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GEOTECHNICAL ENGINEERING REPORT

VETERANS AFFAIRS MEDICAL CENTER
NEW CENTRAL UTILITY PLANT

SOUTH LEBANON TOWNSHIP, LEBANON COUNTY, PENNSYLVANIA

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1.0 INTRODUCTION

This report was prepared by Advantage Engineers, LLC (Advantage), on behalf of Harrell, Saltrick & Hopper, of Charlotte, North Carolina, and contains the results of a geotechnical engineering investigation conducted at the site of the proposed addition to Building #23 within the Veterans Affairs Medical Center complex in South Lebanon Township, Lebanon County, Pennsylvania. The purpose of this investigation has been to define the stratification of subsurface soils and the engineering properties of these materials beneath the footprint of the proposed addition. Based on the results of our field investigation and laboratory analysis, foundation design and construction recommendations have been formulated.

The scope of work for this project included the completion of a subsurface field investigation, laboratory testing program, and geotechnical engineering analysis. This report summarizes the results of the work performed and provides recommendations regarding foundation design, soil strength conditions, and general construction criteria.

2.0 SITE AND PROJECT DESCRIPTION

The project site currently consists of the existing Veterans Affairs Medical Center facility located at 1700 South Lincoln Avenue in South Lebanon Township, Lebanon County, Pennsylvania. Existing topography across the project site is relatively flat, sloping gently down gradient toward the south. The site is bordered to the north by building #22, to the east and west by parking areas, drive lanes, and the existing building (building #23), and to the south by the existing building. The location of the site in relation to the surrounding area is presented on the *Topographic Map* (Dwg. No.: 130063901-A-100) within the Appendix.

The project will consist of constructing an addition onto Building #23. The a new central utility plant is expected to be 1-story in height, measure a total of approximately 11,000 square feet in plan area, and will have a basement. Maximum column and wall loads are expected to be on the order of 100 kips and 4 kips per linear foot, respectively. At the time of this report, existing and proposed finished site grades were unknown; however the 1st floor elevation is anticipated to match that of the adjacent existing structure. Development of the project will also consist of constructing new parking areas and drive lanes.

3.0 SUBSURFACE INVESTIGATION PROGRAM

In an effort to evaluate subsurface conditions across the footprint of the proposed addition, 7 standard earth borings and 3 test pits were conducted on October 22, 2013 and November 4, 2013, respectively. Supervision and monitoring of the field investigations were provided by representatives of Advantage, who field located the test borings and test pits based on the *Existing Site Plan*, provided by Harrell, Saltrick & Hopper, dated September 25, 2013. Each test boring location was “cleared” based on a GPR investigation prior to the advancement of drilling augers. The approximate locations of the test borings and test pits, designated as B-1 through B-7 and TP-1 through TP-3, respectively, are shown on the *Subsurface Investigation Location Plan* (Dwg. No.: 130036201-A-102), presented in the Appendix.

The test borings were advanced using a truck-mounted drill rig equipped with hollow-stem augers. Split-spoon samples, conducted in accordance with ASTM standard D1586, were taken at suitable intervals throughout the entire depth of the borings and the Standard Penetration Test (SPT) values were recorded for each sample obtained. The SPT values, which are a measure of relative density or consistency, are the number of blows required to drive a 2-inch (outer-diameter), split-barrel sampler 2 feet using a 140-pound weight dropped 30 inches. The number of blows required to advance the sampler over the 12-inch interval from 6 to 18 inches is considered the "N" value.

Test pits were excavated along portions of the existing building utilizing a rubber-tire backhoe until the bottom of the foundation was identified. Details regarding the results of these test pits are presented within **Section 5.5**.

Data pertaining to the subsurface investigation was documented in the field and is presented in detail on the *Test Boring Profiles* and *Test Boring Logs*, presented within the Appendix. The *Test Boring Profiles* (Dwg. No.: 130063901-A-103) depict cross-sections of the subsurface conditions encountered within each test boring, including: soil and rock types, depths of individual strata, and recorded “N” values. The *Test Boring Logs* contain general information about the subsurface program and specific data regarding each test boring, including: sample depths, blow counts per 6 inches of penetration, and detailed characterizations of the subsurface materials encountered.

4.0 LABORATORY TESTING

All soils encountered at the site were visually reviewed and classified by Advantage personnel. Two (2) representative soil samples were subjected to laboratory analyses, in an effort to verify visual classification and to establish the engineering parameters required for foundation design analysis. The laboratory testing conducted on the samples consisted of standard classification testing, completed in accordance with ASTM standard D2487. The tests performed included Natural Moisture Content (ASTM D2216), Sieve Analysis (ASTM D422), and Atterberg Limits Determination (ASTM D4318).

Unified Soil Classification System (USCS) Group Symbols and ASTM Group Names have been assigned to the soils analyzed. Graphical depictions of the particle size analyses are presented in the Appendix. The results of the testing conducted are presented below in Table I.

TABLE I

LABORATORY RESULTS		
Boring Number	B-2	B-7
Sample Depths (ft.)	6 – 8	6 – 8
Soil Type	Stratum I	Stratum I
Particle Size Distribution (Percent)		
Gravel	5.7	4.8
Sand	22.9	19.9
Silt/Clay	71.4	75.3
Atterberg Limits		
Liquid Limit	47	37
Plastic Limit	25	32
Plasticity Index	22	5
Natural Moisture Content	26.5%	27.9%
USCS Group Symbol	CL	ML
ASTM Group Name	Lean Clay with Sand	Silt with Sand

5.0 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 GEOLOGY

According to the Pennsylvania Geologic Survey, Atlas of Preliminary Geologic Quadrangles, Fourth Series, 1981, the project site is underlain by the Cambrian Richland Formation (geologic symbol Cr). A graphical depiction of the project site within its geologic setting is presented on the *Geologic and Karst Features Map* (Dwg. No.: 130036201-A-101) within the Appendix.

The Pennsylvania Geologic Survey publication *The Engineering Characteristics of the Rocks of Pennsylvania*, Second Edition, 1982, describes the rock in this formation as consisting of gray finely crystalline dolomite interbedded with medium-gray oolitic limestone, chert, calcarenite, and conglomerate. This formation is moderately well bedded and thick. Joints have a regular pattern and are moderately developed, moderately to highly abundant, and regularly spaced. The rock in this formation is slightly to moderately resistant to weathering and is weathered to a shallow depth. The overlying mantle is thin with pinnacles typically characterizing the soil-to-bedrock interface. This formation is described as difficult to excavate with pinnacles and boulders creating a special problem. The rock in this formation is of carbonate lithology and therefore subject to classification and the development of sinkholes.

5.2 SOIL

The surfaces of the test borings were covered by approximately 3 to 6 inches of topsoil or approximately 10 to 12 inches of asphalt and stone sub-base material. Beneath the surficial materials, subsurface conditions were generally uniform, consisting of a layer of Fill, followed by a single, naturally-occurring soil stratum, referenced herein as Stratum I. A general description of the soils encountered at the site is as follows:

Fill – Brown to orange tan gravel with varying amounts of silt, clay and sand

Fill was encountered immediately beneath the surficial materials, and extended to depths ranging from approximately 3 to 11.5 feet below existing site grades. The "N" values, recorded within this soil, ranged from 5 to greater than 50 blows per 1-inch, and show the Fill to range from stiff to very stiff in consistency or medium dense to very dense in relative density.

Upon review, the Fill was found to be well graded, of varying plasticity, and to consist primarily of gravel with varying amounts of silt, clay and sand. The Fill was found to be free of deleterious material (i.e. ash, cinder, slag, topsoil and/or organic debris). However, these samples were taken from discrete locations and the possibility does exist for deleterious materials to exist in uninvestigated portions of the site.

Stratum I – Tan to brown to orange silt and clay with sand

Stratum I was encountered in all the test borings completed, with the exception of test borings B-5 and B-6, extending to depths ranging from approximately 14.5 to 22 feet below existing site grades. The "N" values, recorded within this soil, ranged from 3 to greater than 50 blows per 11-inches, and show Stratum I to range from medium stiff to very stiff in consistency.

Laboratory testing conducted on representative samples of Stratum I, show this soil to be poorly graded and of varying plasticity, with natural moisture contents of 26.5% and 27.9%. Stratum I is described under the Unified Soil Classification System (USCS) as Lean Clay with Sand and Silt with Sand, with the accompanying group symbols of CL and ML, respectively.

5.3 BEDROCK

The bedrock surface was encountered in test borings B-3 through B-7, at depths ranging from approximately 5.5 to 22 feet below existing site grades. The bedrock surface was defined as the depth at which the drilling augers could no longer advance.

Based on the results of the test boring data, the bedrock surface beneath the project site is highly pinnacles with considerable variation in the elevation of the bedrock surface over short lateral distances. The data points were collected from discrete locations and the possibility exists for the bedrock surface to be encountered at depths which may vary significantly from those stated above.

In order to determine the composition and integrity of the bedrock present beneath the site, a single bedrock sample was retrieved through rock coring. The percent recovery and rock quality designation (RQD) were determined for the core sample retrieved. Percent recovery is calculated by dividing the length of the rock core retrieved from the core barrel by the total length of the core run, and multiplying by 100. RQD is calculated by summing the length of all of the rock fragments in the core run which are greater than or equal to 4 inches in length, and dividing by the total length of the core run and multiplying by 100. The percent recovery and rock quality designation of the bedrock core sample are provided below in Table II.

TABLE II

BEDROCK CORING DATA SUMMARY				
Test Boring/ Run Number	**Bedrock Core Sample (ft)**	**Length of Core (ft)**	**Percent Recovery (%)**	**RQD Value (%)**
B-5/R-1	5.5 – 10.5	5	87	10

The bedrock sample retrieved was found to consist of dark grey limestone. Based on the percent recovery and RQD value of the rock core obtained, the limestone encountered is slightly weathered and highly fractured.

5.4 GROUNDWATER

Groundwater was not encountered during the test boring operation. These observations were made at the time of the field operation and the groundwater table elevation will vary with daily, seasonal, and climatological variations.

5.5 EXISTING FOUNDATION OBSERVATION

Three (3) observatory test pits were excavated adjacent to the northern exterior walls of the existing structure. The test pits were extended until the bottom of the foundation was identified. In test pit TP-1, the foundation was found to be approximately 46 inches thick, with a termination depth of approximately 54 inches below existing site grade. In test pit TP-2, the foundation was found to be approximately 46 inches thick, with a termination depth of approximately 54 inches below existing site grade. In test pit TP-3, the foundation was found to be approximately 38 inches thick, with a termination depth of 42 inches below existing site grade. It should be noted, concrete was noted below the existing foundation in test pit TP-3 and terminated at approximately 78 inches below existing grade. It is unknown what it’s intended use is.

No evidence of groundwater or soil mottling was found upon observation. Details regarding dimensions and elevations of the existing foundations are presented on the attached *Existing Foundation Profiles* (Dwg. No. 130063901-A-104), within the Appendix.

6.0 CONSIDERATION OF KARST GEOLOGY

The project site is underlain by the Richland Formation which is of carbonate lithology and is subject to dissolution and the development of sinkholes and other karst-geologic features. The *Sinkhole and Karst Related Features Map of Pennsylvania,* prepared by William Kochonov of the Pennsylvania Geologic Survey, shows no mapped closed depressions and/or sinkholes within the project site. In addition, no karst features, including; sinkholes, lineaments, outcroppings, and/or closed depressions were identified across the project site during the field investigation.

The following recommendations are provided in an effort to minimize the potential for the development of sinkholes at the site both during and following construction.

- Surface water should not be allowed to collect or pool in low lying areas of the site and should be directed to appropriate stormwater channels. Expeditious backfilling or grading of low-lying areas will also help minimize the potential for the development of sinkholes.
- The bases of all foundation excavations should be reviewed for unusually soft or wet soil conditions. Any unstable areas encountered should be further excavated and reviewed by the geotechnical engineer to determine the extent of any solution activity so that remedial measures can be designed and implemented.
- The extent of excavations should be kept to a minimum and the influx of surface water into excavations should be minimized.
- Positive drainage away from the proposed structure should always be maintained. Roof drains should also be directed away from the structure and into designated, storm sewer connections.
- Unpaved areas, swales or surface basins should be minimized adjacent to building/foundation areas.
- Exterior backfill around foundations should consist of fine-grained, on-site soils, (i.e. silt and clay) in an effort to limit stormwater infiltration in foundation areas.

The site owner must recognize the risks associated with development in areas underlain by carbonate geologic formations. Contingencies should be made in the construction schedule and budget for the repair of sinkholes and unstable soil conditions encountered during development of the site.

7.0 SITE DEVELOPMENT CONSIDERATIONS

7.1 SITE PREPARATION

At the outset of the project, all topsoil and pavement should be stripped from all structural areas. Structural areas are defined as those areas to be covered by the proposed addition, extending to a minimum of 5 feet beyond all proposed foundation lines, and any portion of the site to be covered by asphalt or concrete pavements.

The topsoil will not be suitable for use as structural fill during construction. The topsoil may be stockpiled on-site and utilized in landscaped areas or non-structural portions of the project site.

7.2 PROOF-ROLLING

Following removal of the surficial elements, required excavation to reach proposed subgrade elevations, and prior to the placement of structural fill or construction of foundation elements, all structural areas should be proof-rolled using a steel-drum, vibratory roller, having a minimum static weight of 10 tons or with a loaded, tandem-axle dump truck. A minimum of 5 overlapping passes of the roller or dump truck should be completed across the entirety of the building pad and other structural areas. Proof-rolling should be performed under the direction of a qualified Geotechnical Engineer. Proof-rolling and compaction procedures are necessary to compact and verify the integrity of the upper zones of the soils and allow for a uniform distribution of loads. Any loose or unstable areas encountered during proof-rolling should be compacted in place or removed and replaced with structural fill, as outlined below in **Section 8.0** of this report.

In areas of the site where a cut or removal of soil is necessary to achieve the required soil subgrade elevation, proof-rolling of the surface may be waived until the proposed subgrade elevation is achieved.

The project site is underlain by existing Fill and a carbonate geologic formation. Proof-rolling of the project site is considered to be an integral part of the foundation design criteria for the project. Proof-rolling will allow for a final evaluation of subgrade conditions for indications of loose/soft soil conditions or sinkhole activity. Proof-rolling should be carried out as specified above under direction of the Geotechnical Engineer of Record.

7.3 EXCAVATION CONSIDERATIONS

Excavation during construction of the proposed addition and associated site features will take place within the existing Fill and naturally-occurring soils of Stratum I, which may be removed using conventional earth moving equipment and techniques. Based on the localized high “SPT” values recorded and slow advancement of augers observed, portions of the existing Fill and soils of Stratum I may be difficult to excavate and might require the use of hydraulic equipment for removal. Based on the data collected, existing site grades and anticipated finished subgrade elevations, bedrock excavation will be required during foundation construction.

The surfaces of carbonate bedrock formations, such as the one which underlies this project site is highly pinnacled, with considerable variation in the elevation of the bedrock surface over short lateral distances. Therefore, bedrock pinnacles may also be encountered during installation of subsurface utilities and overall site grading.

Construction of the proposed addition will require excavations adjacent to the existing structure. Based on a conversation with the client, the existing building contains a crawl space. Details regarding the existing foundation elements observed within the test pits excavated, are provided in **Section 5.5** of this report and on the attached *Existing Foundation Profiles*. Care must be exercised to provide temporary support to existing foundations and subsurface utilities as necessary. This may be accomplished with shoring, bracing, or underpinning. The temporary support systems should be designed by the contractor and reviewed by the structural and geotechnical engineers of record prior to implementation.

All excavations should be adequately sloped, benched, or supported to minimize collapse and protect personnel. All excavations should be completed in accordance with OSHA requirements.

8.0 STRUCTURAL FILL

8.1 IMPORTED FILL

Imported structural fill should meet the following criteria:

- free of organic matter, ash, cinders, trash, demolition debris or other unsuitable materials
- particle size distribution that is well-graded
- plasticity index less than 10; liquid limit less than 30
- less than 15 percent by weight rock fragments larger than 3" with no particle size exceeding 6", less than 30 percent by weight larger than the 3/4" and less than 30 percent smaller than the no. 200 sieve

Alternate soils proposed for use which differ from those specified above should be evaluated by the Geotechnical Engineer of Record regarding their suitability prior to placement at the site.

8.2 REUSE OF ON-SITE SOILS

Comments regarding the suitability of the on-site soil for use as structural fill are provided below.

Fill – This soil was found to be well graded, of varying plasticity, and to consist primarily of gravel with secondary amounts of silt, clay and sand. Based on this information, these soils are considered to be well suited for use as structural fill provided any unsuitable material encountered within the Fill are discarded prior to it's placement.

Stratum I - This soil was found to be poorly graded and of varying plasticity, and consist predominantly of silt and clay with varying amounts sand and gravel. Based on this information, this soil is considered to be suitable for use as structural fill. **Due to the high amounts of fines (silt & clay), this soil will be moisture sensitive and difficult to place during periods of adverse weather. It addition, the optimum moisture content is expected to be significantly below the in-place moisture content; therefore, this soil will likely require mixing or scarifying to reduce the moisture content to acceptable levels prior to placement.**

Our analysis of the suitability of the on-site soil for use as structural fill is based on data collected from the test borings completed at the site. Soil suitability should be confirmed in the field by the Geotechnical Engineer of Record during construction.

8.3 PLACEMENT & COMPACTION REQUIREMENTS

Structural fill should be placed in lifts not exceeding 10 inches in loose thickness and compacted with a vibratory roller having a minimum static weight of 10 tons. Structural fill placed in areas where hand-operated compaction equipment will be required, maximum loose lift thickness of 4 inches is recommended. The optimum lift thickness and number of repetitive passes with compaction equipment necessary to achieve the required percentage compaction values should be determined in the field with test passes of the chosen compaction equipment.

All fill should be placed at, or deviate nominally from (±2%) the optimum moisture content as determined in accordance with ASTM D698 and compacted to the minimum percentage of the soils' maximum dry density as indicated in Table III.

TABLE III

COMPACTION CRITERIA	
Fill Area	**Percent of Maximum Dry Density as per ASTM D698**
Foundation Support Fill	100%
Foundation Backfill	100%
Slab-On-Grade, Parking Areas	100%
Non-Structural Areas	92%

9.0 FOUNDATION DESIGN RECOMMENDATIONS

9.1 SHALLOW FOUNDATIONS

After site preparation operations have been satisfactorily completed, firm and stable existing soils and/or the underlying bedrock may be utilized for the support of the proposed addition's foundation elements using a shallow foundation system. The soil bearing conditions at the site were evaluated based on the information derived from this investigation. The following conclusions and engineering recommendations are provided regarding the proposed addition's foundation systems.

1. A foundation system, consisting of strip and/or spread footings are recommended for support of the proposed addition.

2. Firm and stable existing soils and/or the underlying bedrock surface may be utilized for support of the proposed addition's foundation elements.

3. An allowable bearing capacity of **3,000** pounds per square foot (psf) should be considered in design of the foundations of the proposed addition.

4. The bottom of all exterior foundations and those in unheated areas should be at least 36 inches below the final exterior grades in order to minimize the potential for frost heave.

5. All foundation bottoms should be completely cleaned of loose material or debris immediately prior to the placement of concrete.

6. Concrete should be placed in excavated foundation areas as quickly as possible to minimize degradation to the foundation subgrade due to exposure.

7. The actual bearing conditions of the soil at the foundation subgrade elevations should be confirmed in the field during excavation by inspection under the supervision of a Professional Engineer qualified in Geotechnical Engineering.

8. Column and wall foundations should be a minimum of 3.0 and 1.5 feet in width, respectively.

9. Should foundation subgrade elevations match the subgrade elevations of the existing adjacent foundation elements, the proposed foundation subgrade may then be stepped up, as necessary, at an interval of 2H:1V, moving away from the existing structure.

10. When encountered, the bedrock surface should be over-excavated a minimum of 6 inches beyond subgrade elevations and backfilled with crushed aggregate to the subgrade elevation prior to the placement of concrete. Proceeding in this manner will minimize the potential for point loading and allows for a uniform distribution of loads.

Prior to the placement of concrete, all foundation bottoms should be densified and compacted using a walk-behind vibratory roller, gas-powered automatic tamper, or similar equipment. Densification is required to provide uniform density of the foundation subgrade and allow for proper distribution of loads. Proper compaction and densification of the foundation soils should be verified by a qualified geotechnical engineer prior to placement of concrete.

It is emphasized that caution should be exercised to not disturb foundation subgrade soils. Should the subgrade be disturbed, the soil should be compacted in place or removed until firm soil is encountered and the resulting excavation backfilled with concrete or controlled structural fill as described above. Every effort should be made to prevent water from entering open foundation excavations. Any water which may accumulate in the bottoms of the excavations should be removed immediately. It is recommended that footing excavation and placement of concrete be performed on the same day and during fair weather conditions. Installation of the foundations should be carried out in accordance with applicable ACI guidelines, under the direction of a licensed Professional Engineer.

9.2 SETTLEMENT

Based on information provided by Harrell, Saltrick, & Hopper, maximum column loads are not expected to exceed 100 kips and wall loads are not expected to exceed 4 kips per linear foot. Based on a 3,000 psf bearing capacity, and our analysis of the conditions encountered, it is estimated that maximum post-construction settlement of the proposed addition's foundations will be less than 1-inch and differential settlement between adjacent columns will be less than ½ of this value. Differential settlement may equal total settlement in areas where adjacent foundations are situated on soil and bedrock, respectively.

9.3 SEISMIC COEFFICIENT

According to *Table 1613.5.2 - Site Class Definitions* of the 2009 International Building Code, the stratigraphic profile underlying the proposed construction area meets the characteristics of *Site Class C, Very Dense Soil and Soft Rock.*

9.4 FLOOR SLAB

The floor of the proposed addition may be constructed as a conventional slab-on-grade and may be supported on firm and stable existing soils. These soils are expected to exhibit a modulus of subgrade reaction of approximately 150 psi/in provided they are compacted to a minimum of 100% of its maximum standard dry density as determined by ASTM D698.

It is recommended that the floor slab be underlain by a layer of crushed stone to provide a capillary break. The stone bedding should be comprised of clean, crushed stone (such as AASHTO NO. 57).

10.0 LATERAL EARTH PRESSURES

The following data is provided for the design of temporary or permanent below grade structures including footings, piers, retaining walls, excavation support, temporary shoring, etc. which may be constructed at the site. The data presented is based on the use of the existing Fill or naturally-occurring soils of Stratum I placed under engineering control for backfill. Should different soil be used, design data should be re-evaluated and changed according to the specific material. Table IV, provides the Earth Pressure Design Data for the use of the above referenced soils.

TABLE IV

EARTH PRESSURE DESIGN DATA		
Parameter	**Fill**	**Stratum I**
Angle of Internal Friction	25º	35º
Unit Weight of Soil	110 pcf	125 pcf
Coefficient of Active Earth Pressure	0.41	0.27
Coefficient of Passive Earth Pressure	2.46	3.69
Coefficient of At-Rest Earth Pressure	0.58	0.43
Cohesion	0.0 psf	0.0 psf

Adequate drainage must be maintained adjacent to all earth retaining walls in an effort to minimize the buildup of hydrostatic pressures on the structures. At a minimum, a drainage blanket consisting of clean, crushed aggregate should be placed behind the retaining wall. The drainage blanket should be connected to a drain at the base of the retaining wall with all water directed to dedicated stormwater channels.

11.0 PAVEMENT DESIGN ANALYSIS

As previously referenced, development of the site will include a new parking lot. It is anticipated that the parking lot will consist of new asphalt paving and will utilize mainly passenger vehicles with occasional heavy trucks, such as trash trucks and/or delivery trucks. Details regarding the flexible pavement design is presented below.

11.1 FLEXIBLE PAVEMENT

The flexible pavement section provided herein was designed in accordance with AASHTO Design Guide and is based on an estimated laboratory-determined CBR value of 6 for the subgrade soils. The design section has been determined for a design life of 20 years, with a reliability level of 85%, an overall standard deviation of 0.35, and a Terminal Service Index of 2.0.

Specific traffic loading information was not available at the time of this writing; therefore, it was estimated that the new parking lot will receive 50,000 ESALs over its design life. Incorporating the above design life ESALs into the AASHTO flexible pavement design methodology yields a structural number (SN) of 2.1 for the proposed standard duty pavement section.

The thickness of the pavement section was determined using the following structural formula:

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

where:

- a_1, a_2, a_3 = Structural coefficients for binder course, wearing course, and sub-base materials, respectively
- D_1, D_2, D_3 = Thickness of binder course, wearing course, and sub-base layers, respectively
- SN = Structural Number for the pavement sections

The layer coefficients (a_1, a_2, a_3) used for the pavement design equation represent the ability of each material in the pavement section to support the design traffic loads. The elastic (resilient) modulus for each material in the pavement section (i.e. sub-base, binder course, wearing course) is often used to establish the layer coefficient for these materials. Absent resilient modulus testing for each of the pavement components, the following values were assigned for this analysis.

- a_1 = 0.34
- a_2 = 0.44
- a_3 = 0.11

Based on the above structural number, the flexible pavement section was calculated to be the following:

9.5 mm Wearing Course	1.5 inches
19 mm Binder Course	2.5 inches
PennDOT 2A Aggregate Base Course	6.0 inches

11.2 GENERAL PAVEMENT CONSIDERATIONS

All areas to be paved should be thoroughly proof-rolled and compacted to a minimum of 100% of the soil's maximum dry density, as determined by ASTM D698, prior to the placement of sub-base materials. The extent and magnitude of undercutting, if required, should be determined in the field by the Geotechnical Engineer during proof-rolling of the site.

Proper drainage will be an important consideration for the overall performance of the pavement design recommended above. We have assumed that proper grading to provide suitable runoff from the pavement surface and beyond the limits of the paved areas will be provided.

As minor cracking in the pavement section occurs with age, and if water is allowed to pond on the surface, seepage into the sub-base may weaken the subgrade, which can enhance degradation of the pavement section. Maintenance of this pavement will be critical to limiting its strength loss over the life of the pavement.

We recommend that the sub-base be placed as soon as possible after the subgrade has been approved. The asphalt or concrete should also be placed as soon as possible after the sub-base has been tested and approved. These recommendations are provided in an effort to help prevent the subgrade and the sub-base from being disturbed by weather and construction traffic. It will also help reduce the potential for the sub-base from becoming contaminated with soil. We also recommend that the flexible pavement section be prepared and placed according to PennDOT specifications. It should be noted that the pavement design has considered the standard loading for its intended use. The design does not consider construction traffic loadings which would make the section substantially more expensive. The general contractor and paving contractor should be advised that they must control the construction traffic so as to limit disturbance of previously approved subgrade, stone sub-base, and/or completed asphalt.

12.0 CONSTRUCTION OBSERVATION AND TESTING

Regardless of the thoroughness of a geotechnical engineering exploration, there is always a possibility that conditions between the test borings and test pits and below the depths explored may be different from those encountered, that conditions are not as anticipated by the designers, or that the construction process has altered the subsurface conditions. Therefore, geotechnical engineering construction observation should be performed under the supervision of the Geotechnical Engineer who is familiar with the intent of the recommendations presented herein. Construction observation is recommended to evaluate whether the conditions anticipated in the design actually exist or whether the recommendations presented herein should be modified where necessary.

13.0 LIMITATIONS

This report has been prepared in accordance with generally accepted geotechnical design practices for specific application to this project. This report has been based on assumed conditions and characteristics of the proposed development where specific information was not available.

The conclusions and recommendations contained in this report are based upon the subsurface data obtained during this investigation and on details stated in this report. The validity of the projections, conclusions and recommendations contained in this report is necessarily limited by the scope of field investigation and by the number of test borings and test pits that were made. It is understood that the scope of the field investigation was consistent with good engineering practice but, given the nature of subsurface conditions, there is a possibility that actual conditions encountered may differ significantly from those projected in this report. Should conditions arise which differ from those described in this report, Advantage should be notified immediately and provided with all available information regarding subsurface conditions.

Our recommendations are based upon the assumption that the services of a qualified Geotechnical Engineer will be retained for observation of the proof-rolling procedures, structural fill placement, foundation subgrade review, and all critical earthwork operations. Advantage has the capability of providing these services and would be pleased to present a proposal to do the on-site quality control observation on the owners behalf.

The subject property is underlain by carbonate lithology which carries with it the potential for sinkhole development. The Owner must evaluate this risk and come to their own conclusion regarding their tolerance for risk with regard to the impact of sinkholes on the planned construction. Advantage makes no warranty or guarantee with regard to the development of sinkholes on the project site.

The scope of this investigation was limited to the evaluation of the load-carrying capabilities and load stability of the subsoils. Oil, hazardous waste, radioactivity, irritants, pollutants, radon or other dangerous substances and conditions were not the subject of this study. Their presence and/or absence are not implied, inferred or suggested by this report or results of this study.

Appendix

Topographic Map

Geologic and Karst Features Map

Subsurface Investigation Location Plan

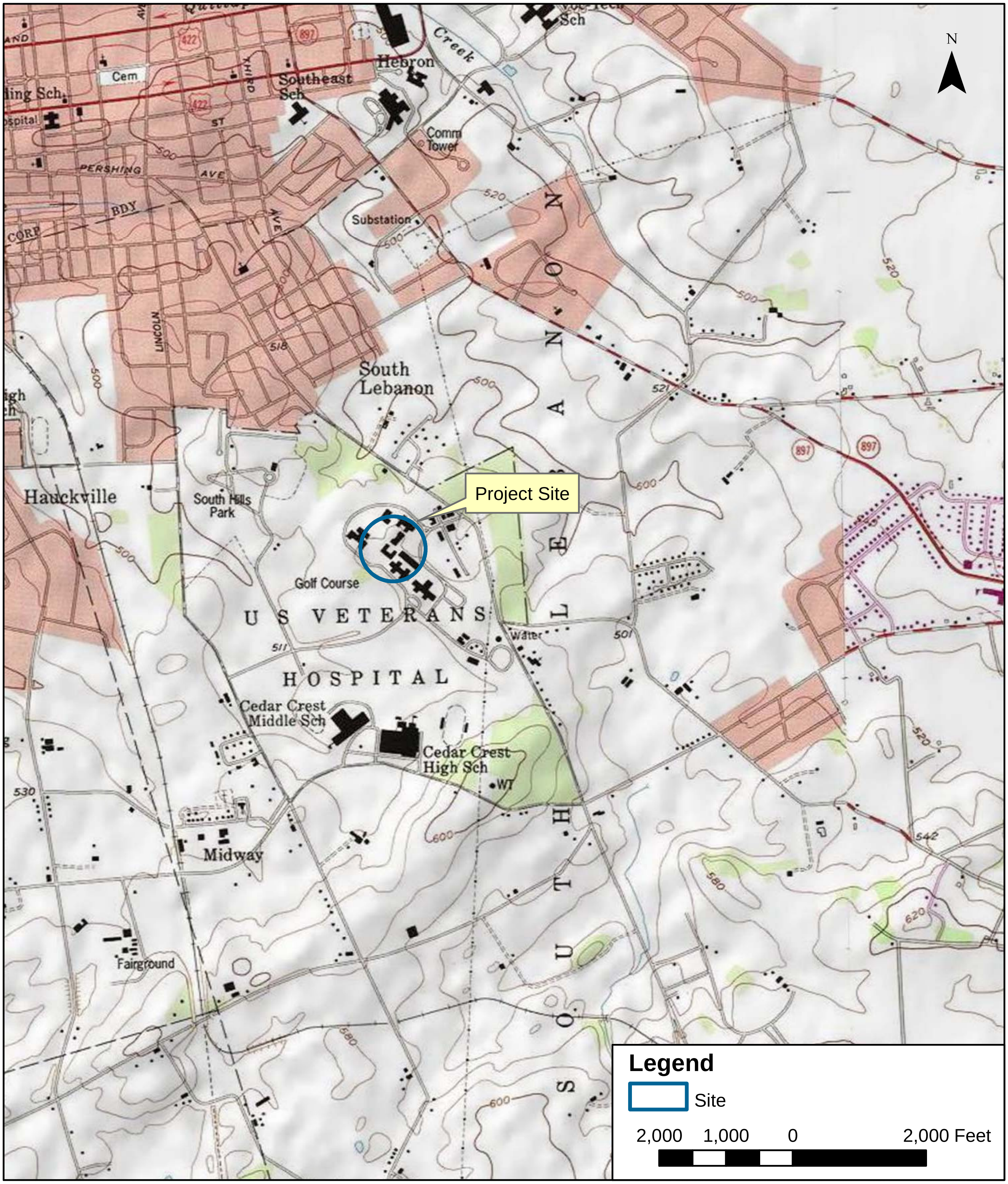
Test Boring Profiles

Existing Foundation Profiles

Laboratory Test Results

Test Boring Logs

Existing Foundation Site Photos

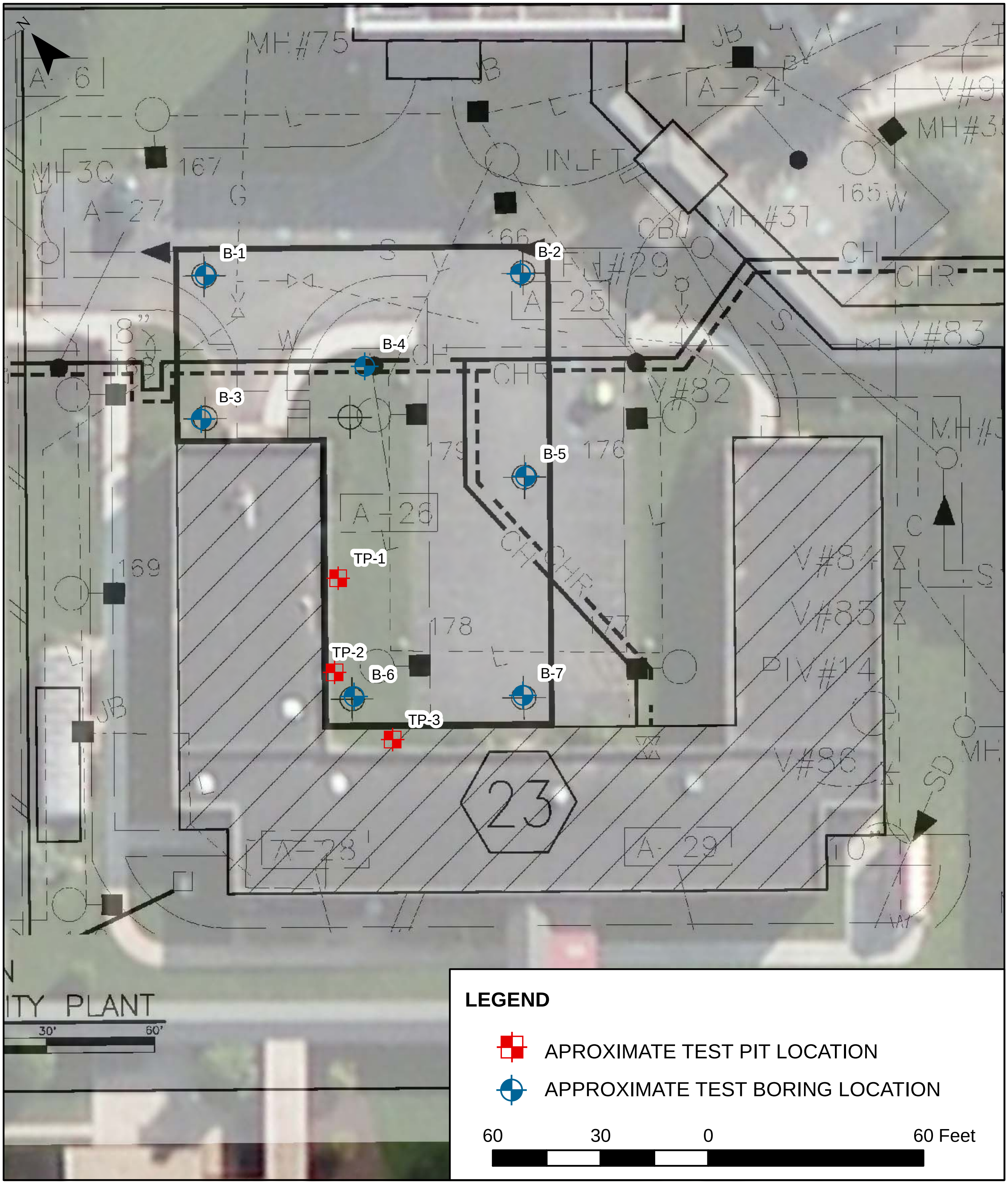


*Source - USGS 15 - Minute Topographic Quadrangle, Provided by ESRI

SCALE: AS SHOWN	DRAWING NUMBER: 130063901-A-100	TOPOGRAPHIC MAP PREPARED FOR NEW CENTRAL UTILITY PLANT	advantage engineers 910 CENTURY DRIVE MECHANICSBURG, PA 17055 PH (717) 458-0800 FAX (717)458-0801
DRAWN BY: K. BARNHART	CHECKED BY: D. BUCKWALTER		
APPROVED BY: D. SCHAUBLE	DATE: 10-16-2013	SOUTH LEBANON TOWNSHIP LEBANON COUNTY PENNSYLVANIA	

*Source - Map 61 - Atlas of Preliminary Geologic Quadrangle Maps of Pennsylvania, 1981, Pa Geological Survey

SCALE: AS SHOWN	DRAWING NUMBER: 130063901-A-101	GEOLOGIC AND KARST FEATURES MAP	advantage engineers
DRAWN BY: K. BARNHART	CHECKED BY: D. BUCKWALTER	PREPARED FOR NEW CENTRAL UTILITY PLANT	910 CENTURY DRIVE MECHANICSBURG, PA 17055 PH (717) 458-0800 FAX (717)458-0801
APPROVED BY: D. SCHAUBLE	DATE: 10-16-2013	SOUTH LEBANON TOWNSHIP LEBANON COUNTY PENNSYLVANIA	



Site Plan: Existing Site Plan New Centeral Utility Plant Prepared By: Harrell, Saltrick & Hopper Dated: 09-25-2013

SCALE: AS SHOWN	DRAWING NUMBER: 130063901-A-102
DRAWN BY: K.BARNHART	CHECKED BY: D. BUCKWALTER
APPROVED BY: D. SCHAUBLE	DATE: 11-05-13

SUBSURFACE INVESTIGATION LOCATION PLAN

PREPARED FOR

NEW CENTRAL UTILITY PLANT

SOUTH LEBANON TOWNSHIP LEBANON COUNTY PENNSYLVANIA

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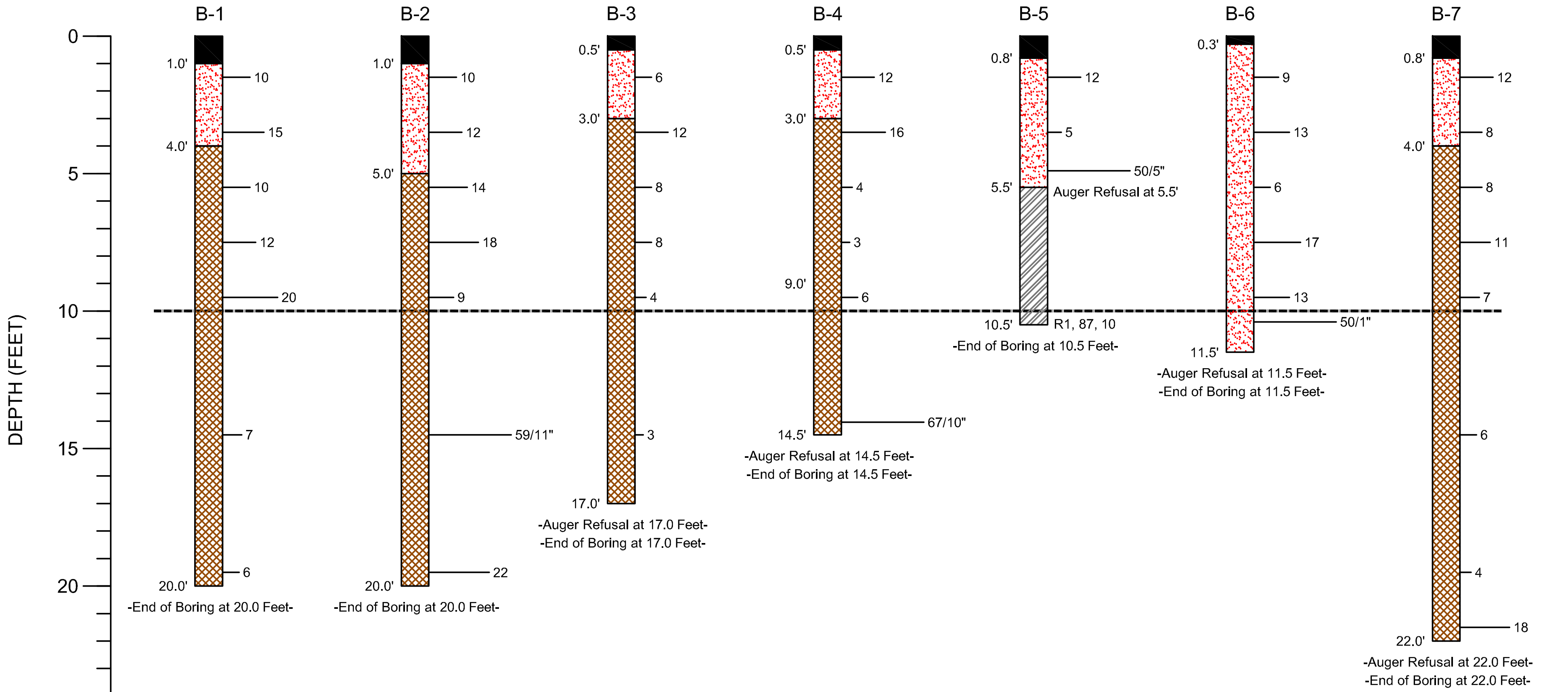
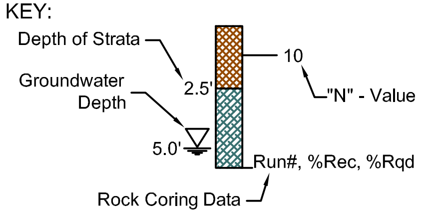


LEGEND

- TOPSOIL/PAVEMENT
- FILL — BROWN TO ORANGE TO TAN GRAVEL WITH VARYING AMOUNTS OF SILT, CLAY, AND SAND
- STRATUM I — TAN TO BROWN TO ORANGE SILT AND CLAY WITH VARYING AMOUNTS OF SAND AND GRAVEL
- BEDROCK — SLIGHTLY WEATHERED, HIGHLY FRACTURED DARK GREY LIMESTONE
- ASSUMED BOTTOM OF BASEMENT ELEVATION

SCALE: AS SHOWN	DRAWING NUMBER: 130063901-A-103
DRAWN BY: K. BARNHART	CHECKED BY: D. BUCKWALTER
APPROVED BY: D. SCHAUBLE	DATE: 10-24-13

KEY:



TEST BORING PROFILES

PREPARED FOR

NEW CENTRAL UTILITY PLANT

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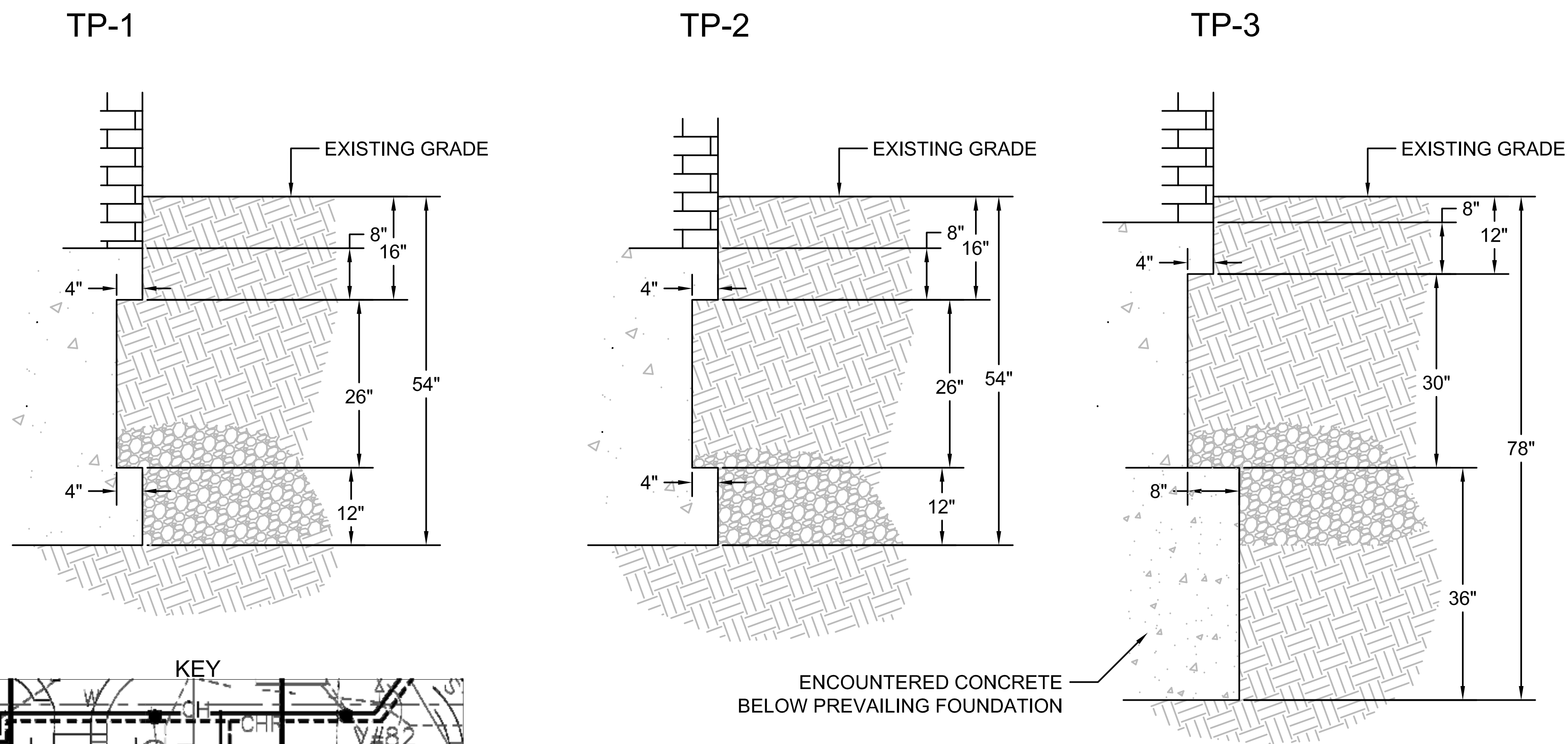

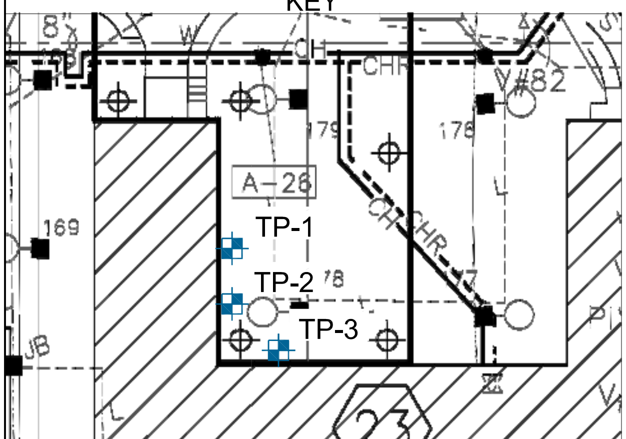

LEGEND

- EXISTING BRICK BUILDING
- EXISTING BUILDING FOUNDATION
- EXISTING SOILS
- CRUSHED STONE FOR EXISTING DRAIN PIPE

SCALE: AS SHOWN	DRAWING NUMBER: 130063901-A-104	EXISTING FOUNDATION PROFILES PREPARED FOR NEW CENTRAL UTILITY PLANT	advantage engineers
DRAWN BY: J. TRIMBLE	CHECKED BY: K. BARNHART		
APPROVED BY: D. SCHAUBLE	DATE: 11-4-13	SOUTH LEBANON TOWNSHIP — LEBANON COUNTY — PENNSYLVANIA	

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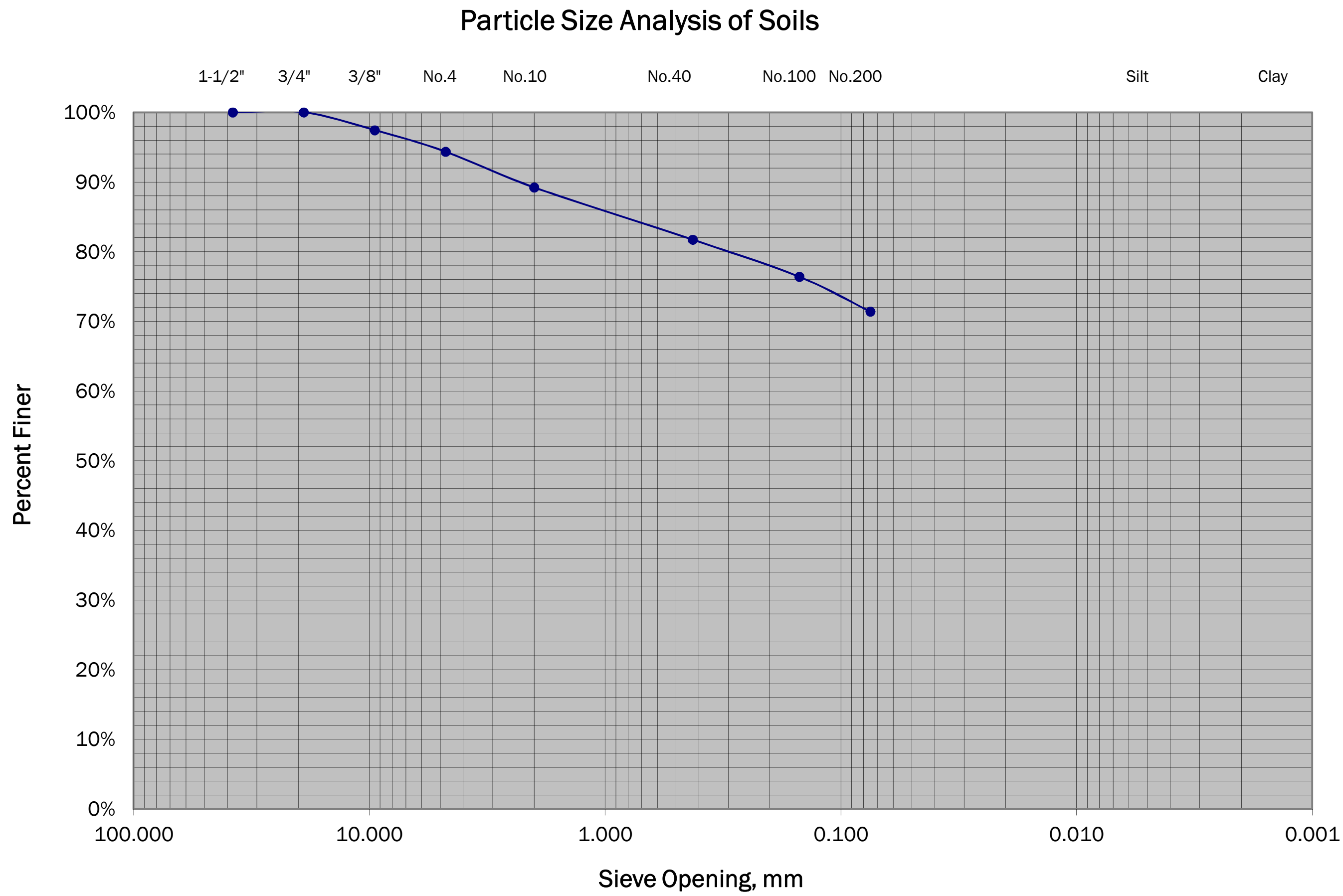
Soil Classification Report

Per ASTM Designations D 2487 - 00 and D 2488 - 00



As-Received Moisture: 26.5%						
USCS Classification:	Lean Clay with Sand (CL)					
Gravel: 5.7%	**Coarse:** 0.0%		**Fine:** 5.7%			
Sand: 22.9%	**Coarse:** 5.1%	**Medium:** 7.5%	**Fine:** 10.3%			
Silt:	**Clay:**	**Colloids:**				
Gravel Description:	Brown to grey subangular to subrounded					
Sand Description:	Brown to grey subangular to subrounded					
Consistency: N/A		**Dry Strength:**	Low			
Dilatancy: Rapid		**Toughness:**	Low			
Structure: Homogeneous		**Cementation:**	N/A			
Boring: B-2						
Sample: S4		**Depth:** 6' - 8'				
Project: New Central Utility Plant						
Client: Harrell, Saltrick, & Hopper						
Advantage Project Number:	130063901					

Particle Size Distribution

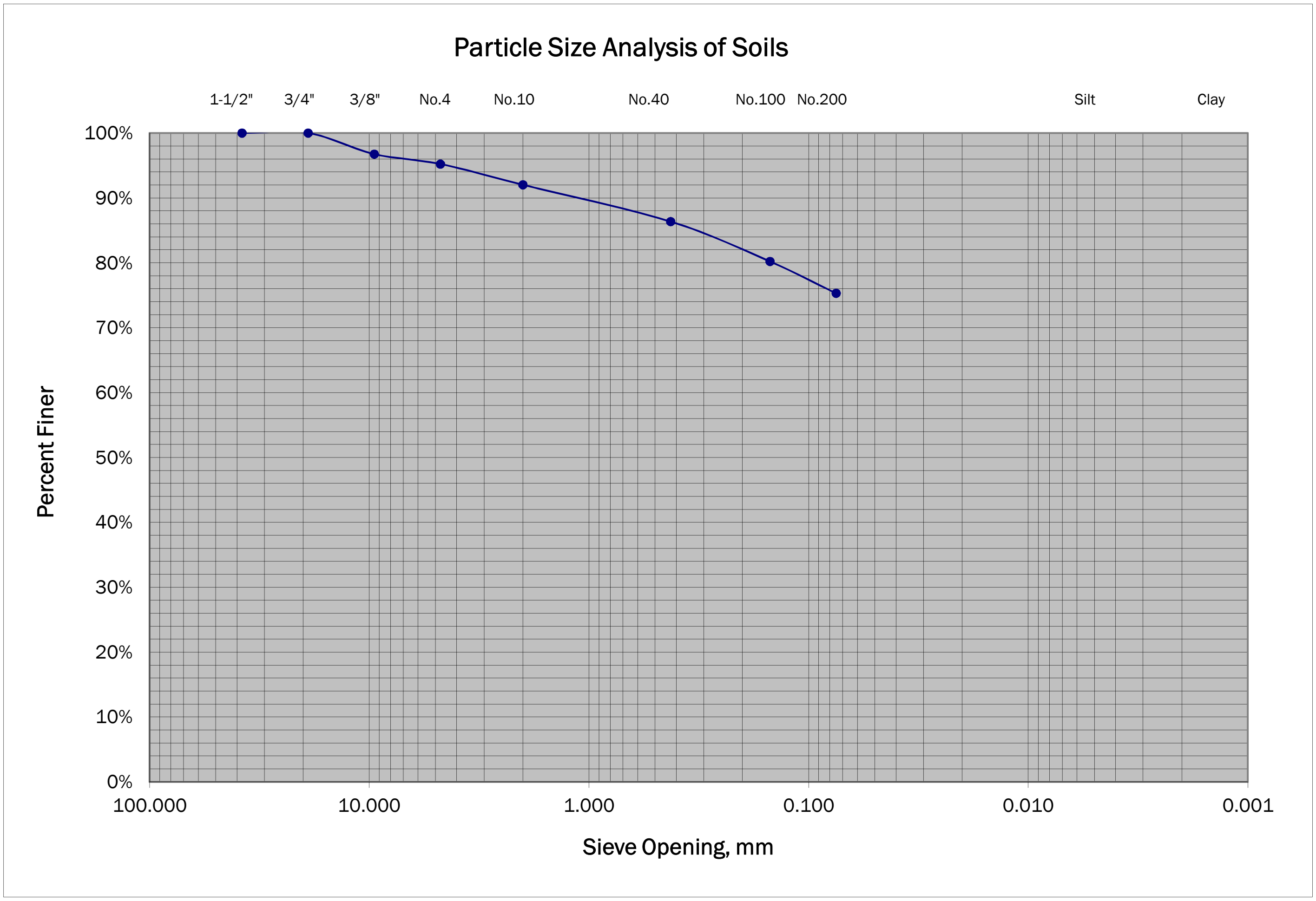
US Standard Sieve Size			Opening (mm)	%Finer
GRAVEL	Coarse	1-1/2"	38.0	100.0%
		3/4"	19.0	100.0%
	Fine	3/8"	9.50	97.4%
		No. 4	4.75	94.3%
SAND	Coarse	No. 10	2.00	89.2%
	Medium	No. 40	0.425	81.7%
	Fine	No. 100	0.150	76.4%
		No. 200	0.075	71.4%
Hydrometer Analysis		Silt Size	0.005	
		Clay Size	0.001	

D_{60}:	D_{30}:	D_{10}:	Cu:	Cc:

Atterberg Limits	**LL:** 47	**PL:** 25	**PI:** 22
Description:	Tan to brown		
Remarks:	Stratum I		
Report Date:	October 25, 2013		

Soil Classification Report

Per ASTM Designations D 2487 - 00 and D 2488 - 00



As-Received Moisture: 27.9%					
USCS Classification:	Silt with Sand (ML)				
Gravel: 4.8%	**Coarse:** 0.0%			**Fine:** 4.8%	
Sand: 19.9%	**Coarse:** 3.2%	**Medium:** 5.7%		**Fine:** 11.0%	
Silt:	**Clay:**	**Colloids:**			
Gravel Description:	Brown to grey subangular to subrounded				
Sand Description:	Brown to grey subangular to subrounded				
Consistency: N/A		**Dry Strength:**	Low		
Dilatancy: Rapid		**Toughness:**	Low		
Structure: Homogeneous		**Cementation:**	N/A		
Boring: B-7					
Sample: S4	**Depth:** 6' - 8'				
Project: New Central Utility Plant					
Client: Harrell, Saltrick, & Hopper					
Advantage Project Number:	130063901				

Particle Size Distribution				
US Standard Sieve Size		Opening (mm)	%Finer	
GRAVEL Coarse	1-1/2"	38.0	100.0%	
	3/4"	19.0	100.0%	
GRAVEL Fine	3/8"	9.50	96.8%	
	No. 4	4.75	95.2%	
SAND Coarse	No. 10	2.00	92.0%	
SAND Medium	No. 40	0.425	86.4%	
SAND Fine	No. 100	0.150	80.2%	
	No. 200	0.075	75.3%	
Hydrometer Analysis	Silt Size	0.005		
	Clay Size	0.001		
D_{60}:	D_{30}:	D_{10}:	Cu:	Cc:
Atterberg Limits	**LL:** 37	**PL:** 32	**PI:** 5	
Description:	Tan to brown			
Remarks:	Stratum I			
Report Date:	October 25, 2013			

TEST BORING LOG

PROJECT NAME: New Central Utility Plant

BORING NO.: **B-1**

PROJECT NUMBER: 130063901 CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED ☐ TOPO ESTIMATE

ELEV TOP OF GROUND: Not Available

GROUNDWATER DATA: Dry

DEPTH: Not Encountered Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"		SOIL DESCRIPTION	REMARKS
				0.0' - 1.0'	Aspalt [6-inches] and stone sub-base [6-inches]	**Pavement**
	S1	1' - 2'	4-10	1.0' - 4.0'	Stiff orange to brown clay with gravel	
	S2	2' - 4'	5-7-8-9		Very stiff tan to brown clay with sand	**Fill**
5				4.0' - 20.0'		
	S3	4' - 6'	5-5-5-5		Stiff tan to orange to brown clay with sand	
	S4	6' - 8'	4-4-8-26		Very stiff orange to brown clay with sand and gravel	
10	S5	8' - 10'	7-12-8-4		Very stiff orange to brown clay with sand and gravel	
15	S6	13' - 15'	4-4-3-4		Stiff orange to brown clay with gravel	
20	S7	18' - 20'	3-3-3-3		Medium stiff tan to brown silt with sand	**Stratum I**
					-End of Boring at 20.0 Feet-	
25						
30						

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

TEST BORING LOG

SHEET 1 OF 1

PROJECT NAME: New Central Utility Plant

BORING NO.: B-2

PROJECT NUMBER: 130063901   CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED   ☐ TOPO ESTIMATE

ELEV

TOP OF GROUND: Not Available

GROUNDWATER DATA: Dry

DEPTH: Not Encountered   Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"		SOIL DESCRIPTION	REMARKS
				0.0' - 1.0'	Aspalt [6-inches] and stone sub-base [6-inches]	**Pavement**
	S1	1' - 2'	9-10	1.0' - 5.0'	Dense tan to brown silty sand with gravel	
	S2	2' - 4'	10-6-6-8		Dense tan to brown silty sand	
5						**Fill**
	S3	4' - 6'	5-6-8-9	5.0' - 20.0'	Very stiff tan to brown lean clay with sand	
	S4	6' - 8'	8-9-9-10		Very stiff tan to brown lean clay with sand	
10	S5	8' - 10'	5-4-5-4		No recovery [auger cuttings consisted of clay with sand and gravel]	
15	S6	13' - 14.4'	3-9-50/5"		Very stiff brown lean clay with gravel [heavy auger resistance from 14 to 17 feet]	
20	S7	18' - 20'	5-4-18-30		Very stiff tan to brown lean clay with sand and gravel	**Stratum I**
					-End of Boring at 20.0 Feet-	

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

TEST BORING LOG

SHEET 1 OF 1

PROJECT NAME: New Central Utility Plant

BORING NO.: B-3

PROJECT NUMBER: 130063901 CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED ☐ TOPO ESTIMATE

ELEV TOP OF GROUND: Not Available

GROUNDWATER DATA: Dry

DEPTH: Not Encountered Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"	SOIL DESCRIPTION	REMARKS
				0.0' - 0.5' Dark brown sandy clay with organic debris	**Topsoil**
	S1	0' - 2'	2-3-3-4	0.5' - 3.0' Medium dense grey sandy gravel	
					Fill
	S2	2' - 4'	6-6-6-7	3.0' - 17.0' Very stiff orange to brown clay	
5					
	S3	4' - 6'	3-3-5-5	Stiff tan to brown silt with sand	
	S4	6' - 8'	4-4-4-6	Stiff tan to brown silt with sand	
10	S5	8' - 10'	2-2-2-2	Medium stiff tan to brown silt with sand	
15	S6	13' - 15'	1-1-2-2	Medium stiff brown silt with sand [moist]	
					Stratum I
				-Auger Refusal at 17.0 Feet-	
				-End of Boring at 17.0 Feet-	
20					

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

TEST BORING LOG

PROJECT NAME: New Central Utility Plant

BORING NO.: **B-4**

PROJECT NUMBER: 130063901 CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED ☐ TOPO ESTIMATE

ELEV

TOP OF GROUND: Not Available

GROUNDWATER DATA: Dry

DEPTH: Not Encountered Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"	SOIL DESCRIPTION		REMARKS
				0.0' - 0.5'	Dark brown sandy clay with organic debris	**Topsoil**
	S1	0' - 2'	2-3-9-13	0.5' - 3.0'	Dense brown clay with gravel	
						Fill
	S2	2' - 4'	10-8-8-7	3.0' - 14.5'	Very stiff tan to brown silt with sand	
5						
	S3	4' - 6'	3-2-2-2		Medium stiff tan to brown silt with sand	
	S4	6' - 8'	1-1-2-3		Medium stiff tan to brown silt with sand [moist]	
10	S5	8' - 10'	2-3-3-4		Medium stiff tan to brown silt with sand	
15	S6	13' - 14.3'	36-17-50/4"		Very stiff grey silt with sand and gravel	**Stratum I**
					-Auger Refusal at 14.5 Feet-	
					-End of Boring at 14.5 Feet-	
20						

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

TEST BORING LOG

SHEET 1 OF 1

PROJECT NAME: New Central Utility Plant

BORING NO.: B-5

PROJECT NUMBER: 130063901 CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED ☐ TOPO ESTIMATE

ELEV

TOP OF GROUND: Not Available

GROUNDWATER DATA: Dry

DEPTH: Not Encountered Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"	SOIL DESCRIPTION		REMARKS
				0.0' - 0.8'	Asphalt [4-inches] and stone sub-base 6-inches]	**Pavement**
	S1	0.5' - 2'	5-6-6	0.8' - 5.5'	Dense tan to brown silty sand with gravel	
	S2	2' - 4'	2-2-3-14		Medium dense tan to brown silty sand with gravel	
5	S3	4' - 4.9'	35-50/5"		Very dense blue to gray silty sandy gravel	**Fill**
					-Auger Refusal at 5.5 Feet-	
						REC: 87% **RQD: 10%**
					Hard, slightly weathered, highly fractured, dark grey limestone	
10	R1	5.5' - 10.5'	Run #1			**Bedrock**
					-End of Boring at 10.5 Feet-	
15						

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

TEST BORING LOG

SHEET 1 OF 1

PROJECT NAME: New Central Utility Plant

BORING NO.: B-6

PROJECT NUMBER: 130063901 CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED ☐ TOPO ESTIMATE

ELEV

TOP OF GROUND: Not Available

GROUNDWATER DATA: Dry

DEPTH: Not Encountered Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"	SOIL DESCRIPTION		REMARKS
				0.0' - 0.3'	Dark brown sandy clay with organic debris	**Topsoil**
	S1	0' - 1.8'	2-3-6-50/4"	0.3' - 11.5'	Stiff orange to brown clay with gravel	
	S2	2' - 4'	3-7-6-8		Dense dense grey sandy gravel with silt	
5						
	S3	4' - 6'	2-3-3-3		Medium dense grey sandy gravel with silt	
	S4	6' - 8'	7-12-5-5		Dense grey sandy gravel with silt	
10	S5	8' - 10'	17-8-5-4		Medium dense grey sandy gravel with silt	
	S6	10' - 10.1'	50/1"		Very dense grey sandy gravel with silt	**Fill**
					-Auger Refusal at 11.5 Feet-	
					-End of Boring at 11.5 Feet-	
15						

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

TEST BORING LOG

PROJECT NAME: New Central Utility Plant

BORING NO.: B-7

PROJECT NUMBER: 130063901 CLIENT: Harrell, Saltrick & Hopper

LOCATION: See Subsurface Investigation Location Plan (130063901-A-102)

☐ FIELD SURVEYED ☐ TOPO ESTIMATE

ELEV
TOP OF GROUND: Not Available
GROUNDWATER DATA: Dry
DEPTH: Not Encountered Time: Completion

DEPTH (feet)	SAMPLE NUMBER	SAMPLE DEPTH (ft)	BLOWS PER 6"		SOIL DESCRIPTION	REMARKS
				0.0' - 0.8'	Aspalt [3-inches] and stone sub-base [7-inches]	**Pavement**
	S1	0.5' - 2'	4-4-8	0.8' - 4.0'	Very stiff orange to brown clay with gravel	
	S2	2' - 4'	7-4-4-5		Stiff orange to brown sandy clay with gravel	**Fill**
5				4.0' - 22.0'		
	S3	4' - 6'	3-4-4-6		Stiff tan to brown silt with sand	
	S4	6' - 8'	5-5-6-6		Stiff tan to brown silt with sand	
10	S5	8' - 10'	3-3-4-4		Stiff tan to brown silt with sand	
15	S6	13' - 15'	2-3-3-4		Medium stiff tan to brown silt with sand	
20	S7	18' - 20'	2-2-2-2		Medium stiff tan to brown silt with sand [moist]	
	S8	20' - 22'	1-3-15-20		Medium stiff tan to brown silt with sand and gravel	**Stratum I**
					-Auger Refusal at 22.0 Feet-	
					-End of Boring at 22.0 Feet-	

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RIG TYPE: Truck-Mounted CME-55

DRILLING METHOD: Hollow Stem Auger

ADVANTAGE REPRESENTATIVE: C. Weems

DATE DRILLED: October 22, 2013

DRAWN/COMPILED BY: M. Owen

Existing Foundation Site Photos

TP-1: Concrete Foundation

TP-1: Top of Foundation and Soil Line

TP-2: Concrete Foundation

TP-3: Concrete Foundation with Concrete Encountered Below Prevailing Foundation