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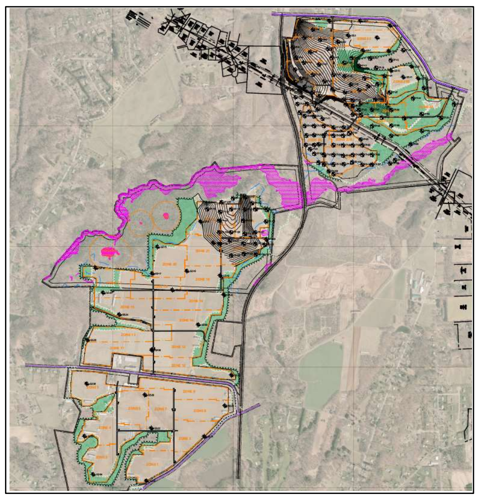
Geotechnical Engineering Report

GRAVEL PIT SOLAR
164 Windsorville Road
East Windsor, Connecticut

April 13, 2020
File No. 05.0046621.00



PREPARED FOR:
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C/O North Light Solar
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Gravel Pit Solar II, LLC
C/O North Light Solar
1166 Avenue of the Americas, 9th Floor
New York, NY 10036

Attn: Aaron Svedlow

Re: Geotechnical Engineering Report
Proposed Solar Farm
164 Windsorville Road
East Windsor, Connecticut 06016

Dear Mr. Svedlow:

In accordance with our agreement signed on January 22, 2020, GZA GeoEnvironmental Inc. (GZA) is pleased to present this geotechnical engineering report to Gravel Pit Solar II, LLC. (Client) for the above-referenced project. The objectives of our work were to evaluate subsurface conditions, provide laboratory analysis of soils, and develop geotechnical recommendations for the proposed photo-voltaic (PV) array foundations and associated site work.

This report is subject to the Limitations outlined in **Appendix A** and the Terms and Conditions of our agreement.

We appreciate the opportunity to work with you on this project. Please contact Jim Davis, P.E. (860-858-3157) or David Barstow, P.E. (860-858-3106) if you have any questions or require additional information.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

James F. Davis, P.E.
Sr. Project Manager

David M. Barstow, P.E.
Associate Principal

Bruce Fairless, P.E.
Consultant Reviewer

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1.0 INTRODUCTION

Our understanding of the project was based on:

- Discussions with you and the project Team;
- Online aerial photography; and
- A proposed layout plan entitled "Draft Overall Site Plan Project Layout Study", Sheet C-1.00, prepared by Krebs & Lansing Consulting Engineers, Inc., dated March 5, 2020.

1.1 EXISTING CONDITIONS

The Site has a total area of about 725 acres of which about 400 acres are planned to be developed for solar photo-voltaic (PV) arrays. The Site is accessed from about 164 Windsorville Road, 6 Chamberlain Road, and between about 21 to 163 Plantation Road in East Windsor, Connecticut. The Site is divided into two areas, separated by woods and train tracks. The Project area located northeast of the train tracks is bordered by Windsorville Road and Apothecaries Hall Road to the north, Apothecaries Hall Road and private properties to the east, by private properties to the south, and by train tracks to the west. The Project area located southwest of the train tracks is bordered by private property to the north, by train tracks to the east, by Wrapping Road to the south, and by private property to the west. An aerial photograph with the proposed solar development limits is presented on **Figure 1**.

The Site area located northeast of the train tracks has an area of about 200 acres which consists of about 51 acres of closed gravel pit, 31 acres of active gravel pit, 25 acres of farm fields, and 93 acres of woodlands. We understand there are no details of how or when the closed gravel pit was closed. The Site area located southwest of the train tracks has an area of about 525 acres and consists of about 30 acres of an active gravel pit, 220 acres of farm fields, and 275 acres of woodlands. Numerous tobacco-drying barns are located at the farm fields in the Site area located southwest of the train tracks.

1.2 PROPOSED CONSTRUCTION

The proposed solar PV development has a total area of about 400 acres and will consist of about 378,000 solar modules. The solar panels will be ground-mounted and we understand that short galvanized driven piles or ground screws are the preferred foundation alternatives. In our experience, solar panel foundations are designed by a specialty design-build contractor based on the geotechnical report and multiple vertical and lateral load tests performed at the Site An approximate 51,600 square-foot substation is planned in the Project area located northeast of the railroad tracks. The proposed development area and location of the substation is presented on **Figure 1**.

2.0 SCOPE OF SERVICES

To meet the stated objectives, GZA performed the following Scope of Services:

- Coordinated, performed and documented an exploration program consisting of 135 test pits, 35 test borings, and 4 electrical resistivity tests at the site;
- Coordinated a laboratory testing program that consisted of 22 gradation analyses; 3 corrosivity tests; and 3 thermal resistivity tests;
- Evaluated subsurface conditions based on the explorations to develop geotechnical design and construction recommendations; and
- Prepared this report summarizing our analyses, conclusions and recommendations.

3.0 SUBSURFACE EXPLORATIONS

GZA performed a subsurface exploration program consisting of 135 test pit excavations (TP-1 through TP-135), 35 test borings (GZ-1 through GZ-35) and 4 electrical resistivity tests (ER-1 through ER-4) for the proposed PV installations. The location and elevation of the explorations were determined in the field by GZA using a handheld GPS unit with a resolution of about plus or minus 0.5 feet. A GZA field representative observed the explorations, classified soil samples based on visual-manual observations, and prepared the logs for each exploration. The test boring logs are included in **Appendix B** and the test pit logs are included in **Appendix C.** Photos of the test pits are included in **Appendix D**. The electrical resistivity testing logs are included in **Appendix F**.

3.1 TEST PITS

The test pit excavations (TP-1 through TP-135) were performed by Conte Company, LLC of Naugatuck, Connecticut between January 27 and February 17, 2020 using a CAT-320 tracked excavator. The test pits were advanced to depths ranging from 5 feet to 14 feet below existing ground surface (bgs). Target depth of the test pit excavations was 12 feet below existing grade. Test pits TP-28 and TP-93 were terminated above the target depth due to refusal on concrete. Refer to **Figure 2** through **Figure 6**, and **Figure 8** for approximate test pit locations.

3.2 TEST BORINGS

The test borings (GZ-1 through 35) were drilled by Seaboard Drilling of Chicopee, Massachusetts, between February 12 and February 19, 2020 using an ATV-mounted drill rig and hollow-stem augers. The test borings were advanced to 17 feet bgs, with the exception of boring GZ-26, which was terminated at 9 feet bgs after encountering a stormwater drainage pipe. The stormwater drainage pipe was exposed at a depth of about 5 feet and repaired by Conte Company, LLC. Split spoon soil samples were collected continuously to a depth of 10 feet bgs and at 5-foot intervals thereafter in general accordance with ASTM D1586, the Standard Penetration Test (SPT). The SPT consists of driving a 1-3/8 inch inside diameter standard split spoon sampler at least 18 inches with a 140-pound hammer dropping from a height of 30 inches. Split spoon soil samples in the test borings were collected using an automatic hammer. The SPT value, referred to as the "N" value, is the number of blows required to drive the sampler from 6 to 18 inches of penetration. Refer to **Figure 7** through **Figure 12** for approximate test boring locations.

3.3 ELECTRICAL RESISTIVITY TESTING

On March 20, 2020, GZA performed four field electrical resistivity tests with an AEMC Model 6470B resistivity meter using the Wenner (Four-Point) Method. Each test included two sets of resistivity readings performed in an orthogonal array pattern with the midpoints at approximately the same locations. The probes were spaced at increments of 5, 10, 15, 20 and 25 feet. The approximate array locations are shown on **Figure 2** and **Figure 8**. Soil electrical resistivity test results, including electrode probe spacing, a, depth, b, and measured resistance, are presented on the testing logs.

The ambient air temperature during the resistivity surveys was in the 40s °F. The tests were conducted after a minimum 48-hour dry period following recorded precipitation. Surface water was not observed in the test areas and test areas were generally level.

4.0 LABORATORY TESTING PROGRAM

Laboratory tests were performed on soil collected from the explorations to confirm the visual-manual classifications made in the field and to assess engineering, thermal resistivity and corrosivity properties of the encountered soil. The laboratory test results are included in **Appendix E**. The soil samples were analyzed by Thielsch Engineering of Cranston, Rhode Island and the testing consisted of:

Geotechnical Index Testing and Results

- 22 Gradation tests

Exploration	Sample Depth (ft.)	Stratum	Percent Silt/Passing No. 200 Sieve
TP-6	2-3	Alluvial Deposits	13.3
TP-6	1-5	Alluvial Deposits	1.9
TP-7	1-5	Alluvial Deposits	14.5
TP-26	1-3	Alluvial Deposits	15.8
TP-26	4-8	Alluvial Deposits	4.7
TP-37	0.5-2.5	Topsoil/Subsoil	80.3
TP-37	2.5-5	Alluvial Deposits	2.6
TP-38	2.5-6.5	Alluvial Deposits	68.1
TP-50	1-4	Alluvial Deposits	4.6
TP-53	1-5	Alluvial Deposits	20.5
TP-57	1.5-5	Alluvial Deposits	17.4
TP-63	3-6	Alluvial Deposits	73.1
TP-64	1-4	Fill	26.2
TP-72	1-2	Alluvial Deposits	27.1
TP-72	5.5-12	Alluvial Deposits	68.5
TP-76	0-6	Fill	29.6
TP-89	1-5	Alluvial Deposits	3.3
TP-89	2-3	Alluvial Deposits	0.9
TP-99	1-3	Alluvial Deposits	48.2
TP-116	0-5	Alluvial Deposits	3.9
TP-118	1-5	Alluvial Deposits	6.7
TP127	1-4	Alluvial Deposits	3.0

Corrosivity Testing

Three soil samples from the test pits were evaluated for corrosion using a suite of tests. Two of the samples were analyzed from the Alluvial Deposits and one sample was analyzed from the Fill. The results from the corrosion tests are summarized in the Summary of Laboratory Corrosion Testing table below. Based on the parameters presented in the Comparison of Corrosion Testing Results table below, steel piles on this site are not considered particularly susceptible to corrosion, according to the cited references, in the Alluvial Deposits. Steel piles may be considered susceptible to corrosion in some portions of the Fill due to elevated Sulfate, according to the cited references.

Summary of Laboratory Corrosion Testing			
Exploration	TP-12	TP-23	TP-99
Sample Depth	1-4 ft	2-3 ft	1-3 ft
Stratum	Alluvial Deposits	Fill	Alluvial Deposits
Sulfate	<54 ppm	284 ppm	<59 ppm
Sulfide	<0.5 ppm	<0.6 ppm	<0.6 ppm
Chloride	<32 ppm	<39 ppm	<35 ppm
Redox Potential	62.6 mv	209 mv	59.7 mv
pH	6.6	7.65	5.9

Comparison of Corrosion Testing Results				
Parameter	Corrosive Based on Corrosivity Criteria[1]			Corrosive Based on Laboratory Results Compared to Corrosivity Criteria?
	CalTrans	AASHTO	FHWA	
Electrical Resistivity (ohm-cm)	Below 1,000 ohm-cm	Below 2,000 ohm-cm	Below 3,000 ohm-cm	No (See Field Electrical Resistivity Logs in Appendix F)
pH	Below 5.5	Below 5.5; or Between 5.5 and 8.5 for organic soils	Below 5 and above 10	No
Sulfate (ppm)	Above 2,000 ppm	Above 1,000 ppm	Above 200 ppm	No, except portions of the Fill
Chloride (ppm)	Above 500 ppm	No Criteria	Above 100 ppm	No

<u>Thermal Resistivity Testing</u>

Three thermal resistivity laboratory tests were performed of on-site soils and the results are included in **Appendix F**.

Summary of Thermal Resistivity Testing			
	TP-6	TP-89	TP-99
Sample Depth	2'-3'	2'-3'	1'-3'
Stratum	Alluvial Deposits	Alluvial Deposits	Alluvial Deposits
Thermal Resistivity Optimum (°C-cm/W)	55.80	58.28	50.21
Thermal Resistivity Mid-Point (°C-cm/W)	64.92	78.36	73.13
Thermal Resistivity Oven Dried (°C-cm/W)	291.56	294.88	189.56

5.0 SUBSURFACE CONDITIONS

The generalized subsurface conditions are described below for each type of existing area at the Site which consist of: Farm Fields, Woodlands, Active Gravel Pit, and Closed Gravel Pit. The subsurface conditions are summarized on **Table 1** and **Table 2**. Refer to the exploration logs in **Appendix B** and **Appendix C** for specific soil descriptions.

5.1 <u>FARM FIELDS</u>

Test borings GZ-1 through GZ-35 were performed within the existing farm fields. Based on the borings, generalized subsurface conditions consisted of, in descending order:

<u>TOPSOIL/SUBSOIL</u> – About 0.7 to 6 feet of Topsoil/Subsoil was encountered at the ground surface. Topsoil/subsoil generally consisted of Silt with up to 50 percent fine Sand or fine Sand with up to 35 percent Silt. SPT N-values ranged from 4 to 15, indicating a loose to medium dense relative density.

[1] Three references used to evaluate corrosion test criteria herein included:
-CalTrans Publication entitled "Memo to Designers 3-1 June 2014". CalTrans considers a site to be corrosive if one or more of the parameters listed in the table are exceeded.
-AASHTO LRFD Bridge Design Specifications (Eighth Edition 2017). AASHTO considers site conditions to be indicative of a potential pile deterioration or corrosion situation if one or more of the parameters listed on the table are exceeded.
-FHWA Publication No.FHWA NHI-05-039 entitled "Micropile Design and Construction" December2005. FHWA uses the criteria listed in the table to determine whether the ground is classified to have strong corrosion potential or is aggressive if any one of the conditions listed is exceeded.

FILL – About 3.3 feet of Fill was encountered below Topsoil at boring GZ-19. Fill consisted of fine to coarse SAND with up to 35 percent Gravel, up to 20 percent Silt, and less than 10 percent Brick. The single SPT N-value in the Fill was 34, indicating a dense relative density.

ALLUVIAL DEPOSITS – Naturally-deposited alluvial deposits were encountered below the Topsoil/Subsoil and/or Fill at each of the test borings. None of the test borings fully penetrated the Alluvial Deposits and the stratum is at least 16.5 feet in thickness. Alluvial Deposits generally consisted of either fine to medium Sand with 0 to 50 percent Gravel and up to 35 percent Silt. SPT N-values ranged from 4 to 47, indicating a loose to dense relative density.

5.2 WOODLANDS

Twenty nine test pits (TP-1, -10, -11, -12, -13, -16, -17, -18, -24, -29, -30, -37, -43, -44, -45, -51, -52, -53, -54, -57, -58, -59, -60, -61, -62, -63, -100, -108 and TP-119) were performed within the existing woodlands. Based on the noted test pits, the generalized subsurface conditions consisted of, in descending order:

TOPSOIL/SUBSOIL – Topsoil/Subsoil was encountered at the ground surface in 17 of the noted test pits and ranged from about 0.5 to 3 feet thick. Topsoil/subsoil generally consisted of Silt with up to 50 percent fine Sand or fine Sand with up to 20 percent Silt. Excavation effort was generally easy in the Topsoil/Subsoil layer.

FILL – Fill was encountered at test pits TP-1, TP-29 and TP-59. The Fill at test pits TP-1 and TP-29 was not fully penetrated and was at least 12 and 14 feet in thickness, respectively. Fill at test pit TP-59 was about 0.5 feet in thickness. The Fill at test pit TP-1 generally consisted of fine to medium Sand with up to 35 percent Silt, up to 20 percent Gravel, and less than 10 percent Wood, Asphalt, Concrete, Wires, and Plastic. Fill at test pit TP-29 consisted of either fine to medium Sand with up to 50 percent Gravel and up to 20 percent Silt or fine Sand with less than 10 percent Silt and less than 10 percent Roots. The Fill at test pit TP-59 consisted of fine to medium Sand with up to 35 percent Gravel and up to 20 percent Silt overlying filter fabric. An approximate 1-foot-diameter and 2-foot-long wood log was encountered at test pits TP-1 and TP-29 at depths of 10 and 10.5 feet, respectively. Excavation effort generally ranged from easy to moderate in the Fill layer.

ALLUVIAL DEPOSITS – Naturally-deposited alluvial deposits were encountered below the Topsoil/Subsoil and the Fill at twenty-seven of the noted test pits. The stratum was not encountered at test pits TP-1 or TP-29. The test pits did not fully penetrate the Alluvial Deposits and the stratum is at least 12-feet thick. Alluvial Deposits generally consisted of either fine to medium Sand with 0 to 50 percent Gravel and up to 20 percent Silt or fine Sand with up to 35 percent Silt. Excavation effort generally ranged from easy to moderate in the Alluvial Deposits layer.

5.3 ACTIVE GRAVEL PIT

Forty-seven test pits (TP-2 through -9, -14, -15, -19 through -28, -34, -35, -36, -99, -11 through -118, and -120 through TP-135) were performed within the active gravel pit. Based on the noted test pits, the generalized subsurface conditions consisted of, in descending order:

TOPSOIL/SUBSOIL – Topsoil/Subsoil was encountered at the ground surface in 2 of the noted test pits (TP-9 and TP-20) and was about 0.5 feet in thickness. Topsoil/subsoil generally consisted of Silt with up to 50 percent fine Sand or fine Sand with up to 20 percent Silt. Excavation effort was generally easy in the Topsoil/Subsoil layer.

FILL – Fill was encountered at the ground surface in 7 of the noted test pits (TP-8, -22, -23, -27, -28, -34, and -36) and ranged from 5.5- to at least 12 feet in thickness. Fill was not fully penetrated at test pits TP-22, -23, -27, -28, or TP-36. The Fill generally consisted of silty Sand with up to 35 percent Gravel, and less than 10 percent Asphalt, Brick, Rebar, Concrete, Wires, and Plastic. Excavation effort ranged from easy to difficult in the Fill layer. The following obstructions were encountered in the Fill:

TP-8: An approximate 2-foot by 3-foot by 1-foot concrete block at a depth of 3 feet.
TP-10: Three 18-inch boulders at a depth of 4 feet.
TP-22: Excavator refusal on concrete at a depth of 3 feet on one side of the test pit.
TP-22: An approximate 6-inch-thick layer of asphalt at a depth of 9.5 feet.
TP-23: An approximate 2-foot by 4-foot by 2-foot concrete block at a depth of 2 feet.
TP-27: An approximate 1-foot-thick layer of asphalt between depths of 1 and 2 feet.
TP-28: An approximate 2-foot by 3-foot by 1-foot concrete block at a depth of 6 feet.
TP-28: Excavator refusal on concrete at a depth of 10 feet.
TP-35: An approximate 2-foot by 5-foot by 1-foot concrete block at a depth of 2 feet.
TP-36: Two, approximately 2-foot by 4-foot by 2-foot concrete blocks at depths of 3 and 6 feet.

ALLUVIAL DEPOSITS – Naturally-deposited alluvial deposits were encountered below the Topsoil/Subsoil and the Fill at each of the test pits, except test pits TP-22, TP-23, TP-27, TP-28 and TP-36. The test pits did not fully penetrate the Alluvial Deposits and the stratum is at least 12 feet in thickness. Alluvial Deposits generally consisted of either fine to medium Sand with 0 to 50 percent Gravel and up to 20 percent Silt or fine Sand with up to 35 percent Silt. Several cobbles that ranged from 6 inches to 18 inches were encountered in the Alluvial Deposits at test pits TP-9 and TP-111. Excavation effort generally ranged from easy to moderate in the Alluvial Deposits layer.

5.4 CLOSED GRAVEL PIT

Fifty nine test pits (TP-31, -32, -33, -38 through -42, -46 through -50, -55, -56, -64 through -98, -101 through -107, -109 and -110) were performed within the footprint of the closed gravel pit and the generalized subsurface conditions consisted, in descending order, of:

TOPSOIL/SUBSOIL – Topsoil/Subsoil was encountered at the ground surface in 19 of the noted test pits and ranged from about 0.5 to 2 feet thick. Topsoil/subsoil generally consisted of Silt with up to 50 percent fine Sand or fine Sand with up to 20 percent Silt. Excavation effort was generally easy in the Topsoil/Subsoil layer.

FILL – Fill was encountered either at the ground surface or below the Topsoil/Subsoil in 32 of the noted test pits. When encountered, the Fill ranged from 3 feet to at least 14 feet in thickness. Fill was not fully penetrated in 18 of the noted test pits. The Fill generally consisted of silty Sand with up to 35 percent Gravel, and less than 10 percent Asphalt, Brick, Rebar, Concrete, Wires, and Plastic. Excavation effort ranged from easy to difficult in the Fill layer. The following obstructions were encountered in the Fill:

TP-31: 4 to 5, 2-foot-long and 1-foot-diameter stumps between depths of 2 and 8 feet.
TP-31: 3, 3- to 4-foot-diameter buried stumps between depths of 8 and 12 feet.
TP-41: Buried tree stumps from depths of 3.5 to 6 feet.
TP-42: Buried roots and stumps between depths of 10 and 12 feet.
TP-49: An approximate 3-inch-thick layer of asphalt at a depth of 8 feet.
TP-66: Tree stumps, logs and branches buried between depths of 3 and 7 feet.
TP-73: An approximate 1-foot by 2-foot by 1-foot concrete block at a depth of 4 feet.
TP-74: An approximate 6- to 12-inch-thick layer of asphalt at a depth of 10 feet.
TP-75: Multiple 18-inch boulders between ground surface and 5-feet depth and two boulders greater than 36 inches at a depth of 11 feet.
TP-76: Multiple 18-inch to greater than 36-inch boulders at depths of between 0 and 11 feet.
TP-77: Tree stumps at depths of between 3 and 12 feet.
TP-78: An approximate 2-foot by 4-foot by 1-foot concrete block at a depth of 4 feet.
TP-79: An approximate 2-foot by 4-foot by 1-foot concrete block at a depth of 1 foot.
TP-91: Several tree stumps between depths of 12 and 14 feet.

TP-93: Excavator refusal on concrete at a depth of about 4 to 5 feet.
TP-103: Ten 18-inch boulders between depths of 3 and 5 feet.
TP-104: Six 18-inch boulders between depths of 10 and 12 feet.

ALLUVIAL DEPOSITS – Naturally-deposited alluvial deposits were encountered at the ground surface or below the Topsoil/Subsoil and the Fill at 40 of the noted test pits. The test pits did not fully penetrate the Alluvial Deposits and the stratum is at least 12-feet thick. Alluvial Deposits generally consisted of either fine to medium Sand with 0 to 50 percent Gravel and up to 20 percent Silt or fine Sand with up to 35 percent Silt. Several cobbles and boulders that ranged from 6 inches to 36 inches were encountered in the Alluvial Deposits at test pits TP-32, -38, -56, -67, -68. -70, -73, -86, -88, -103, -107, -109, and TP-110. Excavation effort generally ranged from easy to moderate in the Alluvial Deposits layer.

5.5 GROUNDWATER

Groundwater was attempted to be measured in each exploration after about a 5- to 10-minute stabilization time. However, groundwater was only encountered at explorations GZ-8, TP-94, TP-95, TP-101 through TP-106, TP-109, and TP-110. The measured depth to groundwater ranged from 11 to 16.3 feet, corresponding to El. 115.7 feet to 175.2 feet. Note that groundwater observations may not represent stabilized groundwater conditions. Fluctuations in groundwater levels may occur due to variations in season, rainfall, site features and other factors different from those existing at the time of the explorations and measurements.

6.0 GEOTECHNICAL CONSIDERATIONS

Based on the conditions encountered in the explorations, the primary geotechnical consideration at this Site is the presence of heterogeneous debris fill material containing obstructions (boulders, concrete blocks, buried asphalt, and stumps) and compressible organics within the subsurface profile. These fill and debris materials may be obstructions to pile driving and decomposition of compressible organics can cause significant settlement over time.

Based on our observations within the explorations completed at the Site, the fill within the upper 3.5 feet (typical frost depth) at some areas of the site has a silt content of up to or over 35 percent and therefore is a highly frost-susceptible soil type. However, the Alluvial Deposit stratum typically has a silt content of less than 15 percent and is generally a non-frost susceptible soil. Soils with a significant silt fraction have the potential of retaining water via capillary action. Groundwater can become "perched" within this upper 3.5 foot frost zone, where surface water from precipitation or snow melt traveling vertically through the soil column is impeded by the relatively low-permeability silty sand soils, creating a localized zone of saturated soils and potential for frost heave in cold weather.

7.0 RECOMMENDATIONS FOR DESIGN

7.1 PILE FOUNDATIONS

Given the nature of the proposed ground-mount PV installations where relatively light vertical loads, but higher lateral loads and moments, are applied at the ground surface, it is GZA's opinion that a pile foundation system is an appropriate foundation system at the Site, with the following exceptions. Pile-supported foundations are typically relatively quick to install. Potential pile foundations include driven steel piles (H-piles or pipe piles) or screw piles (such as hollow, tapered ground screws). Ground screw piles and driven piles should be galvanized to protect against corrosion.

Obstructions were encountered in numerous test pits located within the closed gravel pit and portions of the active gravel pit. **Figure 2** and **Figure 5** include a footprint of where obstructions were encountered at the Site. However, due to the heterogeneous nature of the fill, obstructions in the fill should be anticipated elsewhere on the Site, particularly in these closed and active gravel pits. Pile design should address the risk of pile not being able to be driven to design depth in these areas where obstruction to pile installation is possible. Driven piles may be difficult to install in these area and particularly within the footprint of obstructions, as shown on the noted figures. Therefore, the contractor may consider supporting the PV units on ground screw foundations to limit the impact of encountering obstructions during construction, as ground screws can sometimes penetrate bouldery soil better than driven piles installed with a lightweight hammer.

We understand that some design-build contractors have a contingency procedure to follow in the field if the pile installation stops because of an obstruction. Moving the pile more than a few inches is not possible due to the pre-made rack placed on the piles. On other sites where driven H-pile have been used with potential boulder obstructions, we understand based on our experience with similar projects that the following criteria have been applied:

- If the obstruction is less than a specified depth, excavate to remove the obstruction, backfill in compacted lifts and then re-drive the pile.
- If the obstruction is greater than a specified depth, terminate the pile driving and excavate around the pile to a specified depth and install a cardboard "Sonotube" concrete form over the pile, backfill and pour concrete within the form. The intent of the concrete collar is to increase the lateral and uplift capacity of the pile to compensate for the decreased pile embedment depth.

The obstructions within the Fill included branches, logs, and tree stumps, herein identified as organic material. As these materials decay over time, there is a potential that the pile foundations can settle several inches to feet, depending on the amount of organic decomposition. If the potential settlement is not permissible for the pile-supported PV arrays, we recommend either excavating and removing the organic material, or supporting the PV arrays on ballast block foundations where organic material was encountered. Recommendations for ballast block foundations are provided below.

We recommend that the structural engineer perform calculations to check the piles for shear and moment capacity before installation. GZA can provide a lateral load evaluation to assess pile embedment depths, if requested.

7.2 BALLAST BLOCK FOUNDATIONS

It is GZA's opinion that ballast block foundations bearing at the ground surface is a feasible foundation alternative for the areas of the Site where organic material was encountered, provided the design can accommodate significant differential settlement of up to several inches to feet over time. Based on our experience on other projects, we understand that ballast block foundations have been used successfully as foundations for PV arrays sited on landfills and other sites where significant vertical and differential settlement may occur. To reduce the potential for differential settlement, the number of foundation elements beneath each array is reduced from three (or more) to two, such that no foundation element is left unsupported due to settlement of adjacent elements. We also understand that ballast blocks are often sized such that bearing pressures are low and on the order of approximately 5 pounds per square inch (psi), or 720 pounds per square foot (psf).

7.3 PERMANENT UNPAVED SITE ACCESS ROADWAYS

Based on our experience with similar sites, we understand that post-construction temporary site access roads typically fall into two categories:

1. Fire truck access, anticipated maximum use 2 times per year.

The following road cross-section is recommended for new proposed fire truck access roads, assuming H-20 loading and assuming that the subgrade consists of the existing fill or alluvial deposit layers. Due to the variability of the existing fill, periodic testing with truck traffic and regrading and augmenting finish course thickness may be required to maintain reliable fire truck access.

	Minimum Thicknesses
Finish Course (Dense-Graded Crushed Stone)	4 inches
Sand-Gravel Base Course	12 inches

2. Pickup truck access, anticipated maximum use 4 times per year.

The following pavement cross-section is recommended for new proposed pickup-truck-only access roads:

	Minimum Thicknesses
Finish Course (Dense-Graded Crushed Stone)	4 inches
Sand-Gravel Base Course	10 inches

*Note that these cross-sections are not intended for construction traffic.

7.3.1 Subgrade Preparation- Permanent Unpaved Site Access Roads

Prior to fill placement for the access roads, the subgrade soils should be proof-compacted with multiple passes of a drum roller (with a minimum dynamic force of 5,000 pounds per foot of drum width) under the observation of the Geotechnical Engineer. Any weak or unstable areas identified should be overexcavated and replaced with compacted Sand-Gravel Fill. If silty subgrades soften during proof-compaction, vibrations should not be used during proof compaction.

7.4 EQUIPMENT PADS

We recommend a base course below the equipment pads of at least 18 inches of ¾-inch crushed stone wrapped in non-woven filter fabric (Mirafi 140N or similar). The filter fabric should envelop the crushed stone so that the crushed stone does not contact adjacent soil.

The 18-inch base course should be supported on either naturally-deposited alluvial deposits, or at least 2 feet of Granular Fill overlying existing Fill. Excavation for the equipment pad area should extend to at least 2 feet outside the edge of the equipment pads and be performed with a smooth-edged bucket to reduce the potential for disturbance to the excavated subgrade. Surface water runoff must not be allowed to or be able to pond against the equipment pad, equipment pad foundation or within the crushed stone. It may be prudent to raise the grades of equipment pads so that soil within the frost zone is above the potential groundwater depth.

The recommended maximum net allowable bearing pressures for design of equipment pads bearing on the crushed stone over natural alluvial deposits or at least 2 feet of compacted Granular Fill over existing fill (after removal of all Topsoil/Subsoil) are 2,500 and 1,500 pounds per square foot (psf), respectively.

The existing fill was observed to include deleterious material including roots, branches, and logs. These materials will degrade over time and there is a potential for several inches to feet of differential settlement for the equipment pads supported on existing fill. If the potential settlement is not permissible, we recommend fully excavating the existing fill below the equipment pads and backfilling with compacted Granular Fill. The excavation should include the equipment pad zone of influence, which is defined by a 1-horizontal to 1-vertical (1H:1V) line, sloping downward and outward from 1-foot outside the bottom edge of footings/pads to naturally-deposited alluvial deposits.

Based on our experience with similar projects, we understand conduit entering equipment pad areas typically require excavation up to 3 feet below finished grade. Backfill over the conduits should be compacted Granular Fill, provided the material does not damage the conduit or inhibit the intended use, or backfilled as otherwise recommended by the conduit manufacturer. The Granular Fill should be compacted to at least 92 percent of the maximum dry density as determined by ASTM Test D1557, Method C. We understand that this 92 percent compaction limit is in line with that used to typically compact electrical trench backfill within the equipment pad areas.

7.4.1 Subgrade Preparation – Equipment Pad

- Excavate topsoil/subsoil within the zone of influence of shallow foundations or equipment pads, as defined by a 1-horizontal to 1-vertical (1H:1V) line, sloping downward and outward from 1-foot outside the bottom edge of footings/pads.
- If subgrade consists of existing fill, overexcavate a minimum of 2 feet below the crushed stone base course. If several inches to feet of differential settlement is not permissible, excavate all Fill below equipment pads down to naturally-deposited alluvial deposits. Excavation geometry should include zone of influence considerations.
- Where practical, final excavation should be undertaken using a smooth-edged bucket to limit disturbance of the subgrade.
- Proof-compact the subgrade with several passes of a 10,000-pound (minimum static weight) roller or a heavy plate compactor in confined areas. Any weak or unstable areas identified should be over excavated and replaced with Structural/Granular Fill.
- Protect the exposed subgrade from frost at all times during construction.
- Equipment pads on this site will likely be supported within the frost zone but underlain by a free-draining base course. Base course material should be able to fully drain by gravity, such that water cannot pond within the base course and freeze.

Subgrade preparations for backfilling, equipment support slabs, and access roads should be conducted in such a way as to minimize disturbance, particularly if silty soils are encountered at subgrade level. Care must be taken to slope all working surfaces to facilitate and control surface water. Appropriate dewatering/surface water control procedures should be implemented prior to performing final excavation to subgrade and proof-compaction. Subgrades should be protected from frost and fill should not be placed over frozen soil.

7.5 RECOMMENDED FILL GRADATIONS

Sand-Gravel (Gravel) should consist of inert material comprised of hard, durable stone (not crushed concrete) and coarse sand, free from trash, ice, snow, tree stumps, roots, organic materials, and other deleterious matter, and conform to the following gradation:

Sieve Size (ASTM D422)	Percent Passing By Weight
2-inch	100
½-inch	50-85
No. 4	40-75
No. 40	10-35
No. 200	0-8

Dense-Graded Crushed Stone should consist of angular fragments of hard, durable crushed rock (not crushed concrete), free from a detrimental quantity of thin, flat, elongated pieces or be durable crushed gravel stone obtained by artificial crushing of gravel, cobbles, boulders or fieldstone. The crushed stone should be free from trash, ice, snow, tree stumps, roots, organic materials, and other deleterious matter. Dense-Graded Crushed Stone should conform to the following gradation:

Sieve Size (ASTM D422)	Percent Passing By Weight
2.5-inch	100
2-inch	95-100
¾-inch	50-75
¼-inch	25-45
No. 40	5-20
No. 100	2-12

Structural Fill (Granular Fill) should be free from trash, ice, snow, tree stumps, roots, organic materials, and other deleterious matter. Structural Fill should conform to the following gradation requirements:

Sieve Size (ASTM D422)	Percent Passing By Weight
3-inch	100
No. 10	30-95
No. 40	10-70
No. 200	0-15

3/4-inch Crushed Stone should consist of angular fragments of hard, durable crushed rock (not crushed concrete), free from a detrimental quantity of thin, flat, elongated pieces or shall be durable crushed gravel stone obtained by artificial crushing of gravel boulders or fieldstone. The crushed stone should be free from trash, ice, snow, tree stumps, roots, organic materials, and other deleterious matter. Crushed Stone should conform to the following gradation:

Sieve Size (ASTM D422)	Percent Passing By Weight
1-inch	100
3/4-inch	90-100
1/2-inch	10-50
3/8 inch	0-20
No. 4	0-5

7.6 RE-USE OF ON-SITE SOILS

Excavated materials are anticipated to consist of topsoil/subsoil, fill, and alluvial deposits. Topsoil/subsoil and fill are not anticipated to meet the recommended gradations above and are not recommended for reuse as such. The existing fill can be used to grade the Site following processing, culling, and /or crushing boulders, concrete and cobbles. We recommend limiting the maximum particle size to 8 inches.

Based on our Site observations and the gradation test results, some of the Alluvial Deposits may meet the gradations of Sand-Gravel Fill and Structural Fill.

8.0 CLOSING

We trust the information presented herein is sufficient for your use. We have enjoyed working with you on this project and look forward to assisting you on future projects. Please call us with any questions.