Geotechnical Engineering Report

The Reserves at Mill Farm – Phase 2
Pella, Iowa
May 16, 2019
Terracon Project No. 08195102-01

Prepared for:
Jones Gillam Renz Architects, Inc.
Salina, Kansas

Prepared by:
Terracon Consultants, Inc.
Des Moines, Iowa
May 16, 2019

Jones Gillam Renz Architects, Inc.
730 N 9th Street
Salina, Kansas 67401

Attn: Mr. Jeffrey S. Gillam - Architect
P: (785) 827 0386
E: jgillam@jgrarchitects.com

Re: Geotechnical Engineering Report
The Reserves at Mill Farm – Phase 2
1123 West 16th Street
Pella, Iowa
Terracon Project No. 08195102-01

Dear Mr. Gillam:

We have performed geotechnical engineering services for the referenced project in general accordance with Terracon Proposal No. P08195102 dated April 25, 2019. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations, floor slabs, and pavements 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.

Ujwala Manchikanti, E.I.
Staff Engineer

Matthew D. Cushman, P.E.
Senior Engineer
REPORT TOPICS

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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

EXPLORATION AND TESTING PROCEDURES
SITE LOCATION AND EXPLORATION PLAN
EXPLORATION RESULTS
SUPPORTING INFORMATION

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

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed structures of The Reserves at Mill Farm Complex-Phase 2 to be located at 1123 West 16th Street in Pella, Iowa. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Site preparation and earthwork
- Excavation considerations
- Foundation design and construction
- Floor slab design and construction
- Pavement design and construction

The geotechnical engineering Scope of Services for this project included the advancement of 12 test borings to depths ranging from approximately 10½ to 20½ feet below existing site grades (bgs).

We previously performed geotechnical services on Phase 1 of this project site (Terracon Project No. 08135021-01, report dated April 18, 2013). Results from this project were reviewed to supplement the findings of the current exploration.

Maps showing the site and boring locations are shown in the Site Location and Exploration Plan section. Results of the laboratory testing performed on soil samples obtained from the site are included on the boring logs in Exploration Results.

SITE CONDITIONS

The following description of site conditions is derived from our field exploration and our review of publicly available geologic and topographic maps.
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The Reserves at Mill Farm – Phase 2 ■ Pella, Iowa
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<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parcel Information</td>
<td>The project is located at 1123 West 16th Street in Pella, Iowa. Latitude/Longitude: 41.4105°, -92.9542° (approximate) See Site Location</td>
</tr>
<tr>
<td>Existing Improvements</td>
<td>None</td>
</tr>
<tr>
<td>Current Ground Cover</td>
<td>Grass-covered open space</td>
</tr>
<tr>
<td>Existing Topography</td>
<td>Relatively flat with site grades varying from about elevation 877 to 882 feet (site datum)</td>
</tr>
</tbody>
</table>

PROJECT DESCRIPTION

Our final understanding of the project conditions is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
</table>
| Project Description       | - Buildings 1 and 2: two-story apartment buildings with footprint areas of about 9,500 square feet each  
                          |   - Building 3: two-story apartment building with a footprint area of about 7,900 square feet, with an attached slab-on-grade single-story fitness center with a footprint area of about 860 square feet.  
                          |   - Parking areas: A 53-stall parking lot between Buildings 2 and 3, and a 43-stall parking lot between Buildings 1 and 3. |
| Building Construction     | The apartment buildings are anticipated to be wood-framed, slab-on-grade (no basement) structures supported on spread footing foundations. |
| Finished Floor Elevation  | - Building 1: 879.5 feet  
                          |   - Building 2: 881.5 feet  
                          |   - Building 3: 879.0 feet |
| (Site Datum)              |                                                                                                                                              |
| Maximum Loads             | - Walls: 2 to 3 kips per linear foot (klf)  
                          |   - Columns: 50 kips  
                          |   - Slabs: 100 pounds per square foot (psf) |
| (estimated by Terracon)   |                                                                                                                                              |
| Grading/Slopes            | - Building 1: Cuts and fills up to 2½ feet are anticipated to achieve the proposed finished floor  
                          |   - Buildings 2 & 3: Fills up to 1 foot are anticipated to achieve the proposed finished floor |
| Pavements                 | We have considered portland cement concrete (PCC) pavement sections for this project. Traffic is expected to consist of personal vehicles (cars/trucks) and occasional garbage and delivery trucks. |
GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface soil and groundwater conditions based on our review of the data, geologic setting, and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical recommendations. Conditions encountered at each exploration point are indicated on the individual logs. The GeoModel and individual logs can be found in Exploration Results.

Stratification boundaries on the GeoModel and boring logs represent the approximate location of changes in soil types; in situ, the transition between materials may be gradual. As noted in General Comments, the characterizations are based on widely spaced exploration points across the site, and variations are likely.

As part of our review, 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.

<table>
<thead>
<tr>
<th>Model Layer</th>
<th>Layer Name</th>
<th>General Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Materials</td>
<td>Root zone of approximately 1½ inches</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Existing Fill</td>
<td>Fat Clays (CH) with traces of sand and organics, encountered to depths of about 1 to 2.5 feet bgs. Dark gray to dark brown.</td>
</tr>
<tr>
<td>2</td>
<td>Upper Clays</td>
<td>Variable clays consisting of fat clays (CH), lean to fat clays (CL/CH), and lean clays (CL), with traces of sand and organics, encountered to depths of about 5 to 5.5 feet bgs. Grayish brown to brownish gray. Generally stiff to very stiff.</td>
</tr>
<tr>
<td>3</td>
<td>Soft Clays</td>
<td>Lean clay (CL), trace sand, encountered to depths of about 12 to 14 feet bgs. Gray brown to brown gray. Generally, very soft to medium stiff.</td>
</tr>
<tr>
<td>4</td>
<td>Lower Clays</td>
<td>Variable clays consisting of fat clays (CH), lean to fat clays (CL/CH), and lean clays (CL) with traces of sand. Grayish brown to light gray. Generally medium stiff to stiff.</td>
</tr>
</tbody>
</table>

The boreholes were observed while drilling and a day after completion of drilling for the presence and level of groundwater. The water levels observed in the boreholes can be found on the boring logs in Exploration Results. Groundwater was observed at depths of about 6 to 8 feet bgs in a majority of the borings, approximately one day after drilling was completed. The Natural Resources Conservation Service Web Soil Survey (WSS) indicates the near surface native soil unit at this site Mahaska silty clay loam. The following table summarizes the properties and qualities of this soil unit as described by the WSS.
Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff, and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structures may be different than the levels indicated on the GeoModel and boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

GEOTECHNICAL OVERVIEW

Existing fill (and possible fill) materials were encountered in the borings performed across the site to depths ranging from about 1 to 2½ feet bgs. Below the existing fill, stiff to very stiff native moderate to high plasticity clays were encountered to depths of about 5 feet. Very soft to medium stiff low plasticity clays were then encountered to depths of about 14 feet bgs. Groundwater was observed as shallow as 6 feet in the boreholes. The Web Soil Survey indicates seasonal groundwater levels at or within about 1 foot of the native ground surface (i.e., 2 to 3 feet bgs).

Support of foundations, floor slabs and pavements on or above existing fill materials is discussed in this report. However, even with the recommended construction procedures, there is an 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.
Floor slabs and pavements supported on high plasticity soils can experience cycles of upward and downward movement due to water content fluctuations that may result in distortion or structural damage to grade-supported structures. This report provides recommendations to help reduce the risk of shrink/swell movement. However, even if these recommendations are followed, some movement should be anticipated.

In addition, samples obtained from depths of about 1 to 3 feet in Borings 1, 2, and 3 appeared desiccated, and similar desiccated soil conditions are likely to be encountered at other locations across the project site. Relatively low moisture content, high plasticity clays increase the risk of movement for lightly loaded foundations, slabs, and pavements due to swelling once these soils are exposed to water and increase in moisture content. Any clays that appear desiccated or that have a low water content (i.e., an in-situ water content that is less than the materials’ plastic limit) should be removed during the site preparation phase.

The recommendations presented in this report regarding high plasticity clay soils are based on our knowledge of the site soil conditions and our experience with similar sites and structures. These recommendations, if followed, will not eliminate the risk of minor movement and cosmetic distress (e.g., cracking in slabs) that is typically considered tolerable for the types of structures planned at this site. The risk of movement could be further reduced if more expensive measures are used during design and construction (e.g., constructing a thicker low plasticity section, structural slabs, etc.).

EARTHWORK

Site Preparation

Site preparation should include stripping of all vegetation, organic soils, root systems, and any soft, frozen or otherwise unsuitable materials from the site surface. Following stripping, the buildings’ footprint, and at least 10 feet beyond the buildings’ perimeter, should be undercut at least two feet below the floor slab bearing elevation (i.e., elevation 877 feet across Building 1, elevation 879 feet across Building 2, and elevation 876.5 feet across Building 3). In areas where placement of at least two feet of low-plasticity structural fill is incidental to site grading, additional undercuts of non-desiccated high plasticity clays below the buildings’ floor slabs is not required. Any soils that appear desiccated or that have a low water content (i.e., an in-situ water content that is less than the materials’ plastic limit) should be undercut during the site preparation phase.

Based on local practices, high-plasticity soils could be left in place beneath pavements, provided the Owner elects to accept the additional risk of pavement distress and maintenance described above. If not, pavement areas should be undercut at least one foot below the final pavement subgrade elevation to remove high plasticity soils.
Alternatively, the on-site high plasticity clays could be modified by incorporation of hydrated lime or portland cement. With this option, we recommend that hydrated lime/portland cement be incorporated into high plasticity clay soils to provide a minimum thickness of two feet of modified clays below floor slabs, or a reduced thickness of modified clays that are topped with other low plasticity structural fill. For estimating purposes, the incorporation rates for either hydrated lime or portland cement for chemical modification are typically 4 to 6 percent (on a dry soil unit rate basis). The use of chemical agents can impact the operation of adjacent facilities (e.g., wind-blown dust), and this should be considered by the designer and contractor.

Following the undercuts described above, we anticipate a majority of the existing fill (and possible fill) materials will be removed below the buildings. Following stripping operations and undercutting of high plasticity soils, the exposed subgrade should be proofrolled to help delineate soft or low-density existing fill materials. Particular attention should be given to areas with existing utility trench backfill. Proofrolling should be accomplished using a fully loaded, tandem axle dump truck or other equipment providing an equivalent subgrade loading (minimum gross weight of 25 tons is recommended for the proofrolling equipment). Unstable areas identified by proofrolling should be undercut to expose stable material and backfilled with low plasticity structural fill.

Prior to placement of fill in areas below design grade and after completion of rough grading in cut areas of the site, the exposed subgrade should be scarified to a depth of 9 inches, moisture conditioned, and compacted to the density and water content ranges recommended in this section. The surficial compaction will aid in providing a firm base for compaction of new fill and delineating soft or disturbed areas that may exist at or near the exposed subgrade level. Unstable areas observed at this time should be improved through use of subgrade stabilization.

**Subgrade Stabilization**

If unsuitable areas are observed, subgrade improvement will then be necessary to establish a suitable subgrade support condition. Terracon should be retained to discuss stabilization options. Potential methods of subgrade improvement are described below. The appropriate method of improvement, if required, would be dependent on factors such as schedule, weather, the size and depth of area to be stabilized, and the nature of the instability. More detailed recommendations can be provided during construction as the need for subgrade stabilization occurs.

- **Scarification and Compaction** – Soils can be scarified, moisture condition (i.e., dried or wetted), and compacted. The success of this procedure depends primarily on favorable weather and sufficient time to manipulate the soils.

- **Undercut and Replacement with Crushed Stone/Aggregate** – The use of crushed stone, crushed concrete, and/or gravel could be considered to improve subgrade stability.
To limit depths of undercuts, the use of a geogrid could be considered after underground work, such as utility construction, is completed. The manufacturer’s specifications for each reinforcement product should be verified prior to material purchase/delivery and placement at this site.

**Chemical Treatment** – Unstable or high-water content clay soils could be chemically dried with hydrated lime, portland cement, or Class C fly ash. Chemical treatment should be performed by a pre-qualified contractor having experience with successfully stabilizing subgrades on similar sized projects with similar soil conditions. The use of chemical agents can impact the operation of adjacent facilities (e.g., wind-blown dust), and this should be considered by the designer and contractor. Terracon should be notified prior to selection of a chemical stabilization agent to allow time for a review the material’s source and chemical constituents data sheet.

### Structural Fill Material Types

High plasticity soils (fat clays) were encountered on this site. The on-site soils do not appear suitable for use as low plasticity structural fill without chemical modification with either hydrated lime or portland cement. We recommend a sample of each material type to be used as structural fill for this project, either from on-site or from an off-site borrow source, be submitted to Terracon for evaluation prior to use on this site.

Structural fill should meet the following material property requirements.

<table>
<thead>
<tr>
<th>Soil Type 1 [1]</th>
<th>USCS Classification</th>
<th>Acceptable Location for Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low plasticity fine-grained 2, 3</td>
<td>CL, ML</td>
<td>Below floor slabs, foundations and pavements</td>
</tr>
<tr>
<td>Moderate to high plasticity fine-grained 4</td>
<td>CL/CH, CH</td>
<td>General site grading fill limited to at least two feet below the buildings’ floor slabs, and at least one foot below pavements (could be used directly below pavements provided the Owner elects to accept additional risk of subgrade volume changes).</td>
</tr>
<tr>
<td>Coarse-grained (granular) 5</td>
<td>GW, GP, GM, GC, SW, SP, SM, SC</td>
<td>Below floor slabs, foundations and pavements</td>
</tr>
</tbody>
</table>
Soil Type | USCS Classification | Acceptable Location for Placement
---|---|---
1. Structural fill should consist of approved materials that are 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 on this site.
2. Fine grained material (e.g., clays) can be difficult to compact in relatively small areas (e.g., excavations for foundations).
3. By our definition, low plasticity materials should have a liquid limit of 45 or less and a plasticity index of 23 or less (ASTM D4318).
4. Recommendations for moderate to high plasticity fine-grained soil apply to on-site materials only. Import of moderate to high plasticity fine-grained soil is not recommended.
5. Specific material requirements will need to be satisfied based on intended use.

### Structural Fill Compaction Requirements

Structural fill should meet the following compaction requirements.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
</table>
| Maximum individual lift thickness | 9 inches or less in loose thickness when heavy, self-propelled compaction equipment is used  
4 inches or less in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used |
| Minimum compaction requirements |  
**Fine-grained soils:**  
95% of maximum  
Not be compacted to more than 100% of maximum since over compacted clays could have increased swell potential.  
**Coarse-grained soils:**  
98% of maximum  
If the 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, coarse-grained soils should be compacted to at least 70% relative density (ASTM D4253 and D4254). |
| Water content range |  
**Fine-grained soils:**  
0 to +4% of optimum  
**Coarse-grained soils:**  
Water content should be maintained at levels satisfactory for compaction to be achieved without the coarse-grained material bulking during placement or pumping when proofrolled.  
1. Maximum density and optimum water content as determined using standard effort (ASTM D698). |
Utility Trench Backfill

All trench excavations should be made with sufficient working space to permit construction, including backfill placement and compaction. If utility trenches are backfilled with relatively clean coarse-grained material, they should be capped with at least 18 inches of fine-grained structural fill to reduce the infiltration and conveyance of surface water through the trench backfill.

Utility trenches are a common source of water infiltration and migration. Utility trenches constructed in fine-grained soils that penetrate beneath the buildings should be effectively sealed to restrict water intrusion and flow through the trenches, which could migrate below the buildings. We recommend constructing an effective clay “trench plug” that consists of low permeability fine-grained soils or flowable fill that extends at least 5 feet out from the face of the buildings’ exterior. The trench plug material should be placed to completely surround the utility line and any coarse-grained (granular) envelope and be placed and compacted as recommended in this report. Care should be taken to not damage the in-place utilities.

Grading and Drainage

During earthwork, the site should be graded to prevent ponding of surface water on the prepared subgrade or in excavations. Surface water should be promptly removed. Water seepage could occur in foundation and utility excavations during construction. Dewatering of excavations during construction should be anticipated and could involve a series of sump pits and pumps within excavations in fine-grained soils.

Final surrounding grades should be sloped away from the planned buildings on all sides to prevent ponding of water next to the structure. Gutters and downspouts that drain water a minimum of 10 feet beyond the footprint of the proposed buildings are recommended. This can be accomplished through the use of downspout extensions or flexible pipes that are designed to attach to the end of the downspout. Flexible pipe should only be used if it is daylighted in such a manner that it gravity-drains collected water.

Planting trees, large shrubs or other vegetation adjacent to structures supported on shallow foundations and/or with grade-supported slabs is not recommended. Trees and large shrubs can develop extensive root systems that can draw moisture from the subgrade soils, causing them to shrink during dry periods of the year. Drying or desiccation of clay soils below shallow foundations and grade-supported floor slabs can result in settlement of the foundations and slabs. Irrigation should be avoided adjacent to the building.

Earthwork Construction Considerations

Unstable subgrade conditions could develop during general construction operations, particularly if the soils are allowed to become saturated and/or subjected to repetitive construction traffic. In
order to improve subgrade stability and help expedite construction, consideration should be given to performing earthwork in the late summer and fall when groundwater levels are generally lower and weather is conducive to drying. Where soft and wet subgrades are encountered, stabilization measures will be required to help provide a stable working base for construction. The use of low contact pressure, track equipment, or remote excavation equipment may be necessary to assist in earthwork operations.

As a minimum, all temporary excavations should be sloped or braced as required by Occupational Safety and Health Administration (OSHA) regulations to provide stability and safe working conditions. Temporary excavations will be required during grading operations and/or installation of utilities. Contractors, by their contract, are usually responsible for designing and constructing stable, temporary excavations and should shore, slope or bench the sides of the excavations as required, to maintain stability of both the excavation sides and bottom. All excavations should comply with applicable local, state and federal safety regulations, including the current OSHA Excavation and Trench Safety Standards.

Upon completion of filling and grading, care should be taken to maintain the subgrade moisture content prior to construction of foundation elements, grade-supported floor slabs, and pavements. Construction traffic over the completed subgrade should be avoided to the extent practical. If the subgrade should become frozen, desiccated, saturated, or disturbed, the affected material should be removed, or these materials should be scarified, moisture conditioned, and compacted prior to floor slab and pavement construction. Consideration could be given to placement of an all-weather crushed stone surface over the building pads to reduce subgrade disturbance prior to floor slab construction.

**Construction Observation and Testing**

Terracon’s involvement during 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.

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer and should include documentation of adequate removal of vegetation and topsoil, undercutting of high plasticity and/or desiccated clays, delineation of areas requiring subgrade stabilization, assessment of existing fill materials, and proofrolling.

Each lift of structural fill should be tested, evaluated, and reworked as necessary until approved by the Geotechnical Engineer prior to placement of additional lifts. Each lift of structural fill should be tested for density and water content at a frequency:
Subgrade Soils – one test for every 2,500 square feet per lift in building areas, and one test for every 5,000 square feet per lift in pavement areas.

Utility Trench Backfill – one test for every 50 linear feet of utility trench length per lift

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

**SHALLOW FOUNDATIONS**

If the site has been prepared in accordance with the requirements noted in *Earthwork*, the following design parameters are applicable for shallow foundations. We’ve considered spread footing foundations will bear at elevation 876 feet, 878 feet, and 875.5 feet, for Buildings 1, 2, and 3, respectively.

**Spread Footing Foundation Design Recommendations**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required bearing materials</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td>■ Stiff native clay soils&lt;br&gt;■ New structural fill extending to stiff native clay soils</td>
</tr>
<tr>
<td><strong>Maximum net allowable bearing pressure</strong>&lt;sup&gt;2, 3&lt;/sup&gt;</td>
<td>1,500 psf&lt;br&gt;30 inches&lt;br&gt;18 inches</td>
</tr>
<tr>
<td><strong>Minimum foundation dimensions</strong></td>
<td>■ Column footings: 30 inches&lt;br&gt;Continuous footings: 18 inches</td>
</tr>
<tr>
<td><strong>Minimum Embedment below finished grade</strong></td>
<td>■ Exterior footings: 42 inches&lt;br&gt;Interior footings in heated areas: 18 inches</td>
</tr>
<tr>
<td><strong>Estimated total settlement</strong>&lt;sup&gt;3, 5&lt;/sup&gt;</td>
<td>1 inch or less&lt;br&gt;7/8 of total settlement</td>
</tr>
<tr>
<td><strong>Estimated differential settlement</strong>&lt;sup&gt;3, 5, 6&lt;/sup&gt;</td>
<td>About 7/8 of total settlement</td>
</tr>
<tr>
<td><strong>Ultimate passive pressure</strong>&lt;sup&gt;7, 8&lt;/sup&gt;</td>
<td>For materials placed adjacent to foundation:&lt;br&gt;■ Fine-grained: 285 pcf&lt;br&gt;■ Coarse-grained: 360 pcf</td>
</tr>
<tr>
<td><strong>Ultimate coefficient of sliding friction</strong></td>
<td>On suitable bearing material: 0.35</td>
</tr>
</tbody>
</table>

1. Unsuitable or soft soils should be undercut and replaced according to the recommendations presented in the *Earthwork* section.
2. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation.
3. Values provided are for maximum loads noted in the *Project Description* section.
4. Embedment necessary to minimize the effects of frost and/or seasonal water content variations.
5. Foundation settlement will depend on the variations within the subsurface soil profile, the structural loading conditions, the embedment depth of the footings, the thickness of structural fill, and the quality of the earthwork operations.

6. Frequent control joints in the structures and sufficiently flexible connections are recommended to accommodate differential settlement across the length of the buildings.

7. 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. Passive resistance in the upper 3½ feet of the soil profile in exterior locations should be neglected due to frost effects.

8. Horizontal movement of the foundation must occur to mobilize passive and sliding resistance.

Spread Footing Foundation Construction Considerations

As noted in Earthwork, the footing excavations should be evaluated under the direction of the Geotechnical Engineer. The use of earth formed “trench” footings generally appears feasible in the on-site soils. However, forming of footings would be required in areas where coarse-grained (granular) materials are used within the recommended low-plasticity zone below floor slabs. 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 unsuitable bearing soils are encountered at the base of the planned footing excavations, corrective measures will be required. The footing excavations should be undercut and widened to allow for structural fill placement below the footings, as shown on the following sketch. The over-excavation should be backfilled up to the footing base elevation with coarse-grained structural fill placed as recommended in the Earthwork section.
FLOOR SLABS

Design parameters for floor slabs expect 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

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor slab support</td>
<td>■ Minimum 4 inches of free-draining granular material (^1)</td>
</tr>
<tr>
<td></td>
<td>■ At least two feet of low plasticity materials should be present below floor slabs (the 4-inch free-draining granular layer is considered to be part of the recommended 2-ft low plasticity material zone)</td>
</tr>
<tr>
<td>Estimated modulus of subgrade reaction (^2)</td>
<td>125 pounds per square inch per inch (psi/in) for point loads</td>
</tr>
</tbody>
</table>

1. Free-draining granular material should have less than 6 percent fines (material passing the No. 200 sieve), e.g., LaDOT granular subbase (Section 4121). Other design considerations such as cold temperatures and condensation development could warrant more extensive design provisions.

2. Modulus of subgrade reaction is an estimated value based on 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.

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.

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 and slab contractor should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

Exterior Slabs and Frost Considerations

The soils on this site are frost susceptible, and small amounts of water can affect the performance of pavements and doorways. Exterior slabs should be anticipated to heave during winter months. If frost action needs to be eliminated in critical areas, we recommend the use of low-frost susceptible fill or structural slabs (e.g., structural stoops in front of building doors). Low-frost susceptible materials should consist of a well-graded, clean granular material with less than 6
percent passing the No. 200 sieve. Placement of low-frost susceptible material in large areas may not be feasible; however, the following recommendations are provided to help reduce potential frost heave:

- Providing surface drainage away from the buildings and slabs and toward the site storm drainage system
- Installing drain tiles around the perimeter of the pavements, and connect them to the storm drainage system
- Grading fine-grained subgrades such that groundwater potentially perched in overlying more permeable subgrades, such as sand or aggregate base layers, slope toward the site drainage system
- Placing low-frost susceptible fill as backfill beneath slabs that are critical to the project

As an alternative to extending the low-frost susceptible fill to the full frost depth, consideration can be made to placing extruded polystyrene or cellular concrete under a buffer of at least 2 feet of low-frost susceptible fill.

**Floor Slab Construction Considerations**

Grading for floor slab subgrades is typically accomplished relatively early in the construction phase. Fills are placed and compacted, and the initial surface is prepared in a relatively uniform manner. However, as construction proceeds, utility excavations, rainfall, and heavy construction traffic can disturb the subgrade. Surface irregularities are often filled with loose materials to temporarily improve trafficability. As a result, the floor slab subgrade, prepared earlier during initial site grading operations should be carefully evaluated as the time for slab construction approaches. Particular attention should be given to high traffic areas that become rutted and disturbed, and to areas where backfilled trenches are located.

Areas where unstable conditions exist should be repaired by removing and replacing the materials with low plasticity structural fill. All floor slab subgrade areas should be moisture conditioned and compacted to the recommendations in Earthwork immediately prior to placement of the aggregate base materials and concrete.

Care will be necessary to avoid contaminating the aggregate base layer located directly below the floor slabs with soil prior to floor slab placement. We recommend the aggregate base layer be placed only immediately prior to slab concrete placement.
PAVEMENTS

We anticipate the pavement subgrade will consist of at least 12 inches of low plasticity fine-grained structural fill. If the Owner elects to accept additional risk of subgrade movements due to shrink/swell, the pavement subgrade could consist of on-site moderate to high plasticity soils. We expect the pavement subgrade materials will be placed and compacted following the recommendations in Earthwork.

Pavement design methods are intended to provide structural sections with adequate thickness over a particular subgrade such that wheel loads are reduced to a level the subgrade can support. The support characteristics of the subgrade for pavement design do not account for movements due to frost heave or shrink/swell. Thus, the pavement may be adequate from a structural standpoint, yet still experience cracking and deformation due to temperature or water content related movements of the subgrade.

Opinions of Minimum Pavement Thickness

Traffic information was not provided at the time this report was written. We anticipate traffic to consist primarily of personal vehicles; however, occasional heavy traffic loads are anticipated along the proposed drives due to delivery trucks and garbage trucks. Similar to Phase 1, we expect parking and drive areas will be constructed after all heavy construction traffic is over.

The portland cement concrete (PCC) pavement thicknesses presented in this section satisfy published industry guidelines (identified below) for minimum thicknesses based on our understanding of anticipated traffic types and volumes.

- American Concrete Institute (ACI), Guide for the Design and Construction of Concrete Parking Lots.
  - Traffic category A (car parking areas) and B (business entrance and service lanes).
  - Subgrade support ‘low’ (fine-grained soils in which silt and clay-size particles predominate).

As a minimum, we suggest the following typical pavement sections be considered.

<table>
<thead>
<tr>
<th>Pavement Area</th>
<th>PCC (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking stalls (for automobiles and light vehicles)</td>
<td>5</td>
</tr>
<tr>
<td>Access drives</td>
<td>6</td>
</tr>
<tr>
<td>Trash collection pads and facility entrance aprons</td>
<td>7</td>
</tr>
</tbody>
</table>

1. All materials should meet the current Iowa Department of Transportation Standard Specifications for Highway and Bridge Construction. Concrete Pavement - IaDOT Portland Cement Concrete Type C (Section 2301)
2. PCC pavement concrete should have a 28-day compressive strength of at least 4,000 psi, and be placed with a maximum slump of 4 inches.

3. Where practical, we recommend “early-entry” cutting of crack-control joints in PCC pavements. Cutting of the concrete in its “green” state typically reduces the potential for micro-cracking of the pavements prior to the crack control joints being formed, compared to cutting the joints after the concrete has fully set. Micro-cracking of pavements may lead to crack formation in locations other than the sawed joints, and/or reduction of fatigue life of the pavement. We anticipate that pavement joints will be doweled.

4. Trash container pads should be large enough to support the container and the tipping axle of the collection truck.

<table>
<thead>
<tr>
<th>Pavement Area</th>
<th>PCC (inches)</th>
<th>1, 2, 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Subsurface Drainage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subsurface drainage systems (i.e., a permeable base and subdrains) below pavement areas generally prolong the life of a pavement and help to prevent saturation of the pavement subgrade that can result in a reduction of subgrade strength and/or possible heaving. The use of a granular base will also reduce the potential for frost action. Although not required for structural support of the PCC sections given above, a minimum 4-inch thick granular base course layer is recommended to help reduce potential for slab curl, shrinkage cracking, and subgrade “pumping” through joints, and to help reduce saturation of the pavement subgrade.

We recommend installing a subdrain system along the shoulders (or back of curb) of new pavement areas, including all openings in the pavement such as decorative landscaped islands or intake structures, to improve long term pavement performance. The pavement subgrade should be crowned at least 2 percent to promote the flow of water towards the subdrains. Design recommendations for the subdrains are provided in the following table:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement aggregate base layer</td>
<td>A minimum of 4 inches of material meeting the specifications for LaDOT granular subbase (Section 4121).</td>
</tr>
</tbody>
</table>
Subdrain pipe

- Perforated drain line with a minimum 4-inch diameter.
- Pipe perforations should be appropriately sized to prevent free-draining granular material from entering the subdrain pipe.
- Pipe invert should be at least 3½ feet below proposed grade.
- Subdrain lines should be sloped to provide positive gravity drainage to a reliable discharge point.
- Subdrain lines should be embedded in at least 4 inches of subdrain trench backfill material.

Subdrain trench backfill

- IaDOT porous backfill (Section 4131), or
- Free-draining coarse-grained material encapsulated with non-woven geotextile filter fabric (Contech C60NW or equivalent).

1. The subdrain trench backfill should extend up to and be hydraulically connected to the recommended aggregate base layer below the pavements.

Pavement Subgrade Construction Considerations

Fine-grained soils, such as those encountered at this site, generally provide relatively poor pavement support and are susceptible to rutting and pumping under repeated heavy vehicle traffic (both during construction and under inadequate pavement sections). The pavement subgrade should be prepared as described in Earthwork.

Construction scheduling often involves grading and paving by separate contractors and can involve a time lapse between the end of grading operations and the commencement of paving. Disturbance, desiccation or wetting of the subgrade soils between grading and paving can result in deterioration of the previously completed subgrade. A non-uniform subgrade can result in poor pavement performance and local failures relatively soon after pavements are constructed.

The pavement subgrade should be proofrolled prior to paving operations to help delineate soft or disturbed areas. Proofrolling should be accomplished using a fully loaded, tandem axle dump truck or other equipment providing and equivalent subgrade loading (minimum gross weight of 25 tons is recommended for the proofrolling equipment). Unstable areas identified by proofrolling should be undercut to expose stable material and backfilled with low plasticity structural fill.

Following proofrolling, the water content of the exposed subgrade should be evaluated. Where water contents are outside the range recommended for structural fill, the exposed subgrade should be scarified, moisture conditioned, and compacted as described in Earthwork. If a significant precipitation event occurs after the evaluation, or if the surface becomes disturbed, the subgrade should be reviewed by qualified personnel immediately prior to paving. The subgrade should be in its finished form at the time of the final review.
Pavement Maintenance

Periodic maintenance of the pavements will be required. All cracks should be sealed, and areas exhibiting distress should be repaired promptly to help prevent further deterioration. Even with periodic maintenance, some movements and related cracking may still occur and repairs will be required.

GENERAL COMMENTS

Our analysis and opinions are based on 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 to review the final design plans and specifications, so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon should be retained to provide observation and testing services during grading, excavation, foundation construction, and other earth-related construction phases of the project. 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 on 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.

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

Matthew D. Cushman, P.E.
My license renewal date is December 31, 2020.
EXPLORATION AND TESTING PROCEDURES

Field Exploration

<table>
<thead>
<tr>
<th>Boring Numbers</th>
<th>Boring Depths (feet)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 through 9</td>
<td>15½ to 20½</td>
<td>Buildings 1,2 and 3</td>
</tr>
<tr>
<td>10 and 12</td>
<td>10</td>
<td>Parking Lots</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
<td>Dumpster Area</td>
</tr>
</tbody>
</table>

Boring Layout and Elevations: Terracon personnel staked the boring locations using handheld GPS equipment with respect to planned building and pavement areas indicated on site plan provided to us and coordinates determined from a “best fit” overlay of the plans on a GIS system. The boring locations are shown on the Exploration Plan. The coordinates of the borings are indicated on the boring logs.

Approximate ground surface elevations were obtained by Terracon personnel using a surveyor’s level and rod referencing the rim of stormwater manhole cover on the northeast of the proposed parking lot to the east of the site. An elevation of 874.5 was given to this benchmark on the Site plan 9019114 provided by JGR Architects. Boring elevations on the boring logs are rounded to the nearest ½ foot. The locations and elevations of the borings are considered accurate only to the degree implied by the means and methods used to define them.

Subsurface Exploration Procedures: The borings were drilled with an ATV-mounted drilling rig using continuous flight solid-stem augers. Soil sampling was performed using thin-walled tube and split-barrel sampling procedures. In the thin-walled tube sampling procedure, a thin-walled, seamless steel tube with a sharp cutting edge is pushed hydraulically into the soil to obtain a relatively undisturbed sample. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon is 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. The samples were placed in appropriate containers and taken to our laboratory for testing. We observed and recorded groundwater levels during, and up to 1 day after drilling and sampling. The borings were backfilled with auger cuttings after drilling.

The drill crew prepared a field log of each boring to record field data including visual descriptions of the materials encountered during drilling as well as the driller’s interpretation of the subsurface conditions between samples. The boring logs included with this report represent an interpretation of the subsurface conditions at each boring location based on field and laboratory data, and observation of the samples.
Laboratory Testing

In the laboratory, water content tests were performed on portions of the recovered samples. The dry unit weight of intact, thin-walled tube samples was determined. Unconfined compressive strength and hand penetrometer tests were performed to estimate the consistency of select samples of fine-grained soils. Atterberg limits tests were performed on select samples of fine-grained soils from Borings 2, 5 and 8. The results of the laboratory tests are shown on the boring logs at their corresponding sample depths in Exploration Results.

The samples were described in the laboratory based on visual observation, texture and plasticity, and the laboratory testing described above. The descriptions of the soils indicated on the boring logs are in general accordance with the General Notes, Unified Soil Classification System (USCS), both summarized and included in Supporting Information.
SITE LOCATION AND EXPLORATION PLAN

Contents:
Site Location
Exploration Plan

Note: All attachments are one page unless noted above.
SITE LOCATION
The Reserves at Mill Farm – Phase 2 ■ Pella, Iowa
May 16, 2019 ■ Terracon Project No. 08195102-01

Diagram is for general location only, and is not intended for construction purposes.

Map provided by Microsoft Bing Maps.
EXPLORATION PLAN
The Reserves at Mill Farm – Phase 2 ■ Pella, Iowa
May 16, 2019 ■ Terracon Project No. 08195102-01

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES
MAP PROVIDED BY MICROSOFT BING MAPS
EXPLORATION RESULTS

Contents:
GeoModel
Boring Logs (B-1 through B-12)

Note: All attachments are one page unless noted above.
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 | Fat Clays with traces of sand and organics. Dark gray to dark brown.
2 | Upper Clays | Variable Clays consisting of fat clays, lean to fat clays and lean clays; with traces of sand and organics. Grayish brown to brownish gray. Generally stiff to very stiff.
3 | Soft Clays | Lean Clay, trace sand. Grayish brown to brown gray. Generally medium stiff to stiff.
4 | Lower Clays | Variable Clays consisting of fat clays, lean to fat clays and lean clays; with traces of sand. Grayish brown to light gray. Generally very soft to medium stiff.

**LEGEND**

- Fill
- Lean Clay/Fat Clay
- Fat Clay
- Lean Clay

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.
### BORING LOG NO. 1

**PROJECT:** The Reserves at Mill Farm - Phase 2  
**SITE:** W 16th St.  
Pella, IA  
**CLIENT:** Jones Gillam Renz Architects, Inc.  
Salina, KS

#### MODEL LAYER

<table>
<thead>
<tr>
<th>GRAPHIC LOG</th>
<th>LOCATION</th>
<th>DEPTH</th>
<th>ELEVATION (FL)</th>
<th>WATER LEVEL OBSERVATIONS</th>
</tr>
</thead>
</table>
| 1           | Approx. 1.5 inch Root Zone | 18    | 5000 (HP)      | Approx. 1.5 inch Root Zone  
FILL - FAT CLAY (CH), trace sand and organics, dark brown, (appears desiccated) |
| 2           | FAT CLAY (CH), trace sand and organics, brown with dark brown, very stiff | 6     | 3 4470 26 92 |
| 3           | LEAN CLAY (CL), trace sand, gray brown, medium stiff to soft | 12    | 4 1400 30 91 |
| 4           | LEAN CLAY (CL), trace sand, grayish brown, stiff | 16    | 1 5 31 |

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>UNCONFOMS COMPRRESSIVE STRENGTH (psf)</th>
<th>WATER CONTENT (%)</th>
<th>DRY UNIT WEIGHT (pcf)</th>
<th>ATTERBERG LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>22</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>26</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>30</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

- None observed while drilling
- Cave-in @ 13' on 5/2/19

**Notes:**

Advancement Method: Flight Augers
Abandonment Method: Boring backfilled with Auger Cuttings after delayed water level observations

**Boring Terminated at 20.5 Feet**

**Hammer Type:** Automatic

**LOCATION**

Latitude: 41.4109° Longitude: -92.9534°
Approximate Surface Elev.: 877.0 (Ft.) +/- 2.5

**Notes:**

- Project No.: 08195102
- Driller: JG
- Drill Rig: 897
- Boring Started: 05-01-2019
- Boring Completed: 05-01-2019
- Site: W 16th St. Pella, IA
- 8' on 5/2/19
- Cave-in @ 13' on 5/2/19
- 600 SW 7th St, Ste M
  Des Moines, IA
- Project No.: 08195102
BORING LOG NO. 2

PROJECT: The Reserves at Mill Farm- Phase 2

SITE: W 16th St.
Pella, IA

CLIENT: Jones Gillam Renz Architects, Inc.
Salina, KS

LOCATION
See Exploration Plan
Latitude: 41.4107° Longitude: -92.9536°

Approximate Surface Elev.: 879.0 (FT) +/-

DEPTH (FT.)  ELEVATION (FT.)

WATER LEVEL OBSERVATIONS
15.5 863.5

FIELD TEST RESULTS

UN confined compressive strength (PSF)

SAMPLE ID

RECOVERY (In.)

SAMPLING TYPE

SAMPLE DATE

DRY UNIT WEIGHT (pcf)

WATER CONTENT (%)

ATTERBERG LIMITS

LOCATION

Latitude: 41.4107° Longitude: -92.9536°

See Exploration Plan

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

Hammer Type: Automatic

Advancement Method: Flight Augers

Abandonment Method: Boring backfilled with Auger Cuttings after delayed water level observations

Notes:

WATER LEVEL OBSERVATIONS

14'I While Drilling

11'I on 5/2/19

6' on 5/2/19

Cave-in @ 11'I on 5/2/19

Boring Terminated at 15.5 Feet

Boring Started: 05-01-2019

Boring Completed: 05-01-2019

Drill Rig: 897

Driller: JG

Project No.: 08195102
**BORING LOG NO. 3**

**PROJECT:** The Reserves at Mill Farm- Phase 2  
**SITE:** W 16th St.  
Pella, IA

**LOCATION**  
See Exploration Plan  
Latitude: 41.4105° Longitude: -92.9537°

Approximate Surface Elev.: 880.0 (Ft.) +/-

**GRAPHIC LOG**

<table>
<thead>
<tr>
<th>MODEL LAYER</th>
<th>DEPTH (Ft.)</th>
<th>ELEVATION (FL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>878+/-</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>875+/-</td>
</tr>
<tr>
<td>3</td>
<td>14.5</td>
<td>866.5+/-</td>
</tr>
<tr>
<td>4</td>
<td>19.0</td>
<td>861+/-</td>
</tr>
<tr>
<td>5</td>
<td>20.5</td>
<td>859.5+/-</td>
</tr>
</tbody>
</table>

Approx. 1.5 inch Root Zone  
FILL - FAT CLAY (CH), trace sand and organics, dark gray to dark brown, (appears desiccated)

FAT CLAY (CH), trace sand and organics, grayish brown, very stiff

LEAN CLAY (CL), trace sand and organics, gray brown, soft to medium stiff

LEAN TO FAT CLAY (CL/CH), with sand, grayish brown, stiff

FAT CLAY (CH), trace sand, light gray, stiff

Boring Terminated at 20.5 Feet

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

Hammer Type: Automatic

**WATER LEVEL OBSERVATIONS**

- 14' While Drilling  
- 6.5' on 5/2/19  
- Cave-in @ 15' on 5/2/19

**FIELD TEST RESULTS**

- RECOVERY (In.)
- UNCONFINED COMPRESSIVE STRENGTH (psf)
- WATER CONTENT (%)
- DRY UNIT WEIGHT (pcf)

**ATTERBERG LIMITS**

- LL-PL-PI

**LOCATION**

Latitude: 41.4105° Longitude: -92.9537°

See Exploration Plan

**Notes:**

- Advancement Method: Flight Augers
- Abandonment Method: Boring backfilled with Auger Cuttings after delayed water level observations
- 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.
- Boring Started: 05-01-2019  
Boring Completed: 05-01-2019
- Drill Rig: 897  
Driller: JG

**Perforated Smart Log No.**

600 SW 7th St, Ste M  
Des Moines, IA

Project No.: 08195102
PROJECT: The Reserves at Mill Farm - Phase 2

SITE: W 16th St.
Pella, IA

CLIENT: Jones Gillam Renz Architects, Inc.
Salina, KS

LOCATION
See Exploration Plan
Latitude: 41.4102° Longitude: -92.9543°
Approximate Surface Elev.: 881.0 (Ft.) +/-

MODEL LAYER

GRAPHIC LOG

DEPTH (FT.)

ELEVATION (FT.)

FIELD TEST RESULTS

SAMPLE ID

UNCONFINED COMRESSIVE STRENGTH (PSF)

WATER CONTENT (%)

DRIED UNIT WEIGHT (Pcf)

ATTERBERG LIMITS

LOCATION
Latitude: 41.4102° Longitude: -92.9543°
See Exploration Plan

WATER LEVEL OBSERVATIONS

DEPTH (FT.)

ELEVATION (FT.)

FIELD TEST RESULTS

SAMPLE ID

UNCONFINED COMRESSIVE STRENGTH (PSF)

WATER CONTENT (%)

DRIED UNIT WEIGHT (Pcf)

ATTERBERG LIMITS

LOCATION
Latitude: 41.4102° Longitude: -92.9543°
See Exploration Plan

Advancement Method:
Flight Augers

Abandonment Method:
Boring backfilled with Auger Cuttings after delayed water level observations

Hammer Type: Automatic

Notes:

Boring Started: 05-01-2019
Boring Completed: 05-01-2019
Drill Rig: 897
Driller: JG
Project No.: 08195102

WATER LEVEL OBSERVATIONS

8' While Drillling
6' on 5/2/19

Cave-in @ 18' on 5/2/19

Boring Terminated at 20.5 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.
## BORING LOG NO. 5

**PROJECT:** The Reserves at Mill Farm- Phase 2  
**SITE:** W 16th St.  
**Pella, IA**  

**CLIENT:** Jones Gillam Renz Architects, Inc.  
**Salina, KS**

### MODEL LAYER

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exploration Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude: 41.4102° Longitude: -92.9546°</td>
<td></td>
</tr>
<tr>
<td>Approximate Surface Elev.: 881.5 (Ft.) +/-</td>
<td></td>
</tr>
</tbody>
</table>

### DEPTH (FL.)

<table>
<thead>
<tr>
<th>WATER LEVEL OBSERVATIONS</th>
<th>ELEVATION (FL.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>879.5 +/-</td>
</tr>
<tr>
<td>5.0</td>
<td>876.5 +/-</td>
</tr>
<tr>
<td>10.0</td>
<td>867.5 +/-</td>
</tr>
<tr>
<td>15.0</td>
<td>866 +/-</td>
</tr>
</tbody>
</table>

### FIELD TEST RESULTS

<table>
<thead>
<tr>
<th>RECOVERY (in.)</th>
<th>SAMPLE TYPE</th>
<th>FIELD TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4-6</td>
<td>2-3-4</td>
<td>5000 (HP)</td>
</tr>
<tr>
<td>1</td>
<td>N=10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>N=2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1000 (HP)</td>
<td></td>
</tr>
</tbody>
</table>

### UNCONFINED COMPRESSION STRENGTH (psf)

<table>
<thead>
<tr>
<th>WATER CONTENT (%)</th>
<th>DRY UNIT WEIGHT (pcf)</th>
<th>LL-PL-PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>57-27-30</td>
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<tr>
<td>89</td>
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<td></td>
</tr>
<tr>
<td>86</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes:

- Advancement Method: Flight Augers
- Abandonment Method: Boring backfilled with Auger Cuttings after delayed water level observations

### WATER LEVEL OBSERVATIONS

- **12' While Drilling**
- **6' on 5/2/19**

- **Cave-in @ 12' on 5/2/19**
**BORING LOG NO. 6**

**PROJECT:** The Reserves at Mill Farm- Phase 2

**SITE:** W 16th St.
Pella, IA

**CLIENT:** Jones Gillam Renz Architects, Inc.
Salina, KS

<table>
<thead>
<tr>
<th>MODEL LAYER</th>
<th>LOCATION</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approx. 1.5 inch Root Zone</td>
<td>Fill - FAT CLAY (CH), trace sand and organics, dark brown with brown</td>
</tr>
<tr>
<td>2</td>
<td>FAT CLAY (CH), trace sand and organics, gray with brown, very stiff</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>LEAN CLAY (CL), trace sand, grayish brown, medium stiff to very soft</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEAN TO FAT CLAY (CL/CH), trace sand, grayish brown, medium stiff</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>FAT CLAY (CH), trace sand, light gray with brown, stiff</td>
<td></td>
</tr>
</tbody>
</table>

**Approximate Surface Elev.: 880.5 (Ft.) +/-**

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

**Hammer Type: Automatic**

### WATER LEVEL OBSERVATIONS

- **Cave-in @ 16' on 5/2/19**
- **6' on 5/2/19**
- **9' While Drilling**

### Boring Terminated at 20.5 Feet

### Notes:

- **Advancement Method:** Flight Augers
- **Abandonment Method:** Boring backfilled with Auger Cuttings after delayed water level observations
- **Notes:**
  - 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.

**Drill Rig:** 897

**Driller:** JG

**Boring Started:** 05-01-2019
**Boring Completed:** 05-01-2019

**Project No.: 08195102**
## Water Level Observations

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

## Field Test Results

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Recovery</th>
<th>Field Test Results</th>
<th>Sample ID</th>
<th>Unconfined Compressive Strength (psf)</th>
<th>Water Content (%)</th>
<th>Dry Unit Weight (pcf)</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-4-5</td>
<td>5000 (HP)</td>
<td>1</td>
<td></td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-1-1</td>
<td>2750 (HP)</td>
<td>2</td>
<td></td>
<td>28</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3-4-5</td>
<td>1340 (HP)</td>
<td>3</td>
<td></td>
<td>32</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-1-1</td>
<td>1000 (HP)</td>
<td>4</td>
<td></td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-3-5</td>
<td>3000 (HP)</td>
<td>5</td>
<td></td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3-4-5</td>
<td>5000 (HP)</td>
<td>6</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Advancement Method
- Flight Augers

## Abandonment Method
- Boring backfilled with Auger Cuttings after delayed water level observations

## Notes
- This boring log is not valid if separated from original report. GeoSmart Log No Well 08195102 The Reserves at Mill Farm-Phase 2
- Project No.: 08195102
- Drill Rig: 897
- Driller: JG
- Boring Started: 05-01-2019
- Boring Completed: 05-01-2019
- Project No.: 08195102

---

**SITE:**  W 16th St.  
Pella, IA  

**PROJECT:** The Reserves at Mill Farm-Phase 2  

**CLIENT:** Jones Gillam Renz Architects, Inc.  
Salina, KS  

---

**Model Layer**

<table>
<thead>
<tr>
<th>Location</th>
<th>Approx. Surface Elev.: 878.0 (FL) +/-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0 Approx. 1.5 inch Root Zone Fill - Fat Clay (CH), trace sand and organics, dark brown</td>
</tr>
<tr>
<td></td>
<td>12 2-4-5 N=9 5000 (HP) Sample ID 1 Recovery 29</td>
</tr>
<tr>
<td>2</td>
<td>9 0-1-1 N=2 1000 (HP) Sample ID 4 Recovery 33</td>
</tr>
<tr>
<td>3</td>
<td>18 2-3-5 N=8 3000 (HP) Sample ID 5 Recovery 27</td>
</tr>
<tr>
<td>4</td>
<td>18 3-4-5 N=9 5000 (HP) Sample ID 6 Recovery 25</td>
</tr>
</tbody>
</table>

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**Water Level Observations**

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>While Drilling</td>
</tr>
<tr>
<td>14.0</td>
<td>864+/-</td>
</tr>
<tr>
<td>19.0</td>
<td>859+/-</td>
</tr>
</tbody>
</table>

---

**Boring Terminated at 20.5 Feet**
**BORING LOG NO. 8**

**PROJECT:** The Reserves at Mill Farm - Phase 2  
**SITE:** W 16th St.  
**Pella, IA**

**CLIENT:** Jones Gillam Renz Architects, Inc.  
**Salina, KS**

**LOCATION**  
See Exploration Plan  
Latitude: 41.4107° Longitude: -92.9545°

Approximate Surface Elev.: 879.0 (Ft.) +/-

<table>
<thead>
<tr>
<th>MODEL LAYER</th>
<th>GRAPHIC LOG</th>
<th>DEPTH (Ft.)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>ELEVATION (Ft.)</th>
<th>FIELD TEST RESULTS</th>
<th>UNCONFINED COMPR. STRENGTH (psf)</th>
<th></th>
<th>DRY UNIT WEIGHT (pcf)</th>
<th>WATER CONTENT (%)</th>
<th>ATTERBERG LL-PL-PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>Approx. 1.5 inch Root Zone</td>
<td>3-4-6</td>
<td>877+/-</td>
<td></td>
<td>12</td>
<td>3-4-6</td>
<td>N=10</td>
<td>5000 (HP)</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>5.0</td>
<td>FILL - FAT CLAY (CH)</td>
<td>2-3-5</td>
<td>874+/-</td>
<td></td>
<td>7</td>
<td>3000 (HP)</td>
<td>2</td>
<td>2220</td>
<td>29</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>LEAN TO FAT CLAY (CL/CH), trace sand, brown gray, stiff</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.0</td>
<td>LEAN CLAY (CL)</td>
<td>18</td>
<td>1000 (HP)</td>
<td>3</td>
<td>650</td>
<td>33</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.5</td>
<td>LEAN TO FAT CLAY (CL/CH), trace sand, grayish brown, medium stiff to stiff</td>
<td>18</td>
<td>2-3-5</td>
<td>3000 (HP)</td>
<td>5</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Boring Terminated at 15.5 Feet**

Stratification lines are approximate. In-situ, the transition may be gradual.  
Hammer Type: Automatic

**Advancement Method:** Flight Augers  
**Abandonment Method:** Boring backfilled with Auger Cuttings after delayed water level observations

**Notes:**

- **WATER LEVEL OBSERVATIONS**
  - 9' while Drilling  
  - 6' on 5/2/19  
  - Cave-in @ 13' on 5/2/19

- **Boring Started:** 05-01-2019  
  **Boring Completed:** 05-01-2019  
  **Drill Rig:** 897  
  **Driller:** JG  
  **Project No.:** 08195102

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.
### BORING LOG NO. 9

**PROJECT:** The Reserves at Mill Farm - Phase 2  
**SITE:** W 16th St.  
Pella, IA  

**CLIENT:** Jones Gillam Renz Architects, Inc.  
Salina, KS

| MODEL LAYER | LOCATION | See Exploration Plan  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPTH</td>
<td>APP. SURFACE ELEV.</td>
<td>WATER LEVEL OBSERVATIONS</td>
</tr>
</tbody>
</table>
| 1 | 2.5 | 876 +/- | Approx. 1.5 inch Root Zone  
FILL - FAT CLAY (CH), trace sand and organics, dark gray with brown | 12 | 3-3-5 | N=8 | 1000 (HP) | 29 |
| 2 | 5.0 | 873.5 +/- | FAT CLAY (CH), trace sand and organics, grayish brown, very stiff | 6 | 5000 (HP) | 2 | 4020 | 29 | 90 |
| 3 | 14.0 | 864.5 +/- | LEAN CLAY (CL), trace sand and organics, brown gray to grayish brown, medium stiff to soft | 16 | 0-1-1 | N=2 | 1000 (HP) | 3 | 1260 | 32 | 86 |
| 4 | 19.0 | 859.5 +/- | LEAN TO FAT CLAY (CL/CH), trace sand, grayish brown, medium stiff to stiff | 18 | 3-3-5 | N=8 | 4000 (HP) | 5 | 24 |
| 5 | 20.5 | 858 +/- | FAT CLAY (CH), trace sand and gravel, light gray, stiff | 18 | 3-5-7 | N=12 | 5000 (HP) | 6 | 25 |

**Boring Terminated at 20.5 Feet**

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

**Hammer Type:** Automatic

**ADVANCEMENT METHOD:** Flight Augers

**ABANDONMENT METHOD:** Boring backfilled with Auger Cuttings after delayed water level observations

**WATER LEVEL OBSERVATIONS**

- **14' While Drilling**
- **6' on 5/2/19**
- **Cave-in @ 17' on 5/2/19**

**NOTES:**

- 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.

**PROJECT NO.:** 08195102

**Drill Rig:** 897  
**Driller:** JG

**Boring Started:** 05-01-2019  
**Boring Completed:** 05-01-2019
### Boring Log No. 10

**Project:** The Reserves at Mill Farm - Phase 2  
**Client:** Jones Gillam Renz Architects, Inc.  
**Site:** W 16th St., Pella, IA

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Location</th>
<th>Sample Type</th>
<th>Field Test Results</th>
<th>Unconfined Compressive Strength (psf)</th>
<th>Water Content (%)</th>
<th>Dry Unit Weight (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>Approx. 1.5 inch Root Zone Fill - Fat Clay (CH), trace sand and organics, dark brown with brown</td>
<td>1-1-2</td>
<td>N=9</td>
<td>4500 (HP)</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>Lean to Fat Clay (CL/CH), trace sand and organics, grayish brown, medium stiff to stiff</td>
<td>2-4-4</td>
<td>N=8</td>
<td>2000 (HP)</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>Lean Clay (CL), trace sand, grayish brown, soft to very soft</td>
<td>1-1-2</td>
<td>N=3</td>
<td>1000 (HP)</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>Boring Terminated at 10.5 Feet</td>
<td>0-0-1</td>
<td>N=1</td>
<td>1000 (HP)</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

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

**Hammer Type:** Automatic

**Advancement Method:** Flight Augers  
**Abandonment Method:** Boring backfilled with auger cuttings upon completion.

**Notes:**

**Water Level Observations:** None observed while drilling

---

**Boring Started:** 05-01-2019  
**Boring Completed:** 05-01-2019  
**Drill Rig:** 897  
**Driller:** JG  
**Project No.:** 08195102
## WATER LEVEL OBSERVATIONS

<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>FIELD TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

## FIELD TEST RESULTS

<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>UNCONFined COMPRESSIVE STRENGTH (psf)</th>
<th>WATEr CONTENT (%)</th>
<th>DRY UNIT WEIGHT (pcf)</th>
<th>ATTERTBerg LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LL-PL-PI</td>
</tr>
</tbody>
</table>

## Advancement Method:
Flight Augers

## Abandonment Method:
Boring backfilled with auger cuttings upon completion.

## Notes:

Boring Started: 05-01-2019
Boring Completed: 05-01-2019
Drill Rig: 897
Driller: JG
Project No.: 08195102
### BORING LOG NO. 12

**PROJECT:** The Reserves at Mill Farm- Phase 2  
**SITE:** W 16th St.  
**Pella, IA**  
**CLIENT:** Jones Gillam Renz Architects, Inc.  
**Salina, KS**

<table>
<thead>
<tr>
<th>MODEL LAYER</th>
<th>GRAPHIC LOG</th>
<th>LOCATION</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>DEPTH (FT)</th>
<th>ELEVATION (FT)</th>
<th>RECOVERY (lbs.)</th>
<th>FIELD TEST RESULTS</th>
<th>UNCONFINED COMPRESSIONSTRENGTH (PSI)</th>
<th>DRY UNITWEIGHT (PCF)</th>
<th>WATER CONTENT (%)</th>
<th>LL-PL-PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approx. 1.5 inch Root Zone</td>
<td>FILL - FAT CLAY (CH), trace sand and organics, dark brown with brown</td>
<td>Approximate Surface Elev. : 877.0 (FT) +/-</td>
<td>2.0</td>
<td>875 +/-</td>
<td>12</td>
<td>4-5-6 N=11</td>
<td>5000 (HP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>LEAN CLAY (CL), trace sand, brownish gray, stiff</td>
<td></td>
<td>5.0</td>
<td>872 +/-</td>
<td>15</td>
<td>3-4-5 N=9</td>
<td>3000 (HP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>LEAN CLAY (CL), trace sand, grayish brown, medium stiff to soft</td>
<td></td>
<td>10.5</td>
<td>866.5 +/-</td>
<td>10</td>
<td>1-2-2 N=4</td>
<td>1000 (HP)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Boring Terminated at 10.5 Feet**

- Hammer Type: Automatic
- Advancement Method: Flight Augers
- Abandonment Method: Boring backfilled with auger cuttings upon completion.

**WATER LEVEL OBSERVATIONS**

None observed while drilling

---

**Graphical Log Model Layer Depth Elevation (FT)**

- Approximate Surface Elev.: 877.0 (FT) +/-

---

**Notes:**

- 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.

---

**Data:**

- Boring Started: 05-01-2019
- Boring Completed: 05-01-2019
- Drill Rig: 897
- Driller: JG
- Project No.: 08195102

---

**Terracon**

600 SW 7th St, Ste M  
Des Moines, IA
SUPPORTING INFORMATION

Contents:
General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted above.
### SAMPLING

- Shelby Tube
- Standard Penetration Test

### WATER LEVEL

- Water Initially Encountered
- Water Level After a Specified Period of Time
- Water Level After a Specified Period of Time

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

### DESCRIBITIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

### LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. 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.

### RELATIVE DENSITY OF COARSE-GRAINED SOILS

(50% or more passing the No. 200 sieve.)

<table>
<thead>
<tr>
<th>Descriptive Term (Density)</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
<th>Unconfined Compressive Strength Qu, (psf)</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Loose</td>
<td>0 - 3</td>
<td>Very Soft</td>
<td>less than 500</td>
</tr>
<tr>
<td>Loose</td>
<td>4 - 9</td>
<td>Soft</td>
<td>500 to 1,000</td>
</tr>
<tr>
<td>Medium Dense</td>
<td>10 - 29</td>
<td>Medium Stiff</td>
<td>1,000 to 2,000</td>
</tr>
<tr>
<td>Dense</td>
<td>30 - 50</td>
<td>Stiff</td>
<td>2,000 to 4,000</td>
</tr>
<tr>
<td>Very Dense</td>
<td>&gt; 50</td>
<td>Very Stiff</td>
<td>4,000 to 8,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>&gt; 8,000</td>
</tr>
</tbody>
</table>

### STRENGTH TERMS

<table>
<thead>
<tr>
<th>Descriptive Term (Consistency)</th>
<th>Unconfined Compressive Strength Qu, (psf)</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Soft</td>
<td>less than 500</td>
<td>0 - 1</td>
</tr>
<tr>
<td>Soft</td>
<td>500 to 1,000</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Medium Stiff</td>
<td>1,000 to 2,000</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Stiff</td>
<td>2,000 to 4,000</td>
<td>8 - 15</td>
</tr>
<tr>
<td>Very Stiff</td>
<td>4,000 to 8,000</td>
<td>15 - 30</td>
</tr>
<tr>
<td>Hard</td>
<td>&gt; 8,000</td>
<td>&gt; 30</td>
</tr>
</tbody>
</table>

### CONSISTENCY OF FINE-GRAINED SOILS

Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance.

- Hard
- Medium
- Soft
- Very Soft
- Very Medium
- Very Soft
- Very Hard
- Very Medium
- Very Soft
- Very Hard
- Medium
- Soft
- Very Soft
- Very Hard
- Medium
- Soft
- Very Soft
- Very Hard
- Medium
- Soft
- Very Soft
- Very Hard
- Medium
- Soft
- Very Soft
- Very Hard
### Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests

<table>
<thead>
<tr>
<th>Group Symbol</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW</td>
<td>Well-graded gravel</td>
</tr>
<tr>
<td>GP</td>
<td>Poorly graded gravel</td>
</tr>
<tr>
<td>GM</td>
<td>Silty gravel</td>
</tr>
<tr>
<td>GC</td>
<td>Clayey gravel</td>
</tr>
<tr>
<td>SP</td>
<td>Poorly graded sand</td>
</tr>
<tr>
<td>SW</td>
<td>Well-graded sand</td>
</tr>
<tr>
<td>SM</td>
<td>Silty sand</td>
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<td>SC</td>
<td>Clayey sand</td>
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<tr>
<td>CL</td>
<td>Lean clay</td>
</tr>
<tr>
<td>ML</td>
<td>Silt</td>
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<tr>
<td>OL</td>
<td>Organic clay</td>
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<tr>
<td>CH</td>
<td>Fat clay</td>
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<tr>
<td>MH</td>
<td>Elastic Silt</td>
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<tr>
<td>OH</td>
<td>Organic silt</td>
</tr>
<tr>
<td>PT</td>
<td>Peat</td>
</tr>
</tbody>
</table>

### 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
- **Gravels with Fines:** More than 12% fines

#### Sands:
50% or more of coarse fraction passes No. 4 sieve

- **Clean Sands:** Less than 5% fines
- **Sands with Fines:** More than 12% fines

### 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” line
- **Organic:** PI plots on or above “A” line

#### Silts and Clays:
Liquid limit 50 or more

- **Inorganic:** PI < 4 or plots below “A” line
- **Organic:** PI plots below “A” line

### Highly Organic Soils:
Primarily organic matter, dark in color, and organic odor

- **CL:** Lean clay
- **ML:** Silt
- **OL:** Organic clay
- **PT:** Peat

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### Other Notes

- **Cu =** D<sub>60</sub>/D<sub>10</sub>  
  **Cc =** (D<sub>30</sub>)<sup>2</sup>/D<sub>10</sub> x D<sub>60</sub>

- **Cu ≥ 4 and 1 ≤ Cc ≤ 3**
- **Cu < 4 and/or [Cc<1 or Cc>3.0]**
- **Cu ≥ 6 and 1 ≤ Cc ≤ 3**
- **Cu < 6 and/or [Cc<1 or Cc>3.0]**

- **Based on the material passing the 3-inch (75-mm) sieve.**
- **If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.**
- **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.

- **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.

- **Cu = D<sub>60</sub>/D<sub>10</sub>  
  **Cc =** (D<sub>30</sub>)<sup>2</sup>/D<sub>10</sub> x D<sub>60</sub>

- **If soil contains ≥ 15% sand, add “with sand” to group name.**
- **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.

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[Diagram showing classification based on PI and LL]