Geotechnical Engineering Report

Outpatient Mental Health Facility
Fort Harrison, Montana
February 7, 2019
Terracon Project No. C4185062

Prepared for:
Valhalla Engineering Group, LLC
Englewood, Colorado

Prepared by:
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February 7, 2019

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Attn: Mr. Mike Vander Ploeg, AIA, NCARB
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Re: Geotechnical Engineering Report
Outpatient Mental Health Facility
3687 Veterans Drive
Fort Harrison, Montana
Terracon Project No. C4185062

Dear Mr. Vander Ploeg:

We have completed the Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. PC4175025 dated June 1, 2017, and subsequent updated Request for Proposal issued July 13, 2018 and revised proposal dated July 20, 2018. Final signed agreement dated December 17, 2018 was prepared in accordance with final scope and fees provided via e-mail to Mr. Vander Ploeg on November 9, 2018. 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.

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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 PLANS
EXPLORATION RESULTS
SUPPORTING INFORMATION

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

Geotechnical Engineering Report

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3687 Veterans Drive
Fort Harrison, Montana
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INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed Outpatient Medical Health Facility to be located on the campus of the Fort Harrison VA Medical Center located at 3687 Veterans Drive in Fort Harrison, Montana. 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
- Frost considerations
- Foundation design and construction
- Floor slab design and construction
- Seismic site classification per IBC
- Lateral earth pressures

The geotechnical engineering Scope of Services for this project included the advancement of four borings to depths ranging from approximately 21.0 to 31.5 feet below existing site grades.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of 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 is located at 3687 Veterans Drive in Fort Harrison, Montana. Approximate GPS coordinates of the OPMH Building are 46.6191° N / 112.0999° W See **Site Location**
Existing Improvements	The project will be constructed on an open area to the east of the existing main hospital building.
Current Ground Cover	Grass covered
Existing Topography	Relatively flat with a gentle slope from west-northwest toward east-southeast.
Geology	The site is located on the western edge of the Helena Valley, to the northwest of Tenmile Creek. Topography of the site is indicative of alluvial and colluvial influences from the Cherry Creek and Sevenmile Creek drainages emanating from the low hills to the west of the site and the Tenmile Creek flood plain to the south of the project site. Soils are primarily alluvial sand and gravel materials, with some interbedding of silt and clay soils that are likely overbank flood deposits.

PROJECT DESCRIPTION

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

Item	Description
Project Description	The project will consist of the construction of a 14,650 square foot stand-alone, single story, slab-on-grade building for an outpatient mental health facility. The OPMH building will have an entrance from the east side of the north parking lot to support patient privacy and shall have appropriate site development of an area not more than 1 acre to facilitate patient support requirements and site utilization. The existing detention basin will be expanded to accommodate the added impervious area.
Maximum Loads	Column: 25 to 100 kips Walls: 4 to 6 kips per lineal foot Floor slab: 150 to 250 pounds per square foot (psf)
Grading/Slopes	Final grading is expected to be minimal, with anticipated cut and/or fill to be less than 3 feet.

Item	Description
Below-Grade Structures	None anticipated
Free-Standing Retaining Walls	None anticipated
Below-Grade Areas	None anticipated
Pavements	None required for the facility, the OPMH building will utilized an existing parking structure to the north.

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 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 of this report.

The subsurface conditions encountered consisted of a nominal thickness of approximately 0.4 to 1.0 feet of fill/topsoil overlying native soils. Below this fill/topsoil layer the general site subsurface conditions are characterized by the nature of their alluvial and colluvial deposition, in that (predominantly recent) coarse-grained deposits of silty, clayey sand with gravel or clayey sand are encountered within the upper zone of the profile. These soils are interbedded with low to moderate plasticity sandy lean clay materials at varying depths. The profile also contains varying amounts of gravel and fines such that the classification of the soils is interchangeable between silty, clayey sand with gravel to silty, clayey gravel with sand depending on the location of the samples. The predominant coarse-grained sands and gravels exhibit varying strength characteristics within the anticipated zone of influence for new foundation load distribution (the upper 15 feet), with Standard Penetration Test (SPT) recorded N-values ranging between 6 to 55 blows per foot (bpf) throughout their depths, indicating loose to very dense conditions. Where encountered within the zone of stress influence, the cohesive soils were generally found to be medium stiff to stiff with SPT N-values in the range of 6 to 12 bpf. The natural moisture content of the cohesionless (coarse-grained) soils was found to be in the range of 1 to 11 percent, varying with the amounts of fines. The cohesive (fine grained) soils encountered had natural moisture contents within the range of 7 to 15 percent.

GEOTECHNICAL OVERVIEW

The near surface sand and gravel soils have varying strength characteristics, along with varying amounts of silt and clay fines. These near surface soils could become unstable under construction traffic resulting in pumping or yielding subgrade conditions that could impact overall construction activities. Effective drainage should be completed early in the construction sequence and maintained after construction to avoid potential issues. If possible, the grading should be performed during the warmer and drier times of the year. If grading is performed during the winter months, an increased risk for possible undercutting and replacement of unstable subgrade will persist. Additional site preparation recommendations, including subgrade improvement and fill placement, are provided in the **Earthwork** section.

The subsurface conditions encountered indicate that varying strength and settlement characteristics are likely to be encountered throughout the footprint of the planned OMHP building, with SPT recorded N-values at planned bearing stratum varying from approximately 6 to 28 bpf. Due to this variability, special foundation preparation is recommended to provide reliable bearing and minimizing the potential for differential settlement. The **Shallow Foundations** section addresses support of the building bearing on Structural Fill extending to properly prepared native sand/gravel soils. The **Floor Slabs** section addresses slab-on-grade support of the building.

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

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 and floor slabs.

Site Preparation

Prior to placing fill, existing vegetation and root mat should be removed. Complete stripping of the topsoil and fill to a nominal depth of 1.0 feet below existing grade should be performed in the proposed building area. Following completion of stripping activities, the foundation excavations should be conducted by excavation equipment operating above and outside the limits of the subgrade area. Excavations should be completed to a minimum depth of 2.0 feet below the base of footing to allow for placement of Structural Fill gravel mat. Following excavation and prior to placement of Structural Fill, the native sand/gravel subgrade should be moisture conditioned and recompacted to a minimum of 98 percent of the maximum laboratory dry density as determined by ASTM D 698. Once the subgrade has been prepared, Structural Fill placement should be conducted based on the recommendations below.

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 or within 2 feet of exterior slabs-on-grade. General fill is material used to achieve grade outside of these areas. Earthen materials used for Structural Fill and general fill should meet the following material property requirements:

Soil Type [1]	USCS Classification	Acceptable Parameters (for Structural Fill)
Structural Fill (imported material)	GP, GW, GM, SP, SW, SM or dual symbols	100% passing 1 1/2-inch size, 30-60% passing the No. 4 screen, and no more than 10% passing the No. 200 screen. The fines portion should have a maximum Liquid Limit and Plasticity Index of 25 and 10 percent, respectively
Crushed Base Course (Leveling Course)	GP, GW, or dual symbols	¾ inch minus crushed material conforming to Montana Public Works Standard Specification - Section 02235 Crushed Base Course
On-site Soils	SC-SM, GC-GM, SM, SC, CL	The on-site soils typically appear suitable for use as general fill only, including site grade raising material and exterior backfill of foundations

1. Structural and general 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 on this site.

Fill Compaction Requirements

Structural Fill and general fill should meet the following compaction requirements.

Item	Structural Fill	General Fill
Maximum Lift Thickness	9 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 maximum below foundations 95% of maximum above foundations (backfill), below floor slabs	92% of max.
Water Content Range [1]	Low plasticity cohesive: -2% to +3% of optimum High plasticity cohesive: 0 to +4% of optimum Granular: -3% to +3% of optimum	As required to achieve min. compaction requirements

Item	Structural Fill	General Fill

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 percent 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 using local practices may be more appropriate. It should be noted that ASTM D698 allows for rock-correction of samples with up to 30% Retained on the 3/4" screen, but that this can lead to values not attainable in the field. ASTM allows for use of engineering judgement of field test strips. Local practice also has utilized successfully for control of the former ASTM D698 method of rock-replacement.

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 into a buried piping system directing water to a positive outlet away from the backfill zone or 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 percent 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 OPMH building 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 top soil, and subgrade preparation for foundation and slab support.

The prepared subgrade and 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, due to the small size of the planned septage receiving facility it is recommended that frequencies as below be utilized:

- Minimum of one test per 50 lineal feet of footing line, for subgrade and per each subsequent lift
- Minimum one test per 2,500 square feet for building slab areas, for subgrade and each subsequent lift
- Minimum two tests per lift of perimeter backfill for every 75 lineal feet of wall line
- Minimum one test per 75 lineal feet of compacted utility trench backfill, per lift

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.

SHALLOW FOUNDATIONS

The primary geotechnical consideration for the proposal Outpatient Mental Health building is to provide reliable bearing support while limiting the potential for differential movement. As the facility will be an isolated facility, not directly connected to any other structures, the risk for adverse performance due to differential movement is slightly reduced. However, the variability within the subsurface encountered within the planned 14,650 square foot plan area could result in unacceptable levels of differential settlement if not properly addressed. As such, the desire to provide uniform support while limiting potential for differential movement within the new facility will be important. The existing native alluvial sands, gravels, and clays exhibit varying strength and compressibility characteristics, with bearing stratum transitioning from one end of the structure (near Boring B-02) from dense silty, clayey gravel with sand to loose silty sand (near Boring B-04). The predominant bearing stratum of sand and gravel provides sufficient strength to support the structure; however, anticipated settlement under the preliminary loading conditions provided without improvement is the critical design case.

Our analysis for bearing capacity and settlement has been based on the controlling case encountered in the profile of Boring B-03, in which loose sand overlies medium dense to dense sand and gravel within the zone of stress influence from new foundations. Based on our analysis, the native alluvial soils would be able to support the anticipated 25 to 100 kips isolated spread footings and/or 4 to 6 kips per lineal foot continuous footing loads anticipated for the structure on a standard shallow foundation from a bearing capacity standpoint. However, when the structure is loaded to the allowable bearing capacity(ies) for the soil, the predicted settlement under load would exceed 1 inch, which is generally considered undesirable. As such, we recommend that a nominal overexcavation and replacement zone of 2 feet of Structural Fill, be utilized to provide uniformity of bearing, act as a stress reduction platform, with the result being predicted settlement less than the 1 inch allowed.

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

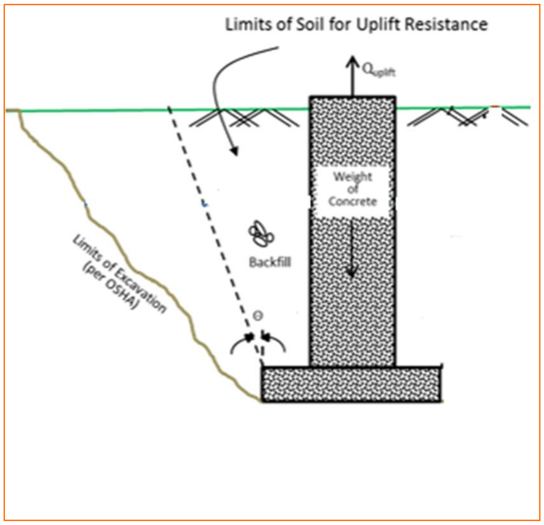
Item	Description
Maximum Net Allowable Bearing pressure [1, 2]	3,000 psf (strip/continuous foundations bearing within Structural Fill) 3,500 psf (isolated spread foundations bearing within Structural Fill)
Required Bearing Stratum [3]	Structural Fill extending to properly prepared native alluvial soils
Minimum Foundation Dimensions	Columns: 32 inches Continuous: 24 inches

Item	Description	
Ultimate Passive Resistance [4] **(equivalent fluid pressures)**	500 pcf (granular backfill)	
Ultimate Coefficient of Sliding Friction [5]	0.40 (Structural Fill)	
Minimum Embedment below Finished Grade [6]	Exterior footings: Interior footings, heated areas:	48 inches 36 inches
Estimated Total Settlement from Structural Loads [2]	Less than about 1 inch	
Estimated Differential Settlement [2, 7]	About 2/3 of total settlement	

1. Assumes proper preparation of native soil bearing surface and placement/compaction of Structural Fill in accordance with **Site Preparation**. Based on a minimum factor of safety of 3.
2. Values provided are for maximum loads noted in **Project Description**.
3. 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.

Design Parameters - Uplift Loads

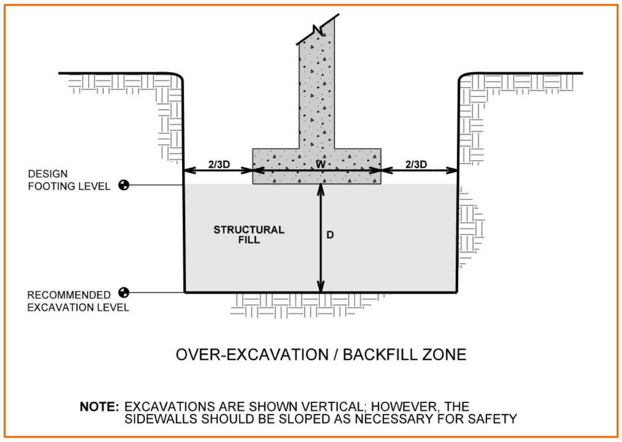
Uplift resistance of spread footings can be developed from the effective weight of the footing and the overlying soils. As illustrated on the subsequent figure, the effective weight of the soil prism defined by diagonal planes extending up from the top of the perimeter of the foundation to the ground surface at an angle, q, of 20 degrees from the vertical can be included in uplift resistance. The maximum allowable uplift capacity should be taken as a sum of the effective weight of soil plus the dead weight of the foundation, divided by an appropriate factor of safety. A maximum total unit weight of 120 pcf should be used for the backfill.



Foundation Construction Considerations

As noted in **Earthwork**, the footing excavations should be evaluated under the direction of the Geotechnical Engineer, and should extend to a minimum of 2 feet below footing depth to accommodate installation of Structural Fill. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete, and any soils loosened by excavation should be re-compacted in accordance with the Fill Compaction Requirements section above. 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.

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.



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 properties encountered at the site and as described on the exploration logs and results, along with past seismic hazard analysis we have conducted at the VA Fort Harrison Campus, it is our professional opinion that the **Seismic Site Classification is C**. Subsurface explorations at this site were extended to a maximum depth of 31.5 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area.

FLOOR SLABS

Based on subsurface conditions encountered, it is anticipated that following topsoil/fill removal, native sand will be encountered at the floor slab subgrade level. These soils should be replaced with Structural Fill so the floor slab is supported on at least 12 inches of compacted Structural Fill to improve uniformity of subgrade support.

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]	Minimum 4 inches of crushed base course (leveling course) aggregate compacted to at least 95% of ASTM D 698 [2, 3] At least 12 inches of Structural Fill below the 4 inches of base course with the Structural Fill extending to properly prepared native sand/clay soils.
Estimated Modulus of Subgrade Reaction [2]	150 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.

Item	Description

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 percent fines (material passing the #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.

Based on details provided by JIRSA/Hedrick Structural Engineers, it is our understanding that the front entry way will be constructed with a turndown slab-on-grade to limit the potential for differential movement affecting performance of entry doors. 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

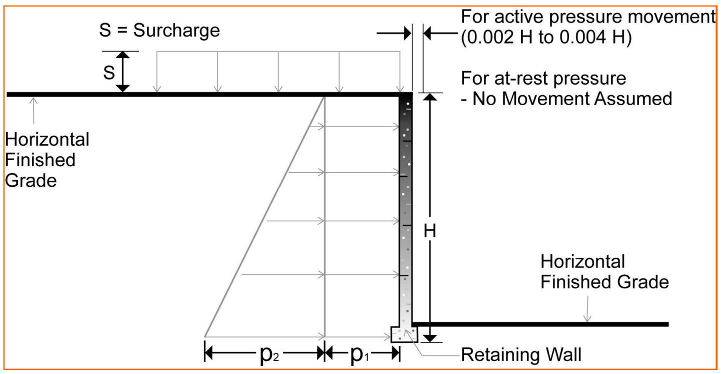
Finished subgrade, within and for at least 10 feet beyond the floor slab, should be protected from traffic, rutting, or other disturbance and maintained in a relatively moist condition until floor slabs are constructed. If the subgrade should become damaged or desiccated prior to construction of floor slabs, the affected material should be removed and Structural 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.

LATERAL EARTH PRESSURES

Design Parameters

Structures with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to values indicated in the following table. Earth pressures will be influenced by structural design of the walls, conditions of wall restraint, methods of construction and/or compaction and the strength of the materials being restrained. Two wall restraint conditions are shown in the diagram below. Active earth pressure is commonly used for design of free-standing cantilever retaining walls and assumes wall movement. The "at-rest" condition assumes no wall movement and is commonly used for basement walls, loading dock walls, or other walls restrained at the top. The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls (unless stated).



Earth Pressure Conditions	Coefficient for Backfill Type	Equivalent Fluid Density (pcf)	Surcharge Pressure, p_1 (psf)	Earth Pressure, p_2 (psf)
Active (Ka)	Structural Fill - 0.26	35	(0.26)S	(35)H
	Native Sand/Gravel – 0.36	40	(0.36)S	(40)H
	Native Clay - 0.45	50	(0.45)S	(50)H
At-Rest (Ko)	Structural Fill - 0.42	55	(0.42)S	(55)H
	Native Sand/Gravel – 0.53	60	(0.53)S	(60)H
	Native Clay - 0.63	70	(0.63)S	(70)H
Passive (Kp)	Structural Fill - 3.8	500	---	---
	Native Sand/Gravel – 2.8	320	---	---
	Native Clay – 2.2	250	---	---

Applicable conditions to the above include:

- For active earth pressure, wall must rotate about base, with top lateral movements of about 0.002 **H** to 0.004 **H**, where **H** is wall height
- For passive earth pressure to develop, wall must move horizontally to mobilize resistance
- Uniform surcharge, where S is surcharge pressure
- In-situ soil backfill weight a maximum of 115 pcf (native soils), 135 pcf (structural fill)
- Horizontal backfill, compacted between 95 and 98 percent of standard Proctor maximum dry density
- Loading from heavy compaction equipment is not included
- No hydrostatic pressures acting on wall
- No dynamic loading
- No safety factor included
- Ignore passive pressure in frost zone

Backfill placed against structures should consist of granular soils or low plasticity cohesive soils. For the granular values to be valid, the granular backfill must extend out and up from the base of the wall at an angle of at least 45 and 60 degrees from vertical for the active and passive cases, respectively.

Subsurface Drainage for Below-Grade Walls

A perforated rigid plastic drain line installed behind the base of foundation walls and which extends below adjacent grade is recommended to prevent hydrostatic loading on the walls and mitigate the potential for moisture infiltration to foundation subgrade elevation. The invert of a drain line around a below-grade building area should be placed at the base of Structural Fill replacement material. The drain line should be sloped to provide positive gravity drainage to daylight or to a sump pit and pump. The drain line should be surrounded by clean, free-draining granular material having less than 5 percent passing the No. 200 sieve. The free-draining aggregate should be encapsulated in a filter fabric such as Mirafi 140N. The granular fill should extend to within 1 foot above base of foundation, where it should be capped with compacted cohesive fill to reduce infiltration of surface water into the drain system.

FROST CONSIDERATIONS

The soils on this site are frost susceptible, and small amounts of water can affect the performance of the slabs on-grade and sidewalks subject to freeze-thaw cycles. Exterior slabs should be anticipated to heave during winter months, with predicted levels of frost action on the order of 1.0 to 3.0 inches possible at the leading edge of exposed slabs. If frost action needs to be eliminated in critical areas, we recommend the use of non-frost susceptible (NFS) fill or structural slabs (for instance, structural stoops in front of building doors). Placement of NFS material in large areas may not be feasible; however, the following recommendations are provided to help reduce potential frost heave:

- Provide surface drainage away from the building and slabs, and toward the site storm drainage system.
- Install drains around the perimeter of the building, stoops, below exterior, and connect them to the storm drainage system.
- Grade clayey subgrades, so groundwater potentially perched in overlying more permeable subgrades, such as sand or aggregate base, slope toward a site drainage system.
- Place NFS fill as backfill beneath slabs critical to the project.
- Place a 3 horizontal to 1 vertical (3H:1V) transition zone between NFS fill and other soils.
- Place NFS materials in critical sidewalk areas.

As an alternative to extending NFS 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 NFS material.

CORROSIVITY

Based on our experience at the VA Fort Harrison site, laboratory saturated paste resistivity testing for native clayey/silty sands generally have minimum resistivity values in the range of 2,000 to 3,200 ohm-cm.

SOIL RESISTIVITY (ohm-cm)	CORROSION POTENTIAL
0 to 1,000	Very High
1,000 to 2,000	High
2,000 to 5,000	Moderate
> 5,000	Mild

Data suggests that the soil pH should not be a dominant soil variable affecting soil corrosion if the soil pH in the range of 5 to 8. Based on historic analytical laboratory pH testing, the site soils generally have pH values in the range of 7.5 to 8.0. The pH falls at the upper end of the recommended range and indicates that the soil pH may provide a minor contribution to corrosion.

This data indicates that the controlling subsurface profile is a moderately corrosive environment for buried metals. Any planned buried metals should be designed in accordance to the recommendation of a corrosion engineer were necessary.

Based on our local experience and results of the past laboratory testing, the sulfate contents of the sand materials are generally to be considered as having the negligible potential for severe sulfate attack on concrete. Based on our experience, concrete in contact with native soils, in the presence of groundwater transporting the sulfate concentrations indicated, or subject to freeze-thaw cycles should be designed according to PCA Design and Control of Concrete Mixtures, utilizing Type I-II cement with minimum 28-day compressive strength of 4,500 psi and minimum water-cement ratio of 0.45.

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.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings	Boring Depth (feet)	Planned Location
4	21.0 to 31.5	building

Boring Layout and Elevations: Unless otherwise noted, Terracon personnel provided the boring layout. Coordinates were obtained with a handheld GPS unit (estimated horizontal accuracy of about ±10 feet) and approximate elevations were obtained by interpolation from the GoogleEarth™. If elevations and a more precise boring layout are desired, we recommend borings be surveyed following completion of fieldwork.

Subsurface Exploration Procedures: Our exploration was completed on December 20, 2018, when we advanced the borings with a subcontracted truck-mounted Mobile B-57 drill rig operated by Boland Drilling. The borings were advanced using continuous flight hollow stem augers. In general, four samples were obtained in the upper 10 feet of each boring and at intervals of 5 feet thereafter. In the thin-walled tube sampling procedure, a thin-walled, seamless steel tube with a sharp cutting edge was 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 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. A 3-inch O.D. split-barrel sampling spoon with 2.5-inch I.D. ring lined sampler was used for sampling in the upper 5 feet. Ring-lined, split-barrel sampling procedures are similar to standard split spoon sampling procedure; however, blow counts are typically recorded for 6-inch intervals for a total of 12 inches of penetration. 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 Great Falls laboratory for testing and classification by a Geotechnical Engineer. Our exploration team, which included the drill crew and a staff engineer, 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.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil 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

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.

SITE LOCATION AND EXPLORATION PLANS

Contents:

Site Location Plan
Exploration Plan

Note: All attachments are one page unless noted above.

SITE LOCATION

VA Fort Harrison - Outpatient Mental Health Addition ■ Fort Harrison, MT

February 7, 2019 ■ Terracon Project No. C4185062

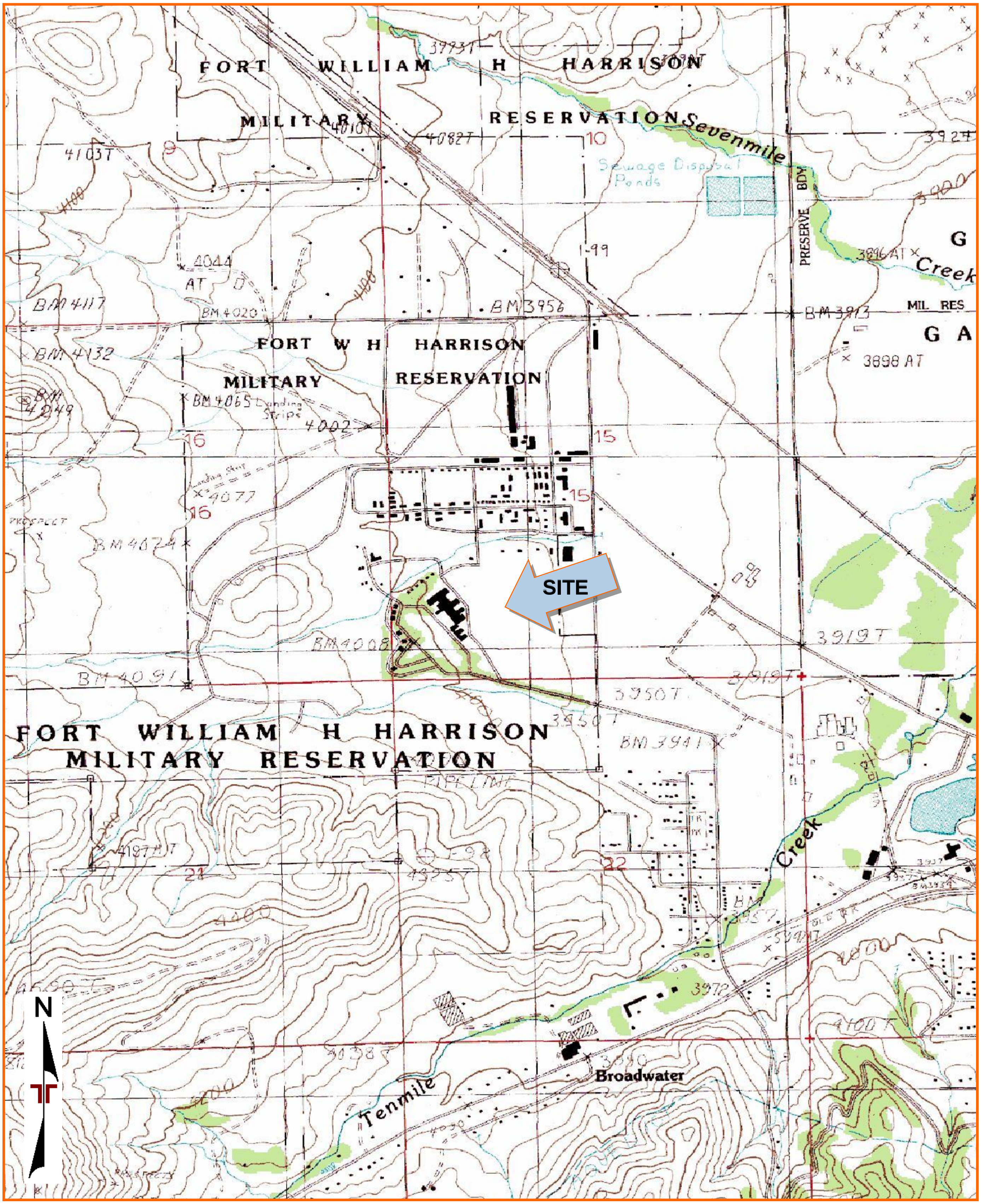


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

TOPOGRAPHIC MAP IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY QUADRANGLES INCLUDE: AUSTIN, MT (1/1/2001), SCRATCHGRAVEL HILLS, MT (1/1/1985), BLACK MOUNTAIN, MT (1/1/2001) and HELENA, MT (1/1/2001).

EXPLORATION PLAN

VA Fort Harrison - Outpatient Mental Health Addition ■ Fort Harrison, MT
February 7, 2019 ■ Terracon Project No. C4185062

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

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

Boring Logs (B-01 through B-04)
Atterberg Limits
Grain Size Distribution

Note: All attachments are one page unless noted above.

BORING LOG NO. B-01

PROJECT: VA Fort Harrison - Outpatient Mental Health Addition

CLIENT: Valhalla Engineering Group, LLC Littleton, CO

SITE: 3687 Veterans Drive Fort Harrison, MT

LOCATION See Exploration Plan

Latitude: 46.619° Longitude: -112.1003°

Approximate Surface Elev.: 3983 (Ft.) +/-

Depth	Material Description	Elevation (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Strength Test: Test Type	Strength Test: Compressive Strength (tsf)	Strength Test: Strain (%)	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI
0.4	**FILL -** , **TOPSOIL**, dark brown, sparse vegetation, organics degreasing through depth, scattered gravels at surface	3982.5+/-										
	SILTY, CLAYEY SAND with GRAVEL (SC-SM), light brown, medium dense to dense, subangular gravels				X	4-4-6 N=10				1		
	Trace of oxidation from 5' to 9' +/-		5		X	5-9-17 N=26				0		22-16-6
9.0		3974+/-			X	14-18-22 N=40				2		
11.5	**SANDY LEAN CLAY (CL)**, light brown, stiff, scattered gravels, trace of oxidation	3971.5+/-	10		X	4-6-6 N=12				12		
	SILTY, CLAYEY GRAVEL with SAND (GC-GM), light brown, dense, scattered large gravels/cobbles		15		X	12-18-26 N=44				2		
19.0		3964+/-										
21.5	**SANDY LEAN CLAY (CL)**, light brown, very stiff, fine sand, bedded, friable, trace of oxidation	3961.5+/-	20		X	5-7-18 N=25				13		

Boring Terminated at 21.5 Feet

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

Hammer Type: Automatic
Logged by A. Proud

Advancement Method:
3 1/4" hollow stem augers

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

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 interpolated from GoogleEarth data

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
1392 13th Ave SW
Great Falls, MT

Boring Started: 12-20-2018	Boring Completed: 12-20-2018
Drill Rig: B-57	Driller: C. Boland
Project No.: C4185062	

BORING LOG NO. B-02

PROJECT: VA Fort Harrison - Outpatient Mental Health Addition

CLIENT: Valhalla Engineering Group, LLC
Littleton, CO

SITE: 3687 Veterans Drive
Fort Harrison, MT

LOCATION See Exploration Plan

Latitude: 46.6191° Longitude: -112.0999°

Approximate Surface Elev.: 3980 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)
0.8	**FILL - , TOPSOIL**, dark brown, sparse vegetation, organics degreasing through depth, scattered gravels at surface	3979+/-
23.5	**SILTY, CLAYEY GRAVEL with SAND (GC-GM)**, light brown, medium dense to very dense, trace of clay and oxidation	3956.5+/-
26.0	**LEAN CLAY (CL)**, orangish brown, hard, scattered gravels, friable	3954+/-
31.5	**SILTY, CLAYEY GRAVEL with SAND (GC-GM)**, light brown, very dense, trace of clay and oxidation	3948.5+/-

Boring Terminated at 31.5 Feet

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
2.5–4		X	11-15-14 N=29				3		
5–6.5		X	9-13-15 N=28				3		
7.5–9		X	10-25-18 N=43				2		
10–11.5		X	14-17-20 N=37				2		
15–16.5		X	25-30-25 N=55				7		
20–21.5		X	50 N= 50+ / 5"				4		
25–26.5		X	3-4-35 N=39				7 / 2		
30–31.5		X	20-27-33 N=60				5		

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

Hammer Type: Automatic
Logged by A. Proud

Advancement Method:
3 1/4" hollow stem augers

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

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 interpolated from GoogleEarth data

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
1392 13th Ave SW
Great Falls, MT

Boring Started: 12-20-2018	Boring Completed: 12-20-2018
Drill Rig: B-57	Driller: C. Boland
Project No.: C4185062	

BORING LOG NO. B-03

PROJECT: VA Fort Harrison - Outpatient Mental Health Addition

CLIENT: Valhalla Engineering Group, LLC Littleton, CO

SITE: 3687 Veterans Drive Fort Harrison, MT

LOCATION See Exploration Plan

Latitude: 46.6189° Longitude: -112.0997°

Approximate Surface Elev.: 3979 (Ft.) +/-

DEPTH	Material Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
1.0	**FILL - , TOPSOIL**, dark brown, sparse vegetation, organics degreasing through depth, scattered gravels at surface	3978+/-										
	CLAYEY SAND (SC), light brown, loose to medium dense, scattered subangluar gravels, trace of silt and oxidation					4-4-2 N=6						
			5			3-5-9-10				9		32-15-17
7.0		3972+/-										
	SILTY SAND with GRAVEL (SM), light brown, medium dense, trace clay and oxidation					6-6-7 N=13				4		
9.5		3969.5+/-										
	SILTY GRAVEL with SAND (GM), light brown, dense, scattered gravels, trace of silt and oxidation		10			11-13-10 N=23				4		
			15			33-25-22 N=47				6		
18.0		3961+/-										
	SANDY LEAN CLAY (CL), light brown, hard, friable, bedded, fine sand, scattered small gravels, trace of silt		20			22-50 50+ / 5"				12		
21.0		3958+/-										

Boring Terminated at 21 Feet

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

Hammer Type: Automatic
Logged by A. Proud

Advancement Method:
3 1/4" hollow stem augers

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

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 interpolated from GoogleEarth data

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
1392 13th Ave SW
Great Falls, MT

Boring Started: 12-20-2018	Boring Completed: 12-20-2018
Drill Rig: B-57	Driller: C. Boland
Project No.: C4185062	

BORING LOG NO. B-04

PROJECT: VA Fort Harrison - Outpatient Mental Health Addition

CLIENT: Valhalla Engineering Group, LLC
Littleton, CO

SITE: 3687 Veterans Drive
Fort Harrison, MT

LOCATION See Exploration Plan

Latitude: 46.6186° Longitude: -112.0999°

Approximate Surface Elev.: 3980 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)
1.0	**FILL - , TOPSOIL**, dark brown, sparse vegetation, organics degreasing through depth, scattered gravels at surface	3979+/-
6.0	**SILTY SAND (SM)**, light brown, loose	3974+/-
11.0	**CLAYEY SAND with GRAVEL (SC)**, light brown, loose medium dense, scattered angular gravels, trace of silt	3969+/-
15.0	**SANDY LEAN CLAY (CL)**, light brown, medium stiff, scattered gravels, trace of oxidation	3965+/-
20.0	**SITLY, CLAYEY SAND with GRAVEL (SC-SM)**, light brown, dense, trace of oxidation	3960+/-
25.0	**SITLY, CLAYEY GRAVEL with SAND (GC-GM)**, light brown, very dense, trace of oxidation	3955+/-
31.5	**SANDY LEAN CLAY (CL)**, light brown, hard, scattered gravels, trace of oxidation	3948.5+/-

Boring Terminated at 31.5 Feet

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	TEST TYPE	COMPRESSIVE STRENGTH (tsf)	STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
		X	3-4-4 N=8				8		
5		X	4-8-10-6				6		
		X	4-6-6 N=12				11		
10		X	3-3-3 N=6				13		
15		X	20-21-25 N=46				15		
20		X	20-21-35 N=56				8		
25		X	35-19-19 N=38				10		
30		X	12-15-25 N=40				10		

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

Hammer Type: Automatic
Logged by A. Proud

Advancement Method:
3 1/4" hollow stem augers

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

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 interpolated from GoogleEarth data

Notes:

WATER LEVEL OBSERVATIONS

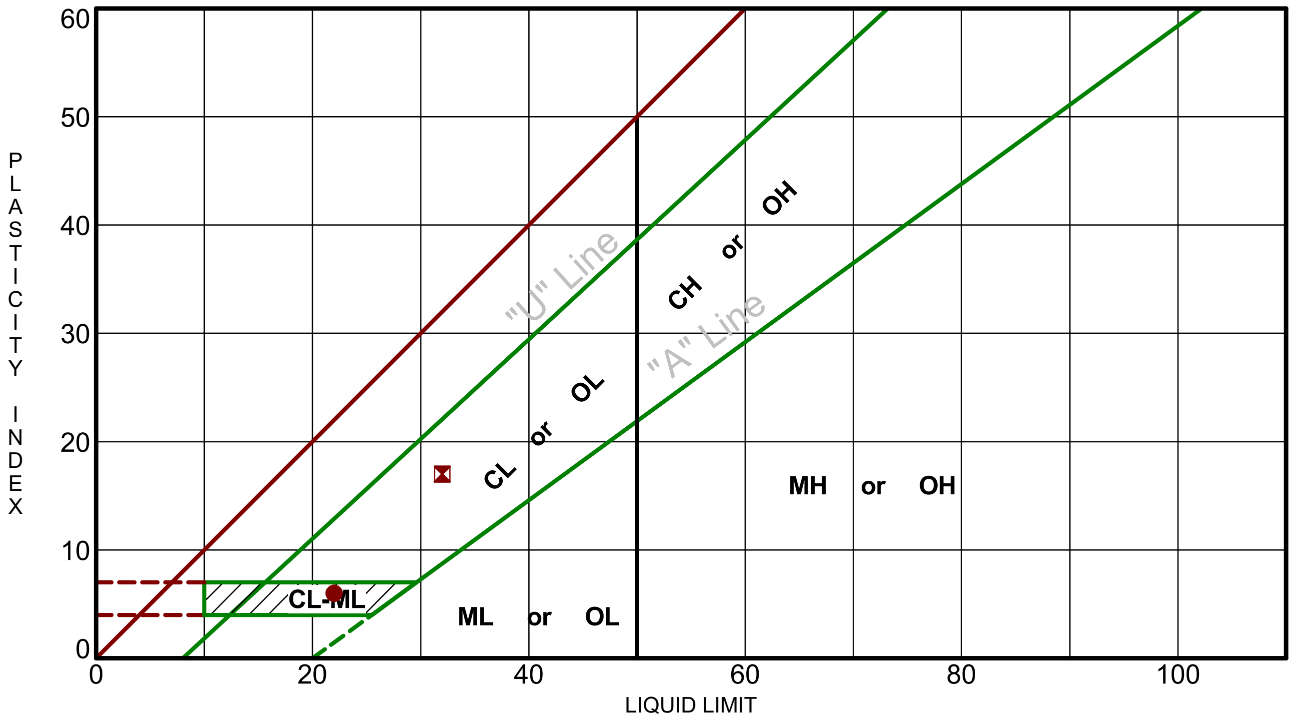
Groundwater not encountered

Terracon
1392 13th Ave SW
Great Falls, MT

Boring Started: 12-20-2018	Boring Completed: 12-20-2018
Drill Rig: B-57	Driller: C. Boland
Project No.: C4185062	

ATTERBERG LIMITS RESULTS

ASTM D4318



	Boring ID	Depth	LL	PL	PI	Fines	USCS	Description
●	B-01	5 - 6.5	22	16	6	15	SC-SM	SILTY, CLAYEY SAND with GRAVEL
⊠	B-03	5 - 7	32	15	17	43	SC	CLAYEY SAND

PROJECT: VA Fort Harrison - Outpatient Mental Health Addition

SITE: 3687 Veterans Drive Fort Harrison, MT

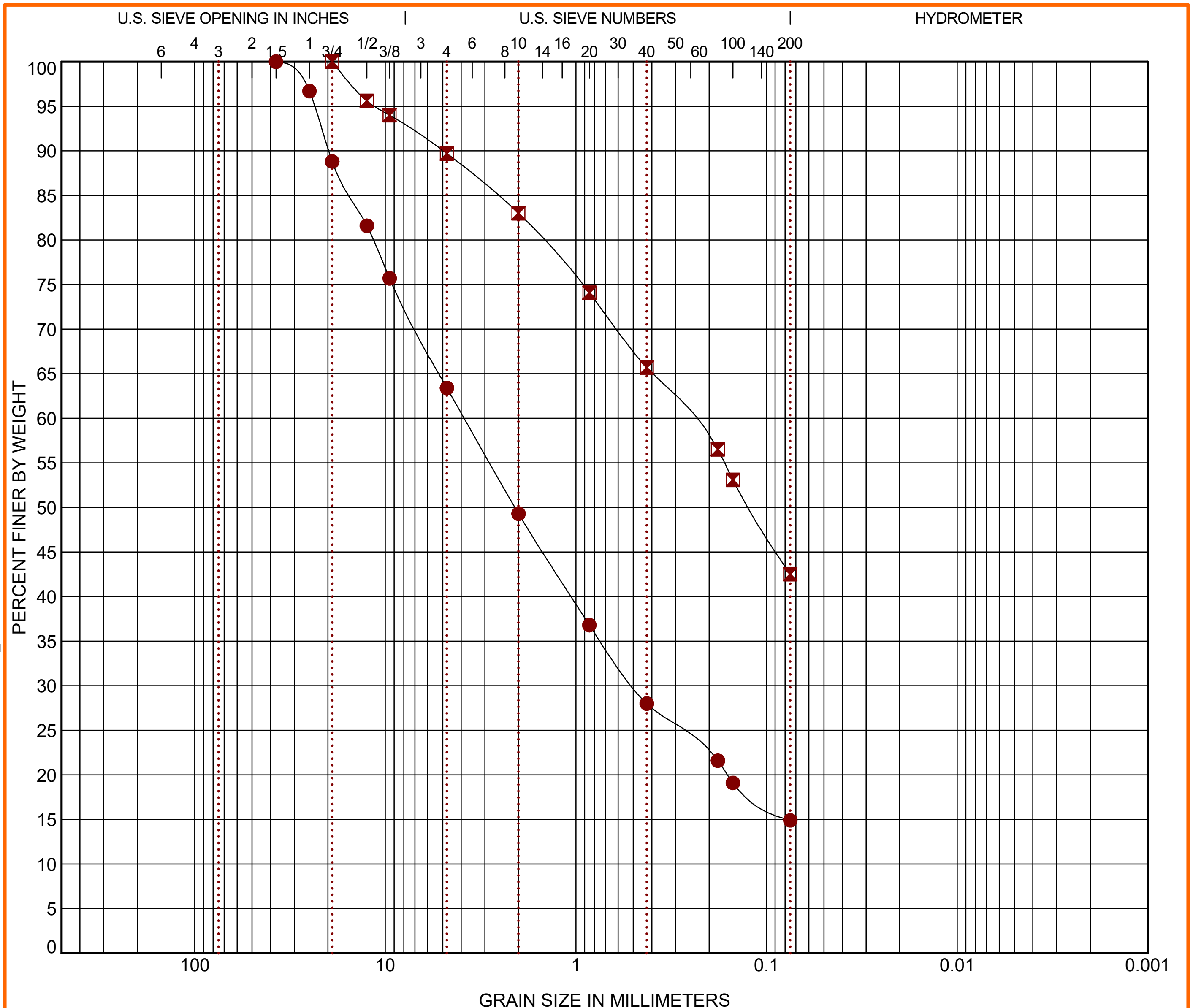
Terracon
1392 13th Ave SW
Great Falls, MT

PROJECT NUMBER: C4185062

CLIENT: Valhalla Engineering Group, LLC Littleton, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	B-01	5 - 6.5	SILTY, CLAYEY SAND with GRAVEL (SC-SM)	0	22	16	6		
⊠	B-03	5 - 7	CLAYEY SAND (SC)	9	32	15	17		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	B-01	5 - 6.5	37.5	3.856	0.498		36.6	48.5		14.9	
⊠	B-03	5 - 7	19	0.25			10.3	47.2		42.5	

PROJECT: VA Fort Harrison - Outpatient Mental Health Addition

PROJECT NUMBER: C4185062

Terracon
1392 13th Ave SW
Great Falls, MT

SITE: 3687 Veterans Drive
Fort Harrison, MT

CLIENT: Valhalla Engineering Group, LLC
Littleton, CO

SUPPORTING INFORMATION

Contents:

General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

VA Fort Harrison - Outpatient Mental Health Addition ■ Fort Harrison, MT

February 7, 2019 ■ Terracon Project No. C4185062

SAMPLING	WATER LEVEL	FIELD TESTS
Ring Sampler; Split Spoon	▽ 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.	**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 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.

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.**	**Ring Sampler Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (tsf)**	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**
Very Loose	0 - 3	0 - 6	Very Soft	less than 0.25	0 - 1	< 3
Loose	4 - 9	7 - 18	Soft	0.25 to 0.50	2 - 4	3 - 4
Medium Dense	10 - 29	19 - 58	Medium Stiff	0.50 to 1.00	4 - 8	5 - 9
Dense	30 - 50	59 - 98	Stiff	1.00 to 2.00	8 - 15	10 - 18
Very Dense	> 50	> 99	Very Stiff	2.00 to 4.00	15 - 30	19 - 42
			Hard	> 4.00	> 30	> 42

RELATIVE PROPORTIONS OF SAND AND GRAVEL		RELATIVE PROPORTIONS OF FINES	
Descriptive Term(s) of other constituents	Percent of Dry Weight	**Descriptive Term(s) of other constituents**	**Percent of Dry Weight**
Trace	<15	Trace	<5
With	15-29	With	5-12
Modifier	>30	Modifier	>12

GRAIN SIZE TERMINOLOGY		PLASTICITY DESCRIPTION	
Major Component of Sample	**Particle Size**	**Term**	**Plasticity Index**
Boulders	Over 12 in. (300 mm)	Non-plastic	0
Cobbles	12 in. to 3 in. (300mm to 75mm)	Low	1 - 10
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)	Medium	11 - 30
Sand	#4 to #200 sieve (4.75mm to 0.075mm	High	> 30
Silt or Clay	Passing #200 sieve (0.075mm)		

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 ³ 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 ³ 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 ³ 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 ³ 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 ³ 30% plus No. 200 predominantly sand, add "sandy" to group name.

[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ³ 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.