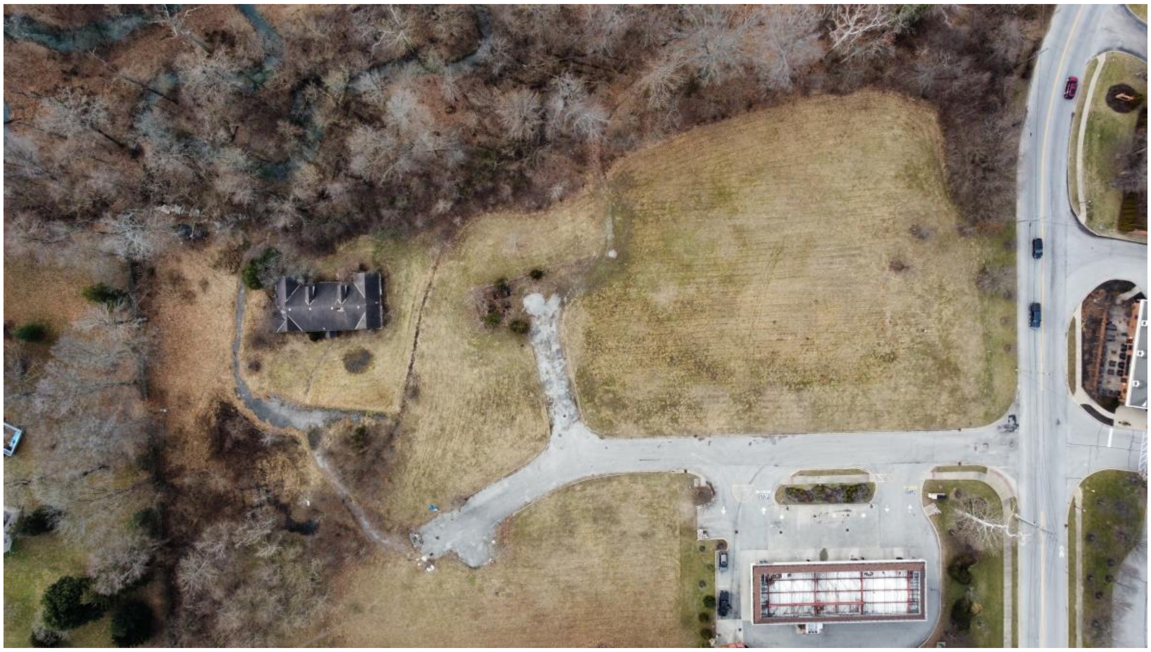
Geotechnical Engineering Report

Prospect Cove Multi-Family
Louisville, Jefferson County, Kentucky

April 22, 2022
Terracon Project No. 57225022



Prepared for:

LDG Development, LLC
Louisville, Kentucky

Prepared by:

Terracon Consultants, Inc.
Louisville, Kentucky

April 22, 2022

LDG Development, LLC
1469 S. 4th Street
Louisville, Kentucky 40208

Attn: Mr. Michael Gross – Development Director
P: (502) 638-0534 x2457
E: lbarlow@ldgdevelopment.com

Re: Geotechnical Engineering Report
Prospect Cove Multi-Family
6500 Forest Cove Ln & 7301 River Rd
Louisville, Jefferson County, Kentucky
Terracon Project No. 57225022

Dear Mr. Gross:

We have completed the Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. P57225022 dated March 1, 2022. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations and floor slabs for the proposed project.

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

Sincerely,
Terracon Consultants, Inc.

STATE OF KENTUCKY
BENJAMIN W. TAYLOR
27823
LICENSED PROFESSIONAL ENGINEER

Munal Pandey, EIT
Staff Engineer

Benjamin W. Taylor, P.E., P.G.
Principal, Regional Manager

REPORT TOPICS

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

ATTACHMENTS

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

Geotechnical Engineering Report

Prospect Cove Multi-Family
6500 Forest Cove Ln & 7301 River Rd
Louisville, Jefferson County, Kentucky

Terracon Project No. 57225022
April 22, 2022

INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed Prospect Cove Multi-Family development to be located at 6500 Forest Cove Ln & 7301 River Rd in Louisville, Jefferson County, Kentucky. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil and rock conditions
- Groundwater conditions
- Site preparation and earthwork
- Pavement design and construction
- Foundation design and construction
- Floor slab design and construction
- Seismic site classification per IBC

The geotechnical exploration Scope of Services for this project included the advancement of 6 test borings to depths ranging from approximately 12 to 42 feet, 2 CPTu soundings to depths ranging from approximately 30 to 34 feet, and 5 geophysical seismic shear wave testing arrays.

Maps showing the site and exploration locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of our exploration and the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs and as separate graphs in the **Exploration Results** section.

SITE CONDITIONS

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

Item	Description
Parcel Information	The project site is approximately 9.76 acres (3 parcels) located at 6500 Forest Cove Ln & 7301 River Rd in Louisville, Jefferson County, Kentucky. Approximate coordinates: 38.218544, -85.816383. See **Site Location**.
Existing Improvements	Vacant residence at south portion of the site will be demolished. Previously razed residential structure to the north of the site. In 2008, aerial imagery indicates site grading for apparent infrastructure and out lots. Review of aerial imagery in Google Earth PRO™ during proposal preparation identified 2 apparent borrow/waste pits across much of the area proposed for development. Our exploration confirmed this as we encountered existing fill within supplemental borings conducted in these areas. Additional exploration, as described in our proposal, is recommended to delineate and better characterize the existing fill.
Current Ground Cover	Predominately grassed with woodland preserve west of the proposed development area. There is a catch basin within a closed depression adjacent to Timber Ridge Drive along with existing asphalt pavement, concrete curbs, and gravel access roads.
Existing Topography Google Earth PRO™ USGS Topographic Map ANCHORAGE, KY 1/1/1987	Site grades range from approximately elevation 460 feet on the eastern portion of the site sloping down to approximately elevation 430 toward the woodland preserve area and tributary of Harrods Creek. From review of the ***Detailed Development Plan DDP***, contours indicate existing slopes of up to 30% in the vicinity of the proposed retaining wall at the west side of the proposed development. The existing slopes are discussed in the **Steep Slope** section.
Geology KGS Geologic Map ANCHORAGE, KY GQ-906	Based on our experience and review of Kentucky Geological Survey (KGS) mapping, the site is located within an area of Outwash underlain by bedrock of the Laurel Dolomite formation. There are no sinkholes mapped by the KGS West of US Highway 42 within about a mile of the site The Laurel Dolomite is reported by the KGS to have a moderate potential for karst development. Below existing fill, our exploration encountered alluvial clays with varying sand content grading into sand and gravel outwash deposits. Dolomitic bedrock was encountered at depths of 27 to 30½ feet below existing site grade.

We also collected photographs at the time of our field exploration program. Representative photos are provided in our **Photography Log**.

PROJECT DESCRIPTION

Our initial understanding of the project was provided in our proposal and was discussed during project planning. Much of the project information, including building construction, structural loading, site grading, and finished floor elevation was unknown at the time of this report. Based on the preliminary nature of the project information provided, we request the opportunity to review project details as they progress and update our recommendations, accordingly Our understanding of the project conditions is as follows:

Item	Description
Information Provided	E-mail request for proposal from LDG Development February 21, 2022, which included: ■ Description of requested scope, ■ Image from Lojic map outlining the site (3 parcels), ■ ***Detailed Development Plan DDP*** prepared by Sabak Wilson Lingo revised March 25, 2022. Additional project details were discussed during a conference call February 24, 2022 with Laura Barlow, Ted Payne (Architect), and Bryce Fuller (Civil). Updated DDP was provided by Kelli Jones of Sabak Wilson Lingo April 14, 2022.
Project Description	Multi-family residential development with paved parking and drive areas.
Proposed Structure	Three-story structure with approximate footprint of 69,674 square feet
Finished Floor Elevation	Not available at the time of this report.
Maximum Loads	Based on discussion with the Project Structural Engineer, CW Yong, PE with Genesis, we understand that maximum structural loading for continuous wall footings will be on the order of 3 kips per linear foot (klf) and up to 100 kips for columns.
Grading/Slopes	Site grading plans were not available at the time of this report. Based on existing site grades, we anticipate grading will be limited to ±2 feet cut/fill
Below-Grade Structures	Not anticipated
Free-Standing Retaining Walls	Proposed retaining walls are planned along the existing slopes to the western side of the proposed development area. At the time of this report, the proposed site characterization and geotechnical engineering services for the retaining wall has not been authorized.
Pavements	Paved driveway and parking will be constructed around the proposed building. We assume both rigid (concrete) and flexible (asphalt) pavement sections should be considered. We anticipated less than 50,000 ESALs. The pavement design period is 20 years.
Estimated Start of Construction	Unknown at the time of this report.

GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of site preparation and foundation options. Conditions encountered at each exploration point are indicated on the individual logs. The individual logs can be found in the **Exploration Results** section and the GeoModel can be found in the **Figures** section of this report.

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

Model Layer	Layer Name	General Description
1	**Existing Fill**	Clay, with sand, gravel, and debris including asphalt and brick
2	**Stiff Clay**	Lean Clay (CL), with silt and sand, stiff to very stiff, brown
3	**Sand**	Sand with Silt (SP-SM), trace gravel, loose to medium dense, brown
4	**Bedrock**	Dolomite, slightly weathered, medium strong, gray

The SPT borings were observed for groundwater while drilling and after completion of borings. The water levels can be found on the logs in **Exploration Results**. Perched groundwater should also be expected within the existing fill. Groundwater level fluctuations should be expected to occur due to seasonal variations in rainfall, runoff and other factors not evident at the time our exploration was performed. Therefore, groundwater may be encountered during construction or at other times in the life of the structure. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

The shear wave velocity cross-sections are displayed on **Exploration Results**. The approximate top of bedrock was interpreted along the seismic lines based on velocity values and boring logs. The interpreted top of bedrock indicates a potential cutter/pinnacle profile commonly associated with karst terrain. In general, low velocity zones (blue to light green on the color scale) are indicative of overburden, clay seams, potential voids, and weathered/fractured rock. Higher velocity zones (dark green to red on the color scale) are indicative of competent bedrock.

GEOTECHNICAL OVERVIEW

The near surface, silty soils could become unstable with typical earthwork and construction traffic, especially after precipitation events. Effective drainage should be completed early in the construction sequence and maintained after construction to avoid potential issues. If possible, construction should be performed during the warmer and drier times of the year. If construction is performed during the winter months, an increased risk for possible undercutting and replacement of unstable subgrade will persist.

As noted in **Geotechnical Characterization**, our exploration encountered existing fill to depths ranging from about 1½ to 10½ feet. Review of historical aerial imagery in Google Earth PRO™ during proposal preparation identified apparent borrow/waste pits across much of the area proposed for the proposed building. Our exploration confirmed the presence of existing fill which consisted of clay with varying amounts of sand and gravel in addition to debris, including asphalt and brick. Supplemental exploration by test pits, as described in our proposal, is recommended to delineate, and better characterize the existing fill. Additionally, it is recommended that records documenting the fill placement and compaction be requested from the property owner to help evaluate the material and support characteristics. Without these records, and noting the debris within the fill, it should be considered uncontrolled and not suitable for direct support.

The existing fill is not suitable for foundation support, all foundation excavations should be extended to completely penetrate the existing fill. Alternatively, **Ground Improvement** can be implemented to mitigate the uncontrolled fill and increase the allowable bearing capacity. Support of floor slabs and pavements on or above existing fill materials is discussed in this report. However, even with the recommended construction procedures, there is inherent risk for the owner that compressible fill or unsuitable material, within or buried by the fill, will not be discovered. This risk of unforeseen conditions cannot be eliminated without completely removing the existing fill but can be reduced by following the recommendations contained in this report. To take advantage of the cost benefit of not removing the entire amount of undocumented fill, the owner must be willing to accept the risk associated with construction over the undocumented fills following the recommended reworking of the material.

Terracon performed desktop review and field reconaissance of areas at the site proposed for development with slopes at grades of 20% or greater as indicated by the ***Detailed Development Plan DDP*** prepared by Sabak Wilson Lingo revised March 25, 2022. From review of elevation contours and field reconaissance, the slopes appear to be generally stable. There is an existing cut/fill access road along the slope near the northern part of the site. During our review, we did not observe any indications of deep-seated slope instability or recent landslide features (i.e. scarps, toe bulges, ect.). As development plans proceed past due diligence, Terracon recommends geotechnical exploration of the proposed retaining wall area to perform slope stability analyses and provide geotechnical recommendations for retaining wall design and construction for stability for the proposed pavement and building foundations.

As noted in the **Site Conditions**, the site is underlain by dolomite of the Laurel Dolomite formation which is reported to have a moderate karst potential. The MASW cross-sections include an interpreted top of bedrock based on the measured shear wave velocities, which indicates a variable cutter/pinnacle profile, weathered/fractured rock, and potential clay seams/voids commonly associated with karst terrain. We did not observe any surficial indications of sinkholes at the site during field reconaissance and note that KGS has not mapped sinkholes within about a mile of the site West of US Highway 42 where the dolomite is overlain by glacial outwash and alluvium.

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

STEEP SLOPE ASSESSMENT

The Louisville Metro Land Development Code (November 2021) requires review of steep slopes. In accordance with the LDC Chapter 4 Part 7 Development on Steep Slopes, Terracon has performed desktop review and field reconaissance of areas at the site proposed for development with slopes at grades of 20% or greater as indicated by the ***Detailed Development Plan DDP*** prepared by Sabak Wilson Lingo revised March 25, 2022. Many of the areas identified as steep slopes are within the proposed woodland preserved area (WPA) and tree canopy which will not be disturbed. The remaining steep slope areas are generally located along and west (outside) of the proposed edge of pavement. Site photos are included in the **Photography Log**.

From review of elevation contours and field reconaissance, the slopes appear to be generally stable. There is an existing cut/fill access road along the slope near the northern part of the site. During our review, we did not observe any indications of deep-seated slope instability or recent landslide features (i.e. scarps, toe bulges, ect.). We did observe rip-rap sized stone that appears to have been placed on the surface of the slope behind one of the residences, which may be an indication of previous instability or erosion.

The proposed site development and grading include a retaining wall in the vicinity of the existing steep slope to facilitate and increase stability for the proposed development. As construction plans are developed, Terracon recommends geotechnical exploration of the proposed retaining wall area to perform slope stability analyses and provide geotechnical recommendations for retaining wall design and construction for stability for the proposed pavement and building foundations.

Slope stability analyses take into consideration material strength, presence and orientation of weak layers, water (piezometric) pressures, surcharge loads, the slope geometry, and proximity to the stream at the toe of the slope. Mathematical computations are performed using computer-assisted simulations to calculate a Factor of Safety (FS). Minor changes to slope geometry, surface water flow and/or groundwater levels could result in slope instability. Reasonable FS values are dependent upon the confidence in the parameters utilized in the analyses performed, among other factors related to the project itself.

EARTHWORK

Earthwork is anticipated to include clearing and grubbing, excavations, and fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria, as necessary, to render the site in the state considered in our geotechnical engineering evaluation for foundations, floor slabs, and pavements.

Site Preparation

As an initial measure of site preparation, existing pavements, vegetation/root mat, topsoil, and any other surficial deleterious material should be completely removed to expose the underlying soil subgrade in the proposed construction areas.

Removal and/or relocation of any “to be abandoned” utilities should also be performed prior to rough site grading activities. We would anticipate removal and relocation, or re-routing, of any existing utilities and catch basins which currently exist within the footprint of the proposed development area that would interfere with new construction. Any abandoned underground pipes, left in place, should be fully grouted. Excavations created due to utility relocations should be backfilled with granular engineered fill material, placed and compacted in accordance with the recommendations provided in the following paragraphs or with lean concrete or flowable fill. If lean concrete is used as backfill, the contractor should refer to the project drawings to confirm that the concrete backfill materials will not conflict with any new item installations or construction. Backfill above utilities to be abandoned in place by grouting should be evaluated in area where these materials will provide subgrade support for new fill or structures. Unsuitable existing backfill should be undercut and replaced with engineered fill.

As noted in **Geotechnical Characterization**, our exploration encountered existing fill to depths ranging from about 1½ to 10½ feet. The existing fill is not suitable for foundation support and foundation excavations should be extended to completely penetrate the existing fill or **Ground Improvement** can be implemented to mitigate the existing fill. If the owner elects to construct the floor slabs above existing fill, once stripping and excavation to rough grade has been completed, the area should be undercut 2 feet below the design subgrade and 10 feet beyond the lateral limits of the building area. If the owner elects to construct pavements above existing fill, the fill can be judged for stability by proofrolling.

Following stripping and undercut of existing fill or other unsuitable material and prior to placing any fill, the subgrade should be proofrolled with an adequately loaded vehicle such as a fully-loaded tandem-axle dump truck. The proofrolling should be performed under the direction of the Geotechnical Engineer. Areas excessively deflecting under the proofroll should be delineated and subsequently addressed by the Geotechnical Engineer. Such areas should either be removed and backfilled with engineered fill. Excessively wet or dry material should either be removed, or moisture conditioned and recompacted. Once unsuitable materials have been remediated, and the subgrade has passed the proofroll test, the existing and undocumented fill that was removed can be evaluated for reuse as structural fill.

Fill Material Types

Fill required to achieve design grade should be classified as structural fill and general fill. Structural fill is material used below, or within 10 feet of structures, pavements or constructed slopes. General fill is material used to achieve grade outside of these areas. Earthen materials used for structural and general fill should meet the following material property requirements:

Soil Type [1]	USCS Classification	Acceptable Locations
Well graded granular	SW or GW [2]	All locations and elevations
Low Plasticity Cohesive	CL, CL-ML (LL<40, PI<25)	All locations and elevations greater than 3 feet below mat foundations
High Plasticity Cohesive	CH, MH (LL > 50)	Not recommended for use as structural fill
On-Site Soils	CL-ML, SP-SM, GP	On-site soils typically appear suitable for reuse as structural fill following moisture conditioning.

1. Structural fill should consist of approved materials free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the Geotechnical Engineer for evaluation prior to use.
2. Crushed limestone aggregate, limestone screenings, or granular material such as sand, gravel or crushed stone. Free-draining granular material, such as used for capillary break beneath the floor slab, should have less than 5% low plasticity fines.

Fill Compaction Requirements

Structural and general fill should meet the following compaction requirements.

Item	Structural Fill	General Fill
Maximum Lift Thickness	8 inches or less in loose thickness when heavy, self-propelled compaction equipment is used 4 to 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used	Same as Structural fill
Minimum Compaction Requirements [1, 2, 3]	98% of max. below foundations and within 1 foot of finished pavement subgrade 95% of max. above foundations, below floor slabs, and more than 1 foot below finished pavement subgrade	92% of max.

Item	Structural Fill	General Fill
Water Content Range [1]	Low plasticity cohesive: -2% to +3% of optimum Granular: -3% to +3% of optimum	As required to achieve min. compaction requirements

1. Maximum density and optimum water content as determined by the standard Proctor test (ASTM D 698).
2. High plasticity cohesive fill should not be compacted to more than 100% of standard Proctor maximum dry density.
3. If the granular material is a coarse sand or gravel, or of a uniform size, or has a low fines content, compaction comparison to relative density may be more appropriate. In this case, granular materials should be compacted to at least 70% relative density (ASTM D 4253 and D 4254).

Utility Trench Backfill

For low permeability subgrades, utility trenches are a common source of water infiltration and migration. Utility trenches penetrating beneath the building should be effectively sealed to restrict water intrusion and flow through the trenches, which could migrate below the building. The trench should provide an effective trench plug that extends at least 5 feet from the face of the building exterior. The plug material should consist of cementitious flowable fill or low permeability clay. The trench plug material should be placed to surround the utility line. If used, the clay trench plug material should be placed and compacted to comply with the water content and compaction recommendations for structural fill stated previously in this report.

Grading and Drainage

All grades must provide effective drainage away from the building during and after construction and should be maintained throughout the life of the structure. Water retained next to the building can result in soil movements greater than those discussed in this report. Greater movements can result in unacceptable differential floor slab and/or foundation movements, cracked slabs and walls, and roof leaks. The roof should have gutters/drains with downspouts that discharge onto splash blocks at a distance of at least 10 feet from the building.

Exposed ground should be sloped and maintained at a minimum 5% away from the building for at least 10 feet beyond the perimeter of the building. Locally, flatter grades may be necessary to transition ADA access requirements for flatwork. After building construction and landscaping have been completed, final grades should be verified to document effective drainage has been achieved. Grades around the structure should also be periodically inspected and adjusted, as necessary, as part of the structure's maintenance program. Where paving or flatwork abuts the structure, a maintenance program should be established to effectively seal and maintain joints and prevent surface water infiltration.

Earthwork Construction Considerations

Shallow excavations for the proposed structure are anticipated to be accomplished with conventional construction equipment. Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of floor slabs. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to floor slab construction.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, “Excavations” and its appendices, and in accordance with any applicable local, and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

Construction Observation and Testing

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of vegetation and topsoil, proofrolling, and mitigation of areas delineated by the proofroll to require mitigation.

Each lift of compacted fill should be tested, evaluated, and reworked, as necessary, until approved by the Geotechnical Engineer prior to placement of additional lifts. Each lift of fill should be tested for density and water content at a frequency of at least one test for every 2,500 square feet of compacted fill in the building areas and 5,000 square feet in pavement areas. One density and water content test should be performed for every 50 linear feet of compacted utility trench backfill.

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

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

GROUND IMPROVEMENT

The existing, undocumented fill can be improved in-place in lieu of over-excavation and replacement. Ground improvement methods are proprietary systems designed by licensed contractors who could provide further information regarding support options. Terracon is available to coordinate feasibility evaluation for **Ground Improvement** options, upon request.

One method for ground improvement which we understand the project structural engineer has experience with is the Geopier® system, which uses replacement Rammed Aggregate Pier (RAP) elements to reinforce good to poor soils. Layers of aggregate are then placed into the drilled hole in lifts of about one foot. A beveled tamper rams each layer of aggregate using vertical impact ramming energy. The tamper densifies aggregate vertically and forces aggregate laterally into cavity sidewalls.

Based on our experience, the encountered subsurface conditions, proposed grading, and structural loading, we expect that with ground improvement implemented, shallow foundations could be designed for allowable bearing capacities in the range of 3,000 to 5,000 psf with settlements of less than 1-inch total and ½-inch differential. For additional information on this ground improvement option, contact:

Geopier® Foundation Company
Mark Salveter, PE, Region Engineer
335 Wellington Way
Springboro, OH 45066
(513) 516-1251
msalveter@geopier.com
www.geopier.com

SHALLOW FOUNDATIONS

The existing undocumented fill is not suitable for foundation support, all foundation excavations should completely penetrate the existing fill to bear on stiff native clays or medium dense sands. If the site has been prepared in accordance with the requirements noted in **Earthwork**, the following design parameters are applicable for shallow foundations.

Design Parameters – Compressive Loads

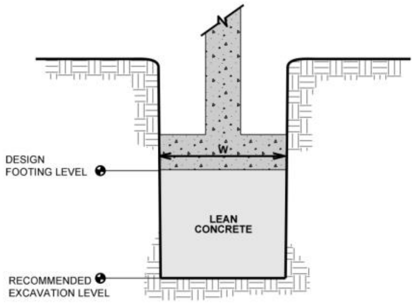
Item	Description
Maximum Net Allowable Bearing pressure [1, 2]	2,000 psf
Required Bearing Stratum [3]	Stiff native soils, engineered fill, or lean concrete.
Minimum Foundation Dimensions	Columns: 24 inches Continuous: 18 inches
Ultimate Passive Resistance [4] **(equivalent fluid pressures)**	240 pcf (cohesive backfill)
Ultimate Coefficient of Sliding Friction [5]	0.3
Minimum Embedment below Finished Grade [6]	24 inches
Estimated Total Settlement from Structural Loads [2]	About 1 inch
Estimated Differential Settlement [2, 7]	About 3/4 of total settlement

1. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. An appropriate factor of safety has been applied. Values assume that exterior grades are no steeper than 20% within 10 feet of structure.
2. Values provided are for maximum loads noted in **Project Description**.
3. Existing fill and otherwise unsuitable or soft soils should be over-excavated and replaced per the recommendations presented in the **Earthwork**.
4. Use of passive earth pressures require the sides of the excavation for the spread footing foundation to be nearly vertical and the concrete placed neat against these vertical faces or that the footing forms be removed and compacted structural fill be placed against the vertical footing face.
5. Can be used to compute sliding resistance where foundations are placed on suitable soil/materials. Should be neglected for foundations subject to net uplift conditions.
6. Embedment necessary to minimize the effects of frost and/or seasonal water content variations. For sloping ground, maintain depth below the lowest adjacent exterior grade within 5 horizontal feet of the structure.
7. Differential settlements are as measured over a span of 50 feet.

Foundation Construction Considerations

As noted in **Earthwork**, the footing excavations should be evaluated under the direction of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry material or any loose/disturbed material in the bottom of the footing excavations should be removed/reconditioned before foundation concrete is placed.

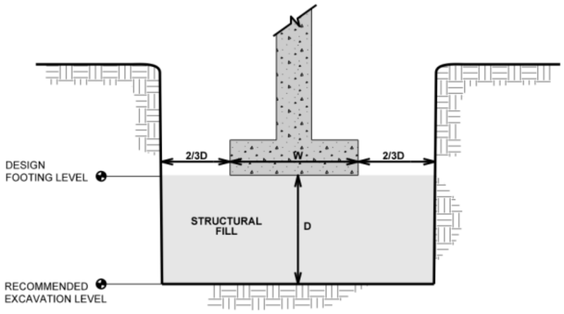
If existing fill or unsuitable bearing soils encountered at the base of the planned footing excavation, the excavation should be extended deeper to suitable soils, and the footings could bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. This is illustrated on the sketch below.



LEAN CONCRETE BACKFILL

NOTE: EXCAVATIONS ARE SHOWN VERTICAL; HOWEVER, THE SIDEWALLS SHOULD BE SLOPED AS NECESSARY FOR SAFETY

Over-excavation for structural fill placement below footings should be conducted as shown below. The over-excavation should be backfilled up to the footing base elevation, with structural fill placed, as recommended in the **Earthwork** section.



OVER-EXCAVATION / BACKFILL ZONE

NOTE: EXCAVATIONS ARE SHOWN VERTICAL; HOWEVER, THE SIDEWALLS SHOULD BE SLOPED AS NECESSARY FOR SAFETY

PAVEMENTS

General Pavement Comments

Pavement designs are provided for the traffic conditions and pavement life conditions as noted in **Project Description** and in the following sections of this report. A critical aspect of pavement performance is site preparation. Pavement designs noted in this section must be applied to the site which has been prepared as recommended in the **Earthwork** section.

Pavement Design Parameters

Design of Asphaltic Concrete (AC) pavements are based on the procedures outlined in the National Asphalt Pavement Association (NAPA) Information Series 109 (IS-109). Design of Portland Cement Concrete (PCC) pavements are based upon American Concrete Institute (ACI) 330; Guide for Design and Construction of Concrete Parking Lots.

A subgrade CBR of 3 was used for the AC pavement designs, and a modulus of subgrade reaction of 110 pci was used for the PCC pavement designs. This value was empirically derived based upon our understanding of the quality of the subgrade as prescribed by the **Site Preparation** conditions as outlined in **Earthwork**. A modulus of rupture of 580 psi was used for pavement concrete.

Minimum Recommended Pavement Section Thickness (inches)

Traffic Area	Pavement Type	Asphalt Concrete Couse		Portland Cement Concrete [1]	Aggregate Base [2]	Total Thickness
		Surface	Base			
Pavement	AC	1.5	2	–	6	9.5
	PCC	–	–	5	6	11
Dumpster Pad	PCC	--	--	7	4	11

1. 4,000 psi compressive strength at 28 days, air entrained mix.
2. KYTC crushed limestone dense graded aggregate

An adequate number of longitudinal and transverse expansion joints should be placed in the rigid pavement in accordance with ACI and/or AASHTO requirements. Control joints should be ¼ of the depth of the concrete and should be cut as soon as the slab can support the weight of a man and saw (usually less than 12 hours). Expansion (isolation) joints must be full depth and should only be used to isolate sections of adjacent slabs or fixed objects within paved areas.

Pavement Maintenance

The pavement section represents minimum recommended thickness and, as such, periodic maintenance should be anticipated. Therefore, preventive maintenance should be planned and provided for through an on-going pavement management program. Maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Maintenance consists of both localized maintenance (e.g., crack and joint sealing and patching) and global maintenance (e.g., surface sealing). Preventive maintenance is usually the priority when implementing a pavement maintenance program. Additional engineering observation is recommended to determine the type and extent of a cost-effective program. Even with periodic maintenance, some movements and related cracking may still occur, and repairs may be required.

Pavement performance is affected by its surroundings. In addition to providing preventive maintenance, the civil engineer should consider the following recommendations in the design and layout of pavements:

- Final grade adjacent to paved areas should slope down from the edges at a minimum 2%.
- Subgrade and pavement surfaces should have a minimum 2% slope to promote proper surface drainage.
- Install below pavement drainage systems surrounding areas anticipated for frequent wetting.
- Install joint sealant and seal cracks immediately.
- Seal all landscaped areas in or adjacent to pavements to reduce moisture migration to subgrade soils.
- Place compacted, low permeability backfill against the exterior side of curb and gutter.
- Place curb, gutter and/or sidewalk directly on clay subgrade soils rather than on unbound granular base course materials.

SEISMIC CONSIDERATIONS

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC). Based on the soil/bedrock properties encountered at the site and as described by the **Exploration Results**, it is our professional opinion that the **Seismic Site Classification is C**. Subsurface exploration at this site included a boring extended to a maximum depth of 42 feet and MASW testing to develop wave velocity profiles along 5 lines. The MASW testing was used to calculate weighted average shear wave velocity for each line and ranged from about 1,400 ft/s to 1,500 ft/s.

FLOOR SLABS

Design parameters for floor slabs assume the requirements for **Earthwork** have been followed. Specific attention should be given to positive drainage away from the structure and positive drainage of the aggregate base beneath the floor slab.

Floor Slab Design Parameters

Item	Description
Floor Slab Support [1]	Existing fill should be undercut at least 2 feet below design subgrade elevation and evaluated for stability prior to backfilling with engineered fill. Minimum 6 inches of free-draining crushed aggregate compacted to at least 95% of ASTM D 698 [2, 3]
Estimated Modulus of Subgrade Reaction [2]	100 pounds per square inch per inch (psi/in) for point loads

1. Floor slabs should be structurally independent of building footings or walls to reduce the possibility of floor slab cracking caused by differential movements between the slab and foundation.
2. Modulus of subgrade reaction is an estimated value based upon our experience with the subgrade condition, the requirements noted in **Earthwork**, and the floor slab support as noted in this table. It is provided for point loads. For large area loads the modulus of subgrade reaction would be lower.
3. Free-draining granular material should have less than 5% fines (material passing the No. 200 sieve). Other design considerations such as cold temperatures and condensation development could warrant more extensive design provisions.

The use of a vapor retarder should be considered beneath concrete slabs on grade covered with wood, tile, carpet, or other moisture sensitive or impervious coverings, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

Saw-cut control joints should be placed in the slab to help control the location and extent of cracking. For additional recommendations refer to the ACI Design Manual. Joints or cracks should be sealed with a water-proof, non-extruding compressible compound specifically recommended for heavy duty concrete pavement and wet environments.

Where floor slabs are tied to perimeter walls or turn-down slabs to meet structural or other construction objectives, our experience indicates differential movement between the walls and slabs will likely be observed in adjacent slab expansion joints or floor slab cracks beyond the length of the structural dowels. The Structural Engineer should account for potential differential settlement through use of sufficient control joints, appropriate reinforcing or other means.

Floor Slab Construction Considerations

Finished subgrade, within and for at least 10 feet beyond the floor slab, should be protected from traffic, rutting, or other disturbance and maintained in a relatively moist condition until floor slabs are constructed. If the subgrade should become damaged or desiccated prior to construction of floor slabs, the affected material should be removed and engineered fill should be added to replace the resulting excavation. Final conditioning of the finished subgrade should be performed immediately prior to placement of the floor slab support course.

The Geotechnical Engineer should approve the condition of the floor slab subgrades immediately prior to placement of the floor slab support course, reinforcing steel, and concrete. Attention should be paid to high traffic areas that were rutted and disturbed earlier, and to areas where backfilled trenches are located.

GENERAL COMMENTS

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

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

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

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

FIGURES

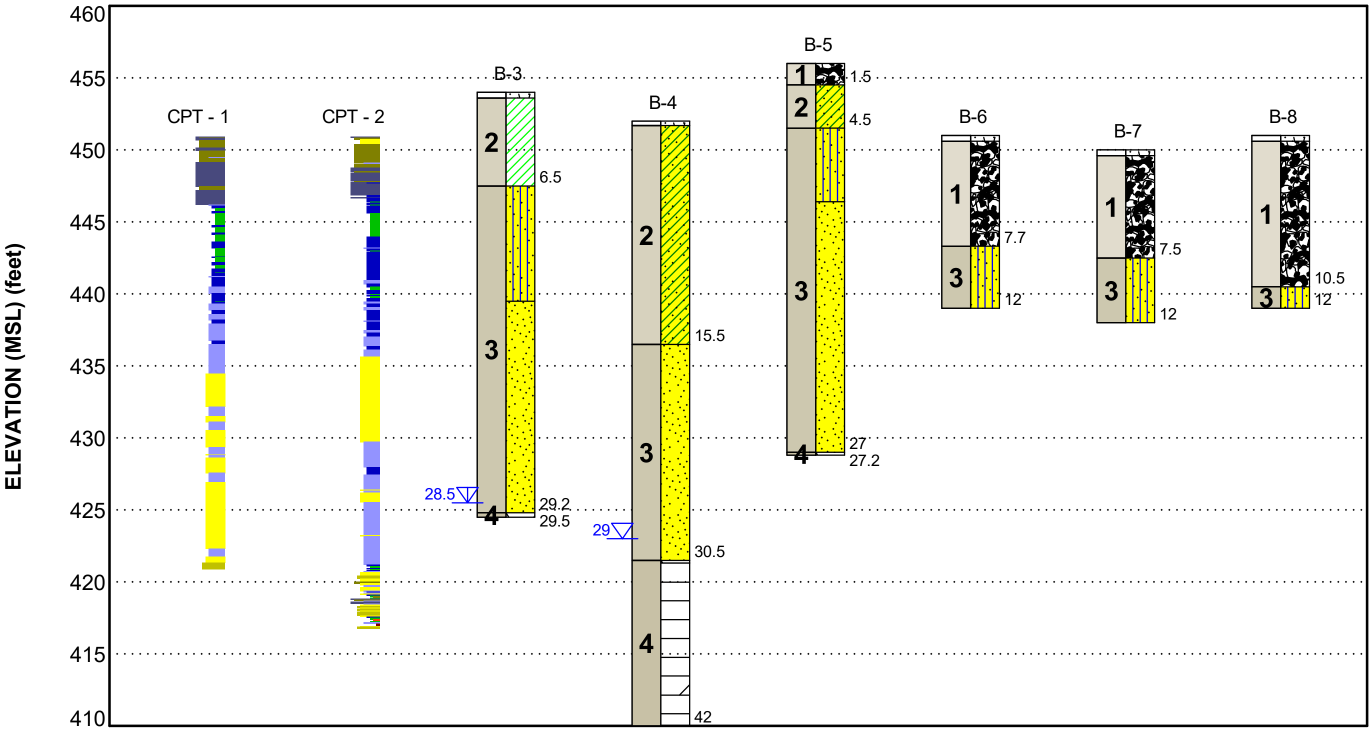
Contents:

GeoModel

GEOMODEL

Prospect Cove ■ Prospect, KY
Terracon Project No. 57225022

Terracon GeoReport



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

Model Layer	Layer Name	General Description
1	**Existing Fill**	Clay, with sand, gravel, and debris including asphalt and brick
2	**Stiff Clay**	Lean clay (CL) with silt and sand, stiff to very stiff, brown
3	**Sand**	Sand with Silt (SP-SM), trace gravel, loose to medium dense, brown
4	**Bedrock**	Dolomite, slightly weathered, medium strong, gray

LEGEND

- ▨ Topsoil
- ▨ Lean Clay
- ▨ Silty Sand
- ▨ Poorly-graded Sand
- ☒ Weathered Rock
- ▨ Sandy Lean Clay
- ☐ Dolomite
- ■ Fill

▽ First Water Observation
▽ Second Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time.
Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

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

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Explorations	Exploration Depth (feet)	Planned Location
2 (CPT Soundings)	30 to 34 feet	Planned building area
8 (SPT borings)	12 to 42 feet	Planned building area

Exploration Layout and Elevations: Terracon personnel provided the exploration layout. Coordinates were obtained with a handheld GPS unit (estimated horizontal accuracy of about ±10 feet) and approximate elevations were obtained from the publicly available database through Google Earth PRO^{TM}. If more precise elevations or layout are desired, we recommend locations be surveyed following completion of fieldwork.

Subsurface Exploration Procedures

Soil Borings with Standard Penetration Testing (SPT): We advanced the borings with a truck-mounted rotary drill rig using hollow stem augers. Four samples were obtained in the upper 10 feet of each boring and at intervals of 5 feet thereafter. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. We observed and recorded groundwater levels during drilling and sampling. For safety purposes, all borings were backfilled with auger cuttings after their completion.

The sampling depths, penetration distances, and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Piezocone Penetration Test (CPTu) Procedures: The Piezocone Penetration Test (CPTu) hydraulically pushes an instrumented cone through the soil while recording to a portable computer. No samples were gathered through this subsurface exploration technique as the soil is tested in its natural state. However, in-situ measurements of tip and side resistance and pore water pressure measurements are recorded practically continuously at 2-cm intervals. We can interpret the data from each test to provide the soil type, relative strength, and other soil parameters. It has been our experience that using in-situ testing methods such as these allows the geotechnical engineer to be much less conservative with design as compared with traditional methods alone.

Seismic Refraction (MASW): The investigation used a seismograph and a linear array of twenty-four 4.5Hz geophones to collect MASW data. MASW is performed by collecting surface waves created by a seismic source consisting of a sledgehammer striking an aluminum ground plate. The data is then processed using dispersion analysis software (SurfSeis, engineered by the Kansas Geological Survey) that extracts the fundamental-mode dispersion curve(s). The curves are inverted and modeled to yield a 1D shear-wave velocity profile along the array for a corresponding depth. Using subsets of geophones, many 1D profiles are created along an array and then combined to yield a 2D profile. These 2D profiles are then examined for changes in shear wave velocities to indicate the top of bedrock and potential karst features within the bedrock.

MASW Survey Line No.	Approximate Orientation	Array Length (feet)	Geophone Spacing (feet)
1	Northeast to Southwest	230	10
2	Northeast to Southwest	230	10
3	Northeast to Southwest	230	10
4	Northeast to Southwest	230	10
5	Northwest to Southeast	230	10

All geophysical testing methods rely on instrument signals to indicate physical conditions in the field. Signal information can be affected by on-site conditions beyond the control of the operator, such as, but not limited to, cultural features, standing water, ground water, buried objects, and cultural noise (e.g. traffic). Interpretation of those signals is based on a combination of known factors combined with the experience of the operator and geophysical scientist evaluating the results. The provided depth measurements are estimations based on an estimation of the electrical properties of the subsurface material.

This report has been prepared for the application discussed and in accordance with generally accepted geophysical practices. No warranties, expressed or implied, are intended or made. The findings presented in this report are based upon the data obtained from the geophysical surveys and from other information discussed in this report. This report does not reflect variations that may occur in areas not tested or inaccessible to the geophysical equipment, across the site, or due to the modifying effects of construction or weather.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil and rock strata, as necessary, for this project. Procedural standards noted below are for reference to methodology in general. In some cases, variations to methods were applied because of local practice or professional judgment. Standards noted below include reference to other, related standards. Such references are not necessarily applicable to describe the specific test performed.

- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D422 Standard Test Method for Particle-Size Analysis of Soils
- ASTM D2938 Unconfined Compressive Strength of Intact Rock Core Specimens

The laboratory testing program often included examination of soil samples by an engineer. Based on the material’s texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System.

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

PHOTOGRAPHY LOG

Photo 1. Site Looking Northwest

Photo 2. Site Looking Northeast Toward Slope at West Perimeter of Proposed Pavement

Photo 3. Site Looking Northeast Toward Existing Access Road on Slope

Photo 4. Site Looking Northwest Toward Slope at West of Proposed Pavement

Photo 5. Site Looking Southwest Toward Slope at West of Proposed Pavement

Photo 6. Site Looking South Toward Slope within the Planned Development

Photo 7. Site Looking Southeast Toward Culvert Headwall Structure at West

Photo 8: Site Location, looking east

Photo 9: Site Location, looking south

Photo 10: Site Location, looking southwest

Photo 11: House within Project Boundary, looking southwest

Photo 12: CPT Sounding B-1, looking southeast

Photo 13: CPT Sounding B-2, looking northeast

Photo 14: Boring B-3, looking southwest

Photo 15: Boring B-4, looking southeast

Photo 16: Boring B-5, looking southwest

SITE LOCATION AND EXPLORATION PLANS

Contents:

Note: All attachments are one page unless noted above.

SITE LOCATION PLAN

Prospect Cove Multi-Family ■ Louisville, Jefferson County, Kentucky
April 22, 2022 ■ Terracon Project No. 57225022

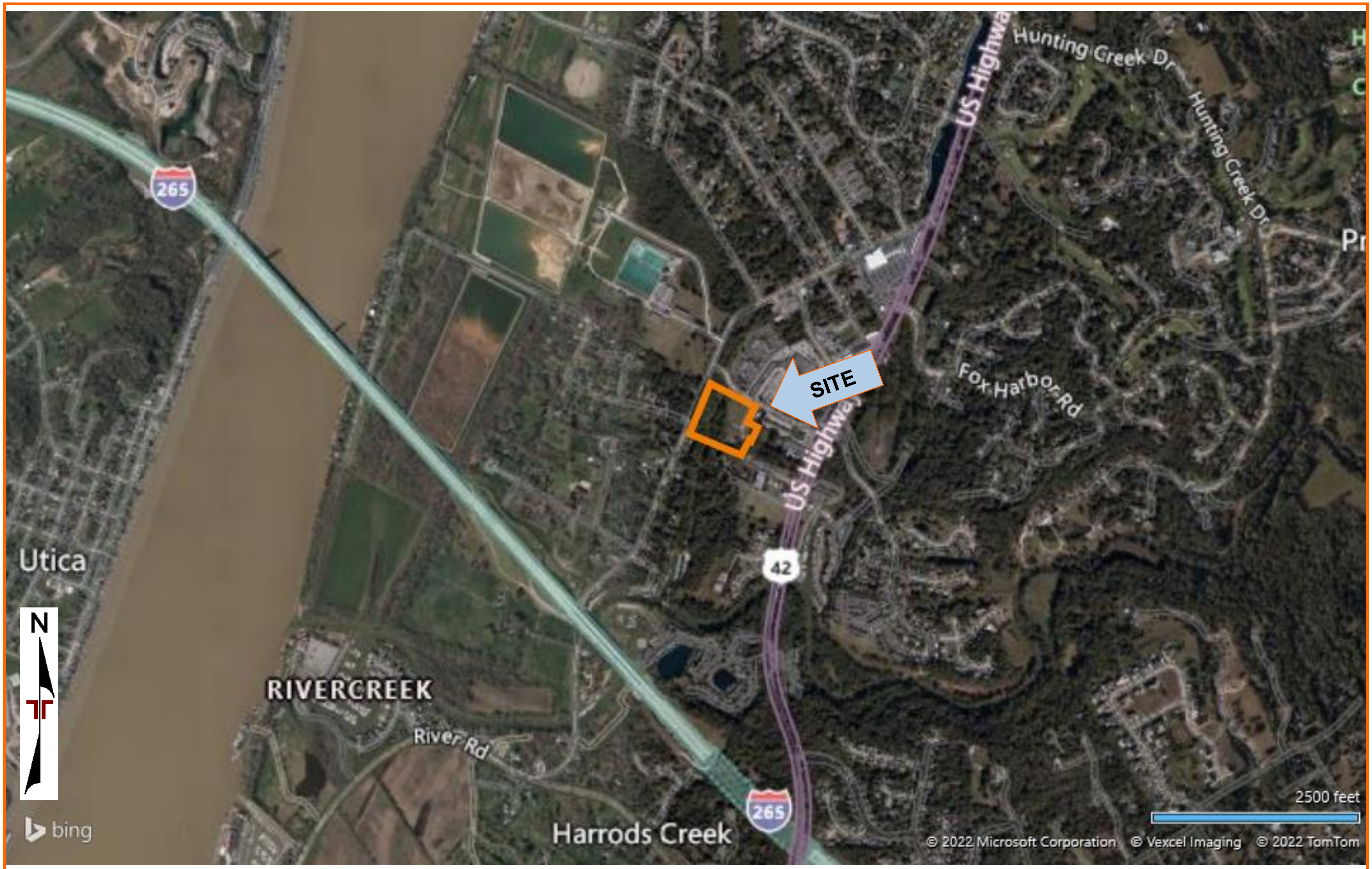


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN

Prospect Cove Multi-Family ■ Louisville, Jefferson County, Kentucky
April 22, 2022 ■ Terracon Project No. 57225022

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

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

Note: All attachments are one page unless noted above.

BORING LOG NO. B-3

PROJECT: Prospect Cove

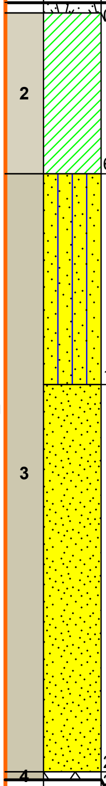
CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

LOCATION See Exploration Plan

Latitude: 38.3383° Longitude: -85.6238°

Approximate Surface Elev.: 454 (Ft.) +/-



DEPTH		ELEVATION (Ft.)
0.4	**TOPSOIL**	453.5+/-
6.5	**LEAN CLAY (CL)**, with silt and sand, brown, stiff	447.5+/-
14.5	**SILTY SAND (SM)**, brown, loose	439.5+/-
29.2	**POORLY GRADED SAND (SP)**, brown, loose to medium dense, fine-grained	425+/-
29.5	**WEATHERED ROCK**, gray, highly weathered	424.5+/-

Auger Refusal at 29.5 Feet

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	LABORATORY HP (tsf)	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
		☒	11	2-3-6 N=9		2.0 (HP)				14.4	
		☒	12	2-6-6 N=12		2.5 (HP)				16.7	21-12-9
5		☒	14	3-5-7 N=12						21.3	
		☒	18	2-4-5 N=9						21.3	
10		☒	17	2-3-4 N=7							
15		☒	18	2-3-4 N=7							
20		☒	18	3-7-12 N=19						0.1	
25		☒	18	3-4-6 N=10							
	▽										

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

Hammer Type: Automatic

Advancement Method:
3 1/4 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with concrete

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

See Supporting Information for explanation of symbols and abbreviations.

Elevations were obtained from Google Earth Pro

Notes:

WATER LEVEL OBSERVATIONS

▽ *At completion of drilling*

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

Boring Started: 03-29-2022	Boring Completed: 03-29-2022
Drill Rig: D-50	Driller: D. Horn
Project No.: 57225022	

BORING LOG NO. B-4

Page 1 of 1

PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

LOCATION See Exploration Plan

Latitude: 38.3386° Longitude: -85.6245°

Approximate Surface Elev.: 452 (Ft.) +/-

MODEL LAYER	DEPTH / DESCRIPTION / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	LABORATORY HP (tsf)	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
2	0.3 **TOPSOIL** 451.5+/-			☒	12	2-3-5 N=8		2.0 (HP)				17.3	
	SANDY LEAN CLAY (CL), with silt, brown, stiff to very stiff			☒	16	3-6-8 N=14		4.0 (HP)				17.5	
		5		☒	14	2-4-4 N=8		2.5 (HP)				23.9	33-17-16
				☒	18	4-8-9 N=17		3.0 (HP)				19.1	
		10		☒	18	3-5-4 N=9		1.5 (HP)					
	15.5 436.5+/-												
3	**POORLY GRADED SAND (SP)**, brown, loose to medium dense, fine-grained	15		☒	18	2-4-6 N=10						0.6	
		20		☒	18	4-6-8 N=14							
		25		☒	18	4-4-5 N=9							
			▽										
	30.5 421.5+/-	30		☒	7	3-50/2"							
4	30.7 **WEATHERED ROCK**, gray, highly weathered 421.5+/-			■	25		57		UC	303.05		906.1	
	DOLOMITE, gray, close fracture spacing, slightly weathered, medium strong	35		■	105		83		UC	970.24		0.0	
		40											
	42.0 410+/-												

Boring Terminated at 42 Feet

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

Hammer Type: Automatic

Advancement Method:
3 1/4 Inch Hollow Stem Auger
NX Rock Coring

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with concrete

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

See Supporting Information for explanation of symbols and abbreviations.

Elevations were obtained from Google Earth Pro

Notes:

WATER LEVEL OBSERVATIONS

▽ *While drilling*

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

Boring Started: 03-29-2022	Boring Completed: 03-29-2022
Drill Rig: D-50	Driller: D. Horn
Project No.: 57225022	

BORING LOG NO. B-5

Page 1 of 1

PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

MODEL LAYER	GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 38.3379° Longitude: -85.6245° Approximate Surface Elev.: 456 (Ft.) +/- DEPTH ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	LABORATORY HP (tsf)	STRENGTH TEST			WATER CONTENT (%)	ATTERBERG LIMITS
										TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)		LL-PL-PI
1		**FILL - EXISTING FILL**, gravel 1.5 454.5+/-			☒	12	3-4-4 N=8		2.0 (HP)				19.1	
2		**SANDY LEAN CLAY (CL)**, with silt, brown, stiff 4.5 451.5+/-			☒	13	6-5-7 N=12		3.0 (HP)				20.4	36-20-16
3		**SILTY SAND (SM)**, brown, loose to medium dense	5		☒	18	2-5-7 N=12						17.0	
		9.6 446.5+/-			☒	18	2-3-3 N=6						24.5	
		POORLY GRADED SAND (SP), brown, loose to medium dense	10		☒	12	2-4-5 N=9							
			15		☒	18	3-5-6 N=11						0.6	
			20		☒	12	2-3-4 N=7							
		with gravel below 24.5 ft. 27.0 429+/-	25		☒	14	3-3-3 N=6							
4		27.2 429+/- **WEATHERED ROCK**, gray, highly weathered, very weak to weak ***Auger Refusal at 27 Feet***												

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

Hammer Type: Automatic

Advancement Method:
3 1/4 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with concrete

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

See Supporting Information for explanation of symbols and abbreviations.

Elevations were obtained from Google Earth Pro

Notes:

WATER LEVEL OBSERVATIONS

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

Boring Started: 03-29-2022
Boring Completed: 03-29-2022
Drill Rig: D-50
Driller: D. Horn
Project No.: 57225022

BORING LOG NO. B-6

Page 1 of 1

PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

LOCATION See Exploration Plan

Latitude: 38.3391° Longitude: -85.6246°

Approximate Surface Elev.: 451 (Ft.) +/-

MODEL LAYER	DEPTH	DESCRIPTION	ELEVATION (Ft.)
	0.4	**TOPSOIL**	450.5+/-
1	7.7	**FILL - EXISTING FILL**, clay with sand, gravel and debris including asphalt and brick, brown	443.5+/-
3	12.0	**SILTY SAND (SM)**, some clay, brown, very loose to medium dense	439+/-

Boring Terminated at 12 Feet

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	LABORATORY HP (tsf)	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
		☒	8	1-2-2 N=4							
		☒	18	6-7-9 N=16							
		☒	14	3-5-7 N=12							
5		☒	15	5-7-10 N=17							
		☒	18	3-5-6 N=11							
10		☒	18	1-2-2 N=4							

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

Hammer Type: Automatic

Advancement Method:
3 1/4 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with concrete

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

See Supporting Information for explanation of symbols and abbreviations.

Elevations were obtained from Google Earth Pro

Notes:

WATER LEVEL OBSERVATIONS

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

Boring Started: 04-07-2022	Boring Completed: 04-07-2022
Drill Rig: D-50	Driller: D. Horn
Project No.: 57225022	

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 57225022 PROSPECT COVE.GPJ TERRACON_DATATEMPLATE.GDT 4/14/22

BORING LOG NO. B-7

Page 1 of 1

PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

LOCATION See Exploration Plan

Latitude: 38.3388° Longitude: -85.6246°

Approximate Surface Elev.: 450 (Ft.) +/-

MODEL LAYER	GRAPHIC LOG	DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	LABORATORY HP (tsf)	STRENGTH TEST TEST TYPE	STRENGTH TEST COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
1		0.4 **TOPSOIL** 449.5+/-			☒	14	3-5-9 N=14							
		FILL - EXISTING FILL, clay with sand, gravel and debris including asphalt, brown			☒	15	14-14-11 N=25							
					☒	14	3-5-5 N=10							
			5		☒	10	5-5-6 N=11							
		7.5 442.5+/-												
3		**SILTY SAND (SM)**, some clay, brown, loose			☒	18	2-3-5 N=8							
			10											
		12.0 438+/-			☒	18	1-2-2 N=4							

Boring Terminated at 12 Feet

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

Hammer Type: Automatic

Advancement Method:
3 1/4 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with concrete

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

See Supporting Information for explanation of symbols and abbreviations.

Elevations were obtained from Google Earth Pro

Notes:

WATER LEVEL OBSERVATIONS

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

Boring Started: 04-07-2022	Boring Completed: 04-07-2022
Drill Rig: D-50	Driller: D. Horn
Project No.: 57225022	

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 57225022 PROSPECT COVE.GPJ TERRACON_DATATEMPLATE.GDT 4/14/22

BORING LOG NO. B-8

PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: **6500 Forest Cove Lane**
Prospect, KY

LOCATION See Exploration Plan

Latitude: 38.3388° Longitude: -85.6242°

Approximate Surface Elev.: 451 (Ft.) +/-

MODEL LAYER	GRAPHIC LOG	DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	LABORATORY HP (tsf)	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI
		0.4	**TOPSOIL**	450.5+/-			☒	8	3-7-9 N=16							
1			**FILL - EXISTING FILL**, clay with sand, gravel and debris including asphalt, brown				☒	18	7-12-13 N=25							
							☒	16	3-6-6 N=12							
					5		☒	18	7-8-9 N=17							
			silty sand with asphalt after 7.5'				☒	13	3-4-5 N=9							
		10.5		440.5+/-	10											
3		12.0	**SILTY SAND (SM)**, some clay, brown, loose	439+/-			☒	18	3-6-3 N=9							

Boring Terminated at 12 Feet

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

Hammer Type: Automatic

Advancement Method:
3 1/4 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with concrete

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

See Supporting Information for explanation of symbols and abbreviations.

Elevations were obtained from Google Earth Pro

Notes:

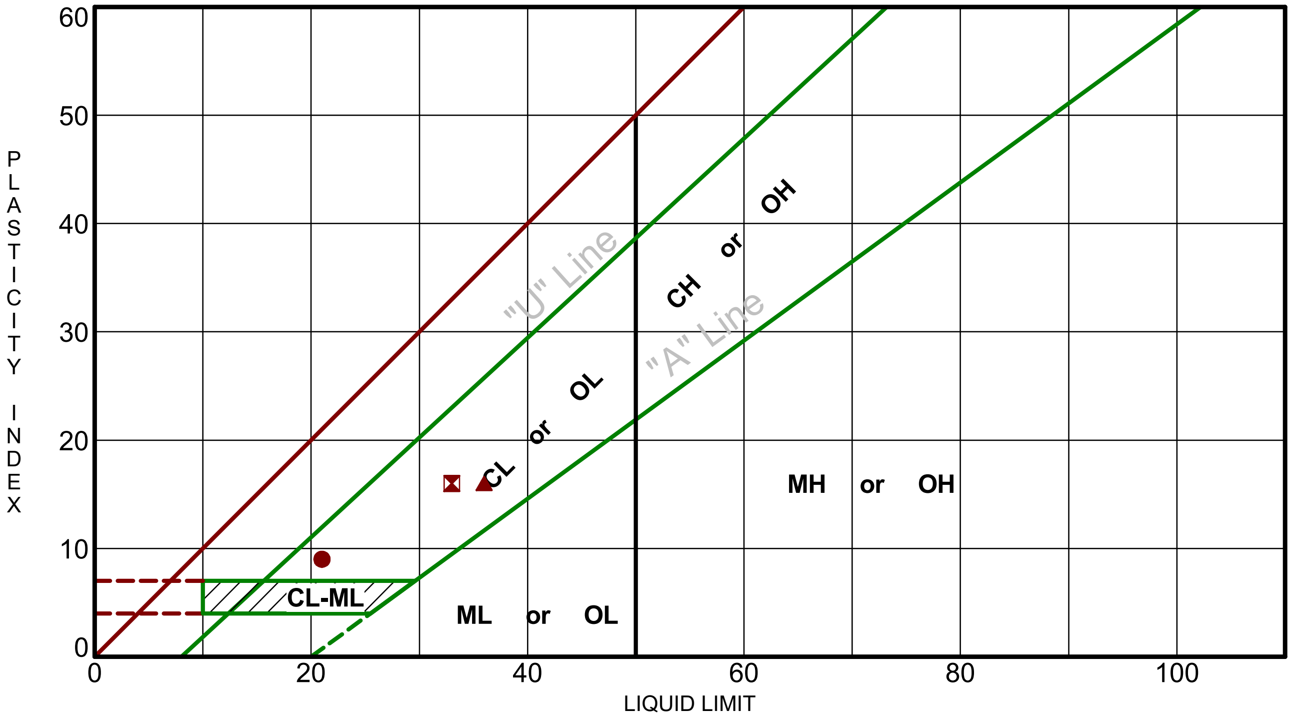
WATER LEVEL OBSERVATIONS

13050 Eastgate Park Way Ste 101
Louisville, KY

Boring Started: 04-07-2022	Boring Completed: 04-07-2022
Drill Rig: D-50	Driller: D. Horn
Project No.: 57225022	

ATTERBERG LIMITS RESULTS

ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	B-3	2.5 - 4	21	12	9			
☒	B-4	5 - 6.5	33	17	16	69.5	CL	SANDY LEAN CLAY
▲	B-5	2.5 - 4	36	20	16			

PROJECT: Prospect Cove

SITE: 6500 Forest Cove Lane
Prospect, KY

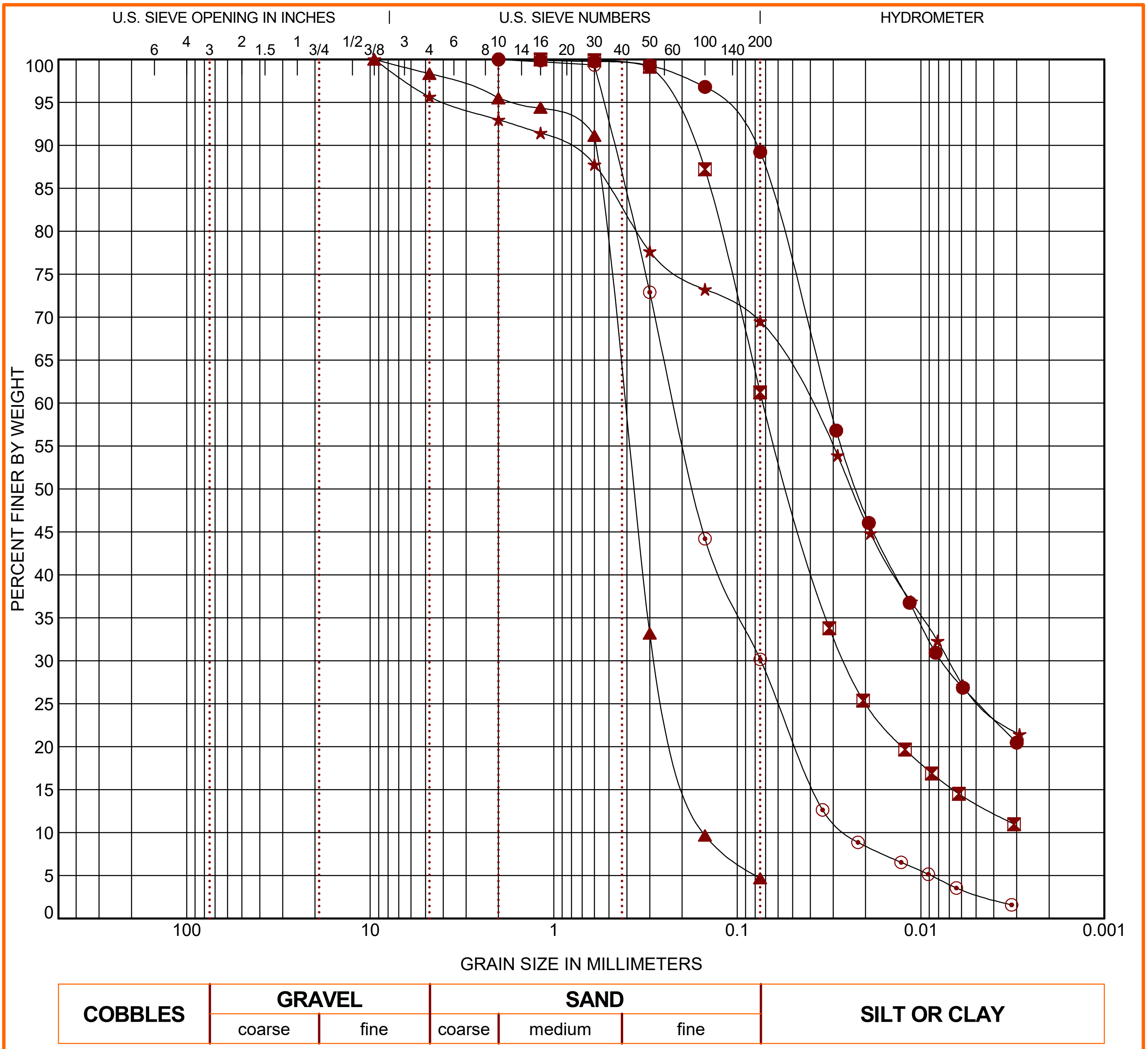
Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

PROJECT NUMBER: 57225022

CLIENT: LDG Development, LLC
Louisville, KY

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	B-3	4.5 - 6		21.3					
☒	B-3	7 - 8.5		21.3					
▲	B-3	19.5 - 21	POORLY GRADED SAND (SP)					1.19	2.73
★	B-4	5 - 6.5	SANDY LEAN CLAY (CL)	23.9	33	17	16		
⊙	B-4	15 - 16.5						1.00	8.73

	Boring ID	Depth	D_{90}	D_{50}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	B-3	4.5 - 6	0.081	0.022	0.008		0.0	10.8	63.9		25.3
☒	B-3	7 - 8.5	0.176	0.053	0.026		0.0	38.7	47.8		13.4
▲	B-3	19.5 - 21	0.592	0.367	0.273	0.152	1.7	93.7		4.7	
★	B-4	5 - 6.5	0.905	0.024	0.007		4.3	26.1	43.7		25.8
⊙	B-4	15 - 16.5	0.47	0.173	0.074	0.025	0.0	69.8	27.3		2.8

PROJECT: Prospect Cove

PROJECT NUMBER: 57225022

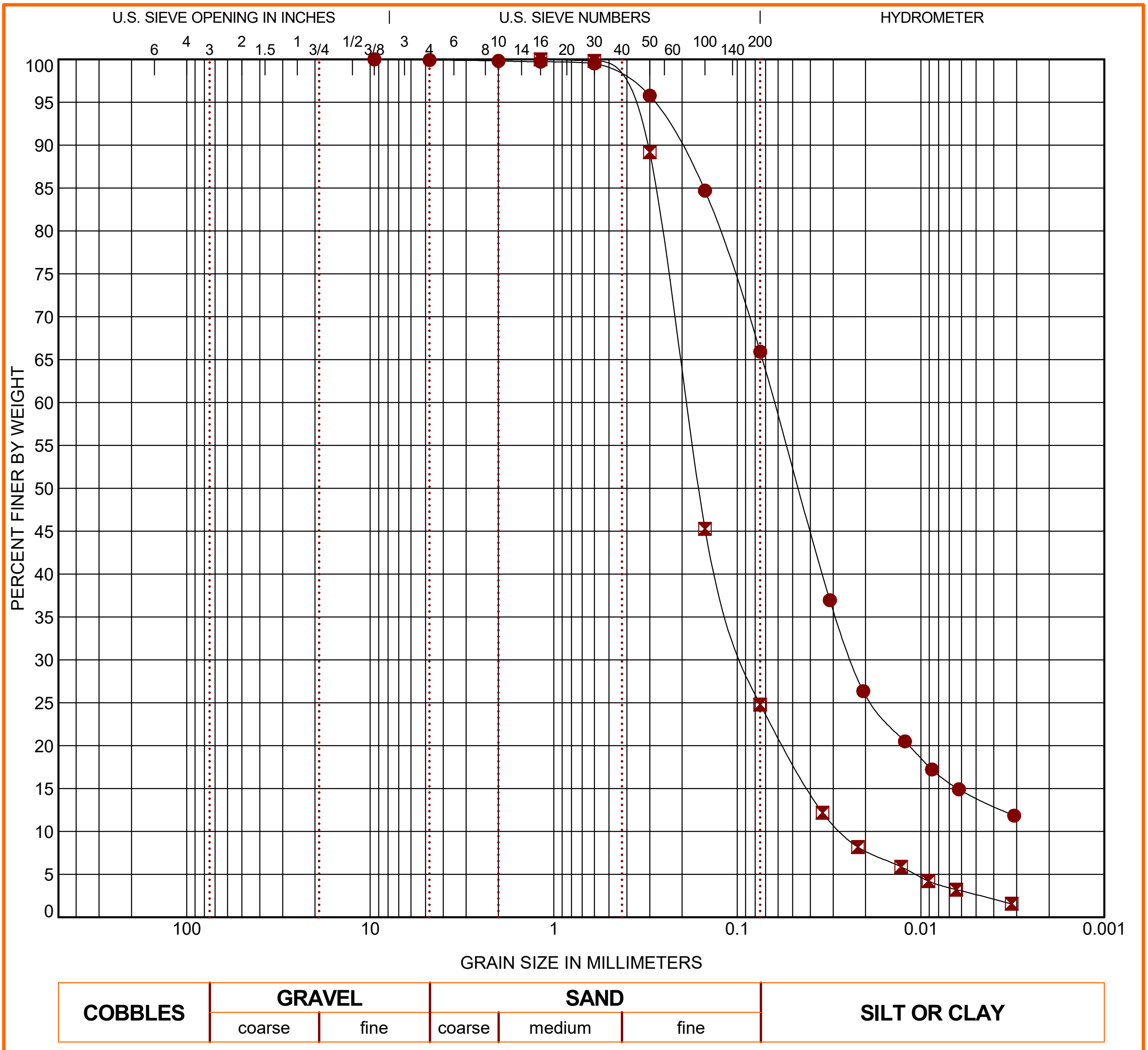
SITE: 6500 Forest Cove Lane
Prospect, KY

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

CLIENT: LDG Development, LLC
Louisville, KY

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	B-5	7 - 8.5		24.5					
☒	B-5	14.5 - 16						1.57	7.03

	Boring ID	Depth	D_{90}	D_{50}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	B-5	7 - 8.5	0.209	0.046	0.024		0.1	34.0	52.0		14.0
☒	B-5	14.5 - 16	0.317	0.162	0.089	0.027	0.0	75.2	22.2		2.6

PROJECT: Prospect Cove

SITE: 6500 Forest Cove Lane
Prospect, KY

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

PROJECT NUMBER: 57225022

CLIENT: LDG Development, LLC
Louisville, KY

CPT LOG NO. CPT - 1

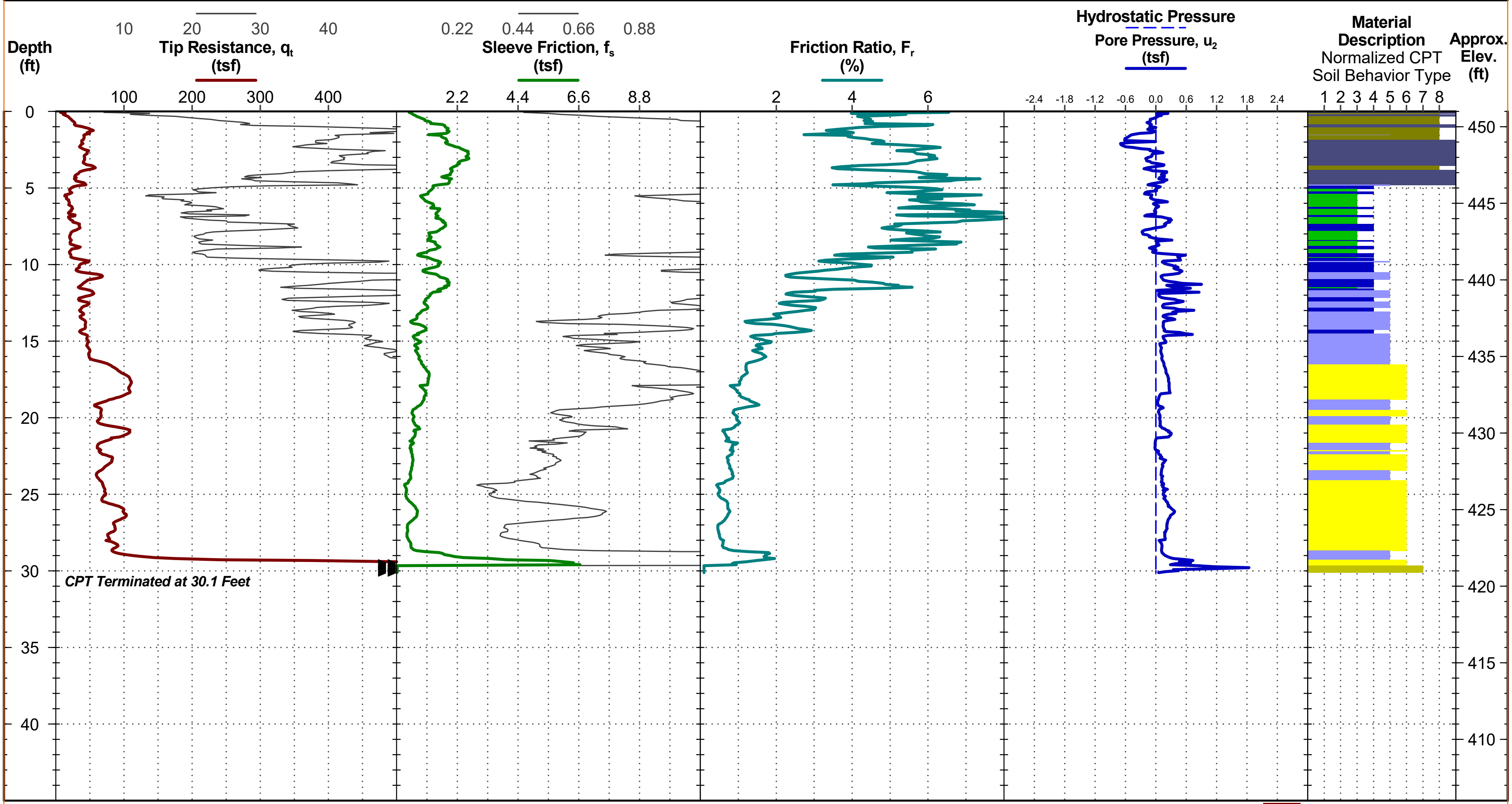
PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

TEST LOCATION: See Exploration Plan

Approx. Surface Elev: 451 ft +/-
Latitude: 38.33890034°
Longitude: -85.62402588°

SITE: 6500 Forest Cove Lane
Prospect, KY



See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).
Elevations were obtained from Google Earth Pro

CPT sensor calibration reports available upon request.

🟥	1 Sensitive, fine grained
🟧	2 Organic soils - clay
🟩	3 Clay - silty clay to clay
🟦	4 Silt mixtures - clayey silt to silty clay
🟪	5 Sand mixtures - silty sand to sandy silt
🟨	6 Sands - clean sand to silty sand
🟨	7 Gravelly sand to dense sand
🟫	8 Very stiff sand to clayey sand
⬛	9 Very stiff fine grained

WATER LEVEL OBSERVATION

▼

(used in normalizations and correlations)

Probe no. DPG1470 with net area ratio of 0.807
U2 pore pressure transducer location
Manufactured by Vertek; calibrated 6/9/2020
Tip and sleeve areas of 15 cm^2 and 225 cm^2
Ring friction reducer with O.D. of 2.0 in

13050 Eastgate Park Way Ste 101
Louisville, KY

CPT Started: 3/29/2022

CPT Completed: 3/29/2022

Rig: CPT-713

Operator: M. May

Project No.: 57225022

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CPT REPORT 57225022 PROSPECT COVE.GPJ TERRACON_DATATEMPLATE.GDT 4/6/22

CPT LOG NO. CPT - 2

Page 1 of 1

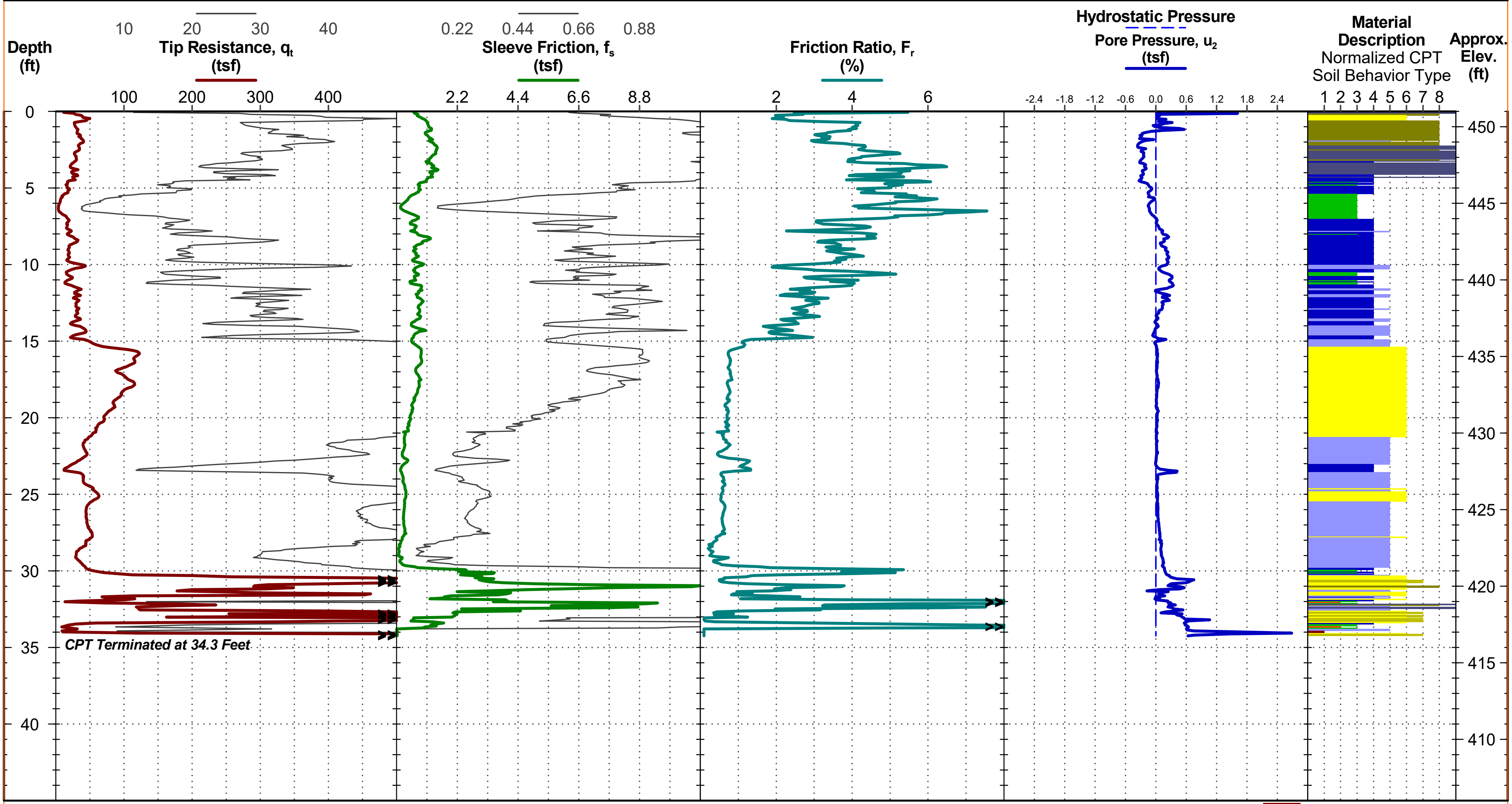
PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

TEST LOCATION: See Exploration Plan

Approx. Surface Elev: 451 ft +/-
Latitude: 38.339198°
Longitude: -85.624457°



See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).
Elevations were obtained from Google Earth Pro

CPT sensor calibration reports available upon request.

🟥 1 Sensitive, fine grained
🟧 2 Organic soils - clay
🟩 3 Clay - silty clay to clay
🟦 4 Silt mixtures - clayey silt to silty clay
🟦 5 Sand mixtures - silty sand to sandy silt
🟨 6 Sands - clean sand to silty sand
🟨 7 Gravelly sand to dense sand
🟫 8 Very stiff sand to clayey sand
⬛ 9 Very stiff fine grained

WATER LEVEL OBSERVATION

▼

(used in normalizations and correlations)

Probe no. DPG1470 with net area ratio of 0.807
U2 pore pressure transducer location
Manufactured by Vertek; calibrated 6/9/2020
Tip and sleeve areas of 15 cm^2 and 225 cm^2
Ring friction reducer with O.D. of 2.0 in

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

CPT Started: 3/29/2022	CPT Completed: 3/29/2022
Rig: CPT-713	Operator: M. May
Project No.: 57225022	

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CPT CORRELATIVE PARAMETERS REPORT 57225022 PROSPECT COVE.GPJ TERRACON_DATATEMPLATE.GDT 4/8/22

CPT CORRELATIVE PARAMETER LOG NO. CPT - 1

Page 1 of 1

SEE CPT LOG NO. CPT - 1 FOR DETAILED TEST RESULTS

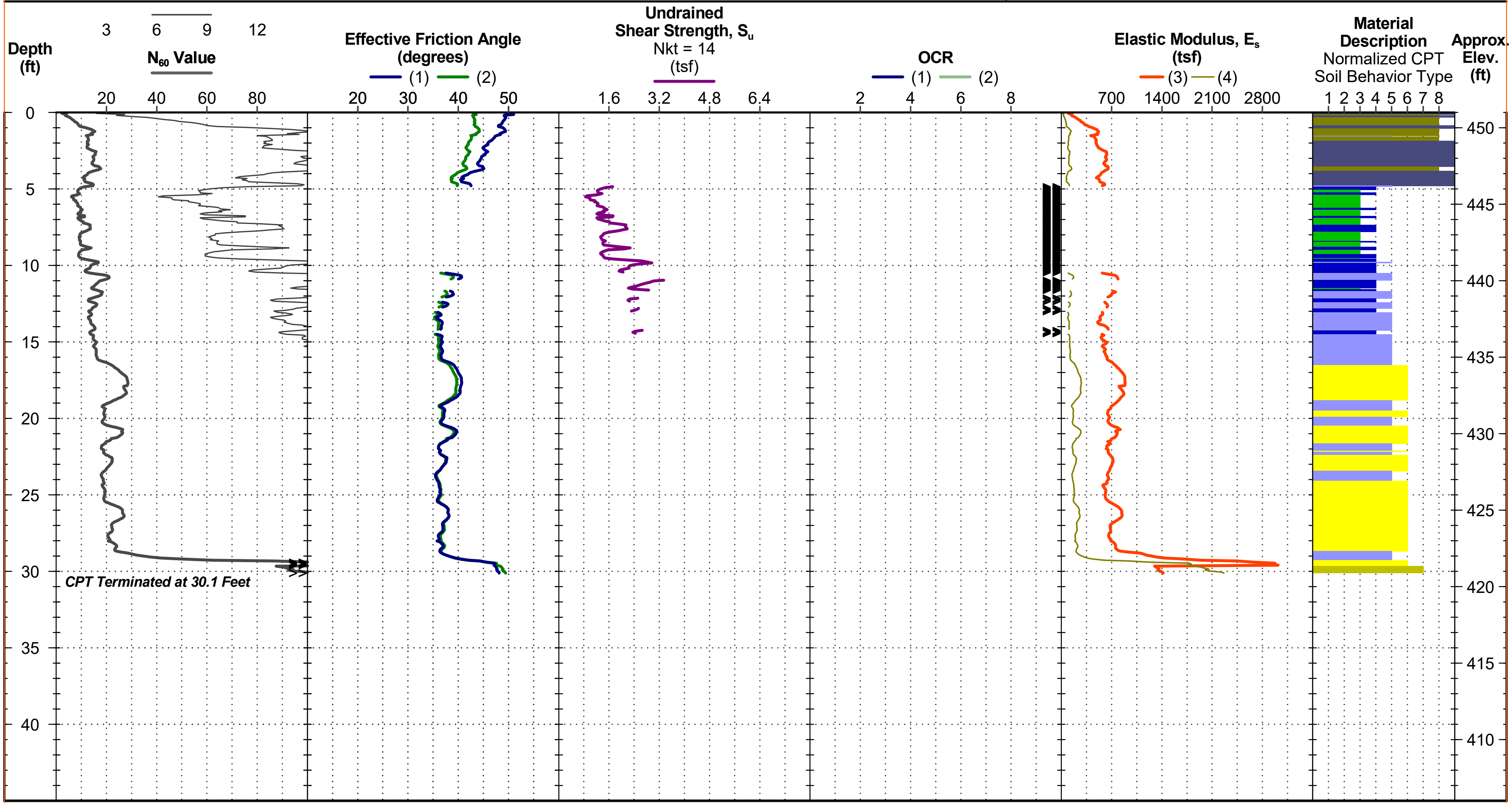
PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

TEST LOCATION: See Exploration Plan

Approx. Surface Elev: 451 ft +/-
Latitude: 38.33890034°
Longitude: -85.62402588°



Tip resistance, sleeve resistance, porewater pressure, and tilt angle are measured. Other parameters presented are derived from interpretations of the measured data, based upon published correlations, but do not necessarily represent actual values that would be derived from direct testing.

WATER LEVEL OBSERVATION

▼

(used in normalizations and correlations; See Supporting Information)

Notes:
Probe no. DPG1470 with net area ratio of 0.807
Manufactured by Vertek; calibrated 6/9/2020
Tip and sleeve areas of 15 cm^2 and 225 cm^2
Ring friction reducer with O.D. of 2.0 in

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

CPT Started: 3/29/2022

CPT Completed: 3/29/2022

Rig: CPT-713

Operator: M. May

Project No.: 57225022

CPT CORRELATIVE PARAMETER LOG NO. CPT - 2

Page 1 of 1

SEE CPT LOG NO. CPT - 2 FOR DETAILED TEST RESULTS

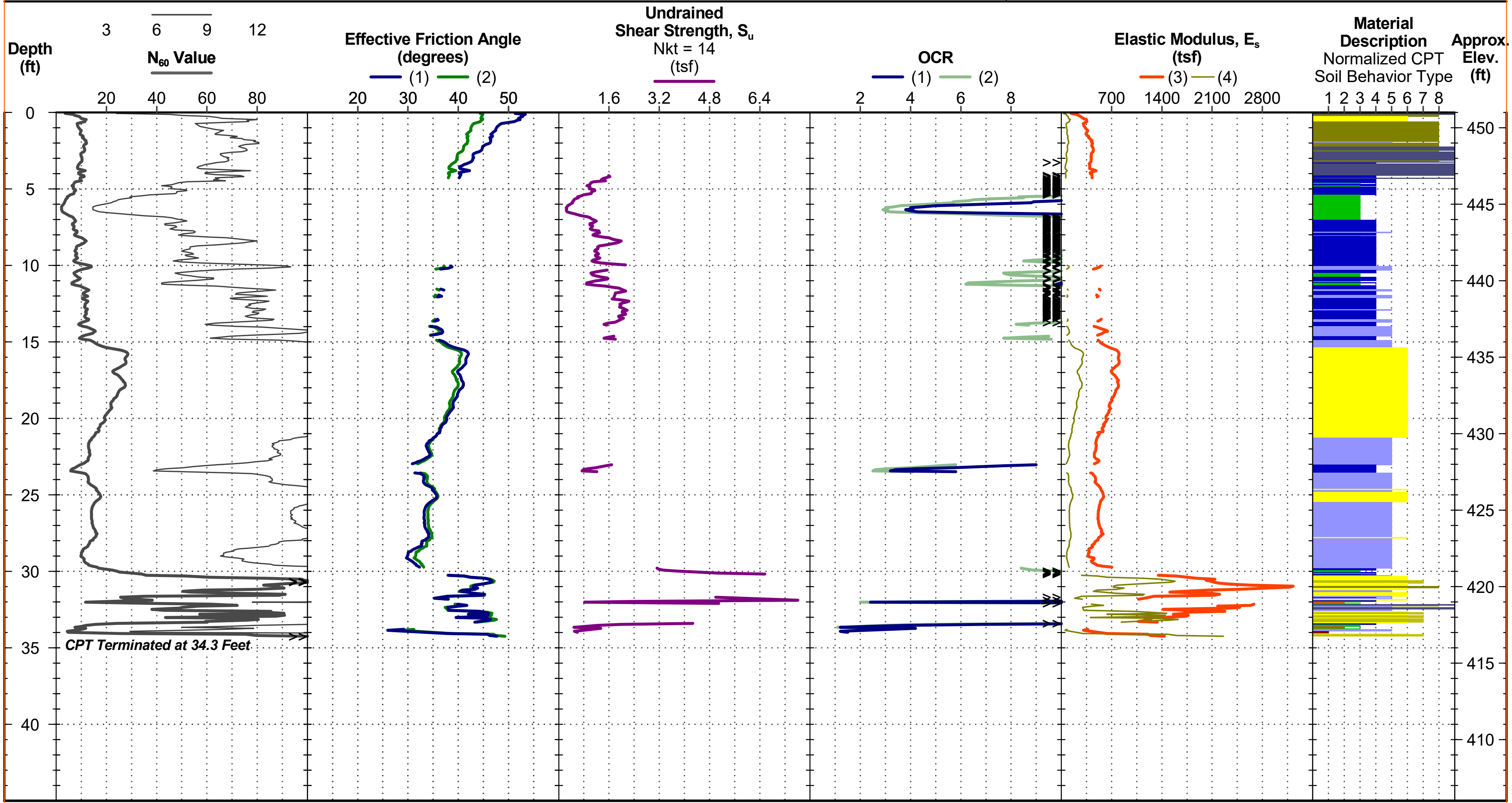
PROJECT: Prospect Cove

CLIENT: LDG Development, LLC
Louisville, KY

SITE: 6500 Forest Cove Lane
Prospect, KY

TEST LOCATION: See Exploration Plan

Approx. Surface Elev: 451 ft +/-
Latitude: 38.33919771°
Longitude: -85.62445657°



Tip resistance, sleeve resistance, porewater pressure, and tilt angle are measured. Other parameters presented are derived from interpretations of the measured data, based upon published correlations, but do not necessarily represent actual values that would be derived from direct testing.

WATER LEVEL OBSERVATION

▼

(used in normalizations and correlations; See Supporting Information)

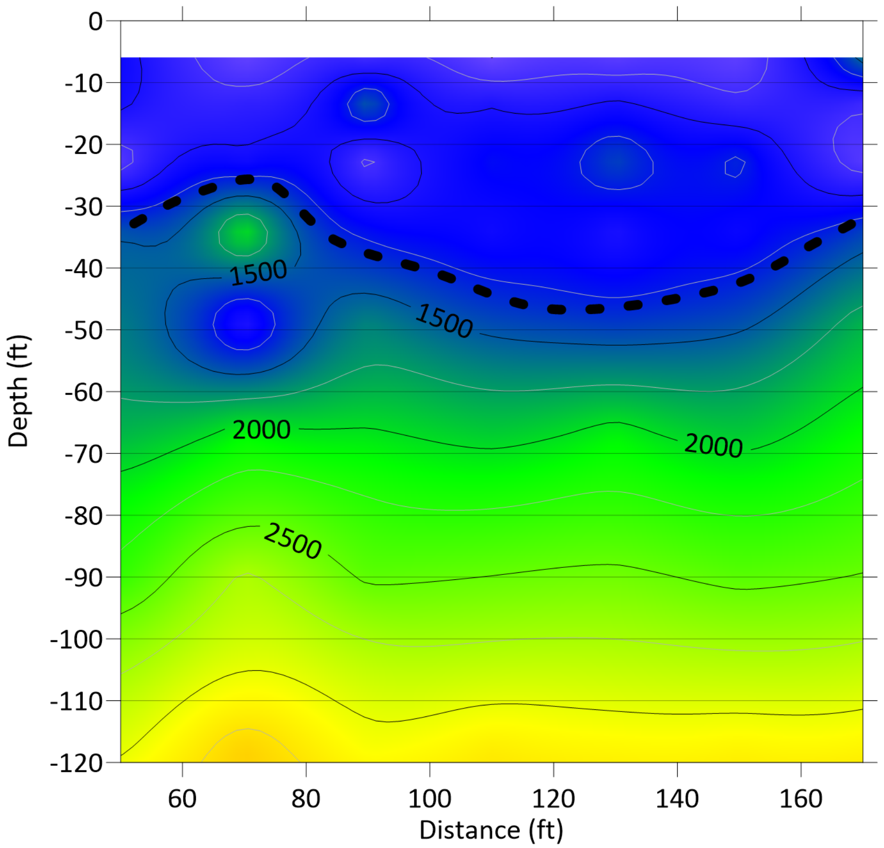
Notes:
Probe no. DPG1470 with net area ratio of 0.807
Manufactured by Vertek; calibrated 6/9/2020
Tip and sleeve areas of 15 cm^2 and 225 cm^2
Ring friction reducer with O.D. of 2.0 in

Terracon
13050 Eastgate Park Way Ste 101
Louisville, KY

CPT Started: 3/29/2022	CPT Completed: 3/29/2022
Rig: CPT-713	Operator: M. May
Project No.: 57225022	

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. CPT CORRELATIVE PARAMETERS REPORT 57225022 PROSPECT COVE.GPJ TERRACON_DATATEMPLATE.GDT 4/8/22

LINE 1
NE-SW



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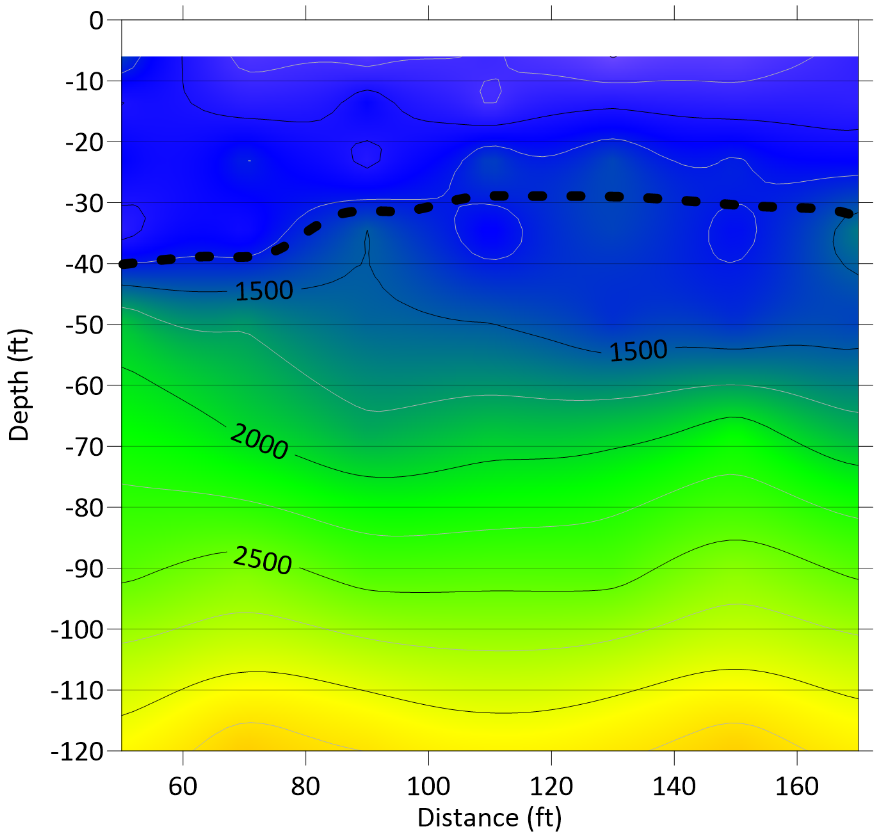
NE-SW



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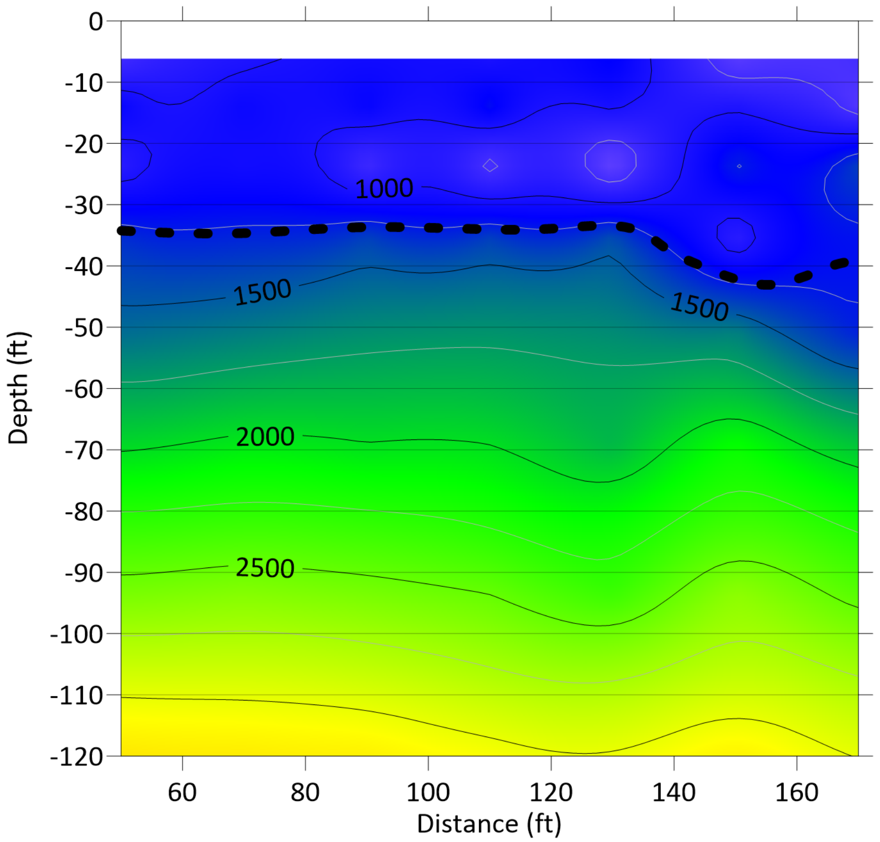
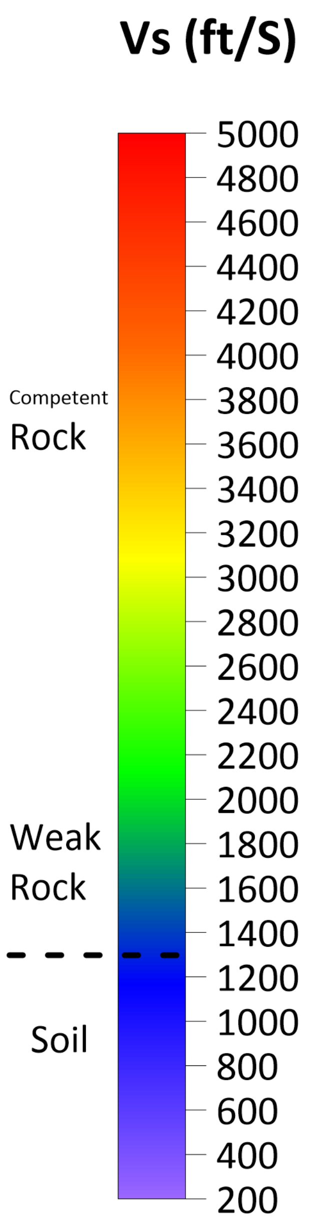
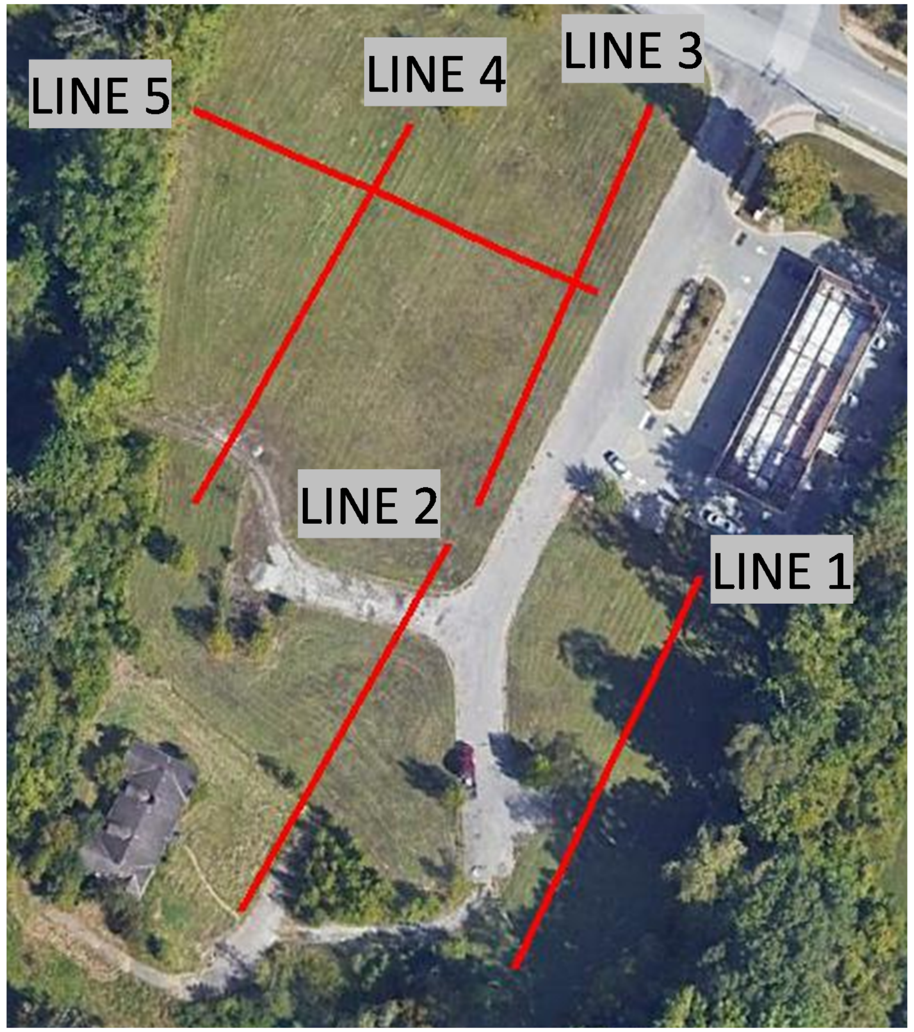
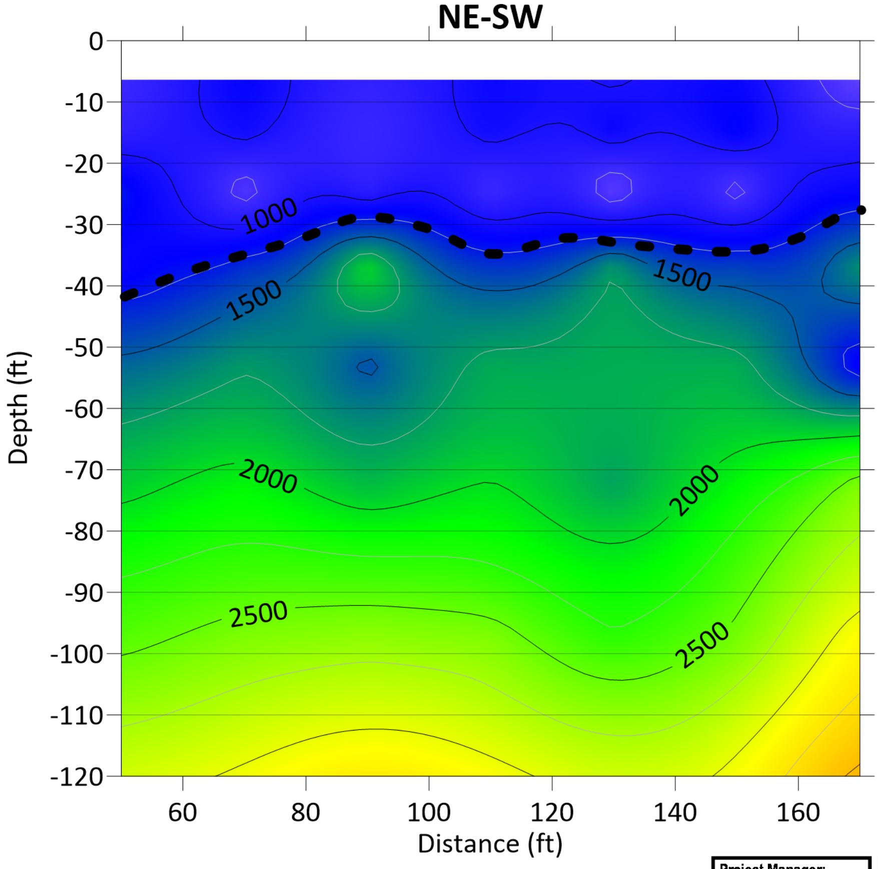
NE-SW



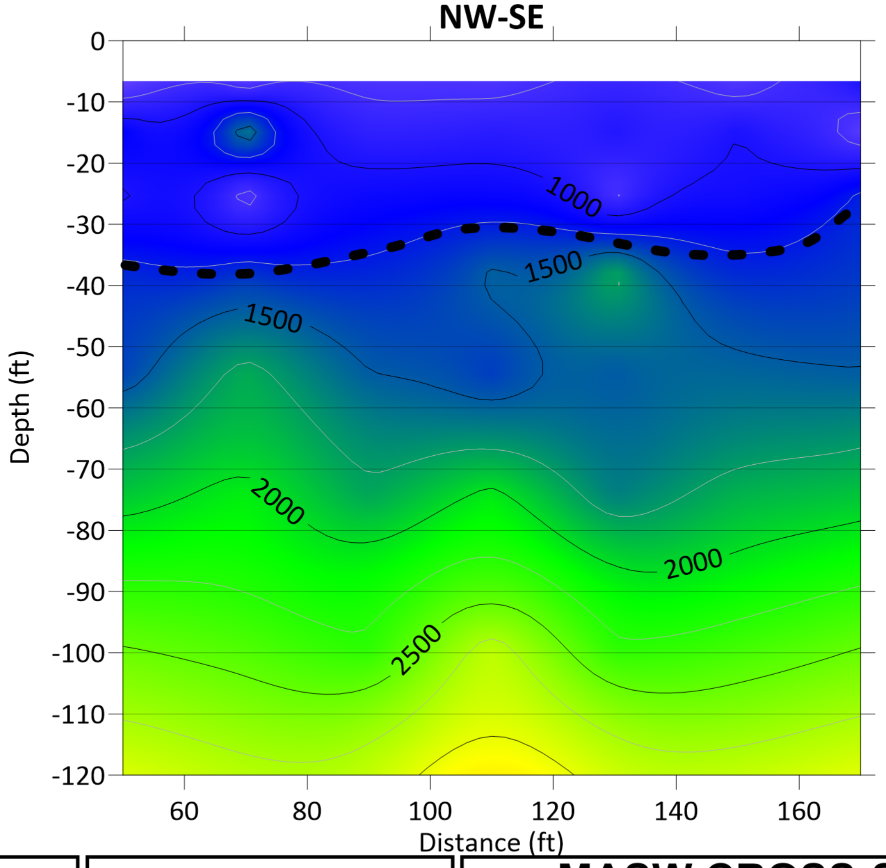




LINE 4
NE-SW



LINE 5
NW-SE



- - - Approximate Top of Bedrock

Project Manager: BT
Drawn by: JCT
Checked by: KJS
Approved by: BT

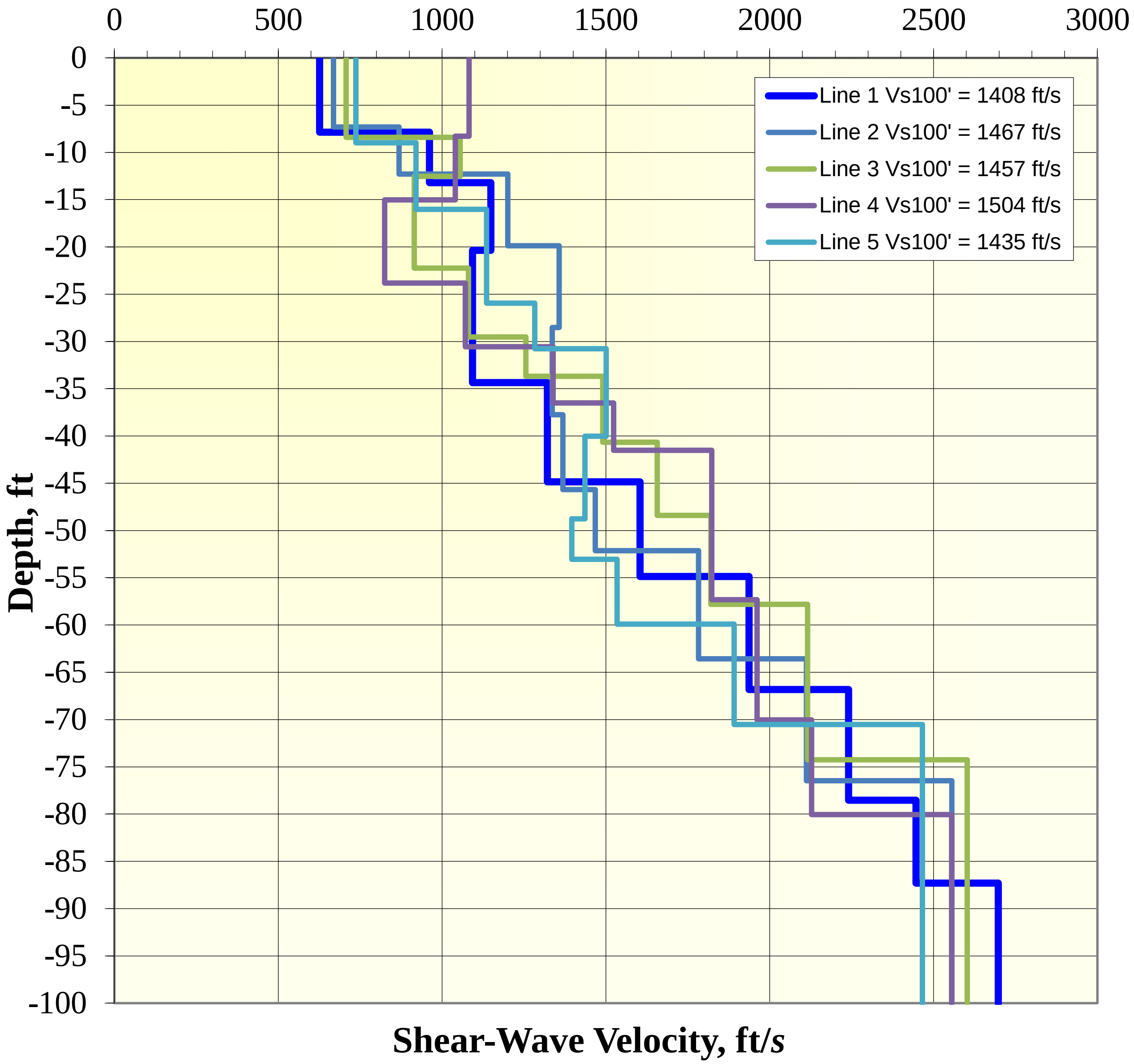
Project No. 57225022
Scale: As Shown
File Name: MASW
Date: 3/28/2022

Terracon
Consulting Engineers & Scientists
611 Lunken Park Drive
Cincinnati, Ohio 45226

MASW CROSS-SECTIONS
Prospect Cove
LDG Development, LLC.
Prospect, Kentucky

Exhibit
1

Shear-Wave Velocity (Vs) Model



SUPPORTING INFORMATION

Contents:

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Prospect Cove 🟧 Prospect, KY

Terracon Project No. 57225022

SAMPLING

▮	Rock Core
☒	Standard Penetration Test

WATER LEVEL

▽	**Water Initially Encountered**
▽	**Water Level After a Specified Period of Time**
▼	**Water Level After a Specified Period of Time**
▨	**Cave In Encountered**

Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.

FIELD TESTS

N	**Standard Penetration Test Resistance (Blows/Ft.)**
(HP)	**Hand Penetrometer**
(T)	**Torvane**
(DCP)	**Dynamic Cone Penetrometer**
UC	**Unconfined Compressive Strength**
(PID)	**Photo-Ionization Detector**
(OVA)	**Organic Vapor Analyzer**

DESCRIPTIVE SOIL CLASSIFICATION

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

LOCATION AND ELEVATION NOTES

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

STRENGTH TERMS

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

RELEVANCE OF SOIL BORING LOG

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

CPT GENERAL NOTES

DESCRIPTION OF MEASUREMENTS AND CALIBRATIONS

To be reported per ASTM D5778:

Uncorrected Tip Resistance, q_c
Measured force acting on the cone divided by the cone's projected area

Corrected Tip Resistance, q_t
Cone resistance corrected for porewater and net area ratio effects
$q_t = q_c + u_2(1 - a)$
Where a is the net area ratio, a lab calibration of the cone typically between 0.70 and 0.85

Pore Pressure, u
Pore pressure measured during penetration
u_1 - sensor on the face of the cone
u_2 - sensor on the shoulder (more common)

Sleeve Friction, f_s
Frictional force acting on the sleeve divided by its surface area

Normalized Friction Ratio, F_r
The ratio as a percentage of f_s to q_t, accounting for overburden pressure

To be reported per ASTM D7400, if collected:

Shear Wave Velocity, V_s
Measured in a Seismic CPT and provides direct measure of soil stiffness

DESCRIPTION OF GEOTECHNICAL CORRELATIONS

Normalized Tip Resistance, Q_{tn}
$Q_{tn} = ((q_t - \sigma_{V0})/P_a)(P_a/\sigma'_{V0})^n$
$n = 0.381(I_c) + 0.05(\sigma'_{V0}/P_a) - 0.15$

Over Consolidation Ratio, OCR
$OCR\ (1) = 0.25(Q_{tn})^{1.25}$
$OCR\ (2) = 0.33(Q_{tn})$

Undrained Shear Strength, S_u
$S_u = Q_{tn} \text{ x } \sigma'_{V0}/N_{kt}$
N_{kt} is a soil-specific factor (shown on S_u plot)

Sensitivity, S_t
$S_t = (q_t - \sigma_{V0}/N_{kt}) \text{ x } (1/f_s)$

Effective Friction Angle, ϕ'
$\phi'\ (1) = \tan^{-1}(0.373[\log(q_t/\sigma'_{V0}) + 0.29])$
$\phi'\ (2) = 17.6 + 11[\log(Q_{tn})]$

Unit Weight, γ
$\gamma = (0.27[\log(F_r)]+0.36[\log(q_t/atm)]+1.236) \text{ x } \gamma_{water}$
σ_{V0} is taken as the incremental sum of the unit weights

Small Strain Shear Modulus, G_0
$G_0\ (1) = \rho V_s^2$
$G_0\ (2) = 0.015 \text{ x } 10^{(0.55Ic + 1.68)}(q_t - \sigma_{V0})$

Soil Behavior Type Index, I_c
$I_c = [(3.47 - \log(Q_{tn})^2 + (\log(F_r) + 1.22)^2]^{0.5}$

SPT N_{60}
$N_{60} = (q_t/atm) / 10^{(1.1268 - 0.2817Ic)}$

Elastic Modulus, E_s (assumes $q/q_{ultimate} \sim 0.3$, i.e. FS = 3)
$E_s\ (1) = 2.6\psi G_0$ where $\psi = 0.56 - 0.33\log Q_{tn,clean\ sand}$
$E_s\ (2) = G_0$
$E_s\ (3) = 0.015 \text{ x } 10^{(0.55Ic + 1.68)}(q_t - \sigma_{V0})$
$E_s\ (4) = 2.5q_t$

Constrained Modulus, M
$M = \alpha_M(q_t - \sigma_{V0})$
For $I_c > 2.2$ (fine-grained soils)
$\alpha_M = Q_{tn}$ with maximum of 14
For $I_c < 2.2$ (coarse-grained soils)
$\alpha_M = 0.0188 \text{ x } 10^{(0.55Ic + 1.68)}$

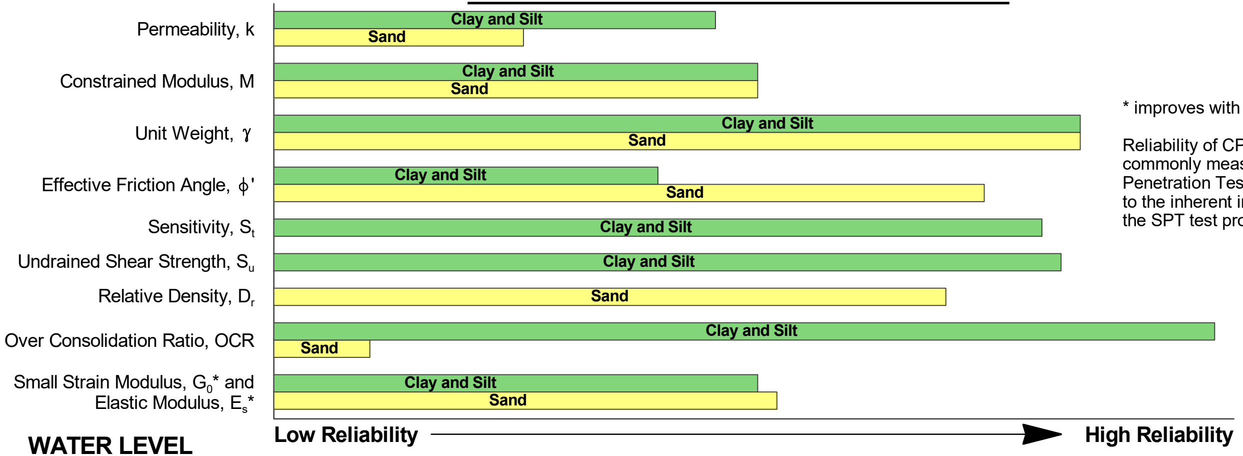
Hydraulic Conductivity, k
For $1.0 < I_c < 3.27$ $k = 10^{(0.952 - 3.04Ic)}$
For $3.27 < I_c < 4.0$ $k = 10^{(-4.52 - 1.37Ic)}$

Relative Density, D_r
$D_r = (Q_{tn} / 350)^{0.5} \text{ x } 100$

REPORTED PARAMETERS

CPT logs as provided, at a minimum, report the data as required by ASTM D5778 and ASTM D7400 (if applicable). This minimum data include q_t, f_s, and u. Other correlated parameters may also be provided. These other correlated parameters are interpretations of the measured data based upon published and reliable references, but they do not necessarily represent the actual values that would be derived from direct testing to determine the various parameters. To this end, more than one correlation to a given parameter may be provided. The following chart illustrates estimates of reliability associated with correlated parameters based upon the literature referenced below.

RELATIVE RELIABILITY OF CPT CORRELATIONS



* improves with seismic V_s measurements

Reliability of CPT-predicted N_{60} values as commonly measured by the Standard Penetration Test (SPT) is not provided due to the inherent inaccuracy associated with the SPT test procedure.

WATER LEVEL

The groundwater level at the CPT location is used to normalize the measurements for vertical overburden pressures and as a result influences the normalized soil behavior type classification and correlated soil parameters. The water level may either be "measured" or "estimated:"

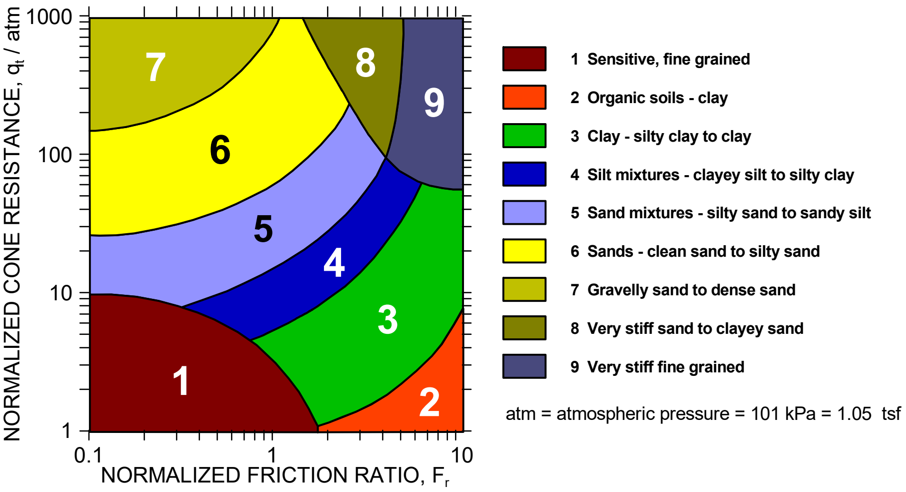
Measured - Depth to water directly measured in the field
Estimated - Depth to water interpolated by the practitioner using pore pressure measurements in coarse grained soils and known site conditions

While groundwater levels displayed as "measured" more accurately represent site conditions at the time of testing than those "estimated," in either case the groundwater should be further defined prior to construction as groundwater level variations will occur over time.

CONE PENETRATION SOIL BEHAVIOR TYPE

The estimated stratigraphic profiles included in the CPT logs are based on relationships between corrected tip resistance (q_t), friction resistance (f_s), and porewater pressure (u_2). The normalized friction ratio (F_r) is used to classify the soil behavior type.

Typically, silts and clays have high F_r values and generate large excess penetration porewater pressures; sands have lower F_r's and do not generate excess penetration porewater pressures. The adjacent graph (Robertson *et al.*) presents the soil behavior type correlation used for the logs. This normalized SBT chart, generally considered the most reliable, does not use pore pressure to determine SBT due to its lack of repeatability in onshore CPTs.



REFERENCES

Kulhawy, F.H., Mayne, P.W., (1997). "Manual on Estimating Soil Properties for Foundation Design," Electric Power Research Institute, Palo Alto, CA.
Mayne, P.W., (2013). "Geotechnical Site Exploration in the Year 2013," Georgia Institue of Technology, Atlanta, GA.
Robertson, P.K., Cabal, K.L. (2012). "Guide to Cone Penetration Testing for Geotechnical Engineering," Signal Hill, CA.
Schmertmann, J.H., (1970). "Static Cone to Compute Static Settlement over Sand," *Journal of the Soil Mechanics and Foundations Division*, 96(SM3), 1011-1043.

Exhibit: C-1

UNIFIED SOIL CLASSIFICATION SYSTEM

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

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

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

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

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

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

[F] If soil contains ≥ 15% sand, add “with sand” to group name.

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

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

[I] If soil contains ≥ 15% gravel, add “with gravel” to group name.

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

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

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

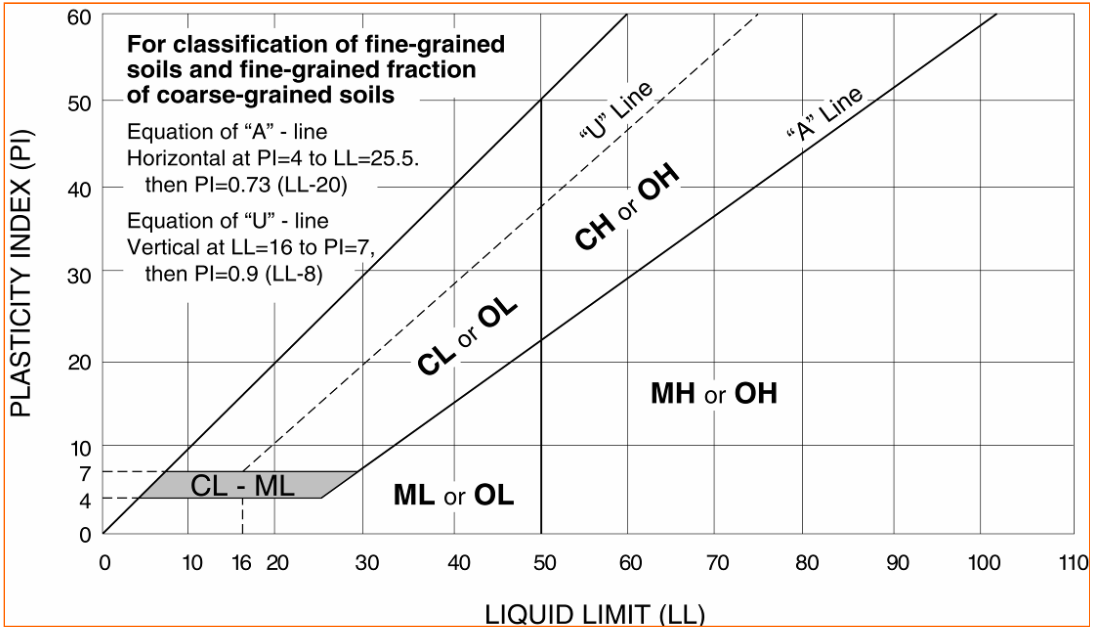
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

[N] PI ≥ 4 and plots on or above “A” line.

[O] PI < 4 or plots below “A” line.

[P] PI plots on or above “A” line.

[Q] PI plots below “A” line.



DESCRIPTION OF ROCK PROPERTIES

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

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

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

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

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

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

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