GEOTECHNICAL EXPLORATION
PAINTED DESERT DEMONSTRATION PROJECT
149 LEUPP ROAD
FLAGSTAFF, ARIZONA
FOR
VERDE ENGINEERING GROUP PLLC

TEC 18C027.01 RPT.01
MARCH 14, 2019

TERRANE ENGINEERING CORPORATION

TERRANE ENGINEERING CORPORATION

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March 14, 2019

Mr. Ralph Bossert
Verde Engineering Group PLLC
1109 N. McLane Rd.
Payson, AZ 85541

Re: Geotechnical Exploration for Painted Desert Demonstration Project (PDDP)
149 Leupp Road, Flagstaff, Arizona
TEC 18C027.01 RPT.01

Dear Mr. Bossert:

Terrane Engineering Corporation *(TEC)* is pleased to provide this geotechnical exploration report for the referenced project. Services were performed for you in general accordance with your request and *TEC* Proposal 18014PR.FC, dated February 20, 2018.

The attached report summarizes project and site data, describes the services we performed, and presents our recommendations regarding foundations, uplift resistance, slabs-on-grade, gravel surfacing, and earthwork. The report appendix presents supporting information such as figures, test pit logs, and laboratory data. The geotechnical engineer or his qualified representative should verify conditions and recommendations presented in this report during construction.

The opportunity to provide services for your project is appreciated. If you have any questions concerning this report or if I may be of service, please contact me.

Sincerely,

TERRANE ENGINEERING CORPORATION

Registered Professional Engineer (Civil)
CERTIFICATE NO
19397
FRANK
COSTELLO
Date Signed 3/14/19
ARIZONA U.S.A.

Frank Costello, P.E.

Copies to: Addressee, rbossert1109@gmail.com (pdf only)

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1. INTRODUCTION

This report presents the results of our geotechnical exploration for the proposed project on Leupp Road, south of Star Charter School, in Flagstaff, Arizona. Its location is shown on the Vicinity Map in the Appendix. It was performed to provide information and recommendations regarding:

- Near-surface soil and groundwater conditions on site,
- Index and engineering characteristics of site soils,
- Foundations, slabs-on-grade, gravel surfacing, earthwork, and surface drainage.

2. PROJECT DESCRIPTION

With respect to this exploration, improvements for the project include a business center south of the water storage tank, an addition on the north side of the main building, gravel surfacing, and solar panels in the southwest part of the site. The current layout of the site is shown on the Site Map in the Appendix.

The addition and center will be one-story, wood-frame structures supported by spread-footing foundations with slab-on-grade floors. Wall and column loads are estimated to be on the order of 1 to 4 kips per lineal foot and 10 to 40 kips, respectively. Traffic loading is expected to be light, and gravel surfacing will be used for drives and parking; well-graded cinders are expected to be used for the surfacing. The solar panels are expected to be supported by piers and be relatively light; uplift and lateral forces are expected to control design of the piers. Finished grades are expected to be near existing grades.

3. SCOPE OF SERVICES

Field, laboratory, and engineering services were performed in general accordance with current, local standards of practice for engineering and testing as described below.

3.1 Field

The field program consisted of site reconnaissance by a field engineer and excavating and sampling with a backhoe provided by PDDP. Four test pits were excavated to depths of 9 to 10 feet at the locations shown on the Site Map. The field engineer logged the test pits, performed moisture and density tests, and obtained bulk samples at selected depths for laboratory testing. The test pits were backfilled with excavated soils upon completion.

3.2 Laboratory

A laboratory program was developed by an engineer to obtain data used in development of foundation, slab-on-grade, gravel surfacing, and earthwork recommendations. The program consisted of gradation, plasticity index, and standard proctor tests.

3.3 Engineering

Field and laboratory data were evaluated by *TEC* to formulate recommendations for foundations, uplift resistance, slabs-on-grade, gravel surfacing, and earthwork.

4. SITE CHARACTERIZATION

Information regarding surface features, subsurface soil and groundwater conditions, and laboratory test results is presented in this section. This information was gathered by *TEC* for geotechnical engineering purposes only. This site characterization does not and was not intended to address the existence or likelihood of contamination on or around the site. Specialized methods and procedures, which were not part of this scope of services, are required for an adequate environmental site assessment.

4.1 Surface

The site was relatively flat with about 8 feet of relief and a mild downward gradient to the southeast. Other than the southeast part of the site and entrance drive, the site was undeveloped with sparse to moderately dense, native brush and a few trees. In the southeast part of the site there was a ranch house, two larger structures related to prior ranching and Agra activities, and related ancillary structures, including a pump house for the well and water storage tanks. Most areas around the structures were surfaced with cinders. Also, there were fine materials (primarily ground cinders) and other things from Agra activities in containers and spread on the surface in several areas of the southeast part of the site.

4.2 Subsurface

As shown on the logs in the Appendix, alluvial and volcanic soils were encountered in the test pits. Silty sands, SM, were encountered at the surface and to depths 1½ to 2 feet, where well-graded sands with gravel, SW, (cinders) were encountered to depths of 3½ to 4 feet. Silty sands were encountered in the remainders of the test pits. In situ dry density and moisture content ranged from 96 pounds per cubic foot (pcf) and 8.9 to 10.4 percent in the surface silty sands to 56 pcf and 6.6 percent in the underlying cinders. Groundwater was not encountered during exploration.

4.3 Laboratory

Index tests indicated a sample of surface soil was non-plastic, silty sand (SM) and a sample of the underlying cinders was non-plastic, well-graded sand with gravel (SW). Standard proctor tests indicated maximum dry density and optimum moisture content of surface and cinder samples were 96.4 pcf at 13.4 percent and 66.5 pcf at 16.2 percent, respectively.

5. DISCUSSION

The recommendations presented herein are based on our understanding of the project as presented in the Project Description and the assumption that the subsurface conditions encountered in the test pits adequately represent conditions near and between the test pits. Because project criteria regarding grading, number and type of structures, foundation loads, etc. can change and because subsurface conditions near and between test pits are not always similar to those encountered during exploration, the geotechnical engineer must be contacted for review and possible revision of the recommendations presented herein when related project criteria are altered during design or construction or when subsurface conditions substantially different from those described in the test pit logs are encountered during construction.

6. RECOMMENDATIONS

This section presents recommendations regarding foundations, uplift resistance, lateral earth pressure, slabs-on-grade, gravel surfacing, earthwork, and surface drainage. They are design-level recommendations that must be confirmed by the geotechnical engineer or his representative by adequate observation and testing during construction. The firm that provides construction observation and testing services must assume the role of geotechnical engineer for this project.

6.1 Foundations

Based on the high permeability and relatively low density of the shallow cinders, the spread-footing foundations planned for support of the addition and center should bear on recompacted, silty-sand, site soils or similar, imported engineered fill. An allowable bearing capacity of up to 2,000 pounds per square foot (psf) may be used for design of footings founded at least 24 inches below finished grade. Total and differential settlements are estimated to be less than one-half inch provided the recommendations presented in this report are followed.

All footing excavations should be reviewed by the geotechnical engineer prior to concrete placement and preferably prior to steel placement. Finished grade is finished floor for interior footings and lowest adjacent finished grade for exterior footings. The recommended minimum lateral dimensions for wall and column footings are 16 and 24 inches, respectively. The allowable bearing capacity may be increased by one-third for wind and seismic loads.

Lightly loaded interior partition walls may be supported on thickened floor slab sections provided that: (1) loads do not exceed 750 pounds per lineal foot, (2) thickened sections are a minimum of 12 inches wide, and (3) section thickness and reinforcement are consistent with structural requirements.

Reinforcement of footings, stem walls, and masonry walls to reduce the potential for distress caused by differential foundation movements should be evaluated during design. The size, quantity, and location of reinforcement should be determined by a qualified structural engineer.

6.2 Uplift Resistance

Because of the relatively light loads associated with solar panels, it is anticipated uplift will control design of pier foundations for their support. The uplift resistance of these circular foundations may be calculated by the cone method. The equation recommended for determining the design uplift capacity as a function of footing depth, diameter, and soil weight is presented below:

$$T = 0.26Dw(3d^2 + 3.5dD + 1.3D^2)/FS$$

where,

T = Design uplift capacity (lbs)
D = Depth of pier below finished grade (ft)
d = Diameter of pier bottom (ft)
w = Unit weight of soil (pcf)*
FS = Factor of safety**

* Unit weights of 100 and 65 pcf are recommended for silty sands and cinders, respectively.
** A minimum FS of 1.5 is recommended.

The pier foundations should be founded at least one foot below the cinders. This may require temporary casing or other measures to maintain the pier excavations while reinforcement and concrete are placed.

6.3 Lateral Earth Pressures

Lateral earth pressures for design of building foundations, and solar-panel piers can be calculated using the equivalent fluid pressures presented below:

- Active:

	Undisturbed subsoil	35 psf/ft
	Compacted granular soils	30 psf/ft

- Passive:

Continuous footings	250 psf/ft for silty sands
Column footings and piers	300 psf/ft for silty sands
	200 psf/ft for cinders

A coefficient of friction of 0.4 between foundations and bearing soils may be used to resist lateral loads. If passive earth pressures are used in conjunction with base friction to resist lateral loads, reduce the coefficient of friction to 0.3.

6.4 Slabs-On-Grade

Slabs-on-grade supported by prepared subgrade may be designed using a modulus of subgrade reaction of 200 pounds per cubic inch (pci). Slabs should bear on aggregate base course that meets gradation and compaction recommendations included in this report. The use of dowels and keyways should be evaluated for use at control and construction joints where load transfer capability is required. All concrete should be placed at minimum water-cement ratios and slumps on moistened surfaces and properly cured to minimize warping and curling. A vapor barrier should be included where moisture-sensitive floor coverings are planned.

6.5 Gravel Surfacing

Use of cinders for gravel surfacing for drives and parking is considered sensible for expected light, traffic loading. They should be well-graded; it is likely their fines content will be very low. To increase the fines content of the gravel surfacing, increase its binding capability, and decrease its permeability, clean, silty-sand, site soils can be incorporated into the cinders. After Site Clearing, gravel surfacing considered adequate for light traffic loading can be made by placing 4 to 5 inches of cinders on the subgrade, scarifying and mixing 2 to 3 inches of subgrade into the cinders, moisture conditioning and compacting the mixture, and grading the paved surface to shed water.

If there are areas where traffic loading is heavier than anticipated, and rutting or other signs of over-loading occur, the geotechnical engineer should be consulted for review of the condition and evaluation of remedial measures. It is likely over-loaded areas can be treated by removing the cinder-soil mixture, scarifying and recompacting the exposed subgrade, placing geotextile or geogrid on the subgrade, placing and compacting the removed mix on the geotextile or geogrid, and grading the surface to shed water. However, the suitability of this alternative for the condition should be confirmed by the geotechnical engineer because there may be more suitable solutions.

6.6 Earthwork

The foundation, slab-on-grade, and gravel-surfacing recommendations presented in this report are predicated on fulfillment of the following earthwork recommendations:

- **6.6.1 Site Clearing:** Existing vegetation, topsoil, debris, and other deleterious materials must be removed from slab-on-grade, gravel-surfacing, and other areas requiring prepared subgrade prior to construction. After site clearing, the exposed surfaces should be relatively flat to allow for proper subgrade preparation.

- **6.6.2 Excavation:** Generally, conventional equipment is expected to be suitable for the proposed foundation and shallow utility excavations can probably be cut with vertical or near-vertical side slopes. However, sloughing and flatter, stable slopes should be anticipated in excavations into the cinders. In all cases, Occupational Safety and Health Administration (OSHA) Standards must be followed.

- **6.6.3 Workability:** At elevated moisture contents, the site soils may "pump" and become unworkable. This may require changes or additions in equipment and procedures such as grading the site to prevent ponding after site clearing, scarification and drying, over-excavation and replacement, or use of lightweight equipment.

- **6.6.4 Foundation Preparation:** The cinders below foundations should be over-excavated and replaced with recompacted, silty-sand, site soils or similar, imported, engineered fill. Over-excavation and replacement should extend to the full depth of the cinders and at least one foot beyond the perimeter of the foundation. After over-excavation, the exposed subgrade should be scarified and recompacted to a depth of 8 inches. Subgrade preparation and fill placement should be accomplished in a manner that results in uniform moisture contents and densities in accordance with Placement and Compaction. Soils disturbed subsequently should be recompacted.

- **6.6.5 Slab-On-Grade and Gravel-Surfacing Preparation:** After Site Clearing, the exposed subgrade in slab-on-grade areas should be scarified and recompacted to a depth of 8 inches. Preparation for gravel surfacing is presented in Section 6.5. Subgrade preparation and fill placement should be accomplished in accordance with Placement and Compaction. Soils disturbed subsequently should be recompacted.

- **6.6.6 Materials:** Clean, site soils or similar imported soils approved by the geotechnical engineer may be used for fill or backfill in foundation, slab-on-grade, and gravel-surfacing areas. Aggregate base, select materials, and portland cement concrete should conform to local, governmental or a qualified professional's specifications.

  Imported soils should have a maximum expansion potential of 1½ percent as determined on a sample compacted to 95 percent of standard proctor density about 3 percent below optimum moisture content and saturated under a surcharge of 100 psf. Imported soils should conform to the gradation, as determined by ASTM D422, presented in Table 6.1, have no more than 0.10 percent soluble sulfates, and be approved by the geotechnical engineer prior to use.

Table 6.1 Gradation Requirements for Imported Soil

U.S Standard Sieve Size	Percent Passing by Weight
6-inch	100
4-inch	70-100
No. 4	50-100
No. 200	50 (maximum)

- **6.6.7 Placement and Compaction:** All fill and backfill materials should be uniformly moisture conditioned to within 3 percent of optimum moisture content, placed in relatively horizontal loose lifts not exceeding the effective depth of compaction equipment (commonly 8 to 10 inches), and uniformly compacted to at least 95 percent of standard proctor maximum dry.

6.7 Construction Observation and Testing

The foundation, slab-on-grade, and gravel-surfacing recommendations presented in this report are predicated on adequate observation and testing during construction by the geotechnical engineer or his qualified representatives, which, at a minimum, should include:

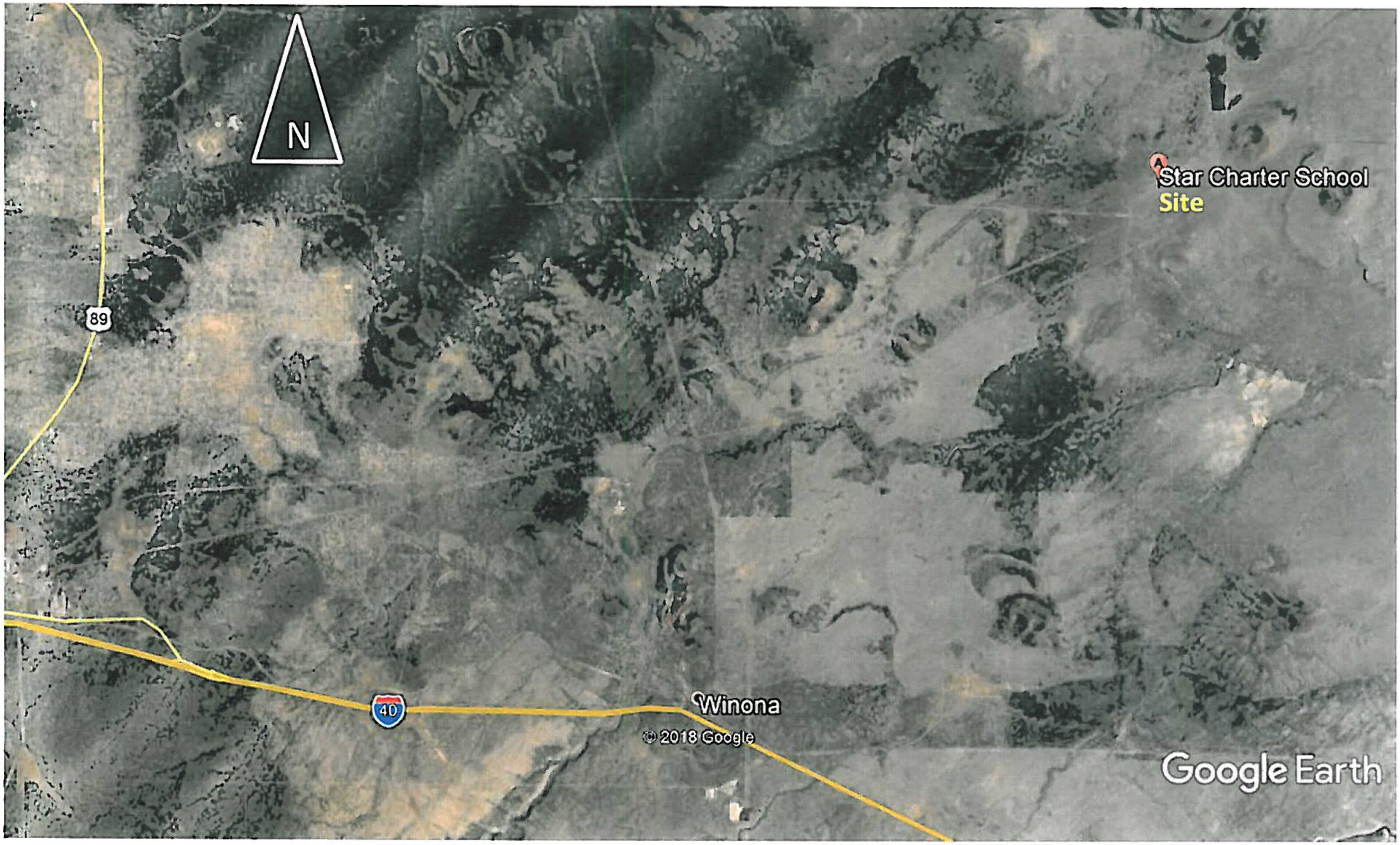
- Review of site clearing and all foundation excavations to evaluate whether actual conditions are consistent with those encountered during exploration.
- Observation and testing of placement and compaction of all fill and backfill materials to evaluate compliance with specifications.
- Field and laboratory sampling and testing of portland cement concrete to evaluate compliance with specifications regarding slump, temperature, entrained air, and strength.

Adequate observation and testing during the construction phase are critical to the performance of constructed improvements and confirmation of the design-level recommendations presented herein. Accordingly, the firm that performs construction observation and testing must assume the role of geotechnical engineer for this project.

6.8 Surface Drainage

Construction and final site grades should be designed to prevent water from ponding in areas on or adjacent to planned improvements. Infiltration of water into foundation and utility excavations must be prevented during construction and throughout the life of the project. Planters and other water-retaining features are not recommended along planned improvements. If planters are planned, they should be designed to prevent over watering and moisture increases under adjacent improvements. Slopes and drainage should be provided to prevent ponding within 5 feet of planned improvements.

APPENDIX

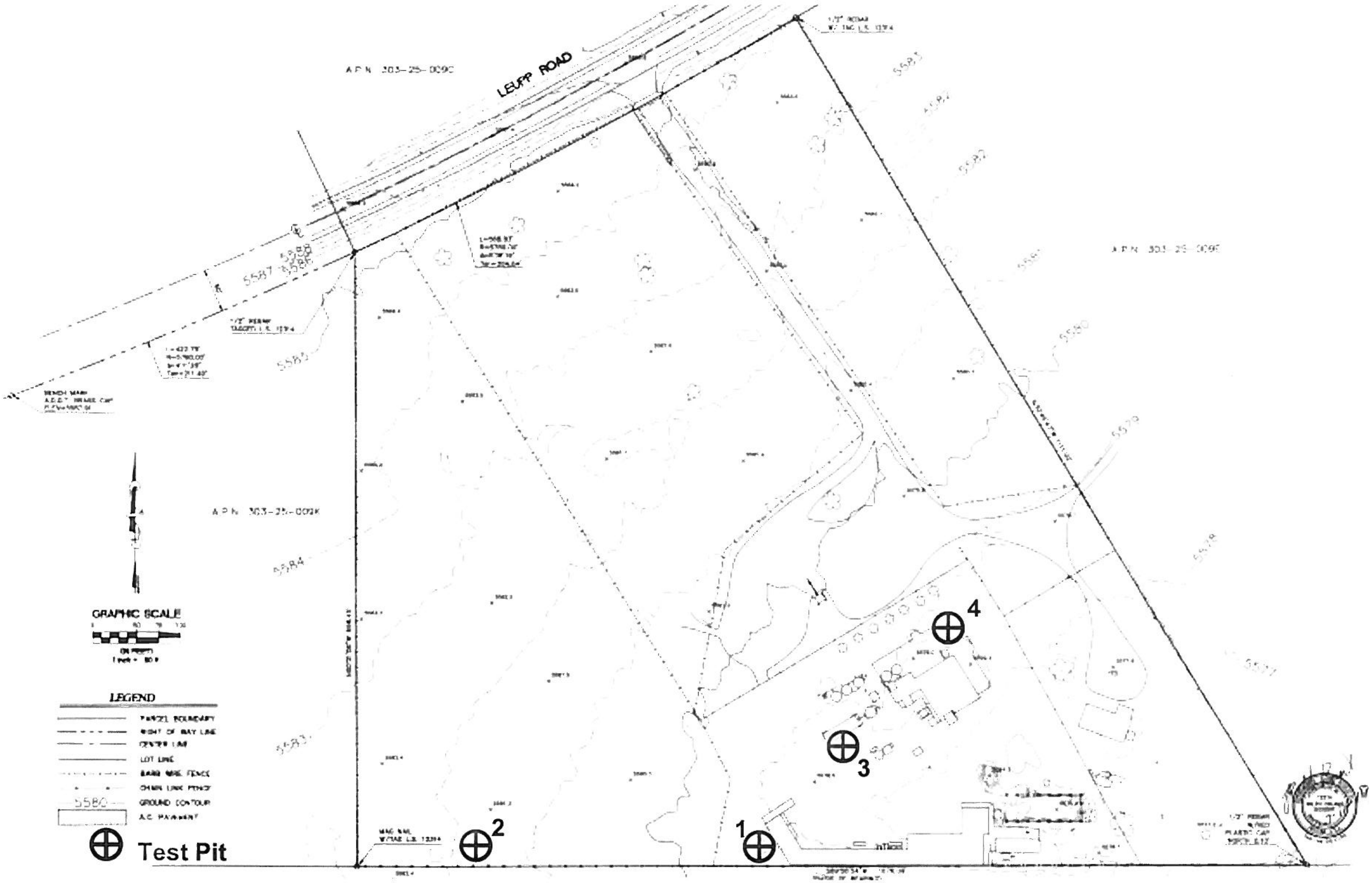


Vicinity Map

Painted Desert Demonstration Project, 149 Leupp Road, Flagstaff, Arizona

TEC Project 18C027.01

A-1



Site Map (ref. Verde Engineering Group PLLC)
Painted Desert Demonstration Project, 149 Leupp Road, Flagstaff, Arizona
TEC 18C027.01

GLOSSARY OF TERMS

ALLOWABLE BEARING CAPACITY: The allowable pressure at the base of the footing in excess of that at the same level due to the surrounding surcharge.

ASTM: American Society for Testing and Materials.

BACKFILL: Material replaced in a confined space, usually a man-made excavation.

BASE COURSE: A layer of specified material, usually granular, of planned thickness constructed on the subgrade for the purpose of serving one or more functions such as distributing load, providing drainage, minimizing frost action, etc.

BENCH: A horizontal surface in a sloped deposit.

CALICHE: A desert soil formed by the near surface crystallization of calcite and/or other soluble minerals by upward-moving solutions.

COLLAPSE POTENTIAL: Ability of a soil to undergo significant decrease in volume upon an increase in moisture content.

COMPRESSIBILITY: The property of a soil or rock pertaining to its susceptibility to decrease in volume when subjected to load.

DIFFERENTIAL SETTLEMENT: The difference in downward movement between two adjacent foundation elements.

ENGINEERED FILL: Specified material placed and compacted under full-time observation of the geotechnical engineer or his qualified representative in accordance with project specifications.

EQUIVALENT FLUID PRESSURE: Horizontal pressure of soil, or soil and water, in combination which increases linearly with depth and are equivalent to those that would be produced by a fluid of a selected unit weight.

EXISTING GRADE: Elevation of ground surface at time of exploration.

EXPANSION POTENTIAL: The ability of a soil to increase its volume upon contact with water.

FILL: Material placed by man to raise the surface of the land.

GLOSSARY Continued

FINISHED GRADE: The final grade of ground surface, floor slab, pavement, etc.

HEAVE: Upward movement of ground or structural element.

MAG: Maricopa Association of Governments.

MAXIMUM DRY DENSITY: The maximum dry density obtainable in the laboratory for a given compactive effort.

MOISTURE CONTENT: The ratio of the mass of water contained in the pore spaces of soil or rock material, to the solid mass of particles in that material, expressed as a percentage.

OPTIMUM MOISTURE CONTENT: The moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

PLASTICITY: The property of a soil that allows it to be deformed beyond the point of recovery without cracking or appreciable volume change.

ROCK: Natural solid mineral matter occurring in large masses or fragments.

SCARIFY: To mechanically loosen or break the existing soil structure.

SETTLEMENT: Downward movement of ground or structural element.

SOIL: Sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter.

STRIP: Remove from present location.

SUBBASE: A layer used in pavement or slab-on-grade system between the subgrade and base course, or between the subgrade and portland cement concrete pavement.

SUBGRADE: The soil prepared and compacted to support a structure or a pavement system.

TERRANE: 1. A geologic formation or group of formations. 2. The area of surface over which a particular rock or group of rocks is prevalent. 3. An area or region considered in relation to its fitness or suitability for some specific purpose.

TEST PIT LOG NOTES

These notes and test pit logs are intended for use with this geotechnical report for the purposes described therein. The logs indicate our interpretation of subsurface conditions at that location on the date noted. Subsurface conditions may vary, and groundwater levels may change because of seasonal or other factors. Accordingly, the test pit logs should not be made a part of the construction plans or be used to define construction conditions.

Test pit locations are based on visually referencing and pacing from existing site features and relating their locations to the improvements shown on the site map provided.

"Bucket Size/Type" refers to the size and type of excavation tool used by the backhoe.

"Sample Type" refers to the sampling method and equipment used during exploration where:

- G indicates a grab sample from backhoe-excavated material.

- R indicates a backhoe-driven, 2.42-inch-inside-diameter ring sampler.

"Dry Density" refers to unit weight of the soil in pounds per cubic foot as determined in the laboratory or field by ASTM methods. Field test results are underlined and were determined by nuclear or sandcone methods. "NS" indicates that the ring sampler could not be driven with the backhoe; "NR" indicates that no sample was recovered; and "*" indicates that the sample was too disturbed for density testing.

"Moisture Content" refers to the moisture content of the soil in percent by weight as determined in the laboratory or field by ASTM methods. Field test results are underlined and were determined by nuclear or Speedy methods.

"Description and Classification" refer to the materials encountered in the test pits. Generally, the descriptions and classifications are based on visual examination in the field. Further examination and testing were performed on selected samples in the laboratory. The terms and symbols used in the test pit logs are in general accordance with the Unified Soil Classification System and the American Society for Testing and Materials.

Log of Test Pit 1

Project: PDDP
Location: Leupp, Arizona
***TEC* Job No:** 18C027.01
Date: February 8, 2019

Excavator: Deere 310k
Bucket Size: 24"
Elevation (ft): Not determined
Logged by: F. Costello

Excavated by: Star School
Groundwater: Not encountered
Other:

Depth (feet)	Sample Type	Dry Density (pcf)	Water Content (%)	Description and Classification
		96	8.9	Silty Sand (SM); yellow-brown
1				
2				Well-Graded Sand with Gravel (SW); dark gray, cinders
3				
4				Silty Sand (SM); .yellow-brown
5				
6				
7				
8				
9				
10				Stopped @ 10 feet

Log of Test Pit 2

Project: PDDP
Location: Leupp, Arizona
***TEC* Job No:** 18C027.01
Date: February 8, 2019

Excavator: Deere 310k
Bucket Size: 24"
Elevation (ft): Not determined
Logged by: F. Costello

Excavated by: Star School
Groundwater: Not encountered
Other:

Depth (feet)	Sample Type	Dry Density (pcf)	Water Content (%)	Description and Classification
				Silty Sand (SM); yellow-brown
1				
2				Well-Graded Sand with Gravel (SW); dark gray, cinders
3				
4				Silty Sand (SM); yellow-brown
5				
6				
7				
8				
9				
10				Stopped @ 10 feet

Log of Test Pit 3

Project: PDDP
Location: Leupp, Arizona
***TEC* Job No:** 18C027.01
Date: February 8, 2019

Excavator: Deere 310k
Bucket Size: 24"
Elevation (ft): Not determined
Logged by: F. Costello

Excavated by: Star School
Groundwater: Not encountered
Other:

Depth (feet)	Sample Type	Dry Density (pcf)	Water Content (%)	Description and Classification
		96	10.4	Silty Sand (SM); yellow-brown
1	G			
2				Well-Graded Sand with Gravel (SW); dark gray, cinders
3				
4				Silty Sand (SM); yellow-brown
5				
6				
7				
8				
9				Stopped @ 9 feet, unknown in W end of pit
10				

Log of Test Pit 4

Project: PDDP
Location: Leupp, Arizona
***TEC* Job No:** 18C027.01
Date: February 8, 2019

Excavator: Deere 310k
Bucket Size: 24"
Elevation (ft): Not determined
Logged by: F. Costello

Excavated by: Star School
Groundwater: Not encountered
Other:

Depth (feet)	Sample Type	Dry Density (pcf)	Water Content (%)	Description and Classification
				Silty Sand (SM); yellow-brown
1				
2	G			Well-Graded Sand with Gravel (SW); dark gray, cinders
		56	6.6	
3				
4				Silty Sand (SM); yellow-brown
5				
6				
7				
8				
9				
10				Stopped @ 10 feet

SUMMARY OF INDEX PROPERTY TESTS - *TEC* 18C027.01 RPT.01

BORING OR PIT NO.	DEPTH (ft)	USCS SOIL TYPE	PARTICLE SIZE ANALYSIS – ASTM D422 (percent passing by weight)								ATTERBERG LIMITS ASTM D4318			MOISTURE-DENSITY RELATIONSHIP			NOTES
			3"	2"	1"	½"	#4	#8	#40	#200	LL	PL	PI	MAXIMUM DENSITY (pcf)	OPTIMUM MOISTURE (%)	ASTM METHOD	
3	0-2	SM			100	99	84	64	41	25			NP	96.4	13.4	D698-A	
4	1½-2½	SW			100	98	76	36	2.9	1.6			NP	66.5	16.2	D698-A	