Information To Build On
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Preliminary Subsurface Exploration Report

of

New Waste Water Treatment Plant
Village of Ashville, Pickaway County, Ohio

Prepared for

URS Corporation
277 West Nationwide Boulevard
Columbus, Ohio 43215

Prepared by

Professional Service Industries, Inc.
4960 Vulcan Avenue
Columbus, OH 43228

Report Date: December 6, 2013

PSI Project No. 0102592

psi Information To Build On
Engineering • Consulting • Testing

December 6, 2013

URS Corporation
277 West Nationwide Boulevard
Columbus, OH 43215

Attn: Mr. Jeffrey Kerr, P.E.

Re: Preliminary Subsurface Exploration Report
New Waste Water Treatment Plant
South of SR 752
Village of Ashville, Pickaway County, Ohio
PSI Project Number: 0102592

Dear Mr. Kerr:

Thank you for choosing Professional Service Industries, Inc. (PSI) as your consultant for the referenced project. Per your authorization, PSI has completed a geotechnical engineering study for the referenced project. The results of the study are discussed in the accompanying report, one (1) copy of which is enclosed.

If you have any questions pertaining to this report, please contact our office at (614) 876-8000. PSI would be pleased to continue providing geotechnical services throughout the implementation of the project, and we look forward to working with you and your organization on this and future projects.

Respectfully submitted,
PROFESSIONAL SERVICE INDUSTRIES, INC.

Matthew A. Archer
Staff Engineer

Paul S. Hundley, P.E.
Regional Engineer

STATE OF OHIO
PAUL S. HUNDLEY
#43741
REGISTERED
PROFESSIONAL ENGINEER

MA/PSH/ma

Enclosures

TABLE OF CONTENTS

Page No.

1.0 PROJECT INFORMATION

1.1 Project Authorization

The following table summarizes, in chronological order, the Project Authorization History for the services performed and represented in this report by Professional Service Industries, Inc. (PSI).

Document and Reference	Date	Requested/Provided By
Request for Proposal	09/24/2013	Jeffrey Kerr, URS
PSI Proposal No.: 102-89907	10/01/2013	Matthew Archer and Paul Hundley, PSI Inc.
Project Authorization	11/07/2013	Jeffrey Kerr, URS

1.2 Project Description

According to the RFP and project documents provided, it is PSI's understanding that the project involves design and construction a new Waste Water Treatment Plant (WWTP) located on a 32 acre parcel, south of SR 752 in the Village of Ashville, Pickaway County, Ohio. The WWTP is expected to consist of a headworks building, oxidation ditch, two final clarifiers, a UV disinfection tank, an aerobic digester, a sludge press and cake storage building and an administration building. Open cut excavations are anticipated to install the clarifiers, oxidation ditch, anaerobic digesters, UV disinfection tank and three buildings.

No preliminary drawings or layouts on this site are currently available at the time of this report.

The following table lists the material and information provided for this project:

DESCRIPTION OF MATERIAL	PROVIDER/SOURCE	DATE
Scope of Services for Subsurface Investigations	URS	09/24/2013
Parcel Data	URS	09/24/2013
Aerial Photo Showing Boring Locations	URS	11/07/2013

The preliminary geotechnical recommendations presented in this report are based on the available project information for the proposed WWTP located in the Village of Ashville, Pickaway County, Ohio and the subsurface materials described in this report. If any of the information noted above is incorrect, please inform PSI in writing so that we may amend the recommendations presented in this report if appropriate and if desired by the client. PSI will not be responsible for the implementation of its recommendations when it is not notified of changes in the project.

1.3 Purpose and Scope of Services

The purpose of this study was to explore the subsurface conditions at the site to prepare preliminary foundation and excavation recommendations for the proposed construction. PSI's contracted scope of services included drilling two (2) soil test borings at the site, to a depth of approximately 40 feet below the ground surface, select laboratory testing, and preparation of this geotechnical report. The geotechnical exploration was planned according to the request of the client to provide opinions and preliminary recommendations foundation design. This report briefly outlines the testing procedures, presents available project information, describes the site and subsurface conditions, and presents recommendations regarding the following:

- A general assessment of area geology based on our local knowledge and study of available geological literature;
- General location, description of materials encountered in the borings which may interfere with construction progress or structure performance, including existing fills, cobbles/boulders, or organic soils;
- Identification of water levels encountered at the time of drilling and recommendations for dewatering if required;
- Recommendations for fill including the selection of materials for use and procedures for placement;
- Foundation system evaluations and the assessment of the feasibility of utilizing shallow foundations;
- Design parameters required for the foundation system, including allowable bearing pressure, minimum foundation width, and foundation bearing levels;
- Site preparation as needed for support of foundations and floor slabs;
- Recommendations for open cut excavation work to install clarifiers, oxidation ditch, anaerobic digesters, UV disinfection tank, and three buildings;
- Identify the swell potential of surface soil based on the laboratory index tests, and provide recommendations, if any, for potentially swelling soils;
- Recommendations, with attachments including a boring location drawing, and computer generated boring logs.

The scope of services did not include an environmental assessment for determining the presence or absence of wetlands, or hazardous or toxic materials in the soil, bedrock, surface water, groundwater, or air on, below, or around this site. Any statements in this report or on the boring logs regarding odors, colors, and unusual or suspicious items or conditions are strictly for informational purposes.

PSI's scope also did not provide any service to investigate or detect the presence of moisture, mold or other biological contaminants in or around any structure, or any service that was designed or intended to prevent or lower the risk of the occurrence or the amplification of the same. Client should be aware that mold is ubiquitous to the environment with mold amplification occurring when building materials are impacted by moisture. Client should be aware that site conditions are outside of PSI's control, and that mold amplification will likely occur, or continue to occur, in the presence of moisture. As such, PSI cannot and shall not be held responsible for the occurrence or reoccurrence of mold amplification.

2.0 SITE AND SUBSURFACE CONDITIONS

2.1 Site Location and Description

The project site is located on a 32 acre parcel, south of SR 752 in the Village of Ashville, Pickaway County, Ohio. The site latitude and longitude is approximately N 39.972113° and 83.96030° W respectively. The approximate site location is depicted on the "Site Location Map" in the Appendix.

The property is bordered by SR 752 to the north, rail road track to the east, residential housing to the south, and a tree line and rail road tracks to the west.

The site is located in an existing agricultural field. Ground cover at the time of our drilling operations consisted of soft topsoil and organic debris.

Site topographic information was not provided to PSI; however, based on visual inspection, the existing site grades appear fairly level with approximately 3 to 5 feet of relief across the site.

2.2 Site Geology

Based on the geologic map published by the Ohio Geological Survey, the site lies within the Columbus Lowland. Geology consists of Loamy, high-lime (west) to medium-lime (east) Wisconsinan-age till and extensive outwash in Scioto Valley over deep Devonian- to Mississippian-age carbonate rocks, shales, and siltstones.

Information obtained from the Ohio Department of Natural Resources (ODNR) website also indicated that no known abandoned mine was recorded in the vicinity of the site area. "Known and Probable Karst in Ohio" map published by ODNR indicates that no Karst (sink hole) is recorded in the vicinity of the project site.

2.3 Subsurface Conditions

The site subsurface conditions were explored with two (2) soil test borings, advanced to a depth of approximately 40 feet, within the proposed construction area on November 14th, 2013. The boring locations/depths were selected by URS Corporation and were staked in the field by URS Corporation personnel. The approximate boring locations are depicted on the, "Boring Location Plan" in the Appendix.

The borings were advanced utilizing 2¼ inch inside diameter, hollow stem auger drilling methods. Soil samples were routinely obtained during the drilling process. Selected soil samples were later tested in the laboratory to obtain soil material properties for the preliminary foundation open cut excavation recommendations. Drilling, sampling, and laboratory testing were accomplished in general accordance with ASTM procedures.

Approximately 8 inches of topsoil was encountered at the surface of both borings.

Glacial soils generally encountered below topsoil consisted fine-grained lean clays in the upper 19 to 20 feet followed by coarse-grained sands to termination depths. Fine-grained soils predominately consisted of sandy lean clays (CL), lean clays with sand (CL) and silt with sand (ML). The standard penetration N-values within these fine-grained soils generally indicates consistencies of “medium stiff” to “stiff.” Moisture contents of these soils ranged from 8 to 27 percent. Coarse-grained sands predominately consisted of Silty Sands (SM). The standard penetration N-values within these coarse-grained soils generally indicates consistencies of “dense” to “very dense.” Moisture contents of these soils ranged from 7 to 18 percent.

The above subsurface descriptions are of a generalized nature to highlight the major subsurface stratification features and material characteristics. The boring logs included in the Appendix should be reviewed for specific information at individual boring locations. These records include soil/rock descriptions, stratifications, penetration resistances, and locations of the samples and laboratory test data. The stratifications shown on the boring logs represent the conditions only at the actual boring locations. Variations may occur and should be expected between boring locations. The stratifications represent the approximate boundary between subsurface materials and the actual transition may be gradual. Water level information obtained during field operations is also shown on these boring logs. The samples that were not altered by laboratory testing will be retained for 60 days from the date of this report and then will be discarded.

The following table briefly summarizes the range of results from the field and laboratory testing programs. Please refer to the attached boring logs and laboratory data sheets for more specific information:

SUMMARY OF SPT N VALUES, MOISTURE CONTENT & GROUND WATER LEVELS

Top of Soil Sampling Depth (ft)	SPT N Values (blows/ft)			Top of Soil Sampling Depth (ft)	Moisture Content (%)		
	B-01	B-02	Average		B-01	B-02	Average
1.0	6	7	***7***	**1.0**	24	27	***26***
3.5	14	13	***14***	**3.5**	13	16	***15***
6.0	15	12	***14***	**6.0**	13	17	***15***
8.5	13	29	***21***	**8.5**	15	9	***12***
13.5	10	11	***11***	**13.5**	12	13	***13***
18.5	90	11	***51***	**18.5**	8	13	***11***
23.5	40	48	***44***	**23.5**	13	5	***9***
28.5	56	26	***41***	**28.5**	16	18	***17***
33.5	100	71	***86***	**33.5**	7	18	***13***
38.5	97	65	***81***	**38.5**	8	7	***8***
ndwater Level Reading and Borehole Caving Dept							
Water Level Encountered While Drilling					22.0	22.0	
Water Level Reading Encountered Upon Completion					22.5	23.0	
Caving Depth after Casing Withdrawal					22.5	23.2	

2.4 <u>Laboratory Test Results</u>

Laboratory testing was performed on representative split-spoon samples obtained during drilling. The laboratory tests included natural moisture content, percent fines, and Atterberg Limits. The laboratory test results are summarized in the table below.

Summary of Laboratory Test Results

Sample Location	Sample Depth (ft)	Moisture Content (%)	Percent Fines (%)	Atterberg Limits			USCS Soil Classification
				LL	PL	PI	
B-01	3.5 - 5.0	16	83.5	NP	NP	NP	ML
B-01	6.0 - 7.5	17	63.7	28	17	11	CL
B-01	28.5 - 30.0	18	19.5	NP	NP	NP	SM
B-02	3.5 - 5.0	13	76.0	22	15	7	CL
B-02	13.5 - 15.0	12	63.5	22	10	12	CL

2.5 Water Level Measurements

Ground water was observed in all borings during our field investigation at a depth of approximately 22.0 feet. Due to the granular nature of the ground water bearing strata, PSI anticipates that the static groundwater level is approximately 22.0 feet.

The groundwater level at the site, as well as perched water levels and volumes, will fluctuate based on variations in rainfall, snowmelt, evaporation, surface run-off and other related hydrogeologic factors. The water level measurements presented in this report are the levels that were measured at the time of PSI's field activities.

3.0 GEOTECHNICAL EVALUATION

3.1 Geotechnical Discussion

According to our investigation findings, the following key items are highlighted for the project design and construction.

- No preliminary drawings or layouts on this site are currently available at the time of this report.
- Natural soils generally consisted of fine-grained clays and silt in the upper 20 feet followed by coarse-grained sands to termination depths. Majority soil samples encountered on the site had relatively moderately high consistency below 3.0 feet. The natural soils should be capable of supporting the proposed building foundations without major soil improvement according to our test boring findings. A geotechnical engineer should inspect footing excavations to ensure consistency with the recommended bearing pressure.
- As an alternative to shallow foundations, a raft or mat foundation may be considered. This option may be viable if the total weight and loads of the proposed structure can be supported within the allowable area to sufficiently reduce the mat contact stress. This foundation could consist of structural grade beams in a waffle pattern or a mass slab supported on a layer of engineered fill. PSI should evaluate the feasibility of a raft foundation after the final building and floor loads are known.
- Open cut excavations are anticipated to install the clarifiers, oxidation ditch, anaerobic digesters, UV disinfection tank and three buildings. Excavations should be designed and constructed in accordance with the OSHA Regulation 29 CRF Part 1926. Temporary

slopes in the upper 20 feet of the soil profile at this site should not exceed steeper than a ratio of three-quarter (¾) horizontal to one (1) vertical where workers or equipment will occupy space at the toe.

- Where excavations are planned in excess of 20 feet below the existing grade, a temporary retaining structure will be required. The retaining structure should extend an adequate distance below the proposed excavation to prevent soil heaving and piping.
- Ground water was observed during our field activities at a depth of 22 feet. However, the presence of gray glacial soils above this level is an indication that the water level could be higher a different times on the site. PSI recommends the water table be lowered a minimum of 2 feet below the excavation bottoms where excavation are planned in excess of 22 feet. The below grade walls should be adequately water-proofed to prevent seepage and dewatering systems should be installed where the water table is not lowered below the excavation limits.
- On-site soil cuttings, free of organic or other deleterious materials, may be reused as fill (since the majority of these soil samples are estimated to be low to medium plasticity clay) if the cuttings are tested and meet the project specification. However, soils having maximum particle size greater than three (3) inches, a liquid limit greater than forty (40) and plasticity index greater than twenty (20), such as encountered in Boring B-02 and B-03, should not be used as fill below lightly loaded structures and slabs. Saturated on-site soil cuttings should not be used as fill in the building or pavement areas. Whether or not the cuttings are suitable for reuse should be determined by proper soils tests under the supervision of an experienced civil/geotechnical engineer. PSI can provide the testing services before and during the construction of this project.
- The non-plastic silt encountered in B-01 at a depth of 1.8 to 5.5 feet is a frost susceptible soil and is difficult to work with when exposed to precipitation. These soils should not be used as fill within the upper 30 inches (frost depth) of the subgrade.
- Since this site contains fine-grained clay soils and relatively high ground water table, it may become difficult to achieve the compaction as required by proof-rolling. The soils may need to be scarified and dried to a moisture content that will facilitate compaction in accordance with the structural fill requirements of this report. Use of geofabric and/or geogrid reinforcement or lime, kiln dust, or fly ash stabilization may be necessary in order to expedite the work and achieve the required level of soil compaction in floor slab areas.

4.0 GEOTECHNICAL RECOMMENDATIONS

The following geotechnical related recommendations have been developed on the basis of the subsurface conditions encountered and PSI's understanding of the proposed development. Should changes in the project criteria occur, a review must be made by PSI to determine if modifications to our recommendations will be required.

4.1 <u>Site Preparation</u>

PSI recommends that topsoil, vegetation, roots, soft, organic, frozen, or unsuitable soils in the building areas be stripped from the site and either wasted or stockpiled for later use in non-structural areas. It should also be noted that it is not unusual for topsoil thickness to vary from these values in the open field. Oftentimes the topsoil can be deeper in low-lying areas, where erosion, wind and precipitation can deposit this material. A minimum width of the undercut areas for footing construction can be estimated as twice the footing width. A representative of the geotechnical engineer should determine and document the depth of removal at the time of construction.

In this region, these otherwise competent silts and lean clays can undergo a significant loss of stability when construction activities are performed during wetter portions of the year. PSI anticipates that the soils in the project area can become easily disturbed if subjected to conventional rubber tire or narrow track-type equipment. Soils that become disturbed would need to be excavated and replaced; however, this remedial excavation may expose progressively wetter soils with depth, thus compounding the problem condition. Thus, a normal approach to subgrade preparation may not be possible. Appropriate wide-track equipment selection should aid in minimizing potential disturbance.

After stripping to the proposed subgrade level, a representative of the geotechnical engineer should inspect bearing surfaces to ensure its consistency with the recommendations presented herein. Care should be taken during construction activities not to allow excessive drying or wetting of exposed soils. The subgrade soils should be scarified and compacted to at least 98% of the materials' standard proctor maximum dry density, in general accordance with ASTM procedures, to a depth of at least twelve (12) inches below the surface. New fill should not be placed on frozen ground.

After subgrade preparation and observation have been completed, fill placement required to establish grade may begin. Low-plasticity structural fill materials placed beneath the structural features or slabs should be free of organic or other deleterious materials and have a maximum particle size of less than three (3) inches. Low-plasticity soils are defined as having a liquid limit less than forty (40) and plasticity index less than twenty (20). The in-situ lean clays can be reused as engineered fill as long they are free of any organic material and meet the requirements outlined in this report. A representative of PSI should be on-site to observe, test, and document the placement of the fill. If the fill is too dry, water should be uniformly applied and thoroughly mixed into the soil by disking or scarifying. Close moisture content control will be required to achieve the recommended degree of compaction. If engineered fill placement must proceed during a wet or cool time of the year, it will likely be infeasible to re-use the on-site soils as engineered fill, and imported fill materials will be required. If wet or cool season earthwork is necessary, PSI recommends the use of imported fill materials meeting the requirements of Ohio Department of Transportation (ODOT) CMS Item 203.

In utility trenches, shallow foundation excavations, and other areas where large compaction equipment cannot be used, granular engineered fill should be placed as backfill. PSI recommends the use of material meeting ODOT CMS Item 703.16.B or 703.16.C, Structure Backfill, for use as granular engineered fill. Engineered fill should be placed in accordance with the recommendations stated in this section of the report.

Fill should be placed in maximum loose lifts of eight (8) inches and compacted to at least 98% of the materials' standard proctor maximum dry density, and within a range of the optimum moisture content as designated in the table below, as determined in general accordance with ASTM procedures. Each lift of compacted-engineered fill should be tested and documented by a representative of the geotechnical engineer prior to placement of subsequent lifts. The edges of compacted fill should extend a minimum of five (5) feet beyond the building footprint, or a distance equal to the depth of fill beneath the footings, whichever is greater. The measurement should be taken from the outside edge of the footing to the toe of the excavation prior to sloping.

The fill placed should be tested and documented by a geotechnical technician and directed by a geotechnical engineer to evaluate the placement of fill material. It should be noted that the geotechnical engineer of record can only certify the testing that is performed and the work observed by that engineer or staff in direct report to that engineer. The fill should be evaluated in accordance with the following Table:

MATERIAL TESTED	PROCTOR TYPE	MIN % DRY DENSITY	PLACEMENT MOISTURE CONTENT RANGE	FREQUENCY OF TESTING *[2]
Structural Lean Clay Fill (Cohesive)	Standard	98%	-2 to +2 %	1 per 5,000 ft^2 of fill placed / lift
Structural Fill (Granular)	Standard	98%	-2 to +2 %	1 per 5,000 ft^2 of fill placed / lift
Random Fill (non load bearing)	Standard	90%	-3 to +3 %	1 per 6,000 ft^2 of fill placed / lift
Utility Trench Backfill	Standard	98%	-2 to +2 %	1 per 150 lineal foot / lift

*[1] Relative Density as determined in general accordance with ASTM D4253 and D4254. *[2] Minimum 2 per lift.

Tested fill materials that do not achieve either the required dry density or moisture content range shall be recorded, the location noted, and reported to the Contractor and Owner. A re-test of that area should be performed after the Contractor performs remedial measures.

4.2 Preliminary Foundation Recommendations

The planned construction can be supported on conventional spread-type footing foundations bearing on either competent naturally deposited soils or properly compacted and documented engineered fill provided existing fill materials are removed. **During footing excavations, a geotechnical engineer should inspect the excavation bottoms to ensure its consistency with the recommended bearing pressures.** If it is desired for the planned foundations to bear on properly compacted and documented fill, the geotechnical engineer should be allowed to review the material as to ensure its consistency with the recommended bearing pressures. Based on the two soil borings, spread footings for building columns, continuous footings for bearing walls, can be designed for allowable soil bearing capacity as presented in the table below. PSI recommends a minimum dimension of thirty (30) inches for square footings and eighteen (18) inches for continuous footings to minimize the possibility of a local bearing capacity failure. A 12 inch layer of crushed stone may be required to stabilize the bearing surface if foundations are planned to bear on silts found in B-01 at a depth of approximately 1.8 to 5.5 feet or silty sands at depths greater than 20 feet. .

Allowable Bearing Capacity

Foundation Depth (ft)	ASTM Soil Classification	Saturated Unit Weight (pcf)	Shear Strength (psf)	Angle of Internal Friction (Degrees)	Allowable Bearing Capacity (psf)
3	CL	115	1500	15	2750
5	CL	115	1500	15	3000
7	CL	115	1500	15	3000
10	CL	115	1500	15	3000
15	CL	110	1250	15	2750
20	SM	100	-	36	>5000
30	SM	100	-	36	>5000

* Based on dead load plus design live load

Exterior footings and footings in unheated areas should be located at a depth of thirty-two (32) inches or deeper below the final exterior grade to provide adequate frost protection. If the building is to be constructed during the winter months or if footings will likely be subjected to freezing temperatures after foundation construction, then the footings should be protected from freezing. PSI recommends that interior footings be a minimum depth of eighteen (18) inches below the finished floor elevation.

The foundation excavations should be observed and documented by a representative of PSI prior to steel or concrete placement to assess that the foundation materials are consistent with the materials discussed in this report, and therefore are capable of supporting the design loads. Soft or loose soil zones encountered at the bottom of the footing excavations should be removed to the level of suitable soils, and replaced with adequately compacted structural fill. Fill placed below the foundations where unsuitable materials are removed should extend 1 foot outside the foundation limits for every one (1) foot in thickness between the intended bearing surface and the underlying, suitable natural soils. Alternately, the foundations may be extended through unsuitable soils to bear on the underlying suitable material. Cavities formed as a result of excavation of soft or loose soil zones should be backfilled with lean concrete or dense graded compacted crushed stone.

After opening, footing excavations should be observed and concrete placed as quickly as possible to avoid exposure of the footing bottoms to wetting and drying. Surface run-off water should be drained away from the excavations and not be allowed to pond. If possible, the foundation concrete should be placed during the same day the excavation is made. If it is required that footing excavations be left open for more than 1 day, they should be protected to reduce evaporation or entry of moisture.

Based on the known subsurface conditions and site geology, laboratory testing and past experience, PSI anticipates that properly designed and constructed footings supported on the recommended materials should experience total and differential settlement between adjacent columns of less than one (1) inch and ¾ inch, respectively.

As an alternative, a raft or mat foundation may be considered. This option may be viable if the total weight and loads of the proposed structure can be supported within the allowable area to sufficiently reduce the mat contact stress. This foundation could consist of structural grade beams in a waffle pattern or a mass slab supported on a layer of engineered fill. At least 6 inches of soil should be removed below the floor subgrade elevation and replaced with compacted granular fill. The rigid frame created by the structural grade beams or mass slab would help to reduce differential settlement by distributing the loads. However, placement of underground utilities for the proposed structure may be complicated with this foundation type. PSI should evaluate the feasibility of a raft foundation after the final building and floor loads are known.

Be advised that as a part of the foundation selection process, there is a cost/benefit evaluation. Although PSI is recommending specific foundation types, we have not accomplished the cost/benefit evaluation.

4.3 Earthquake and Seismic Design Consideration

The 2006 International Building Code (IBC) requires a site class for the calculation of earthquake design forces. This class is a function of soil type (i.e., depth of soil and strata types). Based on the depth to rock and the estimated shear strength of the soil at the boring locations, **Site Class "C"** is recommended. The USGS-NEHRP probabilistic ground motion values near latitude N 39.972113° and longitude 83.96030° W are as follows:

Period (seconds)	2% Probability of event in 50 years (g%)	Site Coefficients	Max. Spectral Acceleration parameters	Design Spectral Acceleration parameters	
0.2 (S_s)	20.3	F_a = 1.2	S_{ms} = 0.244	S_{Ds}= 0.163	T_0= 0.093
1.0 (S_1)	6.7	F_v = 1.7	S_{m1} = 0.114	S_{D1}= 0.076	T_s= 0.466

The Site Coefficients, F_a and F_v were interpolated from IBC 2006 Tables 1613.5.3 (1) and 1613.5.3 (2) as a function of the site classifications and the mapped spectral response acceleration at the short (S_s) and 1 second (S_1) periods.

According to Section 1613.5.6 of IBC 2006, sites supporting structures in design category "C" and below must be evaluated for slope instabilities, liquefaction and surface rupture due to faulting or lateral spreading. A detailed study of these effects was beyond PSI's scope of services. However, the following table presents a qualitative assessment of these issues considering the site class, the subsurface soil properties, the groundwater elevation, and probabilistic ground motions:

Hazard	Relative Risk	Comments
Liquefaction	Low	The soil within the upper 50 feet of the subsurface profile is a relatively dense and/or cohesive soil
Slope Stability	Low	The site is relatively flat and does not/will not incorporate significant cut or fill slopes
Surface Rupture	Low	The site is not underlain by a mapped Holocene-aged fault

4.4 Floor Slab Recommendations

The floor slab can be grade supported on naturally occurring soils with minor remediation or stabilization practices. Proof-rolling, as discussed earlier in this report, should be accomplished to identify soft or unstable soils that should be removed from the floor slab area prior to fill placement and/or floor slab construction and replaced with properly compacted structural fill.

PSI recommends that a minimum four (4) inch thick compactable and trimmable granular material mat be placed beneath the floor slab to enhance drainage. The soil surface shall be graded to drain away from the building without low spots that can trap water prior to placing the granular drainage layer. Polyethylene sheeting should be placed to act as a vapor retarder where the floor will be in contact with moisture sensitive equipment or products such as tile, wood, carpet, etc., as directed by the design engineer. The decision to locate the vapor retarder in direct contact with the slab or beneath the layer of granular fill should be made by the design engineer after considering the moisture sensitivity of subsequent floor finishes, anticipated project conditions, and the potential effects of slab curling and cracking. The floor slabs should have an adequate number of joints to reduce cracking resulting from differential movement and shrinkage.

For subgrade prepared as recommended and properly compacted fill, a modulus of subgrade reaction, *k* value, of 150 pounds per cubic inch (pci) may be used in the grade slab design. However, depending on how the slab load is applied, the value will have to be geometrically modified. The value should be adjusted for larger areas using the following expression for cohesive and cohesionless soil:

Modulus of Subgrade Reaction, $k_s = \left(\frac{k}{B}\right)$ for cohesive soil and

$k_s = k\left(\frac{B+1}{2B}\right)^2$ for cohesionless soil

where: k_s = coefficient of vertical subgrade reaction for loaded area,
k = coefficient of vertical subgrade reaction for 1 square foot area, and
B = effective width of area loaded, in feet

The precautions listed below should be followed for construction of slab-on-grade pads. These details will not reduce the amount of movement, but are intended to reduce potential damage should some settlement of the supporting subgrade take place. Some increase in moisture content is inevitable as a result of development and associated landscaping. However, extreme moisture content increases can be largely controlled by proper and responsible site drainage, building maintenance and irrigation practices.

- Cracking of slab-on-grade concrete is normal and should be expected. Cracking can occur not only as a result of heaving or compression of the supporting soil and/or bedrock material, but also as a result of concrete curing stresses. The occurrence of concrete shrinkage crack , and problems associated with concrete curing may be reduced and/or controlled by limiting the slump of the concrete, proper concrete placement, finishing, and curing, and by the placement of crack control joints at frequent intervals, particularly where re-entrant slab corners occur. The American Concrete Institute (ACI) recommends a maximum panel size (in feet) equal to approximately three times the thickness of the slab (in inches) in both directions. For example, joints are recommended at a maximum spacing of twelve (12) feet based on having a 4-inch slab. PSI also recommends that the slab be independent of the foundation walls. Using fiber reinforcement in the concrete can also control shrinkage cracking.

- Areas supporting slabs should be properly moisture conditioned and compacted. Backfill in all interior and exterior water and sewer line trenches should be carefully compacted to reduce the shear stress in the concrete extending over these areas.

Exterior slabs should be isolated from the building. These slabs should be reinforced to function as independent units. Movement of these slabs should not be transmitted to the building foundation or superstructure.

4.5 Utilities Trenching

Excavation for utility trenches shall be performed in accordance with Occupational Safety & Health Administration (OSHA) regulations as stated in 29 CFR Part 1926. It should be noted that utility trench excavations have the potential to degrade the properties of the adjacent fill materials. Utility trench walls that are allowed to move laterally can lead to reduced bearing capacity and increased settlement of adjacent structural elements and overlying slabs.

Backfill for utility trenches is as important as the original subgrade preparation or structural fill placed to support either a foundation or slab. Therefore, it is imperative that the backfill for utility trenches be placed to meet the project specifications for the structural fill of this project. PSI recommends that Low Strength Mortar (LSM) be utilized for utility trench backfill. If on-site soils are placed as trench backfill, the backfill for the utility trenches should be placed in four (4) to six (6) inch loose lifts and compacted to a minimum of 98% of the maximum dry density achieved by the standard Proctor test. The backfill soil should be moisture conditioned to be within 2% of the optimum moisture content as determined by the standard Proctor test. Up to four (4) inches of bedding material placed directly under the pipes or conduits placed in the utility trench can be compacted to the 98% compaction criteria with respect to the standard Proctor. Compaction testing should be performed for every 200 cubic yards of backfill place or each lift within 200 linear feet of trench, which ever is less. Backfill of utility trenches should not be performed with water standing in the trench. If granular material is used for the backfill of the utility trench, the granular material should have a gradation that will filter protect the backfill material from the adjacent soils. If this gradation is not available, a geosynthetic non-woven filter fabric should be used to reduce the potential for the migration of fines into the backfill material. Granular backfill material shall be compacted to meet the above compaction criteria. The clean granular backfill material should be compacted to achieve a relative density greater than 75% or as specified by the geotechnical engineer for the specific material used.

4.6 Below-Grade Structures

Below-grade structures should be designed to resist lateral earth pressures. Lateral earth pressure is developed from the soils present within a wedge formed by the vertical below-grade wall and an imaginary line extending up and away from the bottom of the wall at an approximate 45° angle. The lateral earth pressures are determined by multiplying the vertical applied pressure by the appropriate lateral earth pressure coefficient K. If the walls are rigidly attached to the structure and not free to rotate or deflect at the top, PSI recommends designing the walls for the “at-rest” lateral earth pressure condition using K_o. Walls that are permitted to rotate and deflect at the top can be designed for the active lateral earth pressure condition using K_a.

Passive pressure can be determined using K_p, with a factor of safety of 2.0. Recommended parameters for use in below grade walls are as follows:

Preliminary Below-Grade Wall Design Parameters

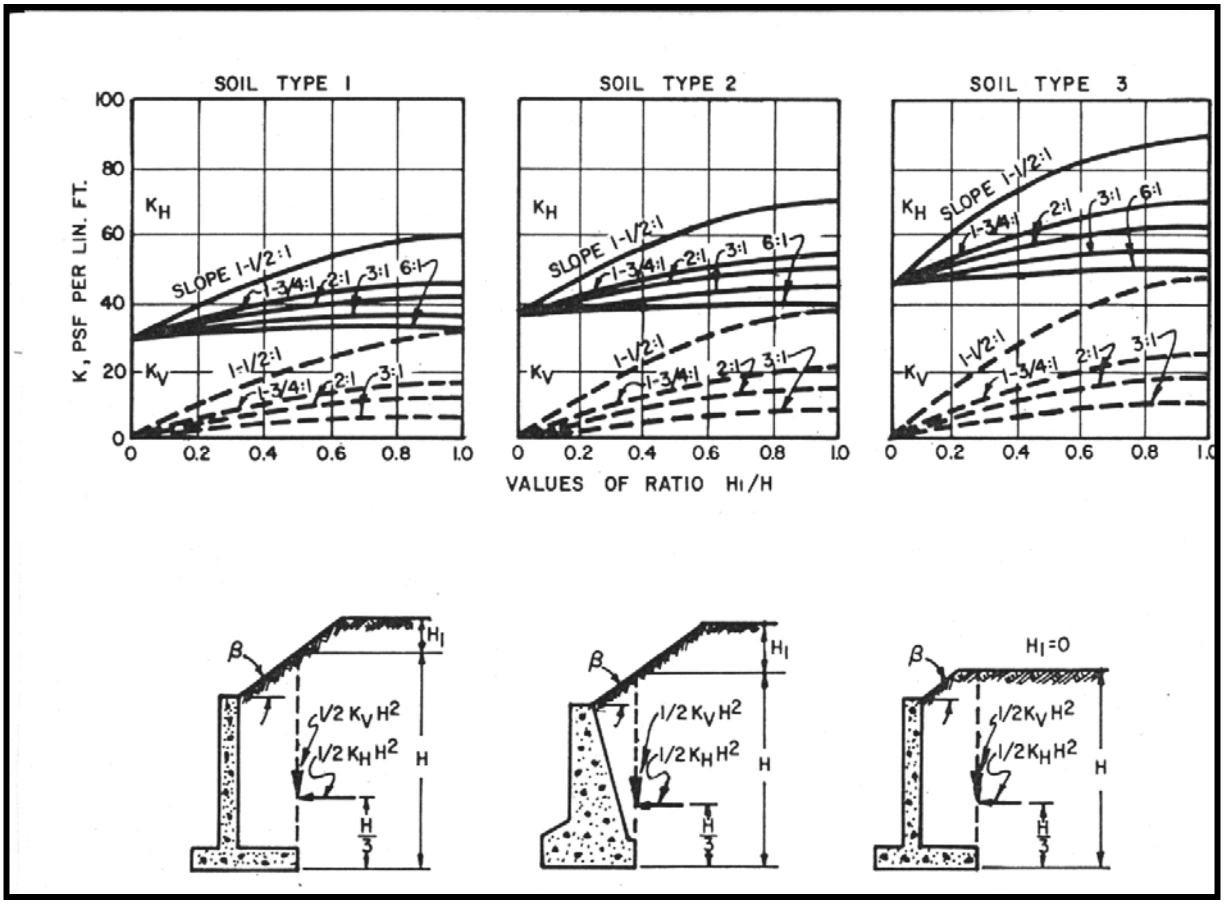
Material Type	Saturated Unit Weight (pcf)	Shear Strength (psf)	Angle of Internal Friction (Degrees)	Active Earth Pressure Coefficient (K_a)	Passive Earth Pressure Coefficient (K_p)	At-Rest Earth Pressure Coefficient (K_o)
Select Granular Fill	120	-	34	0.28	3.54	0.44
Sandy Lean Clay (CL)	115	1500	15	0.59	1.70	0.74
Silty Sand (SM)	100	-	36	0.41	3.85	0.26

* Earth pressure coefficients are based upon the angle of internal friction only. The coefficients assume that the grades are level and does not account for wall friction. Sloping ground surfaces and surcharge loads need to be considered in the design

The values presented above were calculated based on positive foundation drainage is provided to prevent the buildup of hydrostatic pressure. If surface loads are placed near the walls, such as traffic loads, they should be designed to resist an additional uniform lateral load of one-half of the vertical surface loads. An “equivalent fluid” pressure can be obtained from the above chart by multiplying the appropriate K-factor times the total unit weight of the soil. This applies to unsaturated conditions only. If a saturated “equivalent fluid” pressure is needed, the effective unit weight (total unit weight minus unit weight of water) should be multiplied times the appropriate K-factor and the unit weight of water added to that resultant. However, PSI does not recommend that earth retaining walls be designed with a hydrostatic load and that drainage should be provided to relieve the pressure.

In specific design cases where water is allowed to build up on the below-grade wall structure, the hydrostatic load correlating to the maximum height of the water build up should be added to the lateral loads acting on the wall.

The designs of below grade walls need to take into account the effects of geometry and loading conditions. The following charts have been included from NAVFAC 7.02 concerning slopes in the grade at the top of below grade wall. Depending on the geometry of the site, the lateral loading on the below grade wall should be modified according to these charts.



Soil Type 1 – Clean Sand and Gravel, GW, GP, SW, SP
Soil Type 2 – Dirty Sand and Gravel of Restricted Permeability, GM, GM-GP, SM-SP, SM
Soil Type 3 – Stiff Residual Silts and Clays, Silty Fine Sands, Clayey Sands and Gravels: CL, ML, CH, MH, SM, SC, GC

4.7 Below-Grade Structure Wall Back-Drain

PSI recommends that the retaining wall be adequately water-proofed and be provided with a wall back-drain system. One possible drainage system is shown in the sketch below and would include:

1) A four (4) or six (6) inch diameter perforated drain tile at the bottom of the backfill to collect seepage water with the tile connected to a suitable means of disposal.
2) Clean ½ inch or one (1) inch gravel classified as "GP" and containing less than 5% passing a #200 sieve surrounding the draintile.
3) Non-woven four (4) ounce per square yard geotextile between the drainage material and the on-site soils to prevent infiltration of fine grained soils into the draintile, granular drainage blanket, or granular backfill.

As an alternative, a geocomposite drain material can be placed between the retaining wall and the backfill soils. Underdrains, sub-drains and underslab drains presented in this report will not prevent moisture vapor that can cause mold growth.

The placement of a limited amount of granular material behind a below-grade wall does not appreciably change the coefficient of lateral earth pressure acting on that wall. The lateral earth pressure acting on a below-grade structure is a function of the weight of the soil that exists above the theoretical plane projecting up from the base of the wall. The soil above this plane is held in place by two forces, the strength of the soil itself and the lateral resistance of the below-grade wall. Therefore, a thin layer of granular material behind the wall is of little consequence on the forces acting on the wall.

4.8 Below-Grade Structure Wall Backfill and Compaction

Backfill of the proposed below-grade walls may consist of low plastic soils or granular material. PSI suggests using granular material to provide improved drainage and to reduce lateral pressures on the walls resulting from water pressure. The backfill materials should be placed in lifts that do not exceed 8-inches loose. The lift thickness may need to be reduced to thinner lifts immediately behind the walls to achieve the desired about of compaction without overstressing the wall with the compaction process.

Backfill should be placed in thin lifts and mechanically compacted to at least 98% of the materials' maximum dry density and within 2% of the optimum water content as determined by the standard Proctor test. PSI advises performing field density tests on the backfill to monitor compliance with the recommendations provided. Care should be exercised during the backfilling operation to prevent overstressing and damaging the walls.

Where the distance between the proposed structure walls and the temporary retaining wall system do not allow for traditional backfilling methods, the annular space may be filled with clean gravel (#57) or controlled low strength mortar (CLSM).

4.1 Temporary Slopes and Retaining Walls

In accordance with OSHA Regulation 29 CRF Part 1926, temporary slopes at this site should not exceed steeper than a ratio of three-quarter (¾) horizontal to one (1) vertical for stiff lean clays (tyoe A soils) and one and one-half (1½) horizontal to one (1) vertical for type A over type C soils where workers or equipment will occupy space at the toe or where the movement of the excavated slope will jeopardize the stability of an adjacent structure. The contractors competent person shall determine actual soil and groundwater conditions and determine the safe slope conditions.

The naturally occurring existing soils should be prepared and fill placed in accordance with the previously described structural fill guidelines. A representative of the geotechnical engineer should monitor the benching and fill placement operations. The following table briefly shows excavation options for soils encountered at this site.

Where the proposed excavation is in excess of 20 vertical feet, a temporary retaining structure will be required. The retaining structure should extend an adequate distance below the proposed excavation to prevent soil heaving and piping. Minimum required embedment depths should be determined by the design engineer.

Where the water table is not lowered below the excavation, PSI recommends that below grade structures be adequately water-proofed to prevent seepage and dewatering systems be installed. A minimum thickness of 12 inches granular layer should be placed behind the wall in order to drain water to sump areas in case water seepage cannot be completely avoided.

If water is allowed to build up on the below-grade wall, the hydrostatic load correlating to the maximum height of the water build up should be added to the lateral loads acting on the wall. If the water table is lowered below excavation bottoms, proper drainage behind the wall should be assured.

5.0 CONSTRUCTION CONSIDERATIONS

PSI should be retained to provide observation and testing of construction activities involved in the foundation, earthwork, and related activities of this project. PSI cannot accept responsibility for conditions that deviate from those described in this report, nor for the performance of the foundation system if not engaged to also provide construction observation and testing for this project.

5.1 Moisture Sensitive Soils/Weather Related Concerns

The upper fine-grained soils encountered at this site are expected may be sensitive to disturbances caused by construction traffic and to changes in moisture content. During wet weather periods, increases in the moisture content of the soil can cause significant reduction in the soil strength and support capabilities. In addition, soils that become wet may be slow to dry and thus significantly retard the progress of grading and compaction activities. It will, therefore, be advantageous to perform earthwork and foundation construction activities during dry weather.

5.2 Drainage and Groundwater Considerations

PSI recommends that the Contractor determine the actual groundwater levels at the site at the time of the construction activities to assess the impact groundwater may have on construction. Undercut or excavated areas should be sloped toward one corner to facilitate removal of collected rainwater, groundwater, or surface runoff.

Dewatering will be required if excavations are planned in excess of 22 feet.

It is possible that seasonal variations will cause fluctuations or a water table to be present in the upper soils. Should excessive and uncontrolled amounts of seepage occur, the Geotechnical engineer should be consulted.

5.3 Excavations

In Federal Register, Volume 54, Number 209 (October 1989), the United States Department of Labor, Occupational Safety and Health Administration (OSHA) amended its "Construction Standards for Excavations, 29 CFR, part 1926, Subpart P". This document was issued to better enhance the safety of workers entering trenches or excavations. It is mandated by this federal regulation that excavations, whether they be utility trenches, basement excavation or footing excavations, be constructed in accordance with the new OSHA guidelines. It is PSI's understanding that these regulations are being strictly enforced and if they are not closely followed, the owner and the contractor could be liable for substantial penalties.

The contractor is solely responsible for designing and constructing stable, temporary excavations and should shore, slope, or bench the sides of the excavations as required to maintain stability of both the excavation sides and bottom. The contractor's "responsible person", as defined in 29 CFR Part 1926, should evaluate the soil exposed in the excavations as part of the contractor's safety procedures. In no case should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations.

PSI is providing this information solely as a service to our client. PSI does not assume responsibility for construction site safety or the contractor's or other parties' compliance with local, state, and federal safety or other regulations.

6.0 GEOTECHNICAL RISK

The concept of risk is an important aspect of the geotechnical evaluation. The primary reason for this is that the analytical methods used to develop geotechnical recommendations do not comprise an exact science. The analytical tools which geotechnical engineers use are generally empirical and must be used in conjunction with engineering judgment and experience. Therefore, the solutions and recommendations presented in the geotechnical evaluation should not be considered risk-free and, more importantly, are not a guarantee that the interaction between the soils and the proposed structure will perform as planned. The engineering recommendations presented in the preceding section constitutes PSI's professional estimate of those measures that are necessary for the proposed structure to perform according to the proposed design based on the information generated and referenced during this evaluation, and PSI's experience in working with these conditions.

7.0 REPORT LIMITATIONS

The preliminary recommendations submitted are based on the available subsurface information obtained by PSI and preliminary design information furnished by URS Corporation. If there are revisions to the plans for this project or if deviations from the subsurface conditions noted in this report are encountered during construction, PSI should be notified immediately to determine if changes in the foundation recommendations are required. If PSI is not retained to perform these functions, PSI will not be responsible for the impact of those conditions on the project.

The geotechnical engineer warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with generally accepted professional geotechnical engineering practices in the local area. No other warranties are implied or expressed.

After the plans and specifications are more complete, the geotechnical engineer should be retained and provided the opportunity to review the final design plans and specifications to check that our engineering recommendations have been properly incorporated into the design documents. At that time, it may be necessary to submit supplementary recommendations. This report has been prepared for the exclusive use of URS Corporation for the specific application to the proposed new Waste Water Treatment Plant located in Ashville, Pickaway County, Ohio.

Appendix

Site Location Map

(NTS)

Note: Base Map Provided by Google Earth, Altered for PSI use.

psi Information To Build On
Engineering • Consulting • Testing

New Waste Water Treatment Plant
Village of Ashvill, Pickaway County, Ohio
PSI Project No.: 0102592

Note: Base Map Provided by Client and Google Earth, Altered for PSI use.

Boring Location Plan

psi Information To Build On
Engineering • Consulting • Testing

New Waste Water Treatment Plant
Village of Ashvill, Pickaway County, Ohio
PSI Project No.: 0102592

BORING B-01

DATE STARTED:	11/14/13	**DRILL COMPANY:**	PSI, Inc.
DATE COMPLETED:	11/14/13	**DRILLER:** J.E.	**LOGGED BY:** J.E.
COMPLETION DEPTH	40.0 ft	**DRILL RIG:**	CME 45 C ATV 2007
BENCHMARK:	N/A	**DRILLING METHOD:**	Hollow Stem Auger
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS
LATITUDE:	39.72103°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-82.95898°	**EFFICIENCY**	88%
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	

REMARKS: Soil symbol in '( )" = Visual Classification

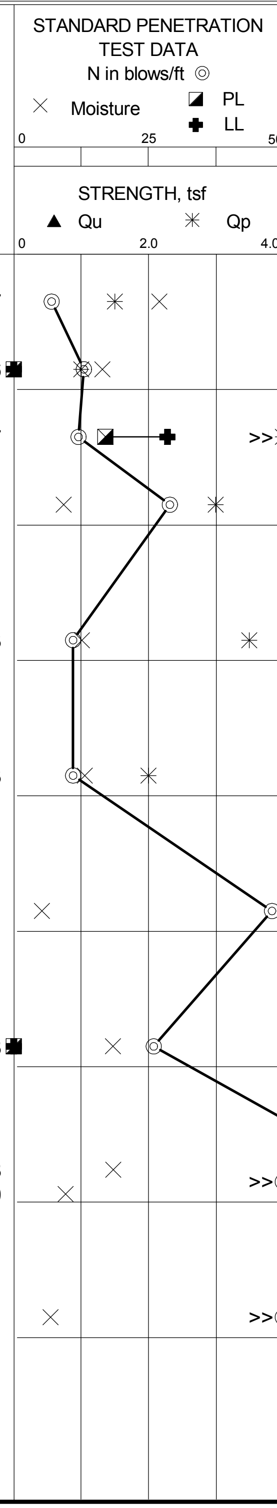
Water

▽ While Drilling	22.0	feet
▼ Upon Completion	23.0	feet
Caved	23.2	feet

BORING LOCATION:

Elevation (feet)	Depth, (feet)	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	Additional Remarks
	0			**TOPSOIL**, (8")				
		1	12	MEDIUM STIFF, BROWN, **LEAN CLAY WITH SAND**, SLIGHTLY ORGANIC, MOIST	(CL)	3-3-4 N=7	27	
		2	17	STIFF, BROWN AND GRAY, **SILT WITH SAND**, TRACE GRAVEL, MOIST	ML	4-6-7 N=13	16	Non-Plastic Fines=83.5%
	5	3	17	STIFF, BROWN, **SANDY LEAN CLAY**, TRACE GRAVEL, DAMP CLAYEY SAND LENSE AT 7.0' COBBLE AT 8.0'	CL	4-6-6 N=12	17	LL = 28 PL = 17 Fines=63.7%
		4	16			5-15-14 N=29	9	
	10			COBBLE AT 10.5'				
				GRAY				
		5	17			4-5-6 N=11	13	
	15							
		6	14	BROWN AND GRAY SILTY SAND LENSE AT 18.8'		1-2-9 N=11	13	
	20			DENSE TO VERY DENSE, BROWN, **SILTY SAND**, LITTLE GRAVEL, MOIST	SM			
		7	14			7-24-24 N=48	5	
	25							
		8	14	GRAY AND BROWN SANDY SILT LAYER AT 29.7' TO 33.5'		7-11-15 N=26	18	Non-Plastic Fines=19.5%
	30							
		9	14	SOME GRAVEL		9-37-34 N=71	18 10	
	35							
		10	15			15-29-36 N=65	7	
	40			BORING DISCONTINUED UPON COMPLETION AT 40.0'				

STANDARD PENETRATION TEST DATA



Professional Service Industries, Inc.
4960 Vulcan Ave, Suite C
Columbus, OH 43228
Telephone: (614) 876-8000

PROJECT NO.: 0102592
PROJECT: Proposed WWTP
LOCATION: South of SR 752, Village of Ashville, Ohio

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING B-02

DATE STARTED:	11/14/13	**DRILL COMPANY:**	PSI, Inc.
DATE COMPLETED:	11/14/13	**DRILLER:** J.E.	**LOGGED BY:** J.E.
COMPLETION DEPTH	40.0 ft	**DRILL RIG:**	CME 45 C ATV 2007
BENCHMARK:	N/A	**DRILLING METHOD:**	Hollow Stem Auger
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS
LATITUDE:	39.72113°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-82.9603°	**EFFICIENCY**	88%
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	

REMARKS: Soil symbol in '( )" = Visual Classification

Water

While Drilling	22.0 feet
Upon Completion	22.5 feet
Caved	22.5 feet

BORING LOCATION:

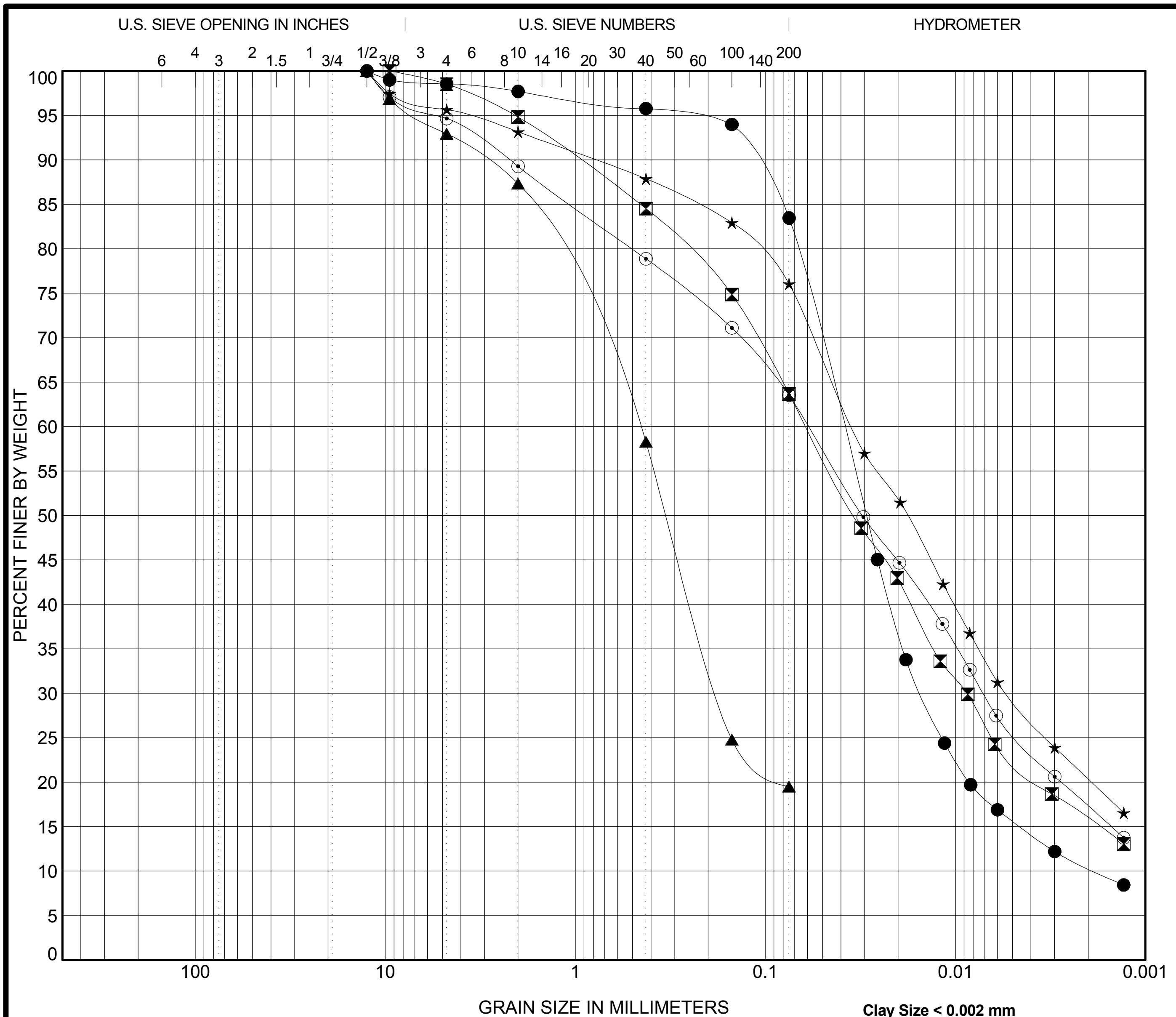
Depth, (feet)	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	Additional Remarks
0			**TOPSOIL**, (8")				
	1	9	MEDIUM STIFF TO STIFF, BROWN, **LEAN CLAY WITH SAND**, TRACE GRAVEL, MOIST TO DAMP	CL	2-3-3 N=6	24	
5	2	17			5-6-8 N=14	13	LL = 22 PL = 15 Fines=76.0%
	3	12	STIFF, BROWN, **SANDY LEAN CLAY**, TRACE GRAVEL, DAMP COBBLE AT 7.5'	CL	4-6-9 N=15	13	
10	4	17	GRAY		4-5-8 N=13	15	
15	5	17			4-4-6 N=10	12	LL = 22 PL = 10 Fines=63.5%
			COBBLE AT 16.0' SANDY SILT LAYER AT 17.0' TO 19.8'				
20	6	15			24-39-50/5"	8	
			DENSE TO VERY DENSE, GRAY AND BROWN, **SILTY SAND**, LITTLE GRAVEL, MOIST TO DAMP	(SM)			
25	7	13			11-21-19 N=40	13 10	
			GRAY				
30	8	15			12-21-35 N=56	16	
35	9	8			43-50/5"	7	
40	10	12			23-42-55 N=97	8	
			BORING DISCONTINUED UPON COMPLETION AT 40.0'				

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL (0–25–50). STRENGTH, tsf: ▲ Qu; ✳ Qp (0–2.0–4.0)

Professional Service Industries, Inc.
4960 Vulcan Ave, Suite C
Columbus, OH 43228
Telephone: (614) 876-8000

PROJECT NO.: 0102592
PROJECT: Proposed WWTP
LOCATION: South of SR 752, Village of Ashville, Ohio

The stratification lines represent approximate boundaries. The transition may be gradual.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-01	4.3	**Silt with Sand (ML)**	NP	NP	NP	3.17	21.21
⧗	B-01	6.8	**Sandy Lean Clay (CL)**	28	17	11		
▲	B-01	29.3	**Silty Sand (SM)**	NP	NP	NP		
★	B-02	4.3	**Lean Clay with Sand (CL)**	22	15	7		
⊙	B-02	14.3	**Sandy Lean Clay (CL)**	22	10	12		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	B-01	4.3	12.5	0.039	0.015	0.002	1.5	15.1	73.1	10.4
⧗	B-01	6.8	9.5	0.061	0.009		1.5	34.8	47.8	15.9
▲	B-01	29.3	12.5	0.466	0.176		7.1	73.4	19.5	
★	B-02	4.3	12.5	0.035	0.005		4.4	19.6	55.7	20.3
⊙	B-02	14.3	12.5	0.059	0.007		5.3	31.1	46.3	17.3

Professional Service Industries, Inc.
4960 Vulcan Ave, Suite C
Columbus, OH 43228
Telephone: (614) 876-8000
Fax: (614) 876-0548

GRAIN SIZE DISTRIBUTION

Project: Proposed WWTP
PSI Job No.: 0102592
Location: South of SR 752
Village of Ashville, Ohio

Information To Build On
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GENERAL NOTES

SAMPLE IDENTIFICATION

The Unified Soil Classification System is used to identify the soil unless otherwise noted.

SOIL PROPERTY SYMBOLS

N: Standard "N" penetration: Blows per foot of a 140-pound hammer falling 30 inches on a 2-inch O.D. split-spoon.

q_u: Unconfined Compressive Strength, tsf

q_p: Penetrometer Value, Unconfined Compressive Strength, tsf

W_c: Water Content, %

LL: Liquid Limit, %

PI: Plasticity Index, %

δ_d: Natural Dry Density, pcf

$\underline{\nabla}$: Apparent Groundwater Level at time noted after completion of boring.

DRILLING AND SAMPLING SYMBOLS

SS: Split-Spoon – 1-3/8" I.D., 2" O.D., except where noted.
ST: Shelby Tube – 3" O.D., except where noted.
AU: Auger Sample
DB: Diamond Bit
CB: Carbide Bit
WS: Washed Sample

RELATIVE DENSITY AND CONSISTENCY CLASSIFICATION

TERM (NON-COHESIVE SOILS)	STANDARD PENETRATION RESISTANCE
Very Loose	0 – 4
Loose	4 – 10
Medium	10 – 30
Dense	30 – 50
Very Dense	Over 50

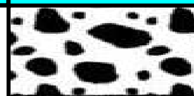
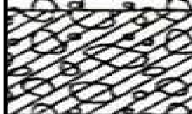
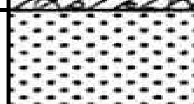
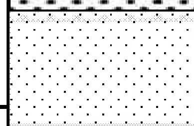
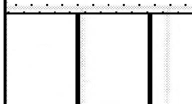
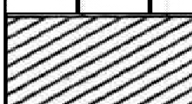
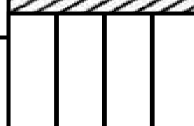
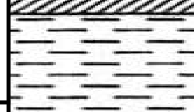
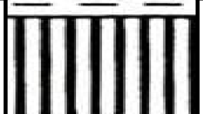
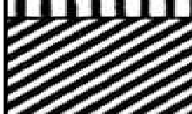
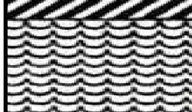
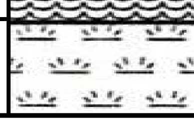
TERM (COHESIVE SOILS)	q_u – (tsf)
Very Soft	0 – 0.25
Soft	0.25 – 0.50
Firm (Medium)	0.50 – 1.00
Stiff	1.00 – 2.00
Very Stiff	2.00 – 4.00
Hard	4.00 +

PARTICLE SIZE (ASTM D-2487 AND D-422)

Boulders	≥12 in. (300mm)	Medium Sand	<2mm (#10 sieve) to 425μm (#40 sieve)
Cobbles	<12 in. (300mm) to 3 in. (75mm)	Fine Sand	<425μm (#40 sieve) to 75μm (#200 sieve)
Gravel	<3 in. (75mm) to 4.75mm (#4 sieve)	Silt	<75μm (#200 sieve) to 5μm
Coarse Sand	<4.75mm (#4 sieve) to 2mm (#10 sieve)	Clay	<5μm

PSI G-100-9 (3)

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE	CLEAN GRAVEL (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVEL WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS 50% OR MORE OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LO W TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS