a manner and sequence that will provide positive drainage throughout construction and provide proper control of erosion. The planned site work areas should be graded to prevent water from ponding in construction areas and/or flowing into exposed subgrade areas. Exposed soils should be crowned, sloped, and smooth-drum rolled at the end of each day to facilitate drainage if inclement weather is forecasted. Accumulated water should be removed from subgrades and work areas

immediately prior to performing further work in the area. Soils that become disturbed or weakened from accumulated water should be improved by aeration and re-compaction, chemical treatment, or removal and replacement with new compacted fill.

The near surface soils are anticipated to be relatively stable upon initial exposure but can be easily disturbed by inclement weather and/or construction traffic. This could limit equipment access, greatly increase the amount of soil determined unfit for use as compacted fill or increase the amount of required stabilization. When subgrade instability becomes apparent, reduced construction traffic or use of low ground pressure construction equipment in these areas can reduce the amount of stabilization required.

Site Preparation

We recommend earthwork begin with stripping of stumps, forest mat soils, topsoil, vegetation, and soft or otherwise unsuitable materials from the surface of the proposed construction areas. We recommend stripping topsoil to depths that expose soils with less than 3 percent organics and no roots having a diameter greater than ¼ inch. We anticipate typical forest mat stripping depths will be up to 12 inches. We recommend actual stripping depths be evaluated by the Geotechnical Engineer during construction.

Stripped materials consisting of vegetation and organic materials should be wasted from the site or used to revegetate landscaped areas or exposed slopes after completion of grading operations. If it is necessary to dispose of organic materials on-site, they should be placed in non-structural areas, at a minimum lateral distance of 50 feet from foundations, and in fill sections not exceeding 5 feet in height.

After stripping and cutting to design subgrade elevation, and prior to placement of new fill, we recommend the exposed subgrades be evaluated for the presence of soft, loose or unsuitable materials. We recommend proof-rolling the exposed subgrades for roadways, crane paths, and crane pads, prior to placing site fill in areas below design grade, and after rough grading is completed in other areas. Soil subgrades steeper than 4H:1V should be benched prior to proof-rolling and fill placement. Proof-rolling should be performed using a minimum 10-ton roller or heavy rubber-tired equipment, such as a loaded dump truck, having a minimum gross weight of about 20 tons.

Proof-rolling aids in providing a firm base for compaction of fill and delineating soft or disturbed areas that may exist at or near the exposed subgrade level. Proof-rolling should not be performed on soft and loose soils that do not appear to be able to support rubber-tired vehicles. These areas should be corrected before unnecessary additional disturbance is imposed. Unsuitable areas observed following proof-rolling should be improved by scarification, adjusting to recommended moisture content, and recompaction or by undercutting and replacement with suitable compacted fill (with or without geosynthetics). The more suitable method of stabilization, if required, will be

dependent upon factors such as construction schedule, weather, the size of area to be stabilized and the nature of the instability.

Winter Considerations: Subgrades should be protected from the effects of frost if earthwork takes place during freezing conditions. No fill should be placed over frozen subgrades. Frozen subgrades should be removed to reveal unfrozen soil prior to placing subsequent lifts of fill or foundation components. Frozen soil should not be used as fill until thawed and adjusted to the proper moisture content, which may not be possible during winter months.

Spring Considerations: Seasonally wet conditions should be anticipated during melting of winter snowpack and rain events. The on-site silty soil will be sensitive to moisture and difficult to compact when above the optimum moisture content. Similarly, silty soil subgrades will be easily disturbed and become unstable if exposed subgrades are allowed to become wet.

Fill Material Types

Structural Fill includes material placed for support of foundations, crane pads, roadways, and other permanent structures or facilities. Structural Fill should be free of deleterious, organic, or frozen matter. Only granular Structural Fill should be used below foundations.

The suitability of soils used for fill depends primarily on the gradation and moisture content of the soil when placed. As the fines content (percentage by weight passing the U.S. No. 200 sieve) of a soil increases, it becomes increasingly sensitive to changes in moisture content and adequate compaction becomes more difficult or impossible to achieve. Soils containing more than about 10 percent fines by weight, such as the native soils encountered in the borings, cannot be consistently compacted to the recommended degree when the moisture content is more than about 4 percent above or below optimum.

The native soils are considered suitable for general site grading in roadway and crane pad areas and for backfilling the sides and the top of foundations, but these soils should not be used as Structural Fill below the proposed foundations. The contractor should expect to perform some moisture conditioning of on-site soils in order to achieve adequate compaction. Scarifying and watering or drying of the soils will likely be required for filling with the on-site soils during favorable weather conditions. Drying may be difficult during periods of wet weather.

Fill material requirements vary based on the intended use of the material. The following table summarizes the fill material designations and the zones where they should be placed.

Fill Type [1]	USCS Classification or NYSDOT Specification	Acceptable Location for Placement
Native Soil	SM, ML, CL-ML (maximum particle size of 3 inches)	Backfill around sides and top of foundations, and other non-structural areas.
Imported Structural Fill	NYSDOT Item 733-04A Select Borrow	All locations and elevations except as Aggregate Base or NFS.
Aggregate Base [4]	Item 304.12 - NYSDOT Type 2, Subbase Course Aggregate	All locations and elevations.
General Fill [2]	Varies	General Fill may be used for general site grading. General Fill should not be used under foundations or frost-sensitive structures (e.g. exterior slabs).
Non-Frost Susceptible (NFS) Fill [3]	GW, GP, SW, SP	All locations and elevations. Should be wrapped in a geotextile separation fabric (Mirafi 140N, or similar).
Crushed Stone	GP (Uniform ¾-inch angular crushed stone)	For use on wet subgrades and NFS Fill (if desired), and as drainage fill. Should be wrapped in a geotextile separation fabric (Mirafi 140N, or similar).
Lean Concrete	Not applicable	Can be used to protect soil subgrades and to level subgrades between foundations and bedrock subgrades. Lean concrete should have a minimum compressive strength of 2,000 psi.

1. Compacted fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used. Fill should not be placed on a frozen subgrade.
2. General Fill should have a maximum particle size of 6 inches and no more than 25 percent by weight passing the No. 200 sieve. Native soils may potentially meet the requirements for General Fill provided they meet these requirements.
3. NFS Fill should have a maximum particle size of 3 inches and contain less than 5 percent material passing No. 200 sieve size.
4. NYSDOT Department of Transportation (NYSDOT) Standard Specifications, January 1, 2019, Section 304 - Subbase Course.

Fill Compaction Requirements

Structural and General fill should meet the following compaction requirements.

Item	Description
Maximum fill lift thickness	■ 9 inches or less in loose thickness when heavy, self-propelled compaction equipment is used. ■ 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used.
Compaction Requirements [1]	■ Upper 8 inches of prepared native subgrade in roadway and crane pad: areas: 98% of the material's maximum Proctor dry density (ASTM D 698).

Item	Description
	■ Backfill placed on sides of turbine foundations: 98% of the material's maximum Proctor dry density (ASTM D 698). ■ Backfill placed above turbine foundations: 92% of the material's maximum Proctor dry density (ASTM D 698) and a dry density of at least 100 pounds per cubic foot (pcf). If these soils extend beneath proposed crane pad areas, they should be compacted to at least 98% of the material's maximum Proctor dry density (ASTM D 698). ■ Structural Fill beneath turbine foundations: 98% of the material's maximum Proctor dry density (ASTM D 698). ■ Granular Subbase and Base Course in roadway or crane pad section: 98% of the material's maximum Proctor dry density (ASTM D 698). ■ Roadway/crane pad embankment fill: 98% of the material's maximum Proctor dry density (ASTM D 698).
Moisture Content – Granular Material	Workable moisture levels.

1. Structural fill should be tested for moisture content and compaction during placement. If the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved. All surfaces should be compacted to a firm, unyielding condition.

Utility Trench Backfill

Based on the explorations, subsurface conditions generally consist of topsoil underlain by overburden soils of variable thickness over bedrock. Utility installation will likely require excavation in soil and/or bedrock for trenches and utility poles.

All trench excavations should be made with sufficient working space to permit construction including backfill placement and compaction. As utility trenches can provide a conduit for groundwater flow, trenches should be backfilled with material that approximately matches the permeability characteristics of the surrounding soil. Consideration should be given to installing seepage collars and/or check dams to reduce the likelihood of migration of water through the trenches.

Grading and Drainage

Proper grading, drainage, and land use restrictions may be necessary for the successful performance of WTGs. Grading measures need to avoid depressions or low points present on the surface of the foundation backfill and adjacent grades. Positive grading sloping away from the completed structures should be established and maintained to direct surface water away from the foundations. We recommend site grades be constructed at a minimum gradient of 5 percent sloped away from the center of the turbines, and other structures.

Groundwater may seep from cut slopes during seasonally wet periods. Groundwater seepage at the face of the soil slopes may result in surface sloughs and erosion if not controlled. Seepage, if encountered at cut slopes during construction, should be evaluated and engineered controls incorporated if applicable. Engineered controls may include drainage blankets or sand layers, riprap armoring, and inclusion of drainage swales at the slope toe. Gradation compatibility of drainage filter and base materials should also be evaluated, or geotextiles considered, where appropriate.

Erosion and sediment controls should be installed and maintained in accordance with construction documents and permits. The native soils encountered are susceptible to erosion and should be protected from erosion over the life of the project.

Earthwork Construction Considerations

Although the exposed soil subgrade is anticipated to be relatively stable upon initial exposure, unstable subgrade conditions could develop during general construction operations, particularly if the soils are wetted and/or subjected to repetitive construction traffic. Should unstable subgrade conditions develop, stabilization measures will need to be employed.

Construction traffic over the completed subgrade should be avoided to the extent practical. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. If the subgrade should become frozen, wet, or disturbed, the affected material should be removed, or should be scarified, moisture conditioned, and recompacted.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, “Excavations” and its appendices, and in accordance with any applicable local, and/or state regulations, to provide stability and safe working conditions. The contractor, by his contract, is usually responsible for designing and constructing stable, temporary excavations and should shore, slope or bench the sides of the excavations, as required, to maintain stability of both the excavation sides and bottom. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

Terracon should be retained during the construction phase of the project to observe earthwork and to perform necessary tests and observations during subgrade preparation; proof-rolling; placement and compaction of controlled compacted fills; backfilling of excavations in the completed subgrade; and for construction of foundations.

Rock Excavation

Shallow bedrock was encountered in T-11 and T-30 at depths ranging from 5.5 to 9. Bedrock was also encountered at deeper depths in T-7, T-18, T-26 and substation, ranging from 15 to 42.5

feet below ground surface. The bedrock encountered in the recovered rock cores is identified as medium strong rock and samples tested had a compressive strength as high as over 16,000 psi. The Rock Quality Designation (RQD) values for the rock cores obtained at the boring locations ranged from 15 to 100 percent, which is indicative of rock quality varying from very poor to excellent. The average RQD value for the recovered cores is about 75 percent, indicating a rock of generally fair to good quality. Photographs of the rock cores obtained from the borings, and the result of unconfined compression tests are presented in **Appendix A**, Exhibit A015 to A021.

Removal of the bedrock material will be difficult and at least locally impractical to rip even with high capacity equipment. Excavations into bedrock will likely require very high capacity excavating equipment, in conjunction with use of pneumatic breakers or blasting to shatter the bedrock prior to removal. If blasting is required, light, closely spaced charges should be used to minimize over-break beneath the footing level. Loose rock pieces should be removed, and the zone filled with clean concrete. In any event, the final footing should be poured in contact with the sides of the excavation for the full designed footing thickness to minimize water intrusion below footing level.

Additional test pits should be excavated prior to construction to better evaluate the rock removal characteristics.

At the time of construction, the contractor will determine where blasting may be preferred and the extent required, considering noise impacts, construction schedule and costs, the volume of rock encountered, the hardness of the rock encountered, required safety precautions, and other factors. Where blasting is required, light, closely spaced charges should be used to minimize over-break beneath the footing level. Loose rock pieces should be removed beneath the footprint of the WTG foundations and the zone filled with lean concrete. The Contractor should be prepared for blasting and to utilize hydraulic or pneumatic breakers to assist in rock removal. We recommend a unit cost for rock excavation be secured in the bid documents that can be used for a basis of add/deduct quantities.

Controlled blasting methods should be specified to reduce over-break below foundations and at the excavation perimeter along final open slopes. Blasting mats should also be used to control fly-rock. If controlled blasting is used to excavate bedrock, care should be taken to limit the depth of over-blast in order to minimize the subgrade preparation efforts. Alternative methods of rock removal, including expansive agents or mechanical methods such as a backhoe-mounted ram, may be employed if blasting is not permissible. We recommend the contractor familiarize her/himself with the anticipated bedrock conditions before construction.

A site-specific Blasting Plan should be prepared by the rock removal contractor prior to beginning construction. The Plan should address contractor qualification; warning measures; safe transportation, handling, and storage of blasting materials; use of blasting mats; coordination with local fire and EMS districts; pre-blasting condition surveys of nearby buildings; minimizing impacts to drinking water wells; and notifications to nearby business and residential owners of 24-hour

contact information for reporting well impacts occurring after blasting operations. The Plan should also be used for notifications, use of explosives, security, monitoring, and documentation.

Rock Crushing

Blast rock can be processed to provide fill material. Based on the lithology, bedrock is suitable for crushing using conventional crushing equipment. Due to its anticipated relative hardness, we recommend the blasting program be designed to yield fragments for crushing having a nominal maximum dimension of 12 inches. A choke layer may be required between rock fill and material placed above the rock fill depending on the gradation of the fill materials. Crushed Rock material should satisfy gradation criteria for the recommended Crushed Stone or Structural Fill use as discussed in **Fill Material Types**.

Construction Observation and Testing

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of vegetation, topsoil, loose or disturbed soil and rock, proof-rolling, and mitigation of areas delineated by the proof-roll to require mitigation.

Each lift of compacted fill should be tested, evaluated, and reworked, as necessary, until approved by the Geotechnical Engineer prior to placement of additional lifts.

In areas of foundation excavations, the bearing subgrade should be evaluated under the direction of the Geotechnical Engineer. If unanticipated conditions are encountered, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.

WIND TURBINE FOUNDATIONS

Based on the boring data, laboratory testing results, and our understanding of the turbine loading outlined in the **Project Description** section, it is our opinion gravity base foundations are feasible for support of proposed WTGs at the locations explored. We note that WTG foundation excavations may be difficult to advance due to the presence of shallow bedrock on some of the turbine sites we investigated thus far. For additional information and recommendations concerning excavations for this project see the **Rock Excavation** section of **Earthwork**.

Wind Turbines Preliminary Allowable Bearing Pressure

Results from the geotechnical exploration and laboratory testing were evaluated to develop the preliminary allowable bearing pressure for the turbine foundations. Net allowable bearing pressures were evaluated by considering the strength of the subsurface materials encountered in our exploratory borings for the proposed WTGs, and by calculating the effective bearing area and average contact stress under the extreme wind load and the mean operating load. Our preliminary recommendations were developed assuming the following:

- The bases of the octagonal-shaped, gravity mat foundations are to bear at 8 feet below grade. Foundation geometry has not yet been determined, but foundation diameters are expected to be on the order of 60 feet. The 8-foot embedment depth will place the foundations below frost depth, which is anticipated to be 4 feet in this area.
- As discussed in Geotechnical Overview, a "reduced" bearing capacity value is presented in this report to account for possible variations in the foundation bearing grade material.
- As mentioned earlier, groundwater level is assumed to be above foundation-bearing levels; foundation-bearing materials are expected to be in a fully saturated condition. Allowable bearing capacity, as shown in the table below, has been reduced to count for the effects of high groundwater table and saturated conditions.

Based on our analyses, provided any over-excavated space created by ripping, hydraulic ram, or any other method of rock excavation are filled from the base of the void or cavity up to the foundation bearing level with lean concrete (minimum 28-day compressive strength of 2,000 psi) the following design parameters are presented below for the proposed WTG locations:

Item	Description
Foundation Type	Mat foundations
Bearing Material	■ Irregular rock surface - leveled with lean concrete ■ Level weathered or competent rock surface – prepared rock surface ■ Glacial Till - minimum 6 inches of Structural Fill placed upon stable native soil
Maximum Net Allowable Bearing Pressure [1]	5 ksf
Ultimate Coefficient of Sliding Friction - tan(d) [2]	
Cast-in-place Concrete on Lean Concrete or Bedrock	0.7
Cast-in-place Concrete on Compacted Structural Fill	0.4

Item	Description
Backfill/Structural Fill Material	Above water table: 100 pcf Below water table: 48 pcf

1. The maximum net allowable bearing pressure is the pressure more than the minimum surrounding overburden pressure at the footing base elevation. An appropriate factor of safety has been applied. These bearing pressures can be increased by 1/3 for transient loads unless those loads have been factored to account for short term or transient live loading conditions, such as extreme wind gusts (we understand these generally have durations of 3 seconds or less) or seismic activity.
2. Can be used to compute sliding resistance where foundations are placed on suitable soil/materials. Should be neglected for foundations subject to uplift conditions. Refer to NAVFAC DM7-02, Table 1 (U.S. Department of the Navy).

If any of the information regarding foundation loading and geometry outlined in this report is incorrect or changes occur during design, Terracon should be contacted so that modifications to our analysis can be made, as appropriate.

During construction of turbine foundations, foundation-bearing materials and their capacities need to be verified by the Geotechnical Engineer or his/her representative. Proof-rolling should be performed on exposed soils with a fully loaded, tandem-axle dump truck or other equipment providing an equivalent subgrade loading. A minimum gross weight of 20 tons is recommended for the proof-rolling equipment. The proof-rolling should consist of several overlapping passes in mutually perpendicular directions over a given area. Soft or pumping areas should be excavated to firm foundation-bearing level. Excavated areas should be backfilled with regular concrete, lean concrete or Structural Fill compacted to the specified density as recommended in our geotechnical report.

Wind Turbines Foundation Settlement

Typical WTG foundations can generally tolerate a maximum permanent rotation of 0.17 degrees under operational conditions. This equates to approximately 2 inches of differential settlement across the width of the proposed mat foundations supporting these structures. Based on site conditions and assumed operational and extreme loading, differential settlements for WTG foundations bearing on soil or bedrock are anticipated to be within these tolerances.

Wind Turbines Lateral and Uplift Loading

Lateral loads transmitted to spread footings can be resisted by a combination of soil-concrete friction on the base of the foundation and passive pressure on the sides of the foundation. Lateral earth pressure against vertical faces on the foundations may be determined using parameters from the following table. Backfill should be placed and compacted as indicated in the **Earthwork** of this report to provide the lateral resistance indicated below.

Item	Equivalent fluid pressure (pcf)		Notes
	Undrained	Drained	
Active Earth Pressure (Ka)	75	33	For active earth pressure, wall must rotate about base, with top lateral movements 0.002 to 0.004 times the height of the vertical face.
At-Rest Earth Pressure (Ko)	80	50	This lateral earth pressure may be assumed to exist prior to lateral movement of the foundation.
Passive Earth Pressure (Kp)	140	250	Movement of the foundation of at least 0.02 times the height of the vertical face will be required to engage passive earth pressure. The granular backfill must extend out and up from the base of the foundation at an angle of at least 60 degrees from vertical for the passive case.

The ultimate uplift capacity of a spread footing due to deadweight forces is limited to the effective weight of the foundation plus the effective weight of soil directly above the foundation. The ultimate uplift capacity should be divided by an appropriate factor of safety in design. We recommend excavated material be tested to evaluate compliance with the minimum design backfill density criterion. Provisions should be made for some potential sorting, mixing or selective use of excavated materials. In addition, density testing of the backfill materials should be performed to evaluate the unit weight is achieved.

Wind Turbine Rock Anchors

Consideration should be given to use pre-stressed/post-tensioned (PT) rock anchor foundations where sound bedrock is within 8 feet of grade to provide additional resistance to uplift and overturning and to decrease the footprint of the foundation. Anchors installed into bedrock will provide overturning resistance in addition to the dead weight of the foundations, structure and backfill. Anchors should be grouted and prestressed. Preliminary capacity of grouted rock anchors should be estimated using the following formula:

$$P = L_b \times \pi \times d \times T_{All}$$

P = Allowable anchor pullout design load
L_b = Anchor bond length
d = Diameter of drill hole
T_{All} = Allowable bond stress between grout and rock surface

For the above equation, the allowable bond stress (T_{All}) may be calculated using an appropriate factor of safety and the ultimate bond stress (T_u) for fair to good quality rock mass presented in the table below.

Based upon the visual observation of the recovered rock cores, laboratory testing results, and our local experience with the regional geology and bedrock, the following preliminary engineering

properties are recommended for competent bedrock encountered at the location of the recovered rock cores:

Competent Rock – Preliminary Engineering Properties [1]			
Parameter	**Description**	**Unit**	**Value**
RQD	Average Value of Rock Quality Designation	%	75
γ	Unit Weight of Rock (above groundwater)	pcf	160
γ'	Effective Unit Weight of Rock (below groundwater)	pcf	100
q_u	Average Value of Uniaxial Compressive Strength (measured from lab test)	psi	13,700
T_u	Ultimate Unit Grout-Rock Bond Stress [2]	psi	100
RMR	Rock Mass Rating (estimated)		40 (Poor Rock)
Ei	Elastic Modulus of Intact Rock (estimated)	psi	2.5E+06
Em	Rock Mass Modulus (estimated)	psi	850,000
Em/Ei	Modulus Ratio (estimated)		0.2 to 0.4
n	Poisson Ratio (estimate)		0.30

1. Values are based on the assumption the foundations are extended to or into competent bedrock.
2. Anchor pullout capacity is influenced by rock conditions, method of anchor hole advancement, hole diameter, bonded length, grout type and grouting pressure. The presumptive ultimate anchor bond stress values presented are intended for evaluation of the feasibility of straight shaft anchors installed in small diameter holes. Pressure-grouted anchors may achieve much higher capacities. Post-grouting can also increase the load carrying capacity of straight shaft anchors by 20-50 percent or more per phase of post-grouting.

We recommend the design, installation, and proof testing of rock anchors be completed in accordance with the *Recommendations for Prestressed Rock and Soil Anchors* by the Post-Tensioning Institute (PTI), *Geotechnical Engineering Circular No. 4 Ground Anchors and Anchored Systems* by the Federal Highway Administration (FHWA), and manufacturer's recommendations. The following recommendations are presented for your consideration:

- As a minimum, horizontal spacing of anchors should be the larger of three times the diameter of the bonded zone or 5 feet, whichever is greater. Greater spacing may be required to satisfy other design considerations.
- The minimum unbonded length should be 10 feet, regardless of calculated design requirement. We also recommend a minimum bonded length of 10 feet, in order to engage higher quality rock and avoid excessive creep and reduction in tensioning as bonds weaken in upper highly fractured rock zones. Longer bonded or unbonded lengths may be needed to satisfy design requirements.

- The anchor depths should be such that a Safety Factor of at least 2 is provided against a pull-out conical failure of the rock mass. The conical failure surface should be assumed to extend from the mid-point of the anchor bond zone to the rock surface at a central angle of 60 degrees (or 30 degrees with respect to the vertical). Side shear resistance along the failure surface should be neglected. Two or more anchors should not "share" the same rock mass. Overlap of the tension pullout cones (if any) should be accounted in the design of the foundation. above).
- Anchor holes should be drilled at specified locations and tolerances as shown on the approved plans. Common practice is to drill at least 6-inches beyond the design length to permit better drill hole cleaning.
- We recommend anchor grout with a minimum compressive strength of 5,000 psi be used.
- At least 10 percent of the anchors should be performance tested prior to production installation of anchors. Pending satisfactory results of performance tests, all anchors need to be proof-tested and locked off to at least the design load. Performance testing will help evaluate load, unload behavior and creep potential. Proof testing will effectively load test the remaining anchors and verify the capacity of each anchor prior to casting the foundations. If performance testing field capacities do not meet design capacities, greater anchor lengths will be required, and/or the fractured bedrock could be pre-grouted to improve the rock mass integrity.

Wind Turbines Foundation Stiffness

Foundation material stiffness was evaluated based upon the geophysical survey, test borings, and laboratory testing results. Geotechnical design parameters to evaluate overall foundation system stiffness are as follows:

Parameter Description	Range (lower – upper; mean)
Design Shear Wave Velocity, V_s (ft/s)[1]	1,100 - 7,510; 3,420
Design Compressive Wave Velocity, Vp (ft/s) [1]	3,100 – 13,120; 7,280
Small Strain Shear Modulus G_o (ksf)	4,980 – 227,970; 47,380
Small Strain Elastic Modulus, E_o (ksf)	13,640 – 624,650; 129,810
Large Strain or Corrected Shear Modulus, G (ksf) [2]	1,490 – 68,390; 14,210
Large Strain or Corrected Elastic Modulus, E (ksf) [2]	4.090 – 187,400; 38,940
Poisson's Ratio, μ	0.3 – 0.45; 0.37

Parameter Description	Range (lower – upper; mean)

1. Based upon the average of wave velocities measured at four turbine locations by performing geophysical tests.
2. Reduced from small strain values based on an assumed strain level of 10^{-3}, following the method from "Guidelines for Design of Wind Turbines", Riso, 2nd Edition, 2002 - Pages 201 to 202, and using a modulus degradation value of 0.3.

The geotechnical parameters outlined above are based upon generalized soil profiles and material values obtained from the exploration data and our interpretation of the variability of the data. The above stiffness values have no factor of safety included. Variations of the soils/rock and their engineering properties are likely to occur across the site that could result in deviations from the parameters discussed in this report. If any of the information regarding foundation loading and geometry outlined in this report is incorrect or changes occur during design, or soil conditions are different than what was presented on the borings Terracon should be contacted so that modifications to our analysis can be made, as appropriate.

Wind Turbines Foundation Excavations

During our preliminary subsurface investigation, shallow groundwater, which may likely be perched groundwater condition, was generally encountered during drilling at the test boring locations completed for the WTGs. It is our opinion dewatering will be required for surface water control and for excavations that encounter perched groundwater conditions, groundwater or seepage. Open sump pumping method is a common and economical method of dewatering and is anticipated to be sufficient based on relatively low permeability soils anticipated.

The base of all foundation excavations should be free of water and loose rock, prior to placing concrete. The following recommendations are herein presented for your consideration:

- Turbine foundations should be placed directly on sound bedrock or on at least 6 inches of compacted Structural Fill placed upon stable native soil or weathered rock.
- Variations in the rock surface can occur over relatively short horizontal distances. If a soil/rock transition is encountered at the proposed footing elevation, the soil should be excavated to the rock surface and replaced with compacted Structural Fill. In addition, the rock should be overexcavated to a depth of at least 1 foot below the bottom elevation of the footing, so that the entire footing is placed on compacted Structural Fill.
- If unsuitable bearing soils are encountered at the base of the planned footing excavation, the excavation should be extended deeper to suitable soils, and the footings could bear directly on these soils at the lower level or on compacted Structural Fill placed on stable native soil or bedrock. The over-excavation should extend from the edge of the foundation a lateral distance of 8-inches for every foot of undercut.

- Rock excavation should be advanced to form level bearing grades at the bottom of the foundation excavation. Loose or shattered rock layers should be removed to provide a sound and unshattered base for foundations. Blasting may result in an uneven surface. For rock anchored foundations, high spots may need to be removed and low areas filled with lean concrete. Otherwise, it would be acceptable to use Crushed Stone to create a level working surface for the foundation.
- Due to the large size of the proposed turbine foundations relative to the small diameter of the sampling equipment used in our borings, it is likely that variations in bearing conditions are present in portions of foundation areas that were not explored. We recommend the Geotechnical Engineer observe and approve bearing grades (prior to the placement of reinforcing steel and concrete forms) to make sure they are free of mud, shattered rock, water or frost, and meet the minimum requirements for bearing resistances presented in this report.

SEISMIC CONSIDERATIONS

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Seismic Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC).

Specific to the Facility site, based on the soil/bedrock properties encountered at the site and as described on the exploration logs and results, it is our professional opinion that the **Seismic Site Classification** for proposed WTGs and associated support structures is **C** or **D**. The actual Seismic Site Class at each turbine locations will be determined after the supplemental geotechnical investigation and geophysical survey is performed for final design.

ACCESS ROADWAYS

General Comments

Surficial materials below the topsoil primarily consist of mixtures of clay, silt, sand, and gravel. It is expected the proposed site grades will be established near the existing site grades using small amounts of Engineered Fill similar to the surficial soils to level the planned access road areas.

We understand proposed access roads may consist of aggregate sections with no asphalt or concrete surface. Recommendations are presented below for two alternative aggregate sections: one assuming the aggregate section placed over stable, proofrolled native subgrade materials; the second for the case where achieving a stabilized subgrade may be difficult or not possible

due to weather conditions at the time of construction. The access roads are expected to experience total lifetime Equivalent Single Axle Loads (ESAL) of 10,000, primarily during construction, with little maintenance traffic thereafter.

The access road area subgrades should be properly sloped to direct water from beneath the drive area gravel section toward the edge, and/or down gradient. Collected water should be channeled away from the access road. Adequate sloping of the gravel surface will minimize the potential for ponding of water on or within proximity to the drive area, which will shorten the life of the unpaved roadways.

The aggregate sections presented in this report are considered minimal sections based upon the expected traffic and the composite subgrade conditions; however, they are expected to function with periodic maintenance if good drainage is provided and maintained.

Aggregate Section Over Stable Subgrade

The access road subgrades should be prepared in accordance with the recommendations provided in **EARTHWORK** section, above, including proof-rolling and removal/replacement of soft/unstable areas identified by the proofrolling. These subgrades should be prepared immediately prior to the time of Aggregate placement to reduce the risk of disturbance due to weather or construction vehicle traffic. If this cannot be done, the subgrades should be reevaluated by a qualified Geotechnical Engineer for disturbance or softening immediately prior to Aggregate placement. For subgrades prepared in accordance with **EARTHWORK** section, we recommend the aggregate section consist of a minimum 9 inches of NYSDOT Type 2 Subbase Course Aggregate compacted to 98 percent of its maximum dry density as determined by the ASTM D698 test procedure (Standard Proctor). Based upon the soil conditions at the time of construction, additional Subbase Course Aggregate and/or multiple layers of high-strength geotextile may be required to stabilize the aggregate section.

To maintain surface drainage, the subgrade should have a minimum ¼-inch per foot slope and the final grade adjacent to the road should slope down from road edges at a minimum 2 percent.

Aggregate Section Over Weak Subgrades

The requested previous access road could also be established over a relatively weak subgrade with CBR values (i.e. less than 3), which would allow placement of the roadway section over on-site soils with minimal subgrade preparation activities, without the need for proofrolling with a heavy construction equipment.

For this scenario, we recommend the Aggregate section consist of a minimum of 18 inches of compacted NYSDOT Type 2 Subbase Course Aggregate placed over high-performance geotextile Mirafi RS380i, or equivalent, installed over the existing subgrade. The high-

performance geotextile will provide reinforcement strength to the aggregate material and will limit migration from the underlying subgrade, which may contribute to its degradation and loss of strength. Based upon the soil conditions at the time of construction, additional Subbase Course Aggregate and/or multiple layers of high-strength geotextile may be required to stabilize the aggregate section.

In areas where fill materials are required to level the proposed subgrade, we recommend fill be compacted to at least 95 percent of its maximum dry density as determined by the ASTM D698 test procedure (Standard Proctor).

Access Road Maintenance

Regardless of the design, unsurfaced roadways will display varying levels of wear and deterioration. We recommend implementation of a site inspection program at a frequency of at least once per year to verify the adequacy of the roadways. Preventative measures should be applied as needed for erosion control and regrading. An initial site inspection should be completed approximately 3 months following construction. For planning purposes, we recommend assuming over time the placement of additional Aggregate will be required to level depressions and long-term rutting. These areas should be filled with additional aggregate rather than scalping of material from adjacent areas.

Shoulder build-up on both sides of proposed roadways should match the road surface elevation and slope outwards at a minimum grade of 10 percent for 5 feet. Surface drainage should be provided away from the edge of roadways to reduce lateral moisture transmission into the subgrade.

When potholes, ruts, depressions or yielding subgrades develop, they must be repaired prior to applying additional traffic loads. Typical repairs could consist of placing additional Aggregate in ruts or depressed areas and, in some cases, removal of Aggregate surfacing, repair of unstable subgrade, and replacement of the Aggregate surfacing. Potholes and depressions should not be filled by blading adjacent ridges or high areas into the depressed areas. New Aggregate should be added to the depressed areas as they develop. Failure to make timely repairs will result in more rapid deterioration of the roadways, making more extensive repairs necessary.

GENERAL COMMENTS

This document is a preliminary report and recommendations presented in this report should not be considered final or intended to be used for final design of proposed structures.

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. After the final/design level exploration has occurred, Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence or collaboration through this system are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

ATTACHMENTS

Appendix A – Field Exploration

Site Location

Exploration Plan

General Notes

Unified Soil Classification System

Description of Rock Properties

Geomodel

Boring Logs (8 pages)

Rock Core Photos (7 pages)

Appendix B – Laboratory Testing

Summary of Lab Test Results

Grain Size Distribution (4 pages)

Atterberg Limits

Moisture-Density Relationship Results (5 pages)

Rock Compressive Strength (3 pages)

Corrosion Testing Results (2 pages)

Thermal Resistivity Analysis Test Results (4 pages)

Appendix C – Field Soil Electrical Resistivity Test Data

Exploration Plan-Electrical Resistivity

Field Soil Electrical Resistivity Test Data (11 Pages)

Appendix D – Seismic Tests Results

Exploration Plan-Seismic Test Locations

1D Seismic Waves Velocity Profile (4 Pages)

APPENDIX A

LOCATION PLAN AND FIELD EXPLORATION RESULTS

(Exhibit: A-001 through A-021)

SITE LOCATION

Preliminary Geotechnical Study - Heritage Wind Farm ■ Barre Center, New York
Terracon Project No. J5195205

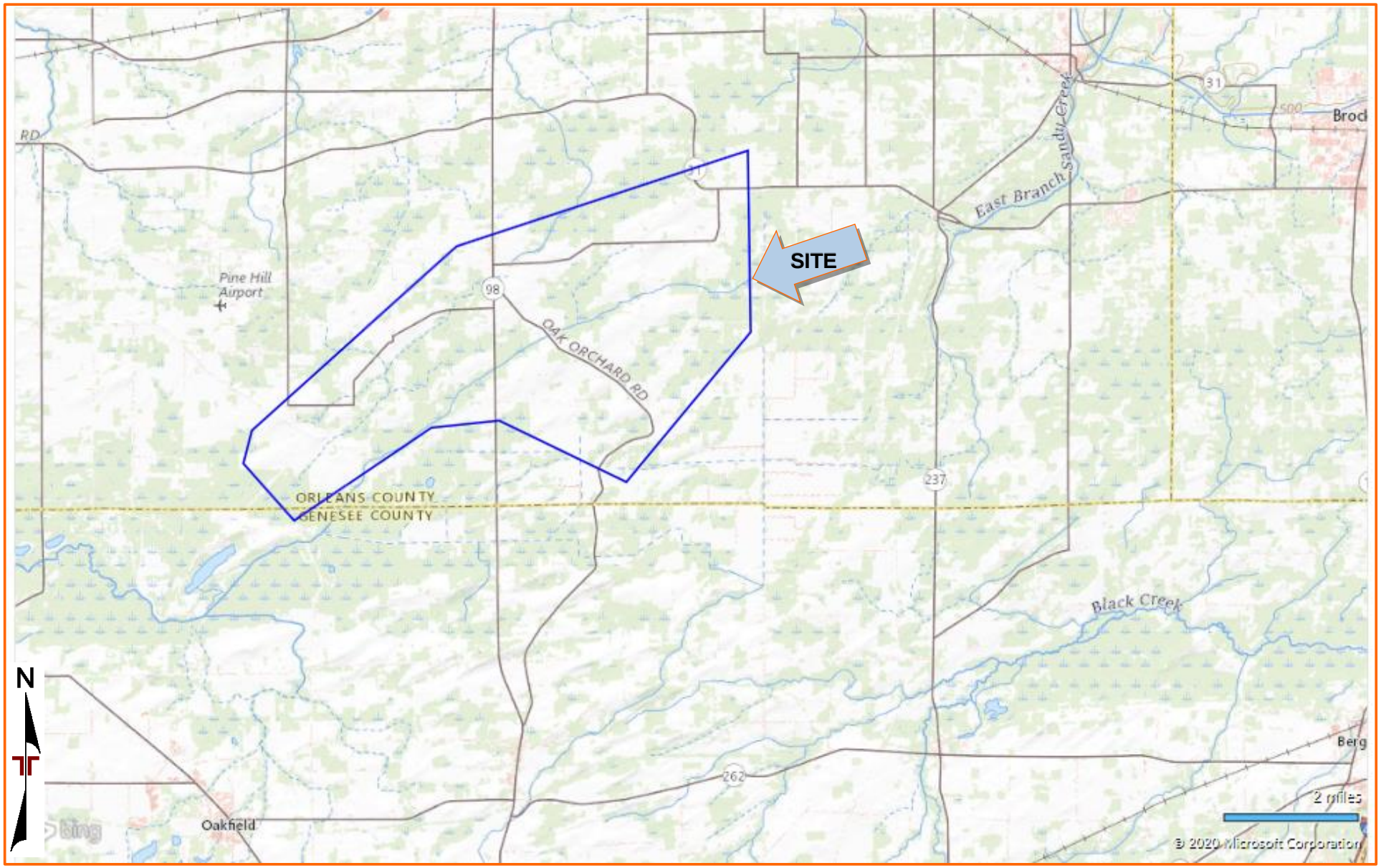


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

TOPOGRAPHIC MAP IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY QUADRANGLES INCLUDE: ALBION, NY (1/1/1976).

Exhibit-A001

EXPLORATION PLAN

Preliminary Geotechnical Study - Heritage Wind Farm ■ Barre Center, New York
Terracon Project No. J5195205

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

Exhibit-A002

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Preliminary Geotechnical Study - Heritage Wind Farm ■ Orleans County, NY

Terracon Project No. J5195205

SAMPLING	WATER LEVEL	FIELD TESTS
Rock Core Standard Penetration Test	**Water Initially Encountered** **Water Level After a Specified Period of Time** **Water Level After a Specified Period of Time** **Cave In Encountered** Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.	**N** Standard Penetration Test Resistance (Blows/Ft.) **(HP)** Hand Penetrometer **(T)** Torvane **(DCP)** Dynamic Cone Penetrometer **UC** Unconfined Compressive Strength **(PID)** Photo-Ionization Detector **(OVA)** Organic Vapor Analyzer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

LOCATION AND ELEVATION NOTES

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See Exploration and Testing Procedures in the report for the methods used to locate the exploration points for this project. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (tsf)**	**Standard Penetration or N-Value Blows/Ft.**
Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
Medium Dense	10 - 29	Medium Stiff	0.50 to 1.00	4 - 8
Dense	30 - 50	Stiff	1.00 to 2.00	8 - 15
Very Dense	> 50	Very Stiff	2.00 to 4.00	15 - 30
		Hard	> 4.00	> 30

RELEVANCE OF SOIL BORING LOG

The soil boring logs contained within this document are intended for application to the project as described in this document. Use of these soil boring logs for any other purpose may not be appropriate.

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification	
					Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ³ 4 and 1 £ Cc £ 3 [E]		GW	Well-graded gravel [F]
			Cu < 4 and/or [Cc<1 or Cc>3.0] [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F, G, H]
			Fines classify as CL or CH		GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu ³ 6 and 1 £ Cc £ 3 [E]		SW	Well-graded sand [I]
			Cu < 6 and/or [Cc<1 or Cc>3.0] [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G, H, I]
			Fines classify as CL or CH		SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A"		CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]		ML	Silt [K, L, M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OL	Organic clay [K, L, M, N]
						Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line		CH	Fat clay [K, L, M]
			PI plots below "A" line		MH	Elastic Silt [K, L, M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OH	Organic clay [K, L, M, P]
						Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ³ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ³ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ³ 30% plus No. 200 predominantly sand, add "sandy" to group name.

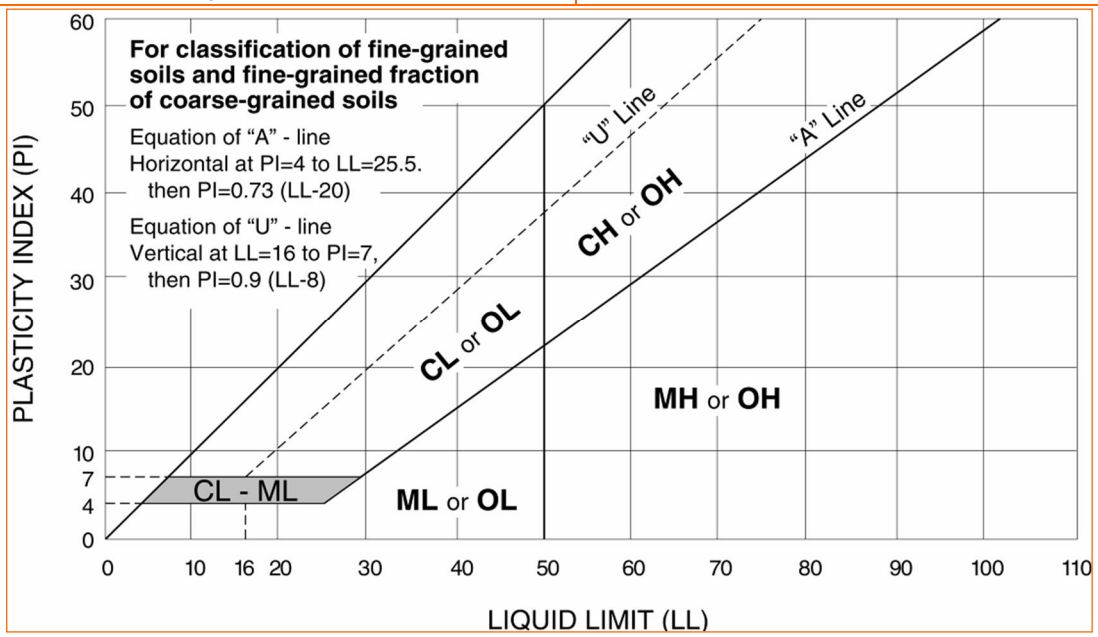
[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ³ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



DESCRIPTION OF ROCK PROPERTIES

WEATHERING	
Term	**Description**
Unweathered	No visible sign of rock material weathering, perhaps slight discoloration on major discontinuity surfaces.
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

STRENGTH OR HARDNESS		
Description	**Field Identification**	**Uniaxial Compressive Strength, psi (MPa)**
Extremely weak	Indented by thumbnail	40-150 (0.3-1)
Very weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	150-700 (1-5)
Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	700-4,000 (5-30)
Medium strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	4,000-7,000 (30-50)
Strong rock	Specimen requires more than one blow of geological hammer to fracture it	7,000-15,000 (50-100)
Very strong	Specimen requires many blows of geological hammer to fracture it	15,000-36,000 (100-250)
Extremely strong	Specimen can only be chipped with geological hammer	>36,000 (>250)

DISCONTINUITY DESCRIPTION			
Fracture Spacing (Joints, Faults, Other Fractures)		**Bedding Spacing (May Include Foliation or Banding)**	
Description	**Spacing**	**Description**	**Spacing**
Extremely close	< ¾ in (<19 mm)	**Laminated**	< ½ in (<12 mm)
Very close	¾ in – 2-1/2 in (19 - 60 mm)	**Very thin**	½ in – 2 in (12 – 50 mm)
Close	2-1/2 in – 8 in (60 – 200 mm)	**Thin**	2 in – 1 ft. (50 – 300 mm)
Moderate	8 in – 2 ft. (200 – 600 mm)	**Medium**	1 ft. – 3 ft. (300 – 900 mm)
Wide	2 ft. – 6 ft. (600 mm – 2.0 m)	**Thick**	3 ft. – 10 ft. (900 mm – 3 m)
Very Wide	6 ft. – 20 ft. (2.0 – 6 m)	**Massive**	> 10 ft. (3 m)

Discontinuity Orientation (Angle): Measure the angle of discontinuity relative to a plane perpendicular to the longitudinal axis of the core. (For most cases, the core axis is vertical; therefore, the plane perpendicular to the core axis is horizontal.) For example, a horizontal bedding plane would have a 0-degree angle.

ROCK QUALITY DESIGNATION (RQD) [1]	
Description	**RQD Value (%)**
Very Poor	0 - 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 - 100

1. The combined length of all sound and intact core segments equal to or greater than 4 inches in length, expressed as a percentage of the total core run length.

Reference: U.S. Department of Transportation, Federal Highway Administration, Publication No FHWA-NHI-10-034, December 2009
Technical Manual for Design and Construction of Road Tunnels – Civil Elements

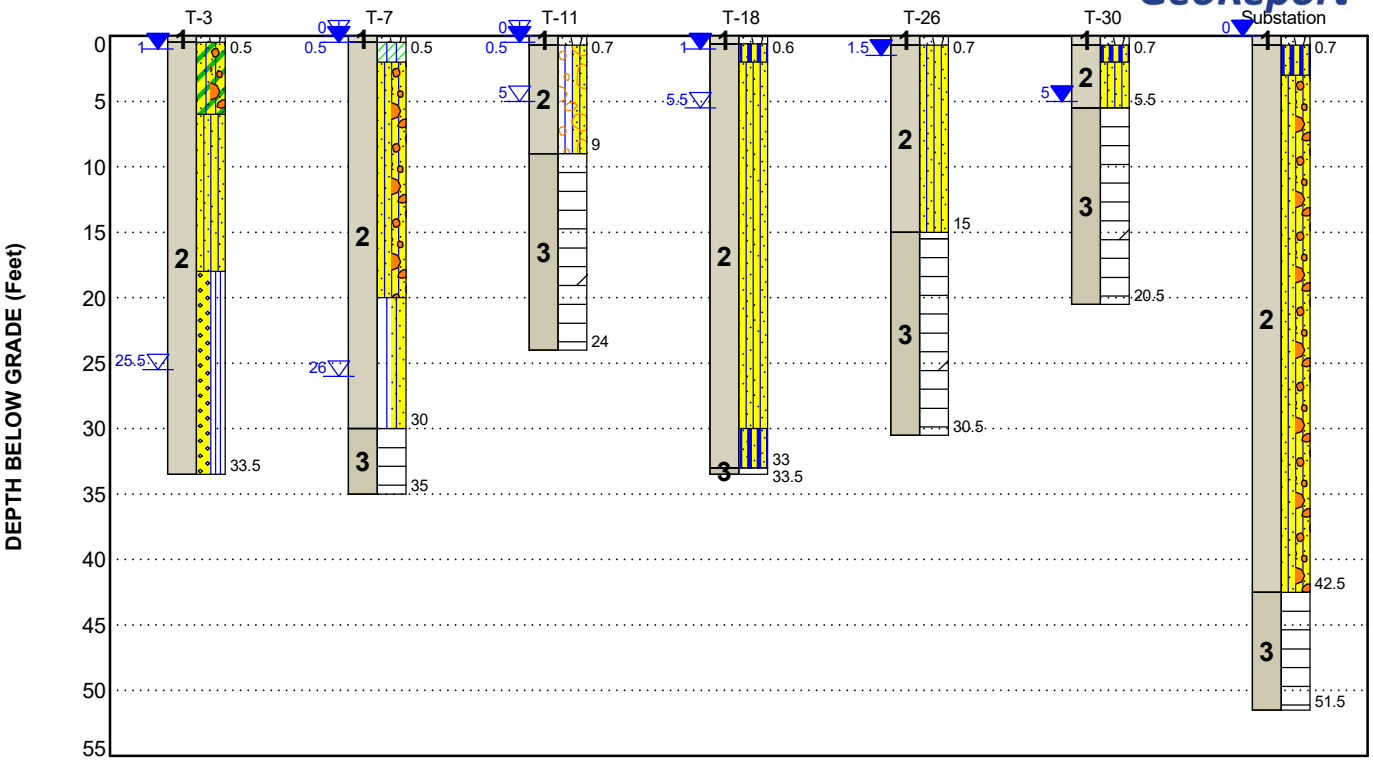
GEOMODEL: (Exhibit: A-006)

BORING LOGS:(Exhibit: A-007 through A-014)

ROCK CORE PHOTOS: (Exhibit: A-015 through A-021)

GEOMODEL

Preliminary Geotechnical Study - Heritage Wind Farm ■ Orleans County, NY
Terracon Project No. J5195205



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

Model Layer	Layer Name	General Description
1	Surfical	Topsoil
2	Native Soil	Mixtures of silt, sand and clay (SM; ML, CL-ML; SW-SM); red brown to gray; medium stiff to hard or medium dense to very dense
3	Bedrock	Dolostone: gray to gray-black; fine-grained, slightly fractured, close fracture spacing, slightly weathered, medium strong

LEGEND

- Topsoil
- Well-graded Sand with Silt
- Silt with Sand
- Sandy Silt
- Silty Clayey Sand with Gravel
- Silty Clay
- Dolomite
- Silty Sand
- Silty Sand with Gravel
- Silty Gravel with Sand

- First Water Observation
- Second Water Observation
- Third Water Observation

NOTES:
Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project. Numbers adjacent to soil column indicate depth below ground surface.

BORING LOG NO. T-3

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

SITE: Barre Center
Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1417° Longitude: -78.2586°

Approximate Surface Elev.: 648 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)	DESCRIPTION
1	0.5	647.5+/-	**TOPSOIL**
2	6.0	642+/-	**SILTY CLAYEY SAND WITH GRAVEL (SC-SM)**, trace organic matter, brown, loose to medium dense Becomes red-brown
	18.0	630+/-	**SILTY SAND (SM)**, trace gravel, brown, dense to very dense Becomes brown-gray, contains occasional cobble fragments
	33.5	614.5+/-	**WELL GRADED SAND WITH SILT (SW-SM)**, trace gravel, brown, dense to very dense Contains occasional cobble fragments

Sample Spoon Penetration refusal Encountered at 33.5 Feet

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
	▼		14	2-2-3-5 N=5		18	
			12	6-5-3-4 N=8			26-21-5
5			14	9-10-5-10 N=15			
			18	12-15-18-20 N=33		5	
			20	7-20-43-39 N=63		7	
10			24	18-30-31-29 N=61		5	
			15	6-19-27-38 N=46		8	
15							
			12	8-18-28-23 N=46		12	
20							
			24	11-22-45-50/5" N=67		6	
25	▽						
			3	50/5"		1	
30							
				50/1"			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

▽ *25.5' BGS at completion of sampling*

▼ *1' BGS on 12/13/19*

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 11-25-2019 | Boring Completed: 11-25-2019

Drill Rig: Diedrich D-50 | Driller: J. Tojdowski

Project No.: J5195205

BORING LOG NO. T-7

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

SITE: Barre Center
Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1488° Longitude: -78.2239°

Approximate Surface Elev.: 646 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)	DESCRIPTION	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
1	0.5	645.5+/-	**TOPSOIL**					
	2.0	644+/-	**SILTY CLAY (CL-ML)**, trace sand, trace organic matter, red-brown, soft	10	1-1-3-3 N=4			
2			**SILTY SAND WITH GRAVEL (SM)**, red-brown, loose	12	5-5-4-4 N=9		29	NP
			Becomes brown; becomes medium dense	6	4-7-9-10 N=16			
			Becomes dense	24	15-19-26-30 N=45		8	
				24	5-13-28-49 N=41		7	
			Becomes very dense	8	22-50/4"		17	
			Becomes gray-brown	8	18-50/5"		3	
	20.0	626+/-						
			SILT WITH SAND (ML), trace gravel, gray, hard	16	25-45-50/5"		21	
					50/5"			
	30.0	616+/-						
3			**DOLOSTONE**, gray, fine-grained, slightly fractured, close fracture spacing, unweathered to slightly weathered, medium strong, occasionally vuggy	49	RUN #1 30.0' - 35.0'	82		
	35.0	611+/-						
			Boring Terminated at 35 Feet					

DEPTH (Ft.): 5, 10, 15, 20, 25, 30, 35

WATER LEVEL OBSERVATIONS

SAMPLE TYPE

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler to 30' BGS.
NQ-2 size rock core barrel 30-35' BGS

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

26' BGS prior to coring

0' BGS after coring

0.5' BGS on 12/13/19

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 11-26-2019	Boring Completed: 11-27-2019
Drill Rig: Diedrich D-50	Driller: J. Tojdowski
Project No.: J5195205	

BORING LOG NO. T-11

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

SITE: Barre Center
Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1812° Longitude: -78.2016°

Approximate Surface Elev.: 659 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)		RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
1	0.7	658.5+/-	**TOPSOIL**					
2			**SILTY GRAVEL WITH SAND (GM)**, red-brown, loose	18	3-4-5-7 N=9			
			Becomes brown; some clay partings; becomes medium dense	10	5-4-8-7 N=12		21	NP
			medium dense	10	3-6-5-6 N=11			
			Occasional cobble fragments	10	8-6-14-9 N=20		6	
	9.0	650+/-	Becomes very dense	6	5-50/1"		10	
3			**DOLOSTONE**, gray, fine-grained, slightly fractured, close fracture spacing, slightly weathered, medium strong	60	RUN #1 9.0' - 14.0'	95		
				57	RUN #2 14.0' - 19.0'	72		
				55	RUN #3 19.0' - 24.0'	84		
	24.0	635+/-						
			Boring Terminated at 24 Feet					

DEPTH (Ft.): 5, 10, 15, 20

WATER LEVEL OBSERVATIONS

SAMPLE TYPE

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler to 9' BGS.
NQ-2 size rock core barrel 9'-24' BGS

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

5' BGS prior to coring

0' BGS after coring

0.5' BGS on 12/13/19

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 11-27-2019	Boring Completed: 11-27-2019
Drill Rig: Diedrich D-50	Driller: J. Tojdowski
Project No.: J5195205	

BORING LOG NO. T-18

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC Charlottesville, VA

SITE: Barre Center Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1495° Longitude: -78.175°

Approximate Surface Elev.: 667 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)	DESCRIPTION
1	0.6	666.5+/-	**TOPSOIL**
2	2.0	665+/-	**SANDY SILT (ML)**, trace gravel, brown, stiff
			SILTY SAND (SM), trace gravel, brown, medium dense to dense
			Becomes dense to very dense
			Becomes brown-gray
			Contains occasional cobble fragments
	30.0	637+/-	
			SANDY SILT (ML), trace gravel, gray, hard
	33.0	634+/-	
3	33.5	633.5+/-	**DOLOSTONE ROCK FRAGMENTS**, gray

Sample Spoon Penetration Refusal Encountered at 33.1' BGS. Auger Penetration Refusal Encountered at 33.5 Feet

DEPTH (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)
	14	1-6-7-10 N=13	11
	13	8-7-11-9 N=18	10
5	12	4-10-17-15 N=27	4
	14	19-21-27-32 N=48	9
	12	16-24-30-24 N=54	9
10	15	8-26-34-42 N=60	8
15	13	8-15-23-26 N=38	9
20	12	16-38-50/5"	7
25	3	7-16-17-14 N=33	8
30	7	34-50/4"	9
	1	50/1"	4

WATER LEVEL OBSERVATIONS: ▽ 5.5' BGS at completion of sampling; ▼ 1' BGS on 12/13/19

SAMPLE TYPE: ATTERBERG LIMITS (LL-PL-PI): RQD (%)

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

▽ *5.5' BGS at completion of sampling*

▼ *1' BGS on 12/13/19*

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 12-02-2019 | Boring Completed: 12-02-2019

Drill Rig: Diedrich D-50 | Driller: J. Tojdowski

Project No.: J5195205

BORING LOG NO. T-26

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

SITE: Barre Center
Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1803° Longitude: -78.1434°

Approximate Surface Elev.: 665 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)	DESCRIPTION
1	0.7	664.5+/-	**TOPSOIL**
2	15.0	650+/-	**SILTY SAND (SM)**, with gravel, brown, loose to medium dense Becomes dense
3	15.5	649.5+/-	**DOLOSTONE ROCK FRAGMENTS**, gray **DOLOSTONE**, gray, fine-grained, slightly fractured, medium bedding, unweathered, medium strong, occasionally vuggy
	30.5	634.5+/-	***Boring Terminated at 30.5 Feet***

DEPTH (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
	6	2-3-3-10 N=6		10	
	16	9-12-12-11 N=24		7	
5	15	6-6-5-5 N=11		11	
	18	8-9-9-10 N=18		8	
	12	8-10-13-17 N=23		10	
10	9	7-14-20-21 N=34		9	
15	4	50/5"		6	
	60	RUN #1 15.5' - 20.5'	100		
20	56	RUN #2 20.5 - 25.5	78		
25	58	RUN #3 25.5' - 30.5'	78		
30					

WATER LEVEL OBSERVATIONS: ▼ 1.5' BGS on 12/13/19

SAMPLE TYPE: Split Spoon; Rock Core

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler to 17.5' BGS.
NQ-2 size rock core barrel 17.5' - 27.5' BGS

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

None encountered at completion of sampling

▼ *1.5' BGS on 12/13/19*

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 12-03-2019 | Boring Completed: 12-03-2019
Drill Rig: Diedrich D-50 | Driller: J. Tojdowski
Project No.: J5195205

BORING LOG NO. T-30

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

SITE: Barre Center
Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.2034° Longitude: -78.1257°

Approximate Surface Elev.: 671 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)	DESCRIPTION	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
1	0.7	670.5+/-	**TOPSOIL**					
	2.0	669+/-	**SANDY SILT (ML)**, trace gravel, brown, medium stiff	15	3-2-5-5 N=7		1	
2			**SILTY SAND (SM)**, with weathered dolostone fragments, brown, medium dense	9	6-6-8-3 N=14		3	
			Becomes very dense	0	50/1"			
	5.5	665.5+/-						
3			**DOLOSTONE**, gray, fine-grained, moderately fractured, very close fracture spacing, very thin bedding, moderately weathered, medium strong, occasional shale partings	58	RUN #1 5.5' - 10.5'	72		
			Becomes thinly bedded, occasionally fractured	58	RUN #2 10.5' - 15.5'	15		
			Becomes thinly bedded to bedded, sound	57	RUN #3 15.5' - 20.5'	84		
	20.5	650.5+/-						
			Boring Terminated at 20.5 Feet					

DEPTH (Ft.): 5, 10, 15, 20

WATER LEVEL OBSERVATIONS

SAMPLE TYPE

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler to 5.5' BGS.
NQ-2 size rock core barrel 5.5' - 20.5' BGS

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

None encountered at completion of sampling

5' BGS on 12/13/19

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 12-04-2019	Boring Completed: 12-04-2019
Drill Rig: Diedrich D-50	Driller: J. Tojdowski
Project No.: J5195205	

BORING LOG NO. Substation

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

SITE: Barre Center
Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1609° Longitude: -78.1823°

Approximate Surface Elev.: 670 (Ft.) +/-

MODEL LAYER	DEPTH	ELEVATION (Ft.)	DESCRIPTION
1	0.7	669.5+/-	**TOPSOIL**
2			**SANDY SILT (ML)**, trace gravel, brown, medium stiff
	3.0	667+/-	**SILTY SAND WITH GRAVEL (GM)**, brown, medium dense to dense
			Becomes brown-gray, contains occasional cobble fragments
			Becomes brown-gray, very dense

DEPTH (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
	16	2-2-3-9 N=5	19	
	0	12-12-11-8 N=23		
5	9	10-9-12-13 N=21	0	NP
	17	14-10-8-14 N=18		
	12	6-14-20-21 N=34		
10	13	8-15-17-16 N=32	4	
15	15	10-30-46-50/4" N=76	2	
20	5	21-50/4"	10	
25	9	18-50/4"	10	
30	7	34-50/2"	8	
35	0	50/2"		

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler to 42.5' BGS.
NQ-2 size rock core barrel 42.5' - 51.5' BGS

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

None encountered at completion of sampling

0' BGS on 12/13/19

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 12-05-2019 | Boring Completed: 12-05-2019
Drill Rig: Diedrich D-50 | Driller: J. Tojdowski
Project No.: J5195205

BORING LOG NO. Substation

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

CLIENT: Apex Clean Energy Management, LLC Charlottesville, VA

SITE: Barre Center Orleans County, NY

LOCATION See Exploration Plan

Latitude: 43.1609° Longitude: -78.1823°

Approximate Surface Elev.: 670 (Ft.) +/-

MODEL LAYER	GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DESCRIPTION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
2		42.5	627.5+/-	**SILTY SAND WITH GRAVEL (GM)**, brown, medium dense to dense *(continued)*	40			0	50/4"			
3		51.5	618.5+/-	**DOLOSTONE**, gray-black, fine-grained, slightly fractured, close fracture spacing, thin bedding, slightly weathered, medium strong	45			41	RUN #1 42.5' - 46.5'	75		
					50			51	RUN #2 46.5' - 51.5'	62		
				Boring Terminated at 51.5 Feet								

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
3.25 inch ID Hollow Stem Augers and 2 Inch OD Split Barrel Sampler to 42.5' BGS.
NQ-2 size rock core barrel 42.5' - 51.5' BGS

Abandonment Method:
Temporary GW observation well installed upon completion

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were interpolated from USGS contours map

Notes:

WATER LEVEL OBSERVATIONS

None encountered at completion of sampling

0' BGS on 12/13/19

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

Boring Started: 12-05-2019 | Boring Completed: 12-05-2019

Drill Rig: Diedrich D-50 | Driller: J. Tojdowski

Project No.: J5195205

ROCK CORE PHOTOS

Heritage Wind Farm■ Barre Center, New York

Terracon Project No. J5195205

Rock cores extracted at borings: T-7 (Run #1) & T-11 (Run #3)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
T-7 Run #1	30.0'- 35.0'	49	82
T-11 Run #3	19.0'- 24.0'	55	84

Notes:

The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

ROCK CORE PHOTOS

Heritage Wind Farm■ Barre Center, New York

Terracon Project No. J5195205

Rock cores extracted at borings: T-11 (Run#1 & #2)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
T-11 Run #1	9.0'- 14.0'	60	95
T-11 Run #2	14.0'- 19.0'	57	72

Notes:

The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

ROCK CORE PHOTOS

Heritage Wind Farm■ Barre Center, New York

Terracon Project No. J5195205

Rock cores extracted at borings: T-26 (Run #1 & #2)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
T-26 Run #1	15.5' - 20.5'	60	100
T-26 Run #2	20.5' – 25.5'	56	78

Notes:

The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

Rock cores extracted at borings: T-26 (Run #3)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
T-26 Run #3	25.5' – 30.5'	58	78

Notes:
The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

Rock cores extracted at borings: T-30 (Run #1 & #2)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
T-30 Run #1	5.5' – 10.5'	58	72
T-30 Run #2	10.5' – 15.5'	58	15

Notes:
The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

Rock cores extracted at borings: T-30 (Run #3)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
T-30 Run #3	15.5' – 20.5'	57	84

Notes:
The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

Rock cores extracted at borings: Substation (Run #1 & #2)

Boring:	Depth (ft)	Recovery (in)	RQD (%)
Substation Run #1	42.5' – 46.5'	41	75
Substation Run #2	46.5' – 51.5'	51	62

Notes:
The ruler presented in the photographs is intended to provide a reference scale only. Therefore, the dimensions of the cores may not be accurately reflected in the photographs. Please refer to the boring logs for accurate core measurements.

APPENDIX B
LABORATORY TESTING

(Exhibit- B001 through B020)

SUMMARY OF LAB RESULTS (Exhibit- B001)

GRAIN SIZE DISTRIBUTION (Exhibit- B002 through B005)

ATTERBERG LIMITS (Exhibit- B006)

MOISTURE-DENSITY RELATIONSIPS (Exhibit- B007 through B011)

ROCK COMPRESSIVE STREGTH (Exhibit- B012 through B014)

SUMMARY OF LABORATORY RESULTS

BORING ID	Depth (Ft.)	Soil Classification USCS	% Gravel	% Sand	% Fines	Liquid Limit	Plastic Limit	Plasticity Index	Proctor Dry Density (pcf) / Opt. Moisture (%) Corrected values
T-3	2 - 4	SILTY, CLAYEY SAND with GRAVEL(SC-SM)	17.6	33.2	49.2	26	21	5	
T-7	2 - 4	SILTY SAND with GRAVEL(SM)	19.4	38.4	42.2	NP	NP	NP	
T-11	2 - 4	SILTY GRAVEL with SAND(GM)	29.5	26.9	43.7	NP	NP	NP	
Substation	4 - 6	SILTY SAND with GRAVEL(SM)	16.3	37.0	46.6	NP	NP	NP	
TP-1	2 - 4	SILTY SAND with GRAVEL(SM)	28.3	35.5	36.3	NP	NP	NP	
TP-1	2 - 4	SILTY SAND with GRAVEL(SM)	28.3	35.5	36.3	NP	NP	NP	129.9/7.7
TP-2	2 - 4	SILTY-CLAY (CL-ML)	0.4	11.3	88.3				103.5 / 20.2
TP-3	2- 4	SILTY SAND(SM)	6.6	47.0	46.4	NP	NP	NP	121.1 / 11.4
TP-4	2- 4	SILTY SAND(SM)	13.4	36.9	47.5	NP	NP	NP	127.6/8.1
TP-5	2- 4	SANDY SILT(ML)	8.2	33.1	58.7	NP	NP	NP	123.5/8.7

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

PROJECT NUMBER: J5195205

SITE: Barre Center
Orleans County, NY

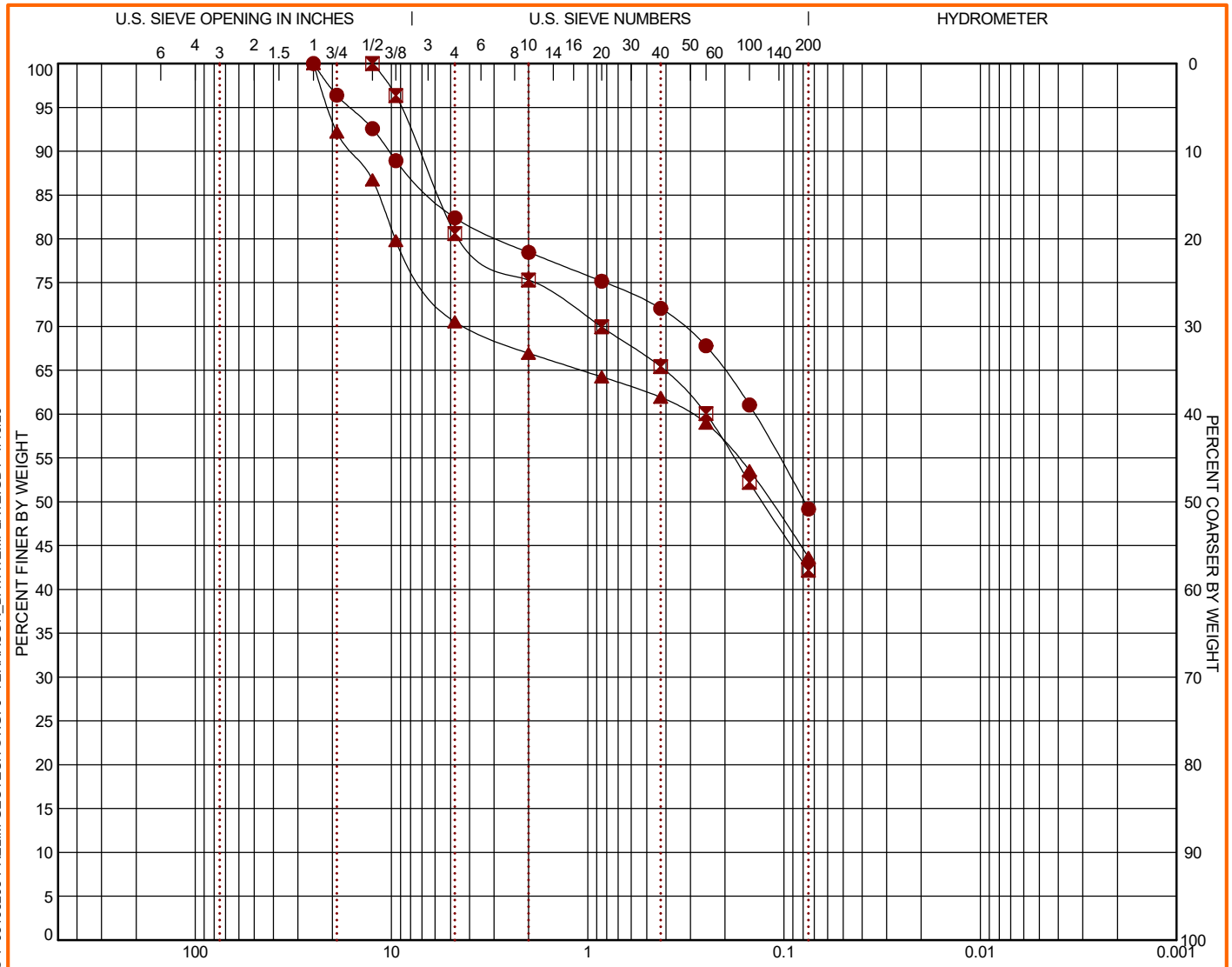
CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

Terracon
15 Marway Cir, Ste 2B
Rochester, NY
PH. 585-247-3471 FAX.

Exhibit-B001

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BORING ID	DEPTH	% COBBLES	% GRAVEL	% SAND	% SILT	% FINES	% CLAY	USCS
●	T-3	2 - 4	0.0	17.6	33.2		49.2		SC-SM
⊠	T-7	2 - 4	0.0	19.4	38.4		42.2		SM
▲	T-11	2 - 4	0.0	29.5	26.9		43.7		GM

GRAIN SIZE

	●	⊠	▲
D_{75}	0.819	1.906	6.635
D_{60}	0.141	0.249	0.3
D_{30}			
D_{10}			

COEFFICIENTS

	●	⊠	▲
C_C			
C_U			

●		⊠		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
1"	100.0	1/2"	100.0	1"	100.0
3/4"	96.39	3/8"	96.34	3/4"	92.18
1/2"	92.57	#4	80.62	1/2"	86.74
3/8"	88.92	#10	75.3	3/8"	79.79
#4	82.4	#20	69.96	#4	70.54
#10	78.45	#40	65.42	#10	66.94
#20	75.17	#60	60.06	#20	64.26
#40	72.06	#100	52.23	#40	61.92
#60	67.79	#200	42.19	#60	58.99
#100	61.05			#100	53.57
#200	49.18			#200	43.67

SOIL DESCRIPTION

●	SILTY, CLAYEY SAND with GRAVEL
⊠	SILTY SAND with GRAVEL (SM)
▲	SILTY GRAVEL with SAND (GM)

REMARKS

●	
⊠	
▲	

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

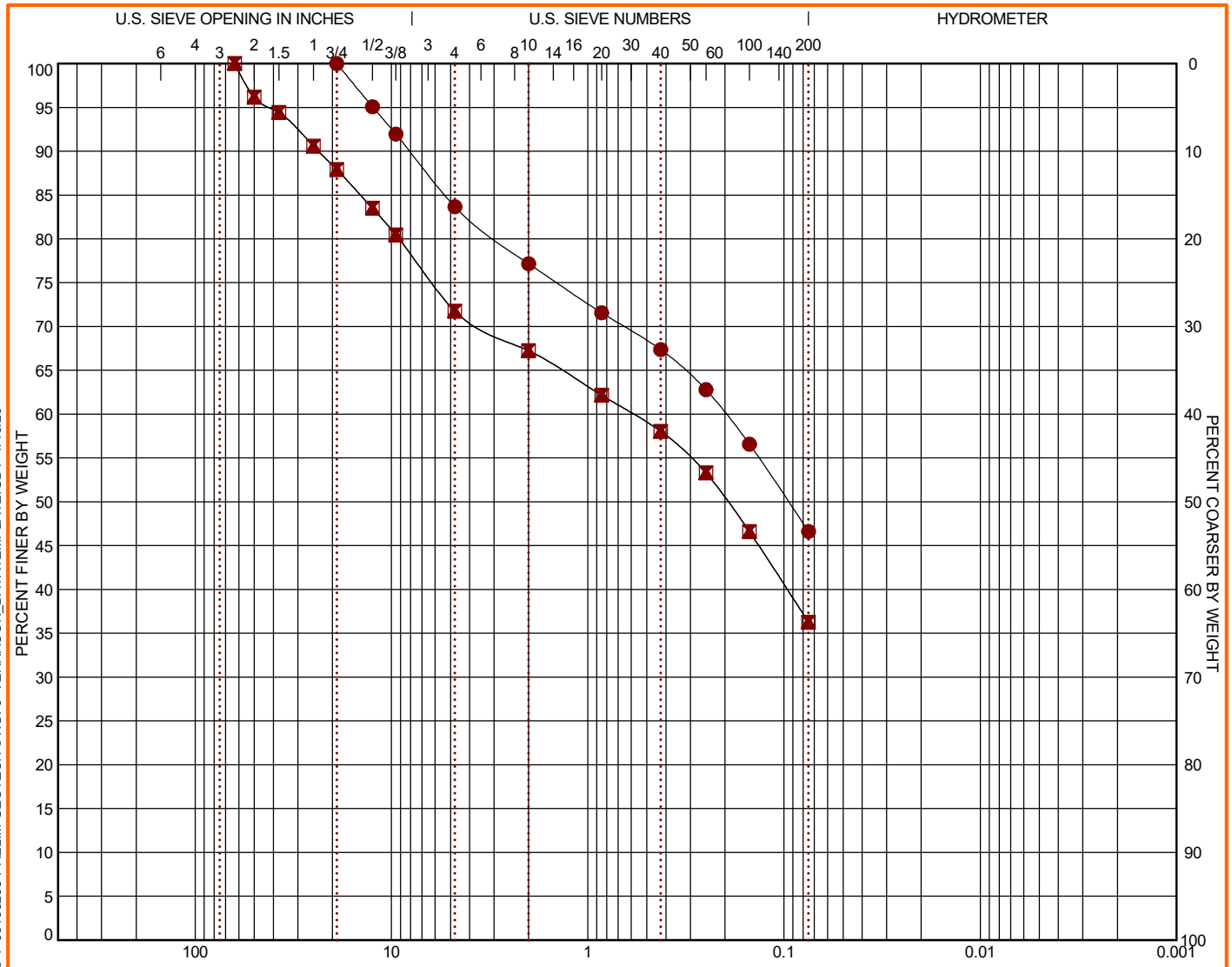
PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

Exhibit-B002

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BORING ID	DEPTH	% COBBLES	% GRAVEL	% SAND	% SILT	% FINES	% CLAY	USCS
●	Substation	4 - 6	0.0	16.3	37.0		46.6		SM
⊠	TP-1	2 - 4	0.0	28.3	35.5		36.3		SM
▲	TP-1	2 - 4	0.0	28.3	35.5		36.3		SM

GRAIN SIZE

	●	⊠	▲
D_{75}	1.438	6.155	6.155
D_{60}	0.199	0.591	0.591
D_{30}			
D_{10}			

COEFFICIENTS

	●	⊠	▲
C_C			
C_U			

●		⊠		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
3/4"	100.0	2 1/2"	100.0	2 1/2"	100.0
1/2"	95.07	2"	96.15	2"	96.15
3/8"	91.95	1 1/2"	94.41	1 1/2"	94.41
#4	83.66	1"	90.58	1"	90.58
#10	77.16	3/4"	87.89	3/4"	87.89
#20	71.56	1/2"	83.48	1/2"	83.48
#40	67.36	3/8"	80.46	3/8"	80.46
#60	62.79	#4	71.74	#4	71.74
#100	56.57	#10	67.23	#10	67.23
#200	46.62	#20	62.16	#20	62.16
		#40	58.05	#40	58.05
		#60	53.31	#60	53.31
		#100	46.59	#100	46.59
		#200	36.26	#200	36.26

SOIL DESCRIPTION

●	SILTY SAND with GRAVEL (SM)
⊠	SILTY SAND with GRAVEL (SM)
▲	SILTY SAND with GRAVEL (SM)

REMARKS

●	
⊠	
▲	

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

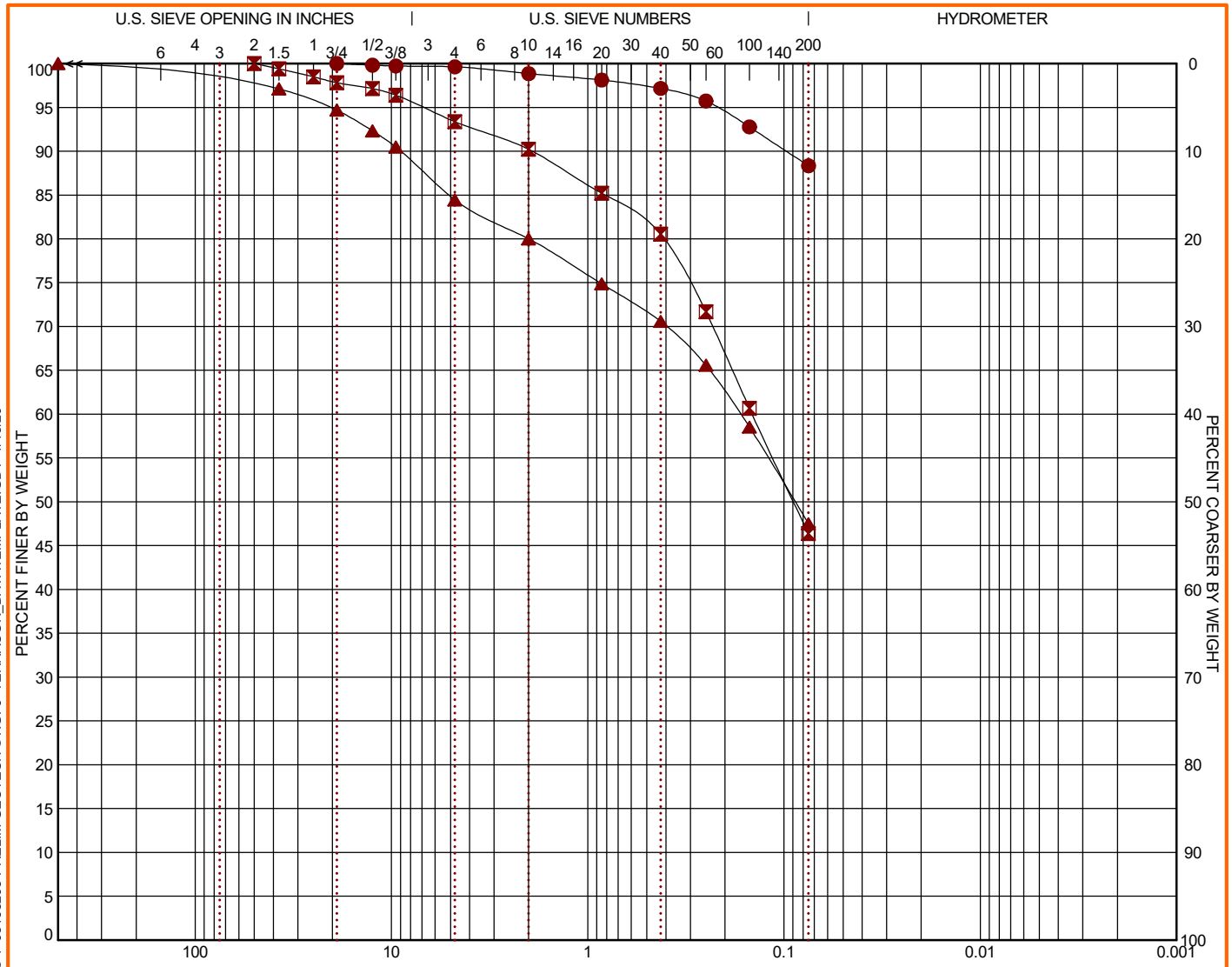
Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BORING ID	DEPTH	% COBBLES	% GRAVEL	% SAND	% SILT	% FINES	% CLAY	USCS
●	TP-2	2 - 4	0.0	0.4	11.3		88.3		CL-ML
⊠	TP-3	2 - 4	0.0	6.6	47.0		46.4		SM
▲	TP-4	2 - 4	1.5	13.4	36.9		47.5		SM

GRAIN SIZE

	●	⊠	▲
D_{75}		0.305	0.868
D_{60}		0.145	0.167
D_{30}			
D_{10}			

COEFFICIENTS

	●	⊠	▲
C_C			
C_U			

●		⊠		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
3/4"	100.0	2"	100.0	1"	100.0
1/2"	99.81	1 1/2"	99.39	1 1/2"	97.11
3/8"	99.72	1"	98.48	3/4"	94.69
#4	99.62	3/4"	97.82	1/2"	92.32
#10	98.85	1/2"	97.15	3/8"	90.47
#20	98.12	3/8"	96.39	#4	84.45
#40	97.16	#4	93.36	#10	80.0
#60	95.73	#10	90.21	#20	74.87
#100	92.77	#20	85.21	#40	70.59
#200	88.34	#40	80.56	#60	65.59
		#60	71.7	#100	58.53
		#100	60.66	#200	47.5
		#200	46.39		

SOIL DESCRIPTION

●	Silty-Clay (CL-ML)
⊠	SILTY SAND (SM)
▲	SILTY SAND (SM)

REMARKS

●	
⊠	
▲	

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

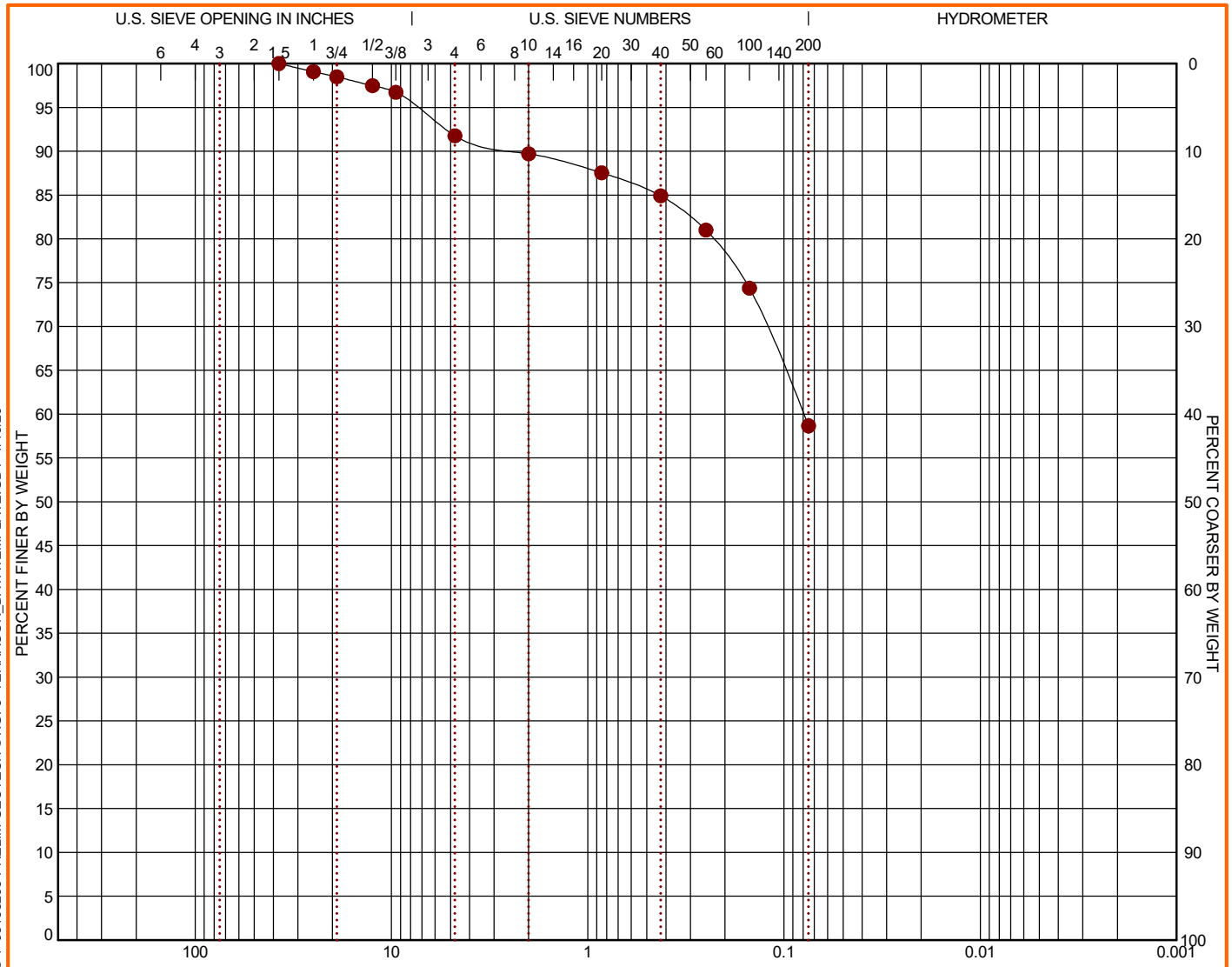
Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BORING ID	DEPTH	% COBBLES	% GRAVEL	% SAND	% SILT	% FINES	% CLAY	USCS
●	TP-5	2 - 4	0.0	8.2	33.1		58.7		ML

GRAIN SIZE			
	●		
D_{75}	0.157		
D_{60}	0.08		
D_{30}			
D_{10}			

COEFFICIENTS			
	●		
C_C			
C_U			

●					
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
1 1/2"	100.0				
1"	99.07				
3/4"	98.48				
1/2"	97.47				
3/8"	96.72				
#4	91.75				
#10	89.7				
#20	87.54				
#40	84.91				
#60	81.01				
#100	74.37				
#200	58.67				

SOIL DESCRIPTION
● SANDY SILT (ML)

REMARKS
●

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

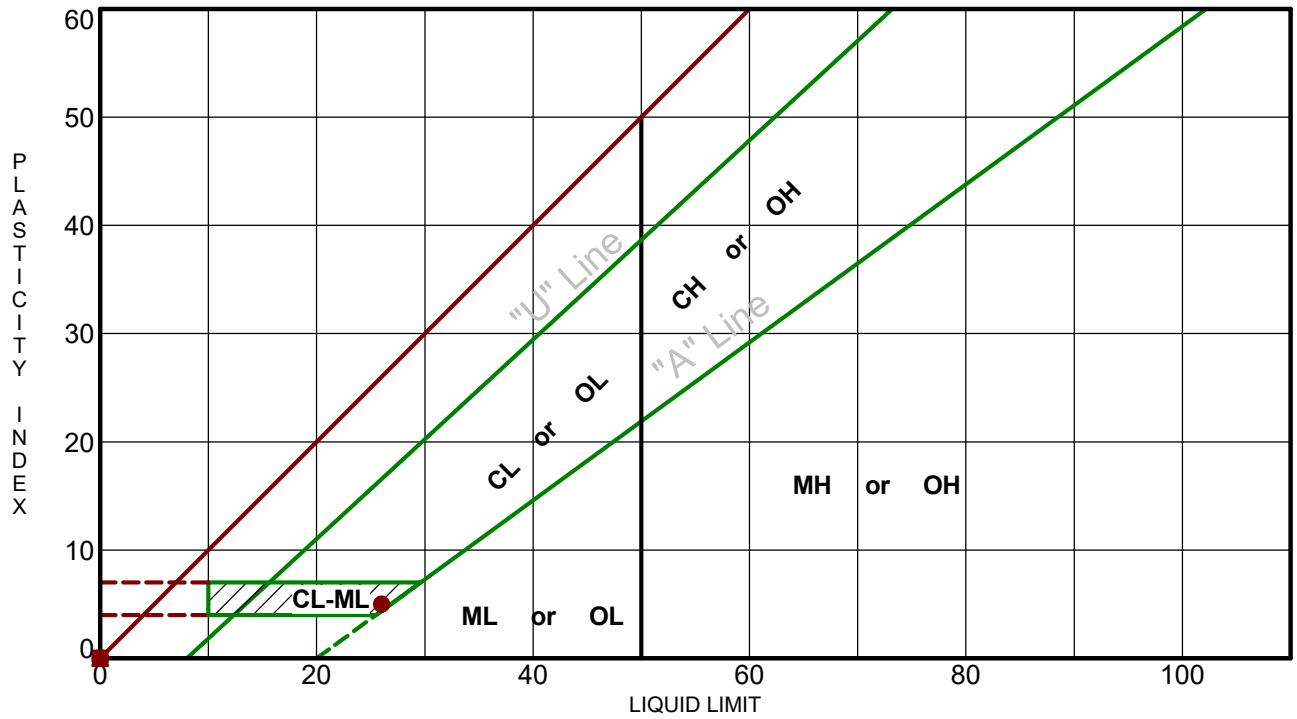
PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

Exhibit-B005

ATTERBERG LIMITS RESULTS

ASTM D4318



	Boring ID	Depth	LL	PL	PI	Fines	USCS	Description
●	T-3	2 - 4	26	21	5	49.2	SC-SM	SILTY, CLAYEY SAND with GRAVEL
⊠	T-7	2 - 4	NP	NP	NP	42.2	SM	SILTY SAND with GRAVEL
▲	T-11	2 - 4	NP	NP	NP	43.7	GM	SILTY GRAVEL with SAND
★	Substation	4 - 6	NP	NP	NP	46.6	SM	SILTY SAND with GRAVEL
⊙	TP-1	2 - 4	NP	NP	NP	36.3	SM	SILTY SAND with GRAVEL
✿	TP-1	2 - 4	NP	NP	NP	36.3	SM	SILTY SAND with GRAVEL
○	TP-3	2 - 4	NP	NP	NP	46.4	SM	SILTY SAND
△	TP-4	2 - 4	NP	NP	NP	47.5	SM	SILTY SAND
⊗	TP-5	2 - 4	NP	NP	NP	58.7	ML	SANDY SILT

PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

MOISTURE-DENSITY RELATIONSHIP

ASTM D698/D1557

Source of Material: **TP-1 @ 2 - 4 feet**

Description of Material: **SILTY SAND with GRAVEL(SM)**

Remarks:

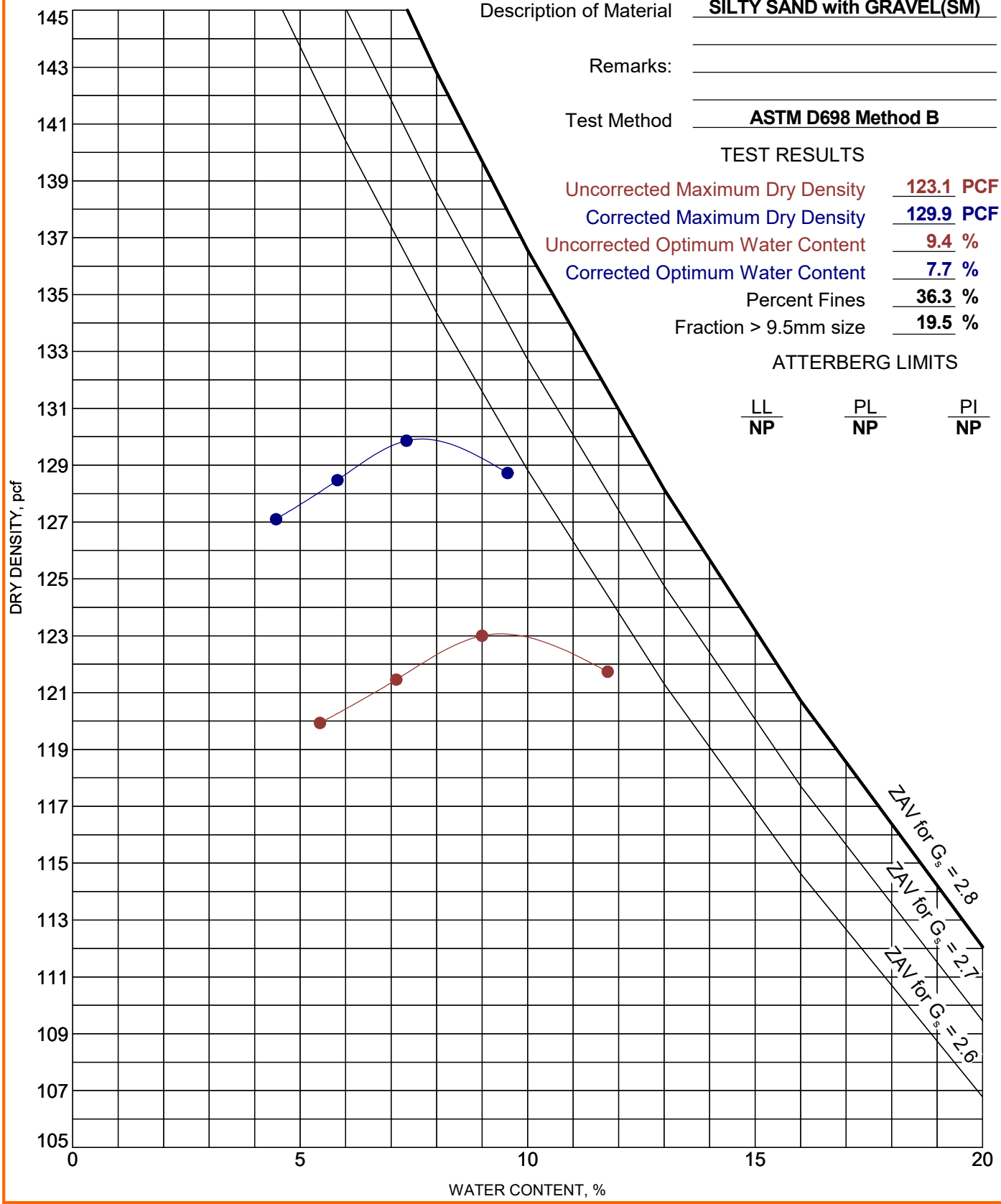
Test Method: **ASTM D698 Method B**

TEST RESULTS

Uncorrected Maximum Dry Density	123.1	PCF
Corrected Maximum Dry Density	129.9	PCF
Uncorrected Optimum Water Content	9.4	%
Corrected Optimum Water Content	7.7	%
Percent Fines	36.3	%
Fraction > 9.5mm size	19.5	%

ATTERBERG LIMITS

LL	PL	PI
NP	NP	NP



PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

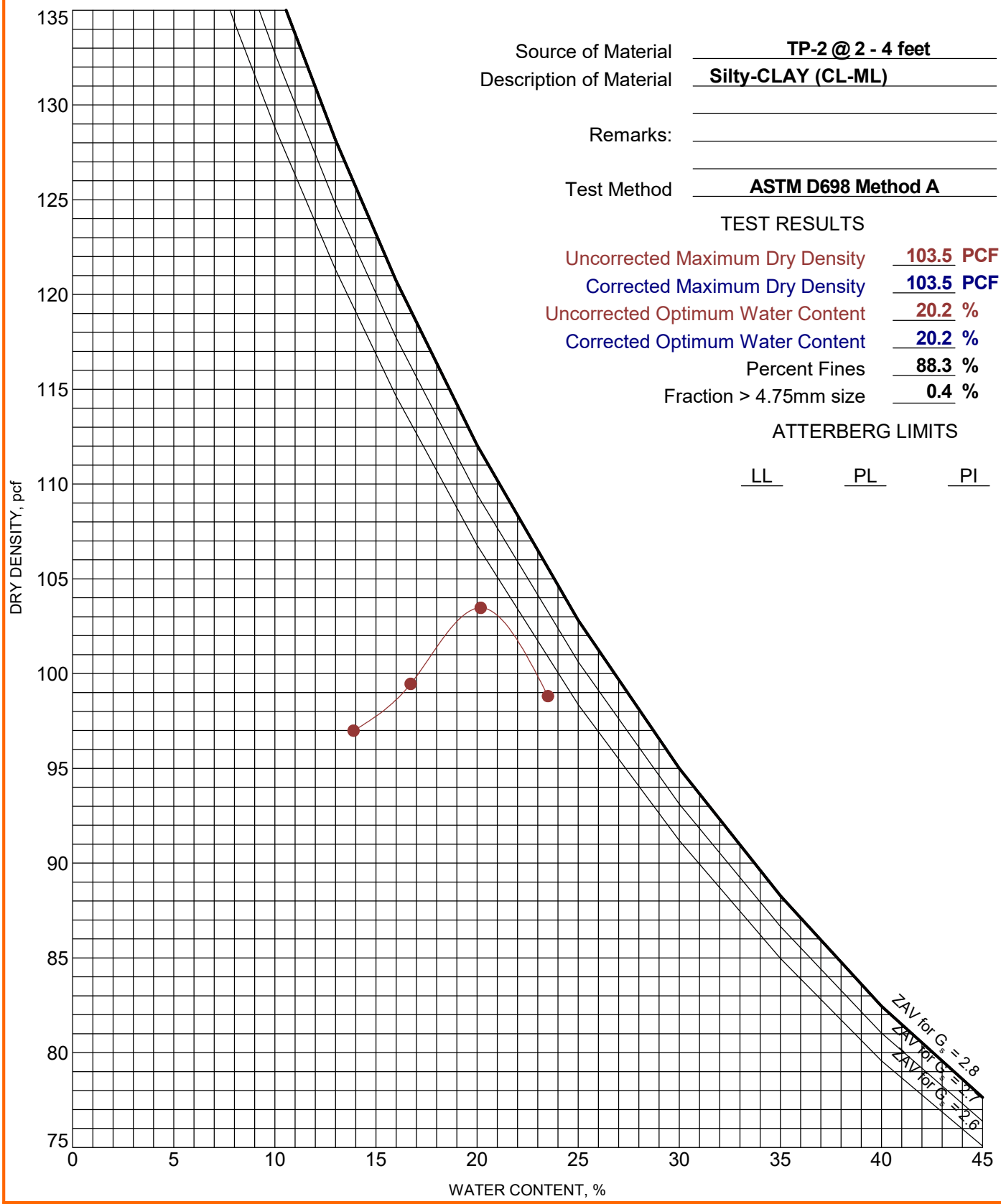
Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

MOISTURE-DENSITY RELATIONSHIP

ASTM D698/D1557



Source of Material	TP-2 @ 2 - 4 feet
Description of Material	Silty-CLAY (CL-ML)
Remarks:	
Test Method	ASTM D698 Method A

TEST RESULTS

Uncorrected Maximum Dry Density	103.5	PCF
Corrected Maximum Dry Density	103.5	PCF
Uncorrected Optimum Water Content	20.2	%
Corrected Optimum Water Content	20.2	%
Percent Fines	88.3	%
Fraction > 4.75mm size	0.4	%

ATTERBERG LIMITS

LL	PL	PI

PROJECT: Prelim Geotech Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

MOISTURE-DENSITY RELATIONSHIP

ASTM D698/D1557

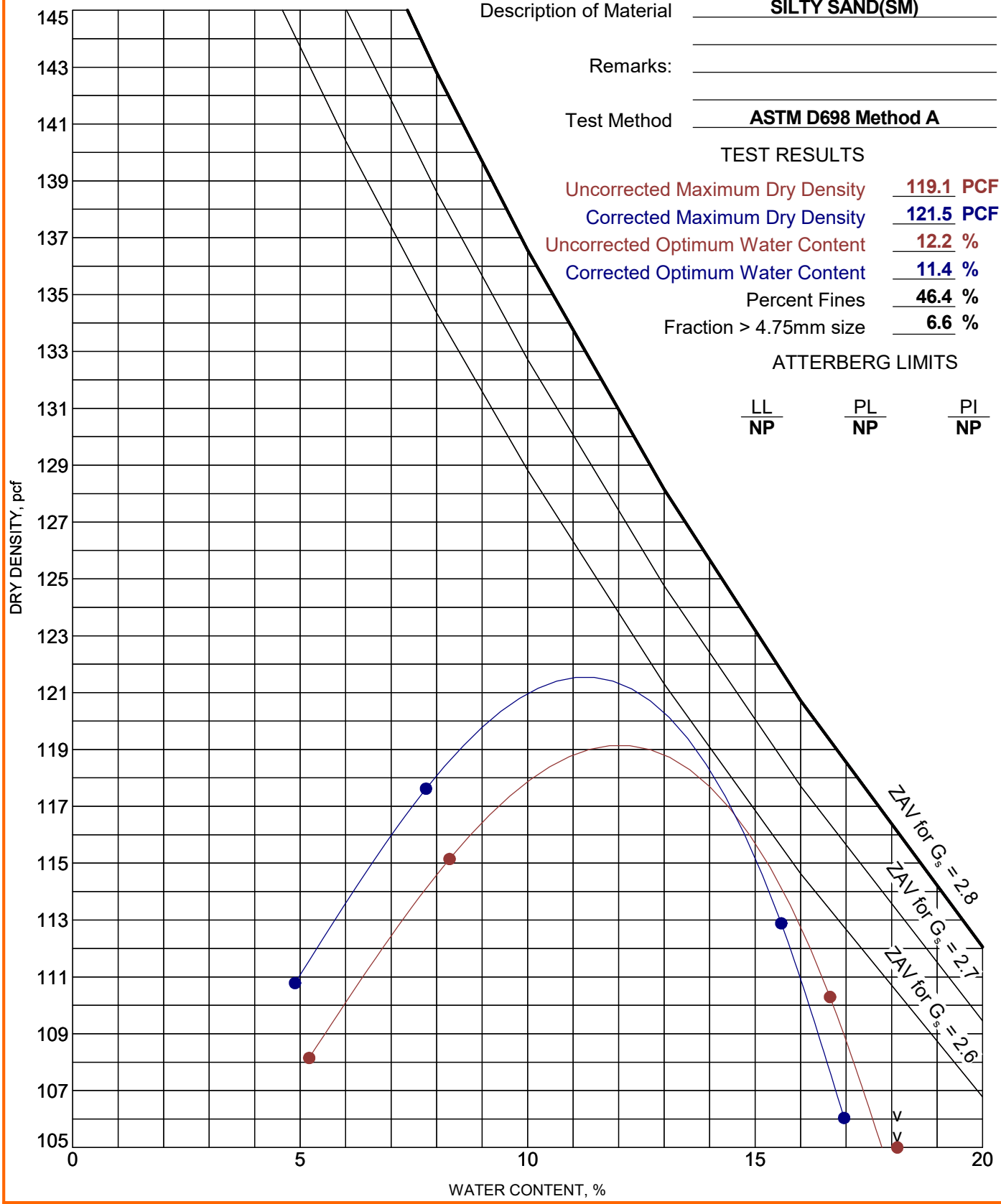
Source of Material	**TP-3 @ 2 - 4 feet**
Description of Material	**SILTY SAND(SM)**
Remarks:	
Test Method	**ASTM D698 Method A**

TEST RESULTS

Uncorrected Maximum Dry Density	**119.1**	**PCF**
Corrected Maximum Dry Density	**121.5**	**PCF**
Uncorrected Optimum Water Content	**12.2**	**%**
Corrected Optimum Water Content	**11.4**	**%**
Percent Fines	**46.4**	**%**
Fraction > 4.75mm size	**6.6**	**%**

ATTERBERG LIMITS

LL	PL	PI
NP	**NP**	**NP**



PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm	Terracon 15 Marway Cir, Ste 2B Rochester, NY	PROJECT NUMBER: J5195205
SITE: Barre Center Orleans County, NY		CLIENT: Apex Clean Energy Management, LLC Charlottesville, VA

MOISTURE-DENSITY RELATIONSHIP

ASTM D698/D1557

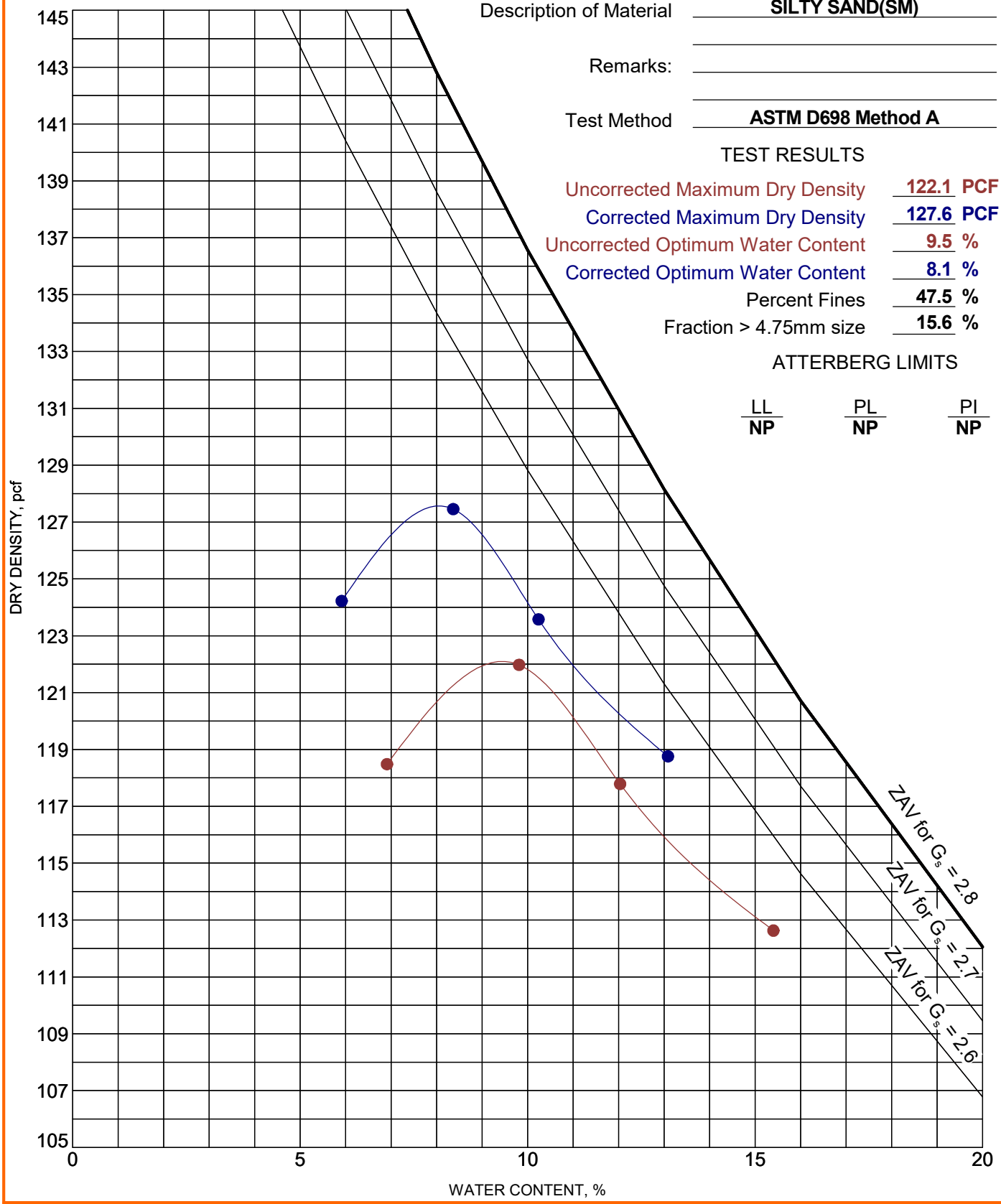
Source of Material	**TP-4 @ 2 - 4 feet**
Description of Material	**SILTY SAND(SM)**
Remarks:	
Test Method	**ASTM D698 Method A**

TEST RESULTS

Uncorrected Maximum Dry Density	122.1	PCF
Corrected Maximum Dry Density	127.6	PCF
Uncorrected Optimum Water Content	9.5	%
Corrected Optimum Water Content	8.1	%
Percent Fines	47.5	%
Fraction > 4.75mm size	15.6	%

ATTERBERG LIMITS

LL	PL	PI
NP	NP	NP



PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

MOISTURE-DENSITY RELATIONSHIP

ASTM D698/D1557

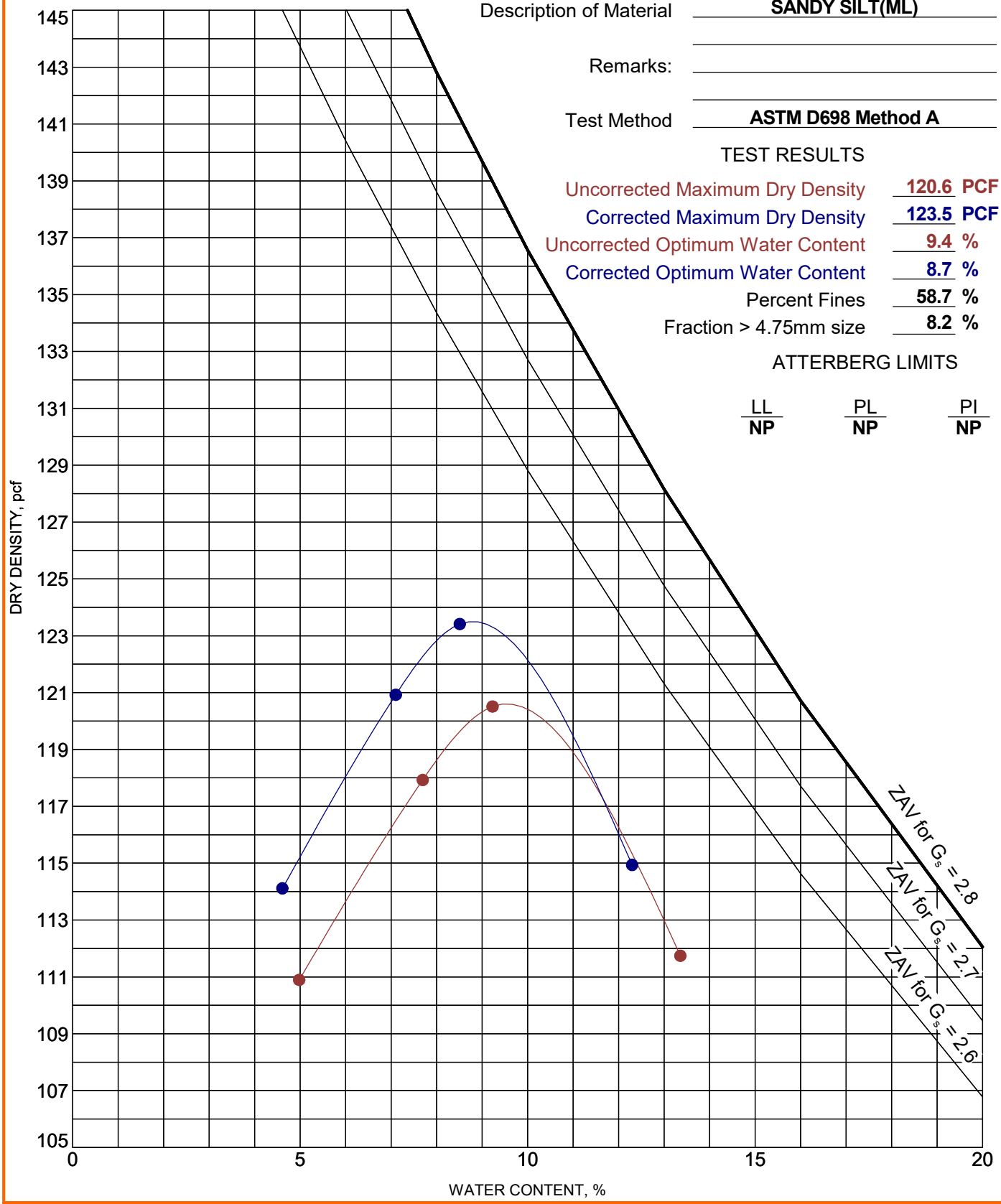
Source of Material	**TP-5 @ 2 - 4 feet**
Description of Material	**SANDY SILT(ML)**
Remarks:	
Test Method	**ASTM D698 Method A**

TEST RESULTS

Uncorrected Maximum Dry Density	120.6	PCF
Corrected Maximum Dry Density	123.5	PCF
Uncorrected Optimum Water Content	9.4	%
Corrected Optimum Water Content	8.7	%
Percent Fines	58.7	%
Fraction > 4.75mm size	8.2	%

ATTERBERG LIMITS

LL	PL	PI
NP	NP	NP



PROJECT: Preliminary Geotechnical Study - Heritage Wind Farm

SITE: Barre Center
Orleans County, NY

Terracon
15 Marway Cir, Ste 2B
Rochester, NY

PROJECT NUMBER: J5195205

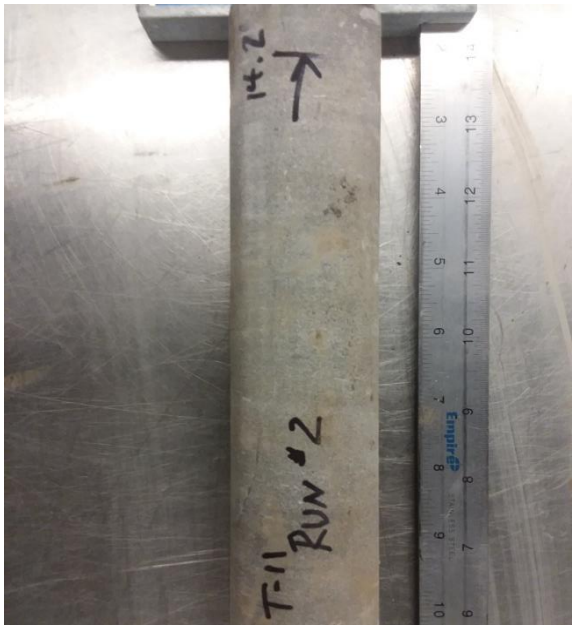
CLIENT: Apex Clean Energy Management, LLC
Charlottesville, VA

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	T-11	Lithology :	Dolostone
Sample No.:	A	Moisture Content :	As Received
Sample Depth:	14'	Lab Temperature :	65 F
Sampling Date:	11/27/20	Loading Rate:	75 psi/s
		Time to Failure:	4 min

Diameter:	1.99 in	**Maximum Axial Load at Failure:**	**51,750 lb**
Length:	4.13 in	**Compressive Strength:**	**16,647 psi**
L/D:	2.08	**Compressive Strength:**	**114.78 Mpa**
End Area:	3.11 in^2		

Before the Test



After the Test

Project:	Heritage Wind Farm	Terracon	Technician:	T. Wooden
Project No.	J5195205		Test Date:	1/17/2020
Location:	Barre Center, NY		Reviewed By :	Z. Kiffle
Client :	Apex Clean Energy	15 Marway Cir. Ste 2B Rochester, NY	Review Date :	1/17/2020

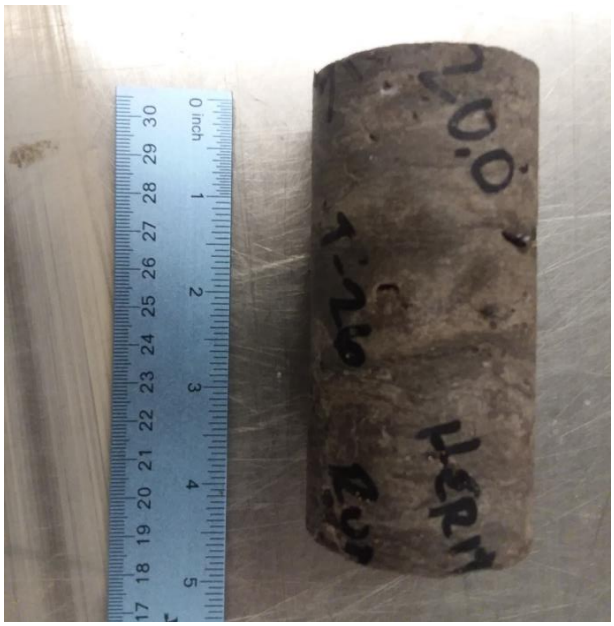
Exhibit-B012

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	T-26	Lithology :	Dolostone
Sample No.:	A	Moisture Content :	As Received
Sample Depth:	20'	Lab Temperature :	65 F
Sampling Date:	11/27/20	Loading Rate:	75 psi/s
		Time to Failure:	3 min

Diameter:	1.99 in	**Maximum Axial Load at Failure:**	**30,290 lb**
Length:	4.14 in	**Compressive Strength:**	**9,744 psi**
L/D:	2.08	**Compressive Strength:**	**67.18 Mpa**
End Area:	3.11 in^2		

Before the Test



After the Test

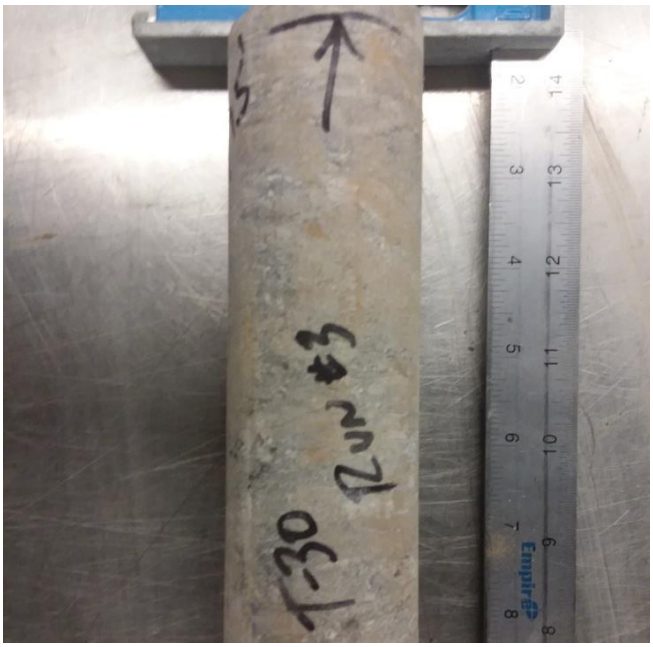
Project:	Heritage Wind Farm	Terracon	Technician:	T. Wooden
Project No.	J5195205		Test Date:	1/17/2020
Location:	Barre Center, NY		Reviewed By :	Z. Kiffle
Client :	Apex Clean Energy	15 Marway Cir. Ste 2B Rochester, NY	Review Date :	1/17/2020

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	T-30	Lithology :	Dolostone
Sample No.:	A	Moisture Content :	As Received
Sample Depth:	15.5'	Lab Temperature :	65 F
Sampling Date:	11/27/20	Loading Rate:	75 psi/s
		Time to Failure:	4 min

Diameter:	1.99 in	**Maximum Axial Load at Failure:**	**46,180 lb**
Length:	4.09 in	**Compressive Strength:**	**14,855 psi**
L/D:	2.05	**Compressive Strength:**	**102.42 Mpa**
End Area:	3.11 in^2		

Before the Test



After the Test

Project:	Heritage Wind Farm	Terracon 15 Marway Cir., St. 2B Rochester, NY	Technician:	T. Wooden
Project No.	J5195205		Test Date:	1/17/2020
Location:	Barre Center, NY		Reviewed By :	Z. Kiffle
Client :	Apex Clean Energy		Review Date :	1/17/2020

CORROSION TESTING

(Exhibits- B015 through B016)

CHEMICAL LABORATORY TEST REPORT

Project Number: J5195205
Service Date: 12/24/19
Report Date: 12/30/19
Task:

Terracon
750 Pilot Road, Suite F
Las Vegas, Nevada 89119
(702) 597-9393

Client

Apex Clean Energy Management, LLC

Project

Prelim Geotech Study - Heritage Wind Farm

Sample Submitted By: Terracon (J5) **Date Received:** 12/23/2019 **Lab No.: 19-1439**

Results of Corrosion Analysis

Sample Number				
Sample Location	T-3	T-7	T-11	T-18
Sample Depth (ft.)	2.0-4.0	2.0-4.0	2.0-4.0	2.0-4.0
pH Analysis, ASTM G 51	8.32	8.49	8.40	7.60
Water Soluble Sulfate (SO4), ASTM C 1580 (mg/kg)	151	62	87	74
Sulfides, AWWA 4500-S D, (mg/kg)	Nil	Nil	Nil	Nil
Chlorides, ASTM D 512, (mg/kg)	23	77	50	48
Red-Ox, AWWA 2580, (mV)	+679	+680	+681	+679
Total Salts, AWWA 2540, (mg/kg)	518	544	574	446
Resistivity, ASTM G 57, (ohm-cm)	9118	7954	5578	8730

Analyzed By: Trisha Campo

Trisha Campo
Chemist

CHEMICAL LABORATORY TEST REPORT

Project Number: J5195205
Service Date: 12/24/19
Report Date: 12/30/19
Task:

Terracon
750 Pilot Road, Suite F
Las Vegas, Nevada 89119
(702) 597-9393

Client

Apex Clean Energy Management, LLC

Project

Prelim Geotech Study - Heritage Wind Farm

Sample Submitted By: Terracon (J5) **Date Received:** 12/23/2019 **Lab No.: 19-1439**

Results of Corrosion Analysis

Sample Number			
Sample Location	T-26	T-30	Substation
Sample Depth (ft.)	2.0-4.0	2.0-4.0	2.0-4.0
pH Analysis, ASTM G 51	7.76	8.33	8.37
Water Soluble Sulfate (SO4), ASTM C 1580 (mg/kg)	66	131	104
Sulfides, AWWA 4500-S D, (mg/kg)	Nil	Nil	Nil
Chlorides, ASTM D 512, (mg/kg)	48	55	90
Red-Ox, AWWA 2580, (mV)	+680	+682	+681
Total Salts, AWWA 2540, (mg/kg)	447	895	673
Resistivity, ASTM G 57, (ohm-cm)	8779	3298	5820

Analyzed By: Trisha Campo

Trisha Campo
Chemist

THERMAL RESISTIVITY TEST RESULTS

(Lab and In-situ Tests)

(Exhibits- B017 through B020)

21239 FM529 Rd., Bldg. F
Cypress, TX 77433
Tel: 281-985-9344
Fax: 832-427-1752
info@geothermusa.com
http://www.geothermusa.com

SOIL THERMAL SURVEY
HERITAGE WIND PROJECT
TOWN OF BARRE, NEW YORK

JANUARY 2020

Prepared for:

TERRACON CONSULTANTS
15 MARWAY CIRCLE, STE 2B
ROCHESTER, NEW YORK 14624

Submitted by:

GEOTHERM USA, LLC

COOL SOLUTIONS FOR UNDERGROUND POWER CABLES
THERMAL SURVEYS, CORRECTIVE BACKFILLS & INSTRUMENTATION

Serving the electric power industry since 1978

Exhibit-B017

A field thermal resistivity survey of the native soils was performed for the proposed underground power cables at the Heritage Wind Project *in Barre County, NY.* In-situ thermal resistivity and ambient temperature measurements were conducted to a depth of 4-ft at five (5) locations along the cable routes. The fieldwork was carried out on December 17th, 2019. ***Terracon*** marked the test location, obtained permits, cleared services and provided a backhoe with an operator to excavate the test pits.

Field Testing and Soil Sampling: A backhoe was used to dig a 4-ft deep test pit, and ambient temperature and thermal tests were performed at depths of 2, 3 and 4-feet below ground surface **(Table 1)**. In addition, samples for laboratory testing - moisture content, density and thermal dryout characterization was also taken.

In-situ thermal test were conducted in accordance with the IEEE Standard 442-2017 using thermal probes and the *Geotherm* **TPA-2000;** run off a portable power source. Laboratory geotechnical testing was conducted in accordance with **ASTM**. Soil description was provided by **Terracon** and the test locations are referenced by the coordinates given by **Terracon**.

The field thermal resistivity values were measured at the given soil moisture on that day. Depending on weather and environmental conditions; i.e. drying due to cable heat or other heat source, seasonal drying (drought), artificial draining, water demand of crops, drying due to frost (ice lenses), etc., the soil may be drier at certain times of the year. Therefore, the design thermal resistivity for the native soils should be based on the driest expected conditions.

The test report contains factual information on the subsurface conditions at the specific test pit location; no warrantee is expressed or implied that materials or conditions other than those described may not be encountered along the cable route.

Laboratory Testing: The tests included the measurement of moisture content, density and thermal dryout characterization (thermal resistivity as a function of moisture content). The bulk samples (2'-4') were re-constituted to the 'in-situ' moisture content and 92% of the Proctor density ***provided by Terracon.*** A series of thermal resistivity measurements were made in stages with moisture content ranging from 'natural' to totally dry condition. The tests were conducted in accordance with IEEE Standard 442-2017. The test results are given in **Table 1** and the thermal dryout curves are presented in **Figure 1.**

Comments:

Ambient Temperature: In-situ testing was conducted at the time of the year when the earth ambient temperature is probably close to the lowest value. At the proposed cable burial depth of about 2 – 4-ft., temperature of about 23 ºC is suggested, *however the engineer of record will ultimately be responsible for the determination of appropriate soil temperature assumptions.*

Please contact us if you or your client have any questions.

Geotherm USA

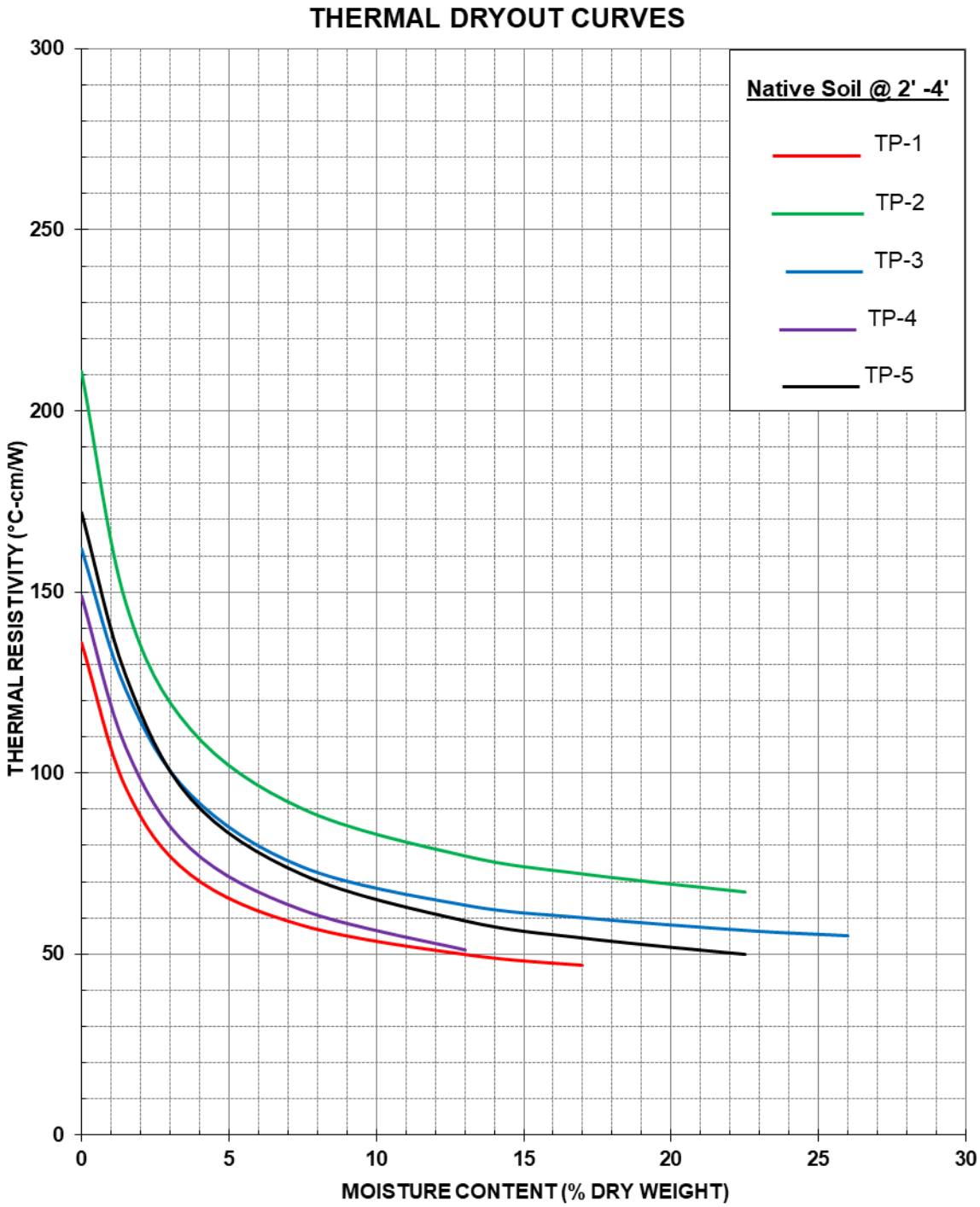
Nimesh Patel

TEST PIT COORDINATES

Test Pit Location	Northing	Easting
TP-1	4783432.95 m N	729214.46 m E
TP-2	4783517.13 m N	726308.75 m E
TP-3	4780320.92 m N	724737.15 m E
TP-4	4785539.65 m N	731967.71 m E
TP-5	4784578.66 m N	728014.30 m E

Table 1 (Field and Lab Results)

Test Pit	Depth (ft)	In-Situ Temp °C	In-Situ TR °C-cm/W	Dry Density (lb/ft³)	Moisture Content (%)	LAB TR °C-cm/W		Soil Description (Ramboll)
						WET	DRY	
TP-1	2	0.7	46	120	17	47	136	Silty Sand with Gravel (SM)
	3	1.8	46					
	4	4.0	45					
TP-2	2	0.7	63	95	22	67	211	Silty-Clay (CL-ML)
	3	0.3	60					
	4	3.3	61					
TP-3	2	0.2	48	112	26	55	162	Silty Sand (SM)
	3	4.7	50					
	4	3.1	51					
TP-4	2	0.2	49	117	13	51	149	Sandy Silt (ML)
	3	0.9	49					
	4	3.6	48					
TP-5	2	0.6	46	114	23	50	172	Sandy Silt (ML)
	3	4.2	48					
	4	5.4	50					



Terracon Consultants (Project No. J5195205)

Thermal Analysis of Native Soil Samples

Heritage Wind Farm Project – Barre County, NY

January 2020 **Figure 1**

APPENDIX C

FIELD ELECTRICAL RESISTIVITY TEST RESULTS

(Exhibits- C001 through C011)

EXPLORATION PLAN-FIELD ELECTRICAL RESISTIVITY

Prelim Geotech Study - Heritage Wind Farm ■ Barre Center, NY

Terracon Project No. J5195205

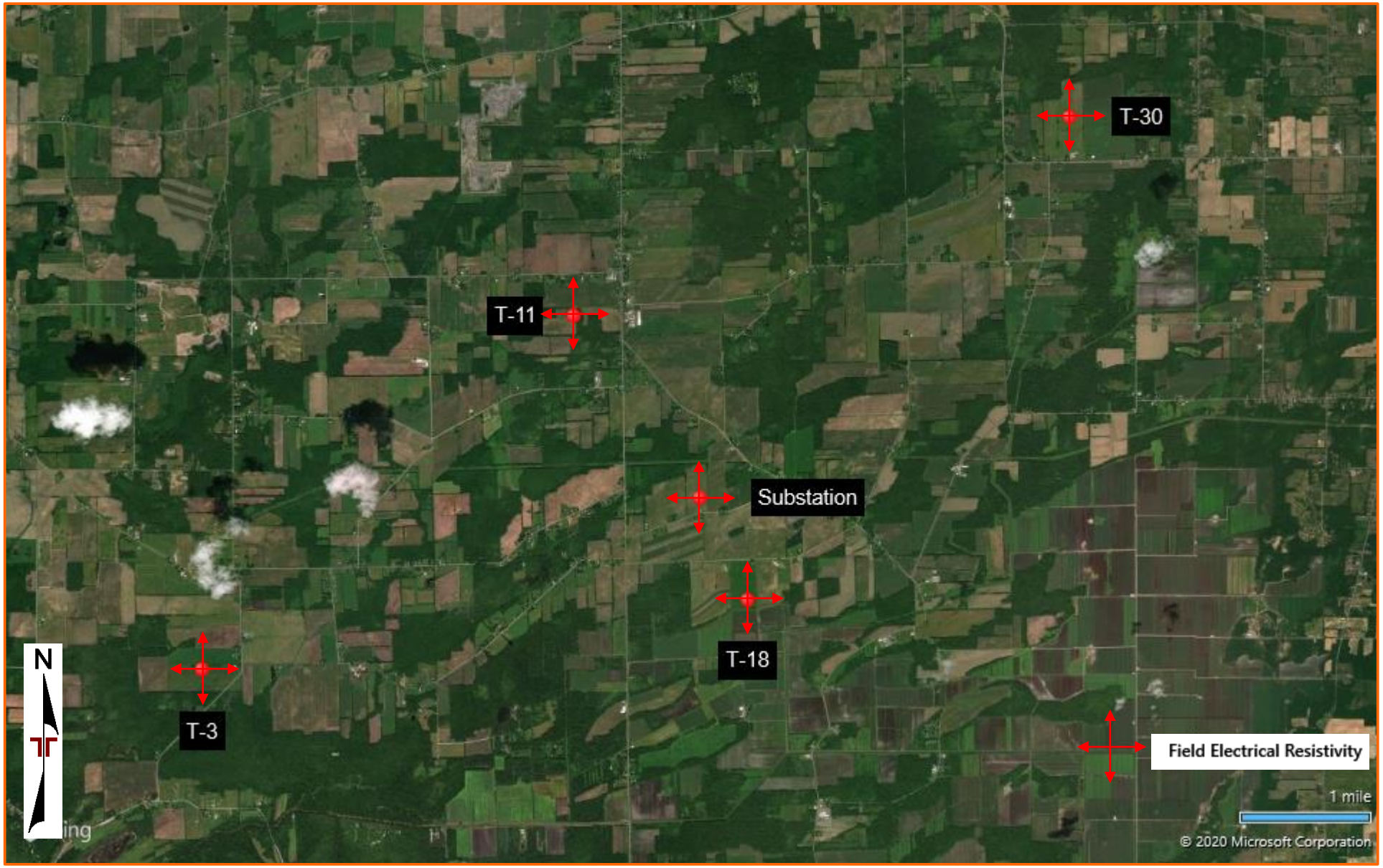


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

Exhibit-C001

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: Substation	Equipment: Mini-Res Resistivity Meter
Test Date: 12-06-2019	Tested by: Tyler Wooden
Weather: Clear	Temperature: 29 Degrees F.

Resistivity Line 1					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
1	38.2	38.2	38.2	38	7,315
2	18.95	18.95	18.95	19	7,258
4	11.54	11.54	11.54	12	8,838
8	7.117	7.117	7.117	7	10,903
10	6.252	6.252	6.252	6	11,973
15	4.656	4.656	4.656	5	13,374
25	3.381	3.381	3.381	3	16,187
50	2.451	2.451	2.451	2	23,468
75	2.181	2.181	2.181	2	31,325
100	2.074	2.074	2.074	2	39,717
150	1.774	1.774	1.774	2	50,964
200	1.470	1.470	1.470	1	56,301
300	1.051	1.051	1.051	1	60,403
400	0.7284	0.7284	0.7284	1	55,795
Center Coordinates: 43.1609, -78.1823					
Line Orientation:North-South					

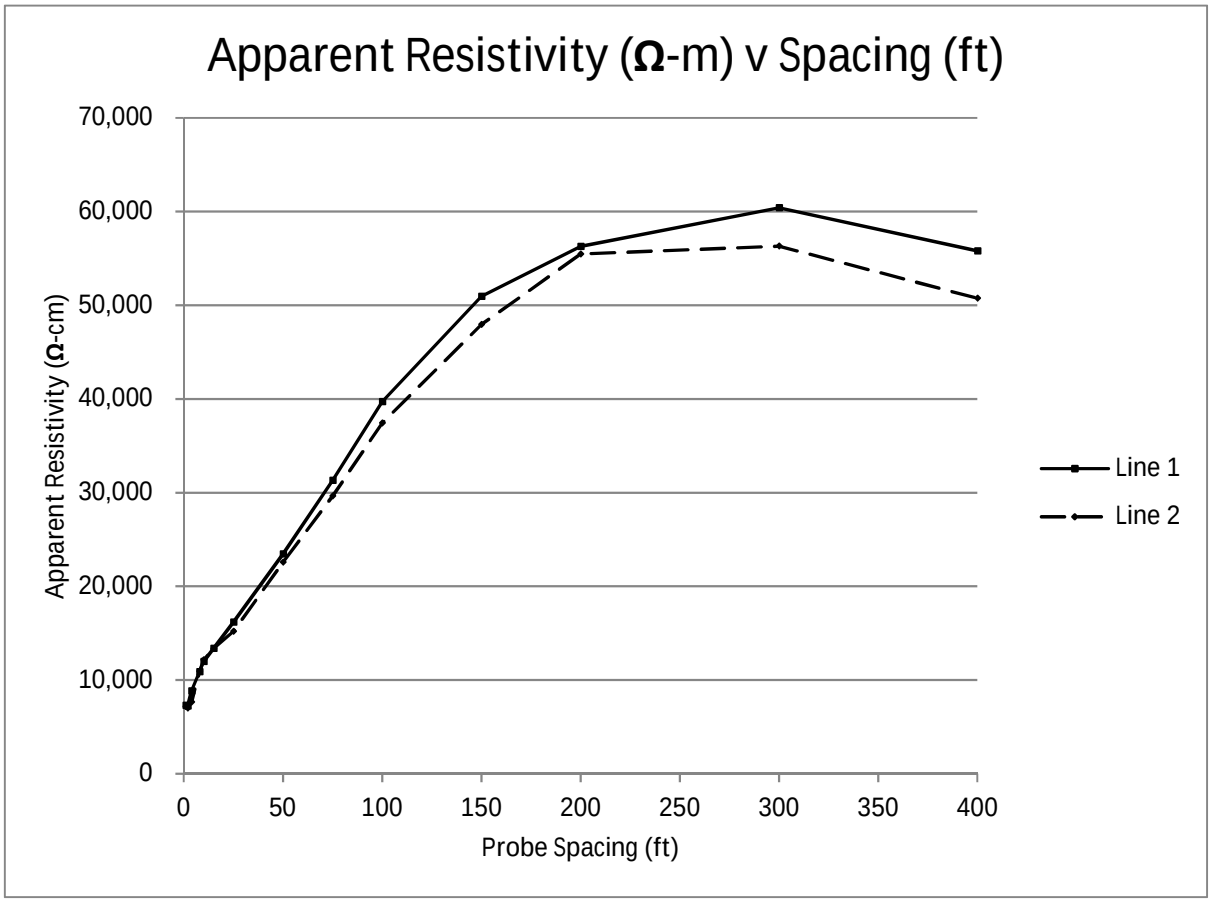
Line Notes: Area of Collection Substation

Resistivity Line 2					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
1	37.5	37.5	37.5	38	7,181
2	18.25	18.25	18.25	18	6,988
4	9.984	9.984	9.984	10	7,648
8	7.128	7.128	7.128	7	10,920
10	6.358	6.358	6.358	6	12,176
15	4.652	4.652	4.652	5	13,363
25	3.174	3.174	3.174	3	15,196
50	2.356	2.356	2.356	2	22,559
75	2.065	2.065	2.065	2	29,659
100	1.954	1.954	1.954	2	37,425
150	1.669	1.669	1.669	2	47,951
200	1.448	1.448	1.448	1	55,470
300	0.9801	0.9801	0.9801	1	56,307
400	0.6626	0.6626	0.6626	1	50,755
Center Coordinates: 43.1609, -78.1823					
Line Orientation: East - West					

Line Notes: Area of Collection Substation

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: Substation



Comments:

1. Field electrical resistivity testing performed per ASTM G57-06, "Standard Test Method for Field Measurement of Electrical Resistivity Using the Wenner Four-Electrode Method"
2. Ground Conditions: Wet crop field. Approx 1" snow, no presence of frost.
3. Resistivity testing may also be influenced by site conditions such as: presence of cobbles, boulders , bedrock, and groundwater; as well as moisture content of the soils and the compactness of the soil.

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-3	Equipment: Mini-Res Resistivity Meter
Test Date: 11-25-2019	Tested by: Tyler Wooden
Weather: Overcast	Temperature: 45 Degrees F.

Resistivity Line 1					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	100.0	100.0	100.0	100	38,300
5	25.50	25.50	25.50	26	24,416
10	9.283	9.283	9.283	9	17,777
20	4.583	4.583	4.583	5	17,553
50	2.916	2.916	2.916	3	27,921
75	2.728	2.728	2.728	3	39,181
Center Coordinates: 43.1417, -78.2586					
Line Orientation:North-South					

Line Notes:

Resistivity Line 2					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	110.1	110.1	110.1	110	42,168
5	24.10	24.10	24.10	24	23,076
10	9.158	9.158	9.158	9	17,538
20	4.316	4.316	4.316	4	16,530
50	2.932	2.932	2.932	3	28,074
75	2.699	2.699	2.699	3	38,764
Center Coordinates: 43.1417, -78.2586					
Line Orientation: East - West					

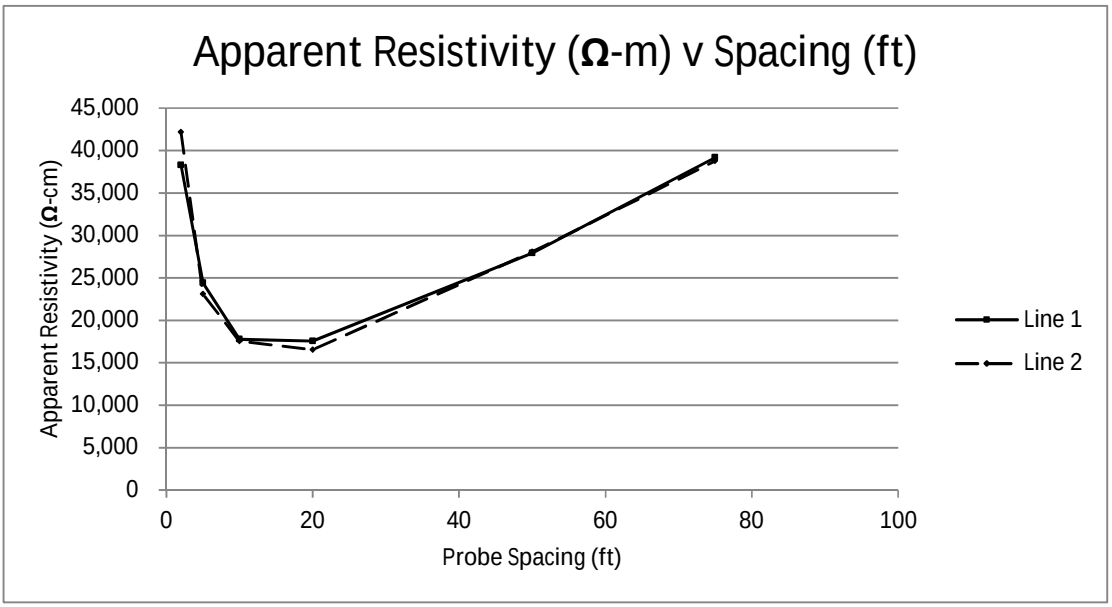
Line Notes:

Comments:

1. Field electrical resistivity testing performed per ASTM G57-06, "Standard Test Method for Field Measurement of Electrical Resistivity Using the Wenner Four Electrode Method"
2. Ground Conditions: Open crop field, Grass, Moist.
3. Field resistivity values may be affected by circumstances such as precipitation, ground temperature and air temperature. Resistivity testing may also be influenced by site conditions such as: presence of cobbles, boulders , bedrock, and groundwater; as well as moisture content of the soils and the compactness of the soil.

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-3



Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-11	Equipment: Mini-Res Resistivity Meter
Test Date: 11-25-2019	Tested by: Tyler Wooden
Weather: Overcast	Temperature: 45 Degrees F

Resistivity Line 1					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	41.3	41.3	41.3	41	15,818
5	14.87	14.87	14.87	15	14,236
10	10.44	10.44	10.44	10	19,998
20	7.383	7.383	7.383	7	28,277
50	5.394	5.394	5.394	5	51,648
75	4.518	4.518	4.518	5	64,890
Center Coordinates: 43.1812, -78.2016					
Line Orientation:North-South					

Line Notes:

Resistivity Line 2					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	43.4	43.4	43.4	43	16,622
5	14.84	14.84	14.84	15	14,213
10	10.26	10.26	10.26	10	19,652
20	7.351	7.351	7.351	7	28,154
50	5.460	5.460	5.460	5	52,280
75	4.514	4.514	4.514	5	64,832
Center Coordinates: 43.1812, -78.2016					
Line Orientation: East - West					

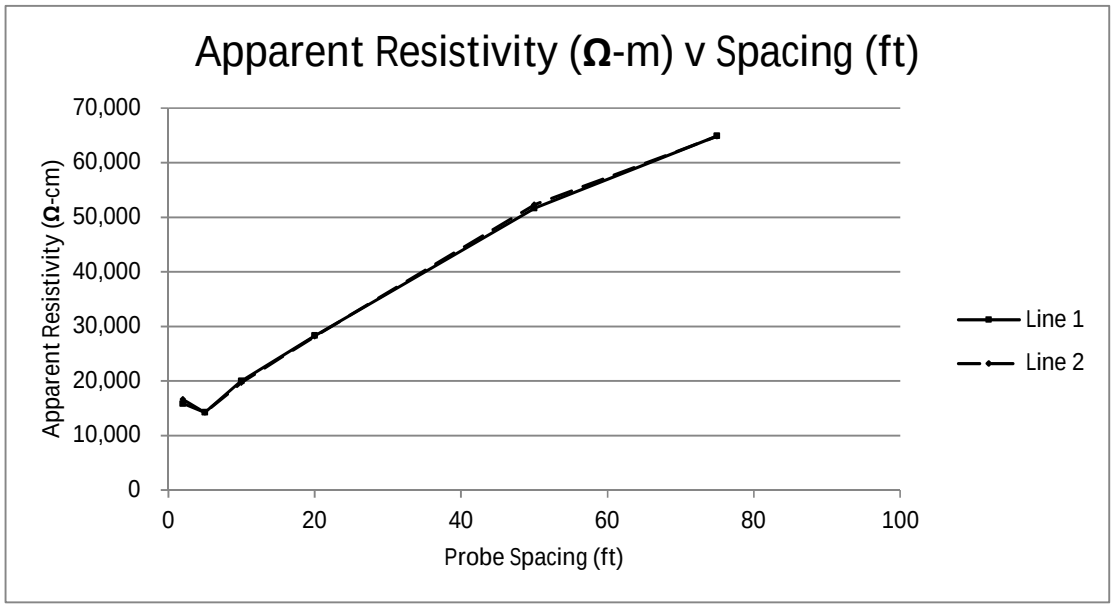
Line Notes:

Comments:

1. Field electrical resistivity testing performed per ASTM G57-06, "Standard Test Method for Field Measurement of Electrical Resistivity Using the Wenner Four Electrode Method"
2. Ground Conditions: Cut corn field, moist
3. Field resistivity values may be affected by circumstances such as precipitation, ground temperature and air temperature. Resistivity testing may also be influenced by site conditions such as: presence of cobbles, boulders , bedrock, and groundwater; as well as moisture content of the soils and the compactness of the soil.

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-11



Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-18	Equipment: Mini-Res Resistivity Meter
Test Date: 12-13-2019	Tested by: Tyler Wooden
Weather: Clear	Temperature: 28 Degrees F.

Resistivity Line 1					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	25.2	25.2	25.2	25	9,652
5	12.63	12.63	12.63	13	12,094
10	7.651	7.651	7.651	8	14,652
20	4.071	4.071	4.071	4	15,592
50	2.912	2.912	2.912	3	27,882
75	2.715	2.715	2.715	3	38,994
Center Coordinates: 43.1495, -78.1750					
Line Orientation:North-South					

Line Notes:

Resistivity Line 2					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	23.9	23.9	23.9	24	9,154
5	12.85	12.85	12.85	13	12,299
10	7.551	7.551	7.551	8	14,460
20	4.106	4.106	4.106	4	15,726
50	2.851	2.851	2.851	3	27,298
75	2.574	2.574	2.574	3	36,969
Center Coordinates: 43.1495, -78.1750					
Line Orientation: East - West					

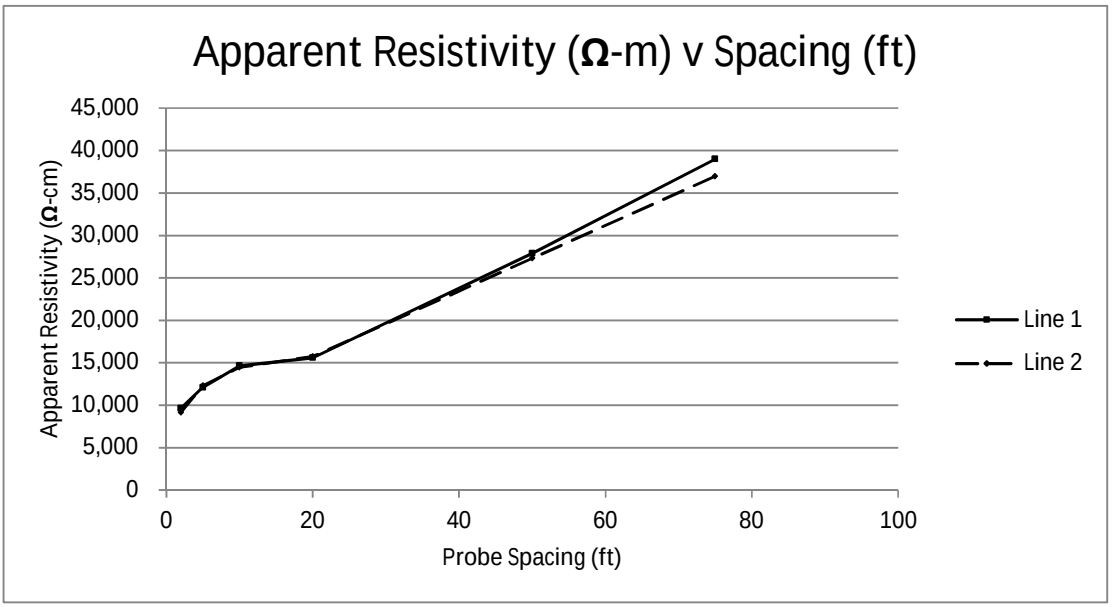
Line Notes:

Comments:

1. Field electrical resistivity testing performed per ASTM G57-06, "Standard Test Method for Field Measurement of Electrical Resistivity Using the Wenner Four-ElectrodeMethod".
2. Ground Conditions: Wet corn field, picked. <1" snow covering non-frozed ground.
3. Field resistivity values may be affected by circumstances such as precipitation, ground temperature and air temperature. Resistivity testing may also be influenced by site conditions such as: presence of cobbles, boulders , bedrock, and groundwater; as well as moisture content of the soils and the compactness of the soil.

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-18



Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-30	Equipment: Mini-Res Resistivity Meter
Test Date: 11-25-2019	Tested by: Tyler Wooden
Weather: Overcast	Temperature: 45 Degrees F.

Resistivity Line 1					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	21.9	21.9	21.9	22	8,388
5	14.07	14.07	14.07	14	13,475
10	12.78	12.78	12.78	13	24,468
20	9.704	9.704	9.704	10	37,166
50	7.010	7.010	7.010	7	67,121
75	6.319	6.319	6.319	6	90,757
Center Coordinates: 43.2034, -78.1257					
Line Orientation:North-South					

Line Notes:

Resistivity Line 2					
Probe Spacing (ft)	Resistance Reading (Ω)				Apparent Resistivity (Ω-cm)
	R1	R2	R3	Average	
2	23.8	23.8	23.8	24	9,115
5	13.78	13.78	13.78	14	13,193
10	12.48	12.48	12.48	12	23,899
20	9.711	9.711	9.711	10	37,193
50	7.294	7.294	7.294	7	69,840
75	6.167	6.167	6.167	6	88,574
Center Coordinates: 43.2034, -78.1257					
Line Orientation: East - West					

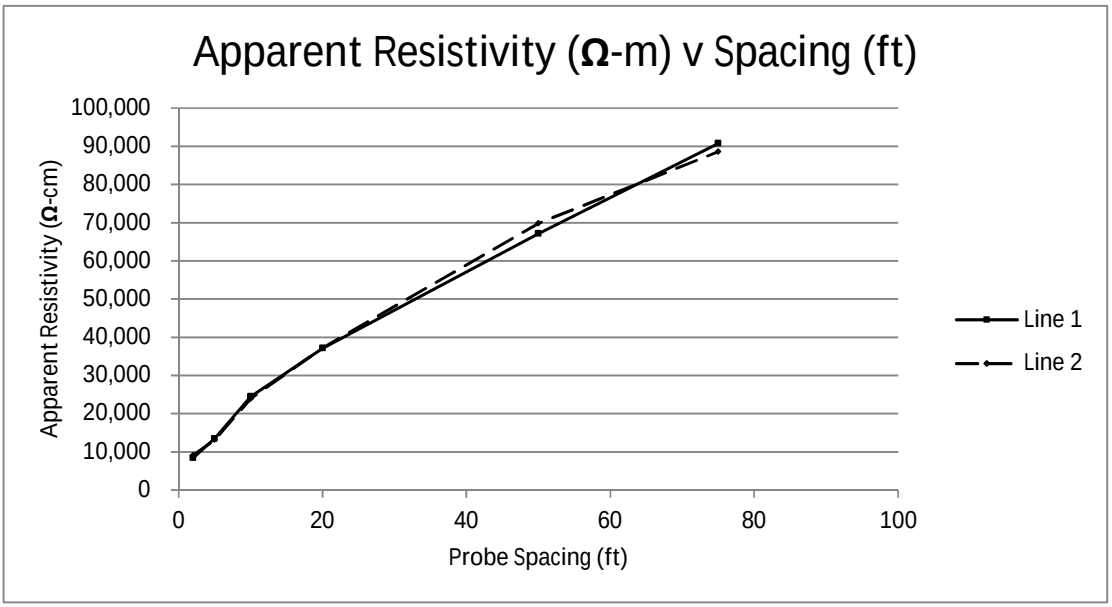
Line Notes:

Comments:

1. Field electrical resistivity testing performed per ASTM G57-06, "Standard Test Method for Field Measurement of Electrical Resistivity Using the Wenner Four-Electrode-Method"
2.Ground Conditions: Open Crop field, Grass, Moist.
3. Field resistivity values may be affected by circumstances such as precipitation, ground temperature and air temperature. Resistivity testing may also be influenced by site conditions such as: presence of cobbles, boulders , bedrock, and groundwater; as well as moisture content of the soils and the compactness of the soil.

Field Electrical Resistivity Test Results
Heritage Wind Project
Town of Barre Center
Project No. J5195205

Test Location: T-30



APPENXID D

SEISMIC TEST RESULTS

(Exhibits- D001 through D005)

EXPLORATION PLAN-SEISMIC TEST LOCATIONS

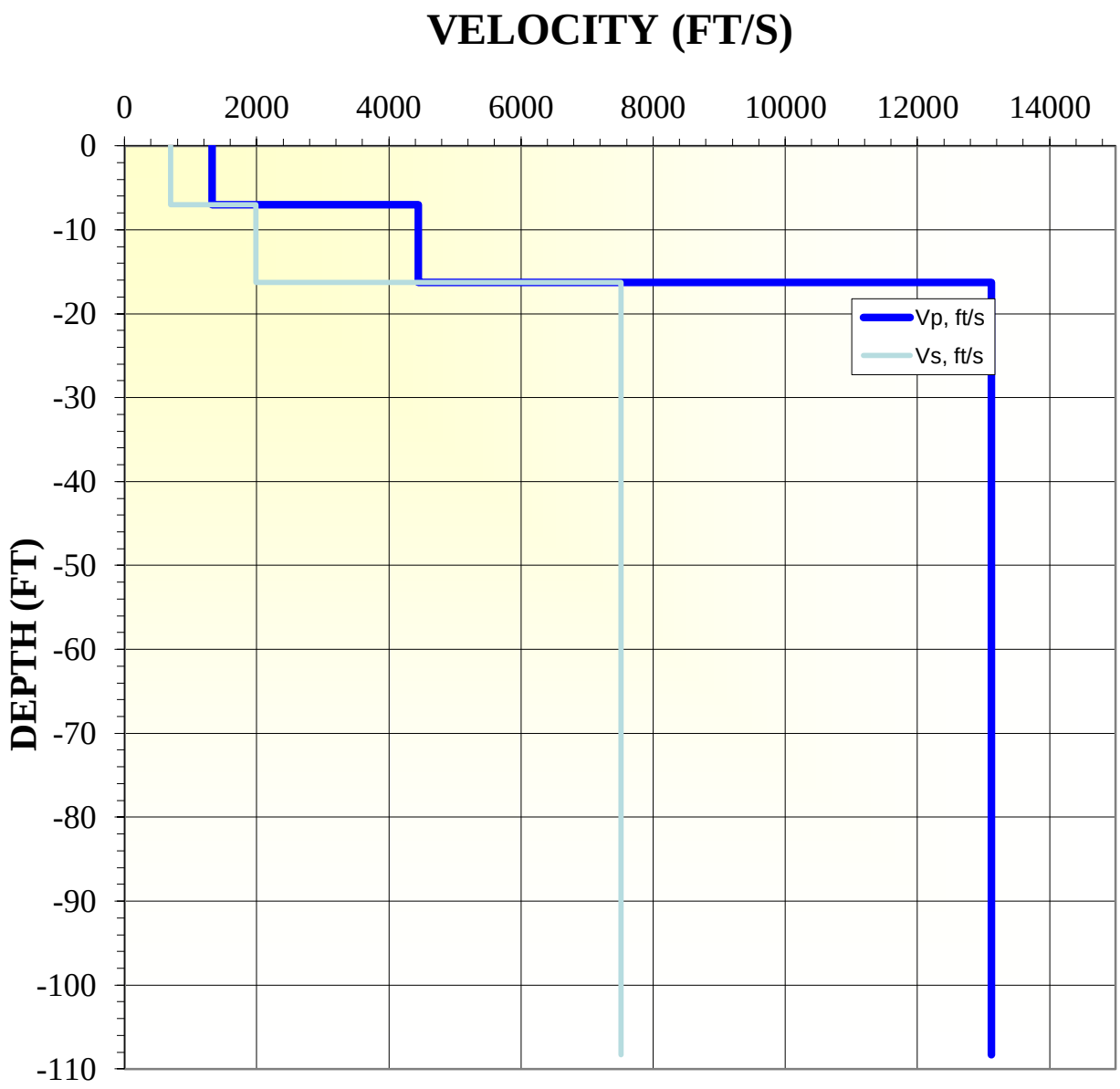
Preliminary Geotechnical Study - Heritage Wind Farm ■ Barre Center, NY

Terracon Project No. J5195205

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

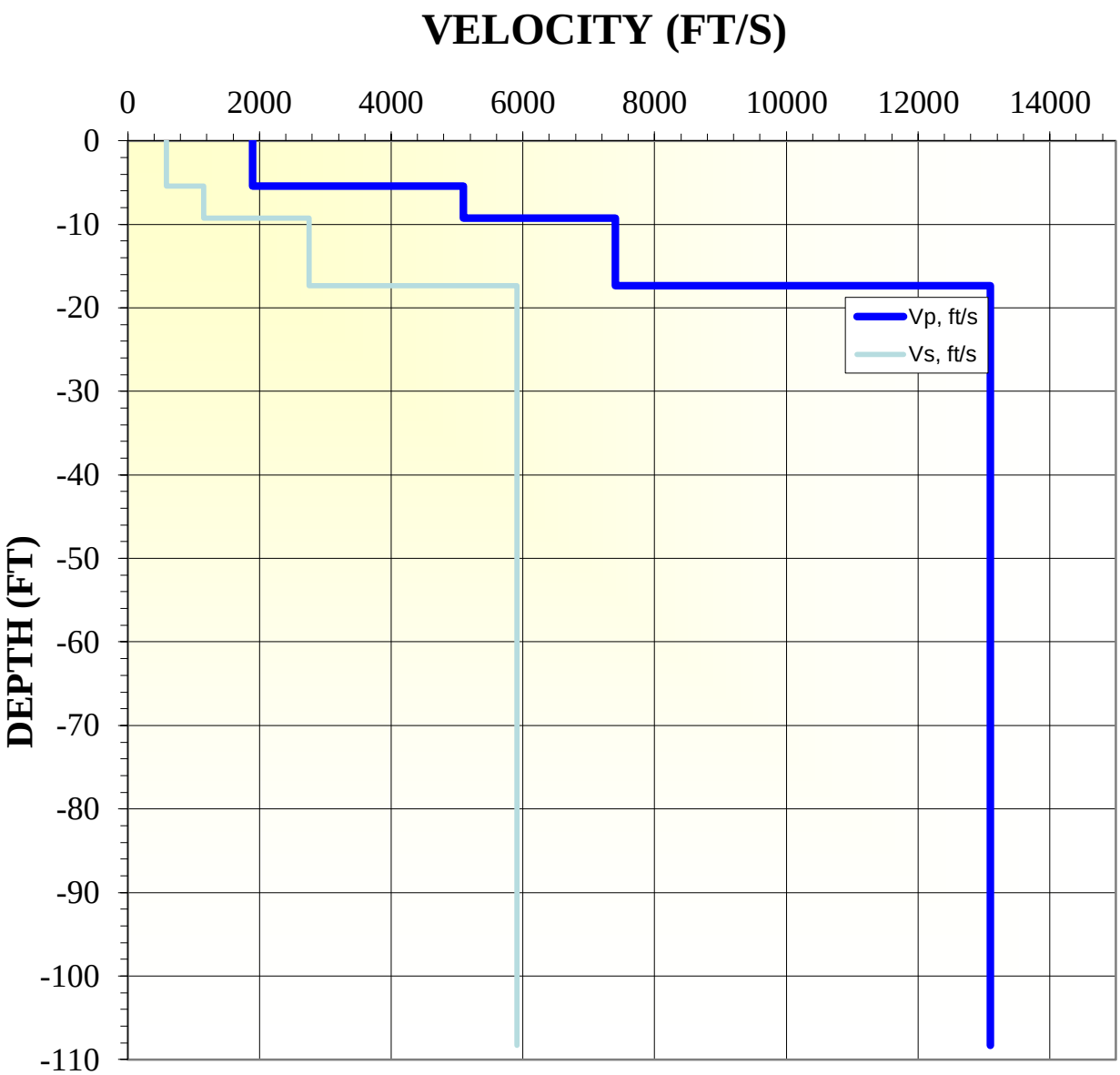
AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

Exhibit-D001



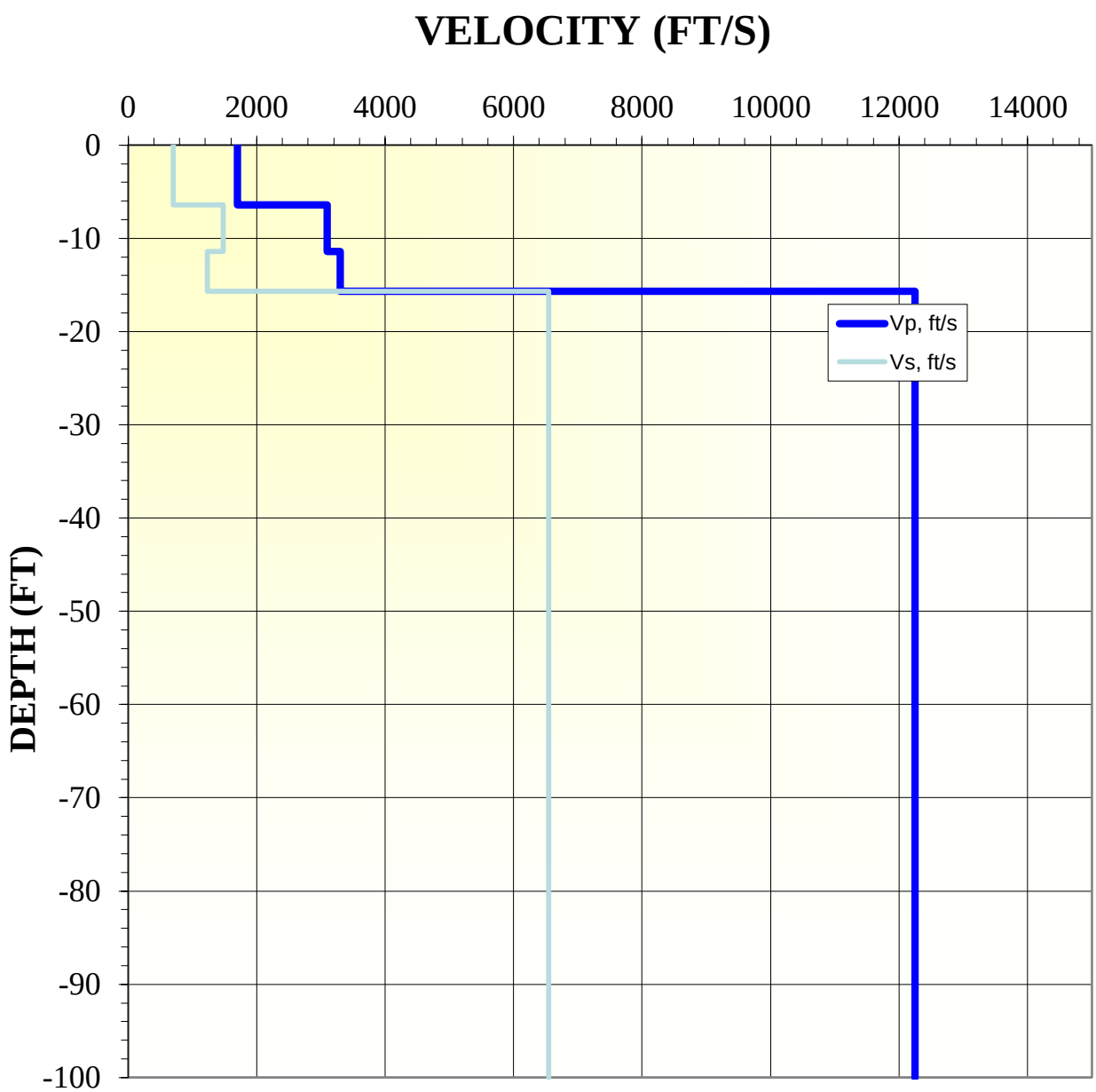
Depth, ft	Vs, ft/s	Vp, ft/s	Poisson's Ratio
0.0	694.2	1325.0	0.31
-7.0	1984.9	4450.0	0.38
-16.2	7511.0	13120.0	0.26
-108.3	7511.0	13120.0	0.26

Project Manager: TMW	Project No. J5195205	Terracon Consulting Engineers & Scientists	T-3	Exhibit
Drawn by: RAK	Scale: N.T.S.	15 Marway Cir. St. 2B, Rochester, NY 14624	Heritage Wind Farm	1
Checked by: MAF	File Name: Exhibits.pdf			
Approved by:	Date: 1/31/2020			



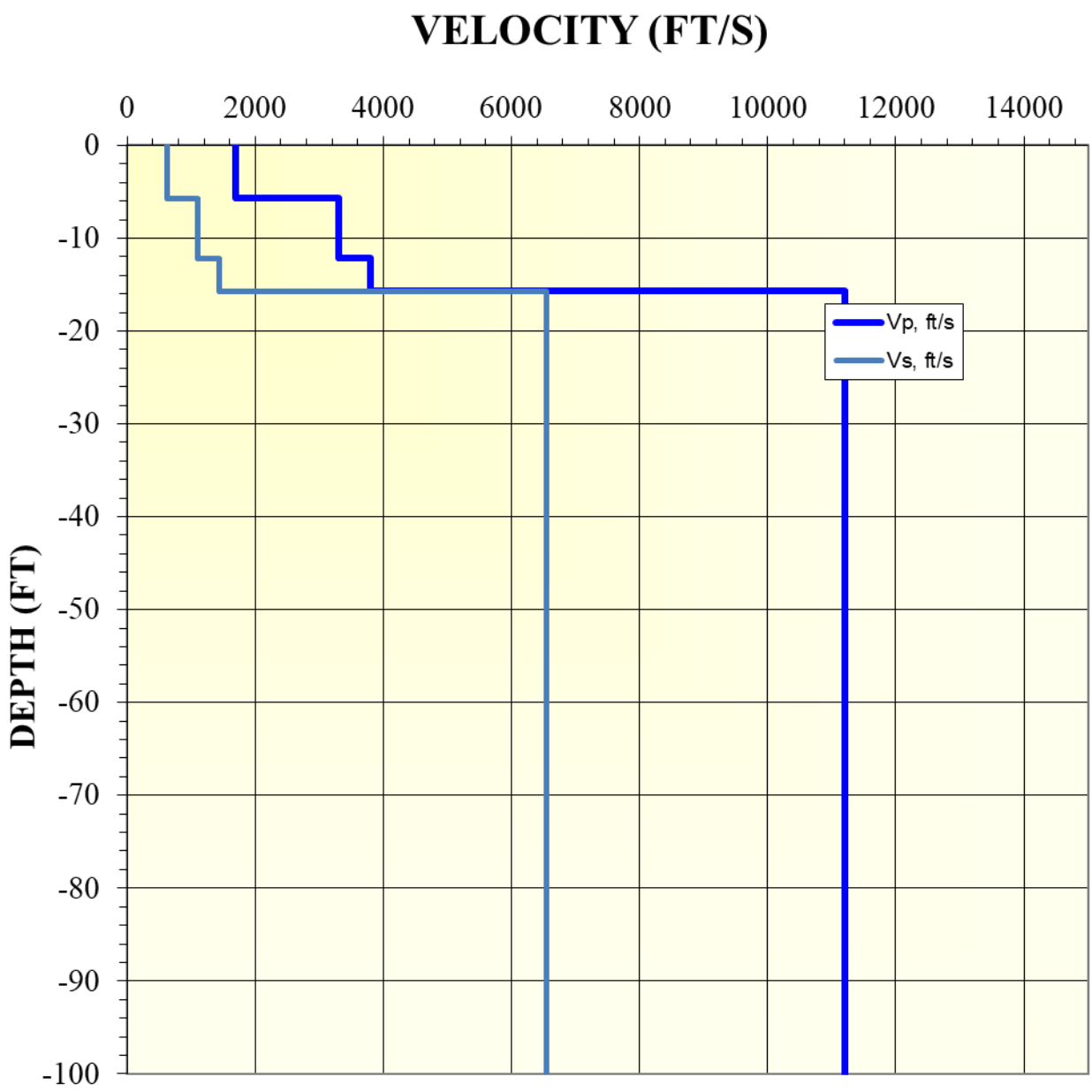
Depth, ft	Vs, ft/s	Vp, ft/s	Poisson's Ratio
0.0	590.5	1900.0	0.45
-5.4	1149.4	5100.0	0.47
-9.3	2752.0	7400.0	0.42
-17.3	5912.2	13100.0	0.37
-108.3	5912.2	13100.0	0.37

Project Manager: TMW	Project No. J5195205	Terracon Consulting Engineers & Scientists	T-11	Exhibit
Drawn by: RAK	Scale: N.T.S.	15 Marway Cir. St. 2B, Rochester, NY 14624	Heritage Wind Farm	2
Checked by: MAF	File Name: Exhibits.pdf			
Approved by:	Date: 1/31/2020			



Depth, ft	Vs, ft/s	Vp, ft/s	Poisson's Ratio
0.0	705.7	1700.0	0.40
-6.4	1477.9	3100.0	0.35
-11.4	1230.1	3300.0	0.42
-15.7	6548.7	12250.0	0.30
-100	6548.7	12250.0	0.30

Project Manager: TMW	Project No. J5195205	Terracon Consulting Engineers & Scientists	T-18	Exhibit
Drawn by: RAK	Scale: N.T.S.	15 Marway Cir. St. 2B, Rochester, NY 14624	Heritage Wind Farm	3
Checked by: MAF	File Name: Exhibits.pdf			
Approved by:	Date: 1/31/2020			



Depth, ft	Vs, ft/s	Vp, ft/s	Poisson's Ratio
0.0	625.0	1700.0	0.42
-5.7	1109.1	3300.0	0.44
-12.2	1443.3	3800.0	0.42
-15.7	6548.7	11200.0	0.24
-100.0	6548.7	11200.0	0.24

Project Manager: TMW	Project No. J5195205	Terracon Consulting Engineers & Scientists	T-30	Exhibit
Drawn by: RAK	Scale: N.T.S.	15 Marway Cir. St. 2B, Rochester, NY 14624	Heritage Wind Farm	4
Checked by: MAF	File Name: Exhibits.pdf			
Approved by:	Date: 1/31/2020			