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# Geotechnical Engineering Services

159th Avenue NE Vault
Tosh Creek Watershed Restoration
Redmond, Washington

*for*
**City of Redmond and**
**HDR Engineering, Inc.**

December 4, 2015

GeoEngineers

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# Redmond, Washington

**File No. 0500-204-00 T0400**

**December 4, 2015**

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## INTRODUCTION

This report presents the results of our geotechnical engineering services for the 159th Avenue NE Vault project in Redmond, Washington. This project is part of the larger Tosh Creek Watershed Restoration project. The site is shown relative to surrounding physical features on the Vicinity Map, Figure 1, and the Site Plan, Figure 2.

The purpose of this study is to evaluate subsurface conditions as a basis of developing preliminary geotechnical recommendations in support of the design of the proposed 159th Avenue NE vault. Our geotechnical engineering services were completed in general accordance with the Subconsultant Agreement between GeoEngineers, Inc. and HDR Engineering, Inc. executed on July 27, 2015. The conclusions and recommendations provided in this report are preliminary and are subject to modification pending further discussion with the project team. Our scope of services summarized in the report includes:

- Review geologic maps and available geotechnical reports for the site and nearby properties.
- Coordinate and complete an exploration program to include four borings at the site; three borings completed with standpipe piezometers (monitoring wells).
- Perform laboratory tests on samples obtained from the borings.
- Evaluate pertinent physical and engineering characteristics of the soils based on the results of the field exploration, laboratory testing and our experience, and provide conclusions and geotechnical recommendations for the following:
    - Site preparation and grading, including underground utility installations;
    - Placement of backfill and structural fill, including fill type and compaction requirements and the reuse of on-site soils;
    - Potential areas of settlement and vibration impacts during construction;
    - Vault wall and foundation recommendations and appropriate design capacities and lateral restraint;
    - Geotechnical considerations for temporary excavation support;
    - Geotechnical considerations related to groundwater conditions including anticipated seasonal fluctuations, and buoyancy and drainage considerations for buried structures;
    - Guideline recommendations for construction dewatering;
    - Seismic design criteria based on the International Building Code (IBC);
    - Recommendations for sedimentation and erosion control during and following construction, and permanent site drainage;
    - Discuss guideline pavement restoration recommendations; and
    - Recommendations as to the feasibility of an infiltration alternative to the proposed 159th Avenue NE vault.
- Preparing this report presenting our preliminary design conclusions and recommendations.

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## PROJECT DESCRIPTION

Our understanding of the project is based on discussions with, and information provided by HDR and the City of Redmond, and our experience with similar projects. We understand that the project will construct a new vault to be located within the right-of-way of 159th Avenue NE in the Tosh Creek watershed. The proposed concrete vault will be approximately 1,000 feet long by 10 feet wide by 16 feet deep. The vault lid will have 2 to 4 feet of soil cover, resulting in excavations on the order of 18 to 20 feet deep.

## FIELD EXPLORATIONS AND LABORATORY TESTING

### Field Explorations

Subsurface soil and groundwater conditions were evaluated by drilling five borings (B-1, B-2, B-2a, B-3, and B-4 on September 14, 15, and 21, 2015. The borings were drilled to depths ranging between 7½ feet to 95 feet below the ground surface (bgs). Borings B-1, B-3, and B-4 were completed with standpipe piezometers (monitoring wells). The approximate locations of the borings are shown on the Site Plan, Figure 2. Details of the exploration program, boring logs, and details of the piezometer installation are presented in Appendix A.

### Laboratory Testing

Soil samples were collected during drilling and taken to GeoEngineers' laboratory for further evaluation. Selected samples were tested for the determination of moisture content, grain size distribution (sieve analysis) and plasticity characteristics (Atterberg limits). A description of the laboratory testing and the test results are presented in Appendix B.

## SITE CONDITIONS

### Geologic Setting

The project area is located within the central portion of the Puget Lowland Physiographic Province. The Puget Lowland Physiographic Province consists of a broad, low-lying region of subdued topography situated between the Cascade Range to the east and the Olympic Mountains and Willapa Hills to the west.

Starting in the early Pleistocene, the Puget Lowland was subject to four periods of extensive glaciation. A glaciation hiatus existed between 200,000 and 740,000 years ago; no deposits of that age are identified from the Puget Lowland. During the late Pleistocene, the climate cooled, and renewed glaciation again modified the Puget Lowland. The Puget Lowland owes its present-day geomorphic features to the last continental glacier that covered the region -- part of the Fraser Glaciation. Named the Cordilleran ice sheet, it consisted of two parts; one called the Puget Lobe, and the other named the Juan de Fuca Lobe. The ice sheet advanced from British Columbia 18,000 years ago to just south of Olympia; the entire Puget Lowland was covered by glacial ice. As during previous glaciations, streams and rivers draining the Cascades were dammed by the Cordilleran ice sheet. By 14,000 years ago the ice had retreated north to Seattle. Large areas south of Seattle were being covered by recessional outwash sands and gravels that are part of the Vashon Stade. These sands and gravels are an important source of raw materials for concrete and other construction uses. At about the same time, thinning ice allowed marine waters to return to the Puget Lowland, and seawater lifted the ice and caused it to break up into berg ice over the entire region.

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Approximately 10,000 years ago, after a short-lived re-advance in the northern Puget Lowland, the Cordilleran ice sheet disappeared, bringing the Ice Age to a close in this region (paragraph adapted from Lasmanis (1991)).

### Site Geology

Geologic information for the project vicinity includes a Pacific Northwest Center for Geologic Mapping Studies map, "Geologic Map of King County, Washington" (Booth et al., 2007). The mapped surficial geology in the project vicinity consists of Vashon age glacial till deposits.

Glacial till was deposited and consolidated by several thousand feet of ice and is mapped in the upland portion of the Tosh Creek project area, including the 159th Avenue NE vault site. Glacial till consists of dense to very dense, non-sorted mixture of clay, silt, sand, gravel, cobbles, and boulders. The upper 2 to 5 feet of glacial till is typically weathered, and the density ranges from medium dense to dense. This weathered zone is somewhat drained, whereas the underlying unweathered till is a barrier to vertical drainage. Water percolating into the weathered till will generally pond and migrate laterally between the weathered and unweathered layers. In its native undisturbed state, glacial till soils are competent load bearing soils.

In contrast, differing surficial geologic units have been mapped by others (City of Redmond et. al, 2015) in the vicinity of Tosh Creek that include glacial lakebed deposits and ice contact deposits. Both of these geologic units typically consist of medium stiff to hard silt and clay.

Fill soils associated with site development (road construction, buried utilities, etc.) are also anticipated at the site.

### Critical/Sensitive Areas Delineation

Review of the City of Redmond Critical Areas Maps and King County Sensitive Areas Maps indicate that the project area is located within the City of Redmond Well Head Zone 4 and is not mapped within a seismic, wetland, erosion, or landslide hazard area.

### Surface Conditions

The project site is located within the right-of-way corridor of 159th Avenue NE. 159th Avenue NE is within a single-family residential area. The roadway terminates into a dead-end to the south of the project site. The existing road surface is relatively flat to gently sloping within the proposed vault footprint. The road surface elevation varies from about Elevation 252 feet at the south end of the vault to about Elevation 248 feet at the north end of the vault.

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## Subsurface Conditions

### Soil

The soil conditions encountered in the explorations are generally consistent with the mapped geology of the region and consist of fill overlying glacially consolidated soils. Each of these units is discussed below.

Fill was encountered below the pavement in each of the borings. The pavement section consisted of 3 to 9 inches of asphalt concrete over 3 to 4 inches of base course. The fill below the pavement is variable and consists of layers of loose to medium dense sand and gravel with varying amounts of silt and medium stiff to stiff silt. The fill extends to depths ranging from 3 to 8 feet bgs.

Glacially consolidated soils were encountered below the fill in each of the borings, except B-2a. The glacially consolidated soils generally consist of layers of stiff to hard silt and clay with varying amounts of sand. These silt and clay layers are interpreted to be glacial lakebed deposits and were encountered to the maximum depth explored, 95 feet bgs. A thin weathered zone was encountered directly below the fill and consists of medium dense to dense silty sand with gravel (glacial till) or medium stiff to stiff silt (glacial lakebed deposits).

### Groundwater

Groundwater levels collected from the standpipe piezometers (monitoring wells) in borings B-1, B-3, and B-4 have been measured at depths ranging between from 17.2 to 25.3 feet bgs. Discrete readings are shown on the boring logs in Appendix A. Pressure transducer readings will be reported as part of our quarterly data download in future reports.

Based on the measured groundwater levels and site soils, the groundwater table is expected to be encountered at a depth of about 15 feet bgs, with capillary rise extending the presence of saturated soils to shallower depths within vadose zone which is composed mainly of low permeability fine-grained soils (silt and clay). Some seasonal variation of the groundwater table is expected in response to changes in recharge from infiltration rainfall between the wet winters and dry summers.

The deeper well completion in boring B-3, screened between 75 and 95 feet bgs, shows a lower piezometric level that is consistent with the regional hydrogeologic setting of the site within an elevated upland above Lake Sammamish. The low-permeability fine-grained soils likely form a regional aquitard that limits the rate of downward percolation and maintains high levels of soil saturation. The difference in groundwater levels between adjacent shallow boring B-4 and deep boring B-3 piezometers indicates a downward hydraulic gradient of about 0.2 feet per foot depth. This is consistent with seepage toward regional discharge zones closer to lake level, as well as elevated discharge zones provided by the adjacent incised Tosh Creek valley.

Additionally, during the wet season, perched groundwater is expected to develop at the contact between the fill and glacially consolidated soils. The majority of the soils above the static groundwater table are expected to be saturated due to these conditions, with perched zones likely diminishing during drier summer periods.

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## CONCLUSIONS AND RECOMMENDATIONS

### Summary of Geotechnical Considerations

We conclude that the planned improvements can be successfully completed from a geotechnical perspective, provided the considerations presented in this report are incorporated into the project planning and design. A summary of the primary site preparation and design considerations for the proposed project is provided below. This summary is presented for introductory purposes and should be used in conjunction with the complete recommendations presented in this report.

- Subsurface conditions are anticipated to consist of an upper layer of fill and/or glacial till overlying stiff to hard silt and clay soils. Excavation can be accomplished in these soils with conventional excavation equipment.
- Temporary shoring will be required to construct the vault due to the limited space within the 159th Avenue NE right of way corridor.
- The planned vault excavation will extend into saturated soils and below the anticipated groundwater table. However, based on the low permeability of the fine-grained soils below the groundwater table, we anticipate that seepage into the planned excavation will be minor and that dewatering, if needed, can be accomplished with sumps and pumps.
- The existing fill and native soils at the site contain sufficient fines (silt and clay) such that they are moisture-sensitive soils that will become easily disturbed when wet. We recommend site development be accomplished during extend periods of dry weather when the site soils will be less susceptible to disturbance due to rain and runoff and when the groundwater seepage is less. If construction is completed during the wet season, additional excavation and replacement of portions of the vault subgrade soils and an increased dewatering effort may be necessary.
- Consideration should be given to placing a gravel layer below the vault subgrades to provide a working surface, especially if construction will extend into the wet season. The gravel layer will help prevent subgrade deterioration under the disturbance of equipment and foot traffic during construction. We recommend a minimum 12-inch-thick clean crushed gravel layer under the foundation elements. This gravel layer can also be incorporated into the underslab drainage system for the vault, if drainage is incorporated into the design.
- Where open cuts may be feasible, we recommend temporary slopes be inclined at 1½H:1V (horizontal to vertical) or flatter at the site. These slopes may need to be modified depending on the excavation depth, seepage conditions, and stability.
- The project site is best designated as seismic Soil Profile Type D per the 2012 IBC.

These and other geotechnical considerations are discussed further, and recommendations pertaining to the geotechnical aspects of the project are presented in the following sections of this report.

### Earthwork

#### Earthwork Considerations

Fill, glacial till, and fine-grained glacial lakebed deposits (silt and clay) were observed in the explorations. While cobbles and/or boulders were not noted during the drilling of the borings, cobbles and boulders are

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known to exist in glacially consolidated soils. The contractor should be prepared to deal with debris in the fill and cobbles and boulders in the glacially consolidated soils.

### Clearing and Grubbing

Significant clearing and grubbing is not expected within the project area and these activities are expected to be limited to the demolition and removal of pavements, concrete hardscapes (sidewalks, curbs, gutters, etc.), utilities, and landscape areas. The asphalt pavement thickness encountered in the borings was between 3 and 9 inches of asphalt pavement and may be locally thicker in the center of the roadway.

### Erosion and Sedimentation Control

Potential sources or causes of erosion and sedimentation depend upon construction methods, slope length, and gradient, amount of soil exposed and/or disturbed, soil type, construction sequencing, and weather. The project's impact on erosion-prone areas can be reduced by implementing an erosion and sedimentation control plan. The plan should be designed in accordance with applicable City and/or county standards. The plan should incorporate basic planning principles including:

- Scheduling grading and construction to reduce soil exposure;
- Retaining existing vegetation whenever feasible;
- Revegetating or mulching denuded areas;
- Directing runoff away from denuded areas;
- Minimizing the length and steepness of slopes with exposed soils;
- Decreasing runoff velocities;
- Confining sediment to the project site;
- Inspecting and maintaining control measures frequently;
- Covering soil stockpiles; and
- Implementing proper erosion control best management practices (BMPs).

Temporary erosion protection should be used and maintained in areas with exposed or disturbed soils to help reduce the potential for erosion and reduce transport of sediment to adjacent areas. Temporary erosion protection should include the construction of a silt fence around the perimeter of the work area prior to the commencement of grading activities. Permanent erosion protection should be provided by reestablishing vegetation using hydroseeding and/or landscape planting.

Until the permanent erosion protection is established and the site is stabilized, site monitoring should be performed by qualified personnel to evaluate the effectiveness of the erosion control measures and repair and/or modify them as appropriate. Provisions for modifications to the erosion control system based on monitoring observations should be included in the erosion and sedimentation control plan.

### Subgrade Preparation

A geotechnical engineer should monitor the subgrade preparation to help determine the condition of the exposed subgrade, and if necessary, the depth of removal of soft or pumping soils, and to evaluate whether subgrade disturbance or progressive deterioration is occurring. Subgrade disturbance or deterioration

could occur if the subgrade is wet and cannot be dried. Prior to constructing foundation elements, placing new fill, subbase or base course materials, subgrade areas should be proof-rolled to locate areas of loose, soft, or pumping soils. Proof-rolling can be completed using a piece of heavy tire-mounted equipment or a loaded dump truck. Probing should be used to evaluate the subgrade during periods of wet weather or if access is not feasible for construction equipment. If soft or pumping soils are observed, such unsuitable subgrade soils should be recompacted or overexcavated and replaced. The depth of overexcavation should be determined by a geotechnical engineer.

If deep pockets of soft or pumping soils are encountered, it may be possible to limit the depth of overexcavation by placing a woven Geotextile for Separation or Soil Stabilization (Washington State Department of Transportation [WSDOT] Standard Specification 9-33) on the overexcavated subgrade and covering the geotextile with structural fill. We recommend using the specified woven fabric for soil stabilization. The geotextile will provide additional support by bridging over the soft material, and will help reduce fines contamination into the structural fill. The need for geotextile fabric and overexcavation should be evaluated by a geotechnical engineer.

Backfill in old utility trenches or previously placed fill to construct existing paved areas that exhibit surface settlement or pavement distress should be tested and recompacted if necessary. The uppermost 2 feet supporting the pavement structure should be compacted to at least 95 percent of the maximum dry density (MDD) estimated in general accordance with ASTM D 1557. Material below this level should be compacted to at least 90 percent.

### Structural Fill

#### *Materials*

Materials used to construct roadways, placed to support buried structures or foundations, or placed behind retaining or buried structures are classified as structural fill for the purpose of this report. Structural fill material quality varies depending upon its use, as described below:

1. As a minimum, structural fill placed to construct embankments and roadways, to backfill utility trenches and to support foundations should meet the criteria for common borrow, WSDOT 9-03.14(3). Common borrow will be suitable for use as structural fill during dry weather conditions only. If structural fill is placed during wet weather, the structural fill should consist of gravel borrow, WSDOT 9-03.14(1).
2. Structural backfill for walls should meet the criteria for gravel backfill for walls, WSDOT 9-03.12(2).
3. Structural fill placed for underslab drainage should consist of 1.5-inch minus clean crushed gravel, WSDOT 9-03.1(4)C, grading No. 57.
4. Structural fill placed to surround collector pipe (drain rock) should meet the criteria for gravel backfill for drains, WSDOT 9-03.12(4).
5. Structural fill placed as crushed surfacing base/top course below pavements should conform to WSDOT 9-03.9(3).

#### *On-site Soils*

The on-site soils have a high percentage of fines (silt and clay). These soils will not be suitable for use as structural fill during wet weather conditions, but may selectively be used for fill during periods of extended dry weather, provided the material meets the criteria for structural fill and can be conditioned to a suitable

moisture content to be adequately compacted. The on-site soils generally meet the criteria for common borrow, WSDOT 9-03.14(3).

If wet weather construction is planned, the on-site soils will not be suitable for use as structural fill. For wet weather construction, we recommend that structural fill consist of imported sand and gravel with little or no silt, WSDOT 9-03.14(1).

***Fill Placement and Compaction Criteria***

Structural fill should be mechanically compacted to a firm, non-yielding condition. Structural fill should be placed in loose lifts not exceeding 1-foot in thickness. Each lift should be conditioned to the proper moisture content and compacted to the specified density before placing subsequent lifts. Structural fill should be compacted to the following criteria:

1. Structural fill placed behind retaining walls and buried structures should be compacted to at least 90 percent of the MDD in general accordance with ASTM D 1557. Care should be taken when compacting fill near the face of structures to avoid overcompaction and hence overstressing the walls.
2. Structural fill in embankment and new pavement areas, including utility trench backfill, should be compacted to 90 percent of the MDD (ASTM D 1557), except that the upper 2 feet of fill below final subgrade should be compacted to 95 percent of the MDD (ASTM D 1557).
3. Structural fill placed to support foundations should be compacted to 95 percent of the MDD (ASTM D 1557).
4. Structural fill placed as crushed rock base course below pavements should be compacted to 95 percent of the MDD (ASTM D 1557).

We recommend that a geotechnical engineer be present during proof-rolling and/or probing of the exposed subgrade soils and during placement of structural fill. The geotechnical engineer will evaluate the adequacy of the subgrade soils and identify areas needing further work, perform in-place moisture-density tests in the fill to evaluate whether the work is being done in accordance with the compaction specifications, and advise on any modifications to procedure that may be appropriate for the prevailing conditions.

***Weather Considerations***

The majority of the on-site soils contain a moderate to high percentage of fines (silt and clay) and are moisture-sensitive. When the moisture content of these soils is more than a few percent above the optimum moisture content, these soils become muddy and unstable, operation of equipment on these soils will be difficult, and it will be difficult or impossible to meet the required compaction criteria. Additionally, disturbance of near-surface soils should be expected if earthwork is completed during periods of wet weather. The contractor will need to take precautions to protect the subgrade during periods of wet weather.

The wet weather season in western Washington generally begins in October and continues through May; however, periods of wet weather may occur during any month of the year. The optimum earthwork period for these types of soils is typically June through September. If wet weather earthwork is unavoidable, we recommend that:

- The ground surface in and around the work area should be sloped so that surface water is directed away from the work area. The ground surface should be graded such that areas of ponded water do not develop. The contractor should take measures to prevent surface water from collecting in

excavations and trenches. Measures should be implemented to remove surface water from the work area.

- Erosion control techniques should be implemented to prevent sediment from leaving the site.
- Earthwork activities should not take place during periods of heavy precipitation.
- Slopes with exposed soils should be covered with plastic sheeting.
- The contractor should take necessary measures to prevent on-site soils and soils to be used as fill from becoming wet or unstable. These measures may include the use of plastic sheeting, sumps with pumps, and grading. The site soils should not be left uncompacted and exposed to moisture. Sealing the surficial soils by rolling with a smooth-drum roller prior to periods of precipitation will help reduce the extent that these soils become wet or unstable.
- Construction activities should be scheduled so that the length of time that soils are left exposed to moisture is reduced to the extent practical.

### Temporary Slopes

We recommend that temporary unsupported cut slopes greater than 4 feet deep be inclined no steeper than 1½H:1V. This applies to fully dewatered conditions. Flatter slopes may be necessary if seepage is present on the cut face. Temporary cut slopes should encroach no closer than 5 feet laterally from roadways, pavements, structures, or other improvements. Some sloughing and raveling of the cut slopes should be expected. Temporary covering, such as heavy plastic sheeting, should be used to protect these slopes during periods of rainfall. Surface water runoff from above cut slopes must be prevented from flowing over the slope face by using curbs, berms, drainage ditches, swales, or other appropriate methods.

If temporary cut slopes experience excessive sloughing or raveling during construction, it may become necessary to modify the cut slopes to maintain safe working conditions and protect adjacent facilities or structures. Slopes experiencing excessive sloughing or raveling can be flattened or can be regraded to add intermediate slope benches, or additional dewatering can be provided if the poor slope performance is related to groundwater seepage.

### Permanent Slopes

We recommend that permanent cut and fill slopes be constructed no steeper than 2H:1V. To achieve uniform compaction, we recommend that fill slopes be overbuilt slightly (several feet) and subsequently cut back to expose properly compacted fill. We recommend that the finished slope faces be compacted by track walking with the equipment running perpendicular to the slope contours so that the track grouser marks help provide an erosion-resistant slope texture.

To reduce erosion, newly constructed slopes should be planted or hydroseeded shortly after completion of grading. Until the vegetation is established, some sloughing and raveling of the slopes should be expected. This may require localized repairs and reseeding. Temporary covering, such as clear heavy plastic sheeting, jute fabric, loose straw, or excelsior or straw/coconut matting, should be used to protect the slopes during periods of rainfall.

### Temporary Shoring Support of Excavations

As currently planned, the vault excavation will extend to about Elevation 233 feet and will require temporary shoring on the order of 18 to 20 feet. Shoring and temporary slope inclinations must conform to the provisions of Title 296 Washington Administrative Code (WAC), Part N, "Excavation, Trenching, and Shoring." Excavation, shoring, trench boxes, or sloped sidewalls will be required under Washington Industrial Safety and Health Act (WISHA). The contract documents should specify that the contractor is responsible for selecting excavation and dewatering methods, monitoring the excavations for safety and providing shoring, as required, to protect personnel and structures.

Vertical excavations deeper than 3 feet should be shored or laid back at a stable slope if workers are required to enter. Because of the diversity of available shoring systems and construction techniques, the design of temporary shoring is most appropriately left up to the contractor proposing to complete the installation. However, we recommend that the shoring be designed by a Professional Engineer (P.E.) licensed in the State of Washington, and that the P.E.-stamped shoring plans and calculations be submitted to the City of Redmond and the Engineer for review prior to construction. The following paragraphs present general recommendations for the type of shoring system and design parameters that we conclude are appropriate for the subsurface conditions at the project.

We anticipate that the excavations will be shored using trench boxes, conventional sheet piles, a braced system, or a slide rail system. It will be preferable to use an "active" system (sheet piles, braced system or slide rail system) over trench boxes because typical trench box shoring results in voids between the trench box and soil, resulting in increased risks of soil caving. The lateral soil pressures acting on temporary supports will depend on the type and density of the soil behind the wall, the inclination of the ground surface behind the wall, and groundwater. For walls that are free to yield at the top at least one thousandth of the height of the wall (i.e., wall height times 0.001), soil pressures will be less than if movement is restrained. The design of temporary shoring should allow for lateral pressures exerted by the adjacent soil, and for surcharge loads resulting from structures, traffic, construction equipment, temporary stockpiles adjacent to the excavation, etc. Lateral load resistance can be mobilized through the use of braces, tiebacks, anchor blocks, and passive pressures on members that extend below the bottom of the excavation. Temporary shoring used to support trench excavations typically uses internal bracing such as hydraulic shoring or trench boxes.

Recommend earth pressures for the design of temporary shoring are presented in Figure 3. We recommend that yielding walls retaining on-site soils be designed using active earth pressures. For non-yielding (i.e., braced) systems, we recommend that the shoring be designed using at-rest earth pressure. The earth pressure values presented in Figure 3 assume that the ground behind the shoring is sufficiently drained (dewatered) such that the hydrostatic pressure do not develop behind the shoring. If the shoring system is not adequately drained then full hydrostatic conditions should be assumed by the shoring designer. We can provide additional earth pressure recommendations appropriate for undrained shoring if requested.

The soil pressure available to resist lateral loads against shoring is a function of the passive resistance that can develop on the face of below-grade elements of the shoring as those elements move horizontally into the soil. The allowable passive resistance presented on Figure 3 assume the native soils are below the groundwater table and includes a factor of safety of about 1.5.

## Construction Dewatering

The excavation to complete installation of the vault will extend approximately 3 to 5 feet below the static groundwater level. However, the quantity and inflow rate of groundwater into the excavation is expected to be less than 5 gallons per minute (gpm) because of the relatively low permeability of the glacially consolidated soils. Although soils appear to be uniformly similar within the four borings, glacial terrain is notoriously variable and more permeable soils could be present between the boring locations. Such features, if encountered in the excavation, may increase potential groundwater inflows to 10 or 20 gpm but may be short-lived if the permeable features are of limited extent and allowed drain. In our opinion, these expected construction inflow rates should be manageable with a system of drainage trenches and pumped sumps. We recommend that construction be completed in the late summer or early fall months when the groundwater level is typically at its lowest elevation.

## Settlement and Vibration Potential during Construction

Peak particle velocity (PPV) is the generally accepted vibration component for assessing the potential for damaging vibrations produced by a wide variety of energy sources, including construction equipment. Empirical studies show that the PPV associated with ground vibrations is inversely and exponentially proportional to the distance for the source vibration. In other words, the PPV decreases very rapidly with distance from the source vibration. For example, the PPV measured at a distance of 100 feet from the source will be approximately 0.1 percent of the PPV measured at the source for typical construction-related vibrations. Because of the exponential rate of energy decay with distance from the source, variations in subsurface material type have only a minor effect on PPV, as compared to source distance.

A PPV of 2 inches per second is generally considered a threshold value for inducing damage to residential structures located near construction sites and quarry blasting operations (ISEE 1998). A PPV of 0.5 inches per second has been proposed as a threshold value of "old residential structures in very poor condition" (Wiss 1981). Similarly, Hudson and Harrison (1997) report the tolerable PPV limit of 0.5 to 2 inches per second for residential masonry buildings. By way of comparison, a PPV of 0.02 inches per second is considered the threshold for human perception of motion. ISEE (1998) reports that a PPF of 5.4 inches per second would be expected to cause minor damage to an average house subjected to quarry blasting vibrations and a PPV of 20 inches per second would be expected to cause damage to nearly all houses. It has been demonstrated that an upper PPV limit of 12 inches per second is adequate to protect buried steel pipelines in most circumstances (Oriard 2002).

For preliminary risk assessment purposes, we evaluated the distance expected to produce PPV values of 0.5 and 2 inches per second for the anticipated construction activities/equipment as summarized in Table 1 below.

**TABLE 1. SUMMARY OF ANTICIPATED CONSTRUCTION VIBRATIONS**

| Construction Equipment/Activity | Distance (feet) | |
|---|---|---|
| | PPV = 0.5 in/sec | PPV = 2.0 in/sec |
| Caisson Drilling and Large Bull Dozers | 8 | 3 |
| Trucks | 7 | < 3 |
| Jack Hammering | 4 | < 2 |
| Crane Idling | < 2 | < 1 |

Using available published information, ground vibrations produced by the anticipated construction activities are expected to be much less than damage threshold values at the nearby homes. However, human perception of vibration is very sensitive and is much lower than the level to damage residential structures. Therefore, we recommended the following be considered to manage the risk associated with potential homeowner claims of damage from the planned construction activities:

- Complete outreach to the community informing them of the construction activities and what to expect by way of vibrations in addition to schedule, noise, street closures, etc.
- Document the exiting conditions of the adjacent homes prior to construction with photographs and/or video. It is not uncommon for homeowners to notice preexisting cracks in their home's foundation, concrete finishes, and masonry until after a construction project is underway.
- Obtain seismographic test data early on during construction to record the real-time vibration intensity with distance for the various construction activities/equipment and to document that construction-included vibrations are below damage thresholds.

We do not anticipate measurable settlement of the near surface soils adjacent to the construction from construction vibrations at the site.

## Infiltration Evaluation

The feasibility of an infiltration alternative that would potentially replace or reduce the need to construct the proposed vault was evaluated based on the subsurface soil and groundwater conditions and laboratory data obtained from the borings completed at the site. Boring B-3 was drilled to 95 feet bgs to identify suitable soil layers, presumably into an advance outwash deposit of relatively clean sand and/or gravel, for stormwater discharge and to perform pumping tests for infiltration evaluation.

Fine-grained silt and clay soils were encountered below the upper fill and/or glacial till soils to the depth explored in each of the borings. Based on the soils encountered in the borings, the site soils are too low in permeability and are not considered favorable for stormwater infiltration. As such, a pumping test was not completed during the field investigation program. It is our opinion that an infiltration alternative to the vault is not appropriate for the site.

## Preliminary Buried Structure Design Parameters

We understand that the dimensions of the proposed concrete vault will be on the order of approximately 1,000 feet long by 10 feet wide by 16 feet deep. The following sections provide preliminary recommendations for the vault design.

### Allowable Bearing Pressure

The soils explored for this study at anticipated foundation depths consist of glacially consolidated materials that will have relatively high allowable bearing capacities in the undisturbed condition. On this basis, preliminary foundation designs for the buried structures can be evaluated using an allowable soil bearing capacity of 4 kips per square foot (ksf) for undisturbed native soils or properly compacted structural fill placed over undisturbed native soils. Retaining wall foundations that are subject to overturning loads can be evaluated using an allowable maximum toe bearing pressure of 4.5 ksf. These allowable soil bearing values apply to the total of dead and long-term live loads and may be increased by up to one-third for seismic loads.

Buried structures that do not extend down to bottom out in glacially consolidated soils should be designed for lesser bearing capacities. Foundation capacities for these shallower structures should be evaluated independently.

A modulus of subgrade reaction equal to 80 pounds per cubic inch (pci) (assuming bottom of vault is approximately 16 feet bgs) can be used for design of structural slab/mat foundations.

#### Settlement Performance

Provided all loose soil is removed and the subgrade is prepared as recommended under "Construction Considerations" below, we estimate the total settlement of buried structure foundations will be on the order of 1 inch or less. The settlements will occur rapidly, essentially as loads are applied. Differential settlements measured along 25 feet of the structure are expected to be less than ½ inch.

#### Lateral Pressures

The lateral earth pressure values presented in Figure 4 and discussed in this section assume relatively level backfill conditions. We can provide additional earth pressure recommendations for specific site geometry (sloping back and fore slopes) to the design team, if necessary.

If the buried structure walls are rigid (restrained against rotation), we recommend that the walls be designed for an at-rest earth pressure. Rigid walls are walls that deflect less than about H/1000 under the at-rest pressure loading, where H is the height of the wall measured from the bottom of the structure to the ground surface. Once the wall moves approximately H/1000, the active pressure state is achieved. Walls that are allowed to deflect more than about H/1000 under loading may be designed for the active earth pressure. Figure 4 presents both the at-rest and active pressures for drained and submerged conditions.

To account for traffic surcharge loading, we recommend that the buried structure walls be designed for a uniform surcharge pressure determined by increasing the height of the fill behind the walls by 2 feet (250 pcf) as shown on Figure 4. Other surcharge loads such as heavy construction equipment or soil stockpiles should be included as appropriate.

If drainage is not provided around the buried structures, the structure should be designed for submerged conditions and the uplift forces on the structures will need to be considered. Uplift forces may be resisted by widening the structure's footings such that the weight of the backfill over the footing exceeds the uplift force.

Seismic earth pressure should be used as a check in the buried structure wall design. We recommend that a rectangular seismic earth pressure distribution equal to 7H in pounds per square foot (psf) (where H is the wall height in feet) be added to the static lateral earth pressures presented above for the rigid wall or active earth pressure condition, whichever is appropriate.

Lateral wall loads on buried structures can be resisted by a combination of friction between the footing and the supporting soil and by the passive lateral resistance of the soil surrounding the embedded portion of the footing. A coefficient of friction between concrete and soil of 0.4 and a passive lateral resistance corresponding to an equivalent fluid density of 162 pcf may be used in the design. We recommend that the upper 2 feet of passive resistance be ignored. The friction coefficient and passive

lateral resistance are allowable values and include a suitable factor of safety of about 1.5. The passive resistance value assumes submerged (undrained) conditions.

### Permanent Drainage

At the current planned depth of 16 feet deep, we anticipate that the vault will extend below the static groundwater table. In addition, perched water should be expected as discussed in the "Groundwater" section of this report. Because of the permeable nature of backfill soils around the vault compared to the adjacent on-site soils, a bathtub effect can result; therefore, hydrostatic pressures, buoyancy, and uplift are concerns. We recommend providing drainage around the vault to help manage groundwater; otherwise the vault should be designed for submerged conditions.

We recommend that the permanent drainage system include underslab drainage and wall drainage. Underslab drainage should consist of a 12-inch thick layer of 1.5-inch minus clean crushed gravel, WSDOT 9-03.1(4)C, grading No. 57. The gravel layer should be placed below the entire footprint of the buried structure and extend at least 18-inches beyond the footprint to connect with the wall drainage. A geotextile filter fabric should be placed between the 12-inch thick gravel layer and the native soil to maintain separation and reduce piping for the fine-grained soil up into the gravel. We recommend using a nonwoven geotextile for underground drainage in accordance with WSDOT 9-33.2(1), Moderate Survivability with Class A filtration properties.

Wall drainage should consist of an 18-inch-wide zone of drainage material such as gravel backfill for walls (WSDOT 9-03.12(2)) placed against the vault walls. Water drained from the gravel backfill can be collected and discharged by means of a perforated collector pipe installed at the base of the drainage zone material The pipe should be a minimum of 6 inches in diameter, enveloped with a minimum thickness of 6 inches of gravel backfill for drains (WSDOT 9-03.12(4)). A non-woven geotextile fabric such as described above for the underslab drainage should be placed between the gravel drain backfill and the native soils.

We recommend using either heavy-wall solid pipe (SDR-35 PVC) or rigid corrugated polyethylene pipe (ADS N-12, or equal) for the perforated collector pipes. The wall drains should be discharged through a tightline pipe connected into stormwater system downstream of the vault.

### Construction Considerations

Subgrade disturbance may occur if foundation excavations are completed during wet weather. A working mat of crushed rock should be placed over the buried structure foundation subgrade immediately following excavation to reduce softening and disturbance of the subgrade if construction occurs during wet weather.

If soft areas are present at the subgrade elevation, the soft areas should be removed and replaced with structural fill at the direction of a geotechnical engineer. In such instances, the zone of structural fill should extend laterally beyond the buried structure foundation edges a horizontal distance at least equal to the thickness of the fill.

The condition of the foundation subgrades should be observed by a geotechnical engineer to evaluate if the work is completed in accordance with these recommendations and that the subsurface conditions are as anticipated.

## Earthquake Engineering

### 2012 IBC Seismic Design Parameters

We recommend the 2012 IBC parameters for Site Class, short period spectral response acceleration ($S_S$), 1-second period spectral response acceleration ($S_1$), and Seismic Coefficients $F_a$ and $F_v$ presented below. The values presented below in Table 2 are based on the 2008 United States Geologic Survey (USGS) National Seismic Hazards Mapping project for determining a peak ground (bedrock) acceleration coefficient for design for an earthquake that has a 2 percent probability of exceedance in a 50-year period (approximate 2,475 year return period).

**TABLE 2. 2012 IBC SEISMIC DESIGN PARAMETERS**

| 2015 IBC Parameter | Recommended Value |
|---|---|
| Site Class | D |
| Short Period Spectral Response Acceleration, $S_S$ (percent g) | 125.8 |
| 1-Second Period Spectral Response Acceleration, $S_1$ (percent g) | 48.1 |
| Seismic Coefficient, $F_A$ | 1.000 |
| Seismic Coefficient, $F_V$ | 1.519 |

### Seismic Hazards

We evaluated the site conditions for seismic hazards including; liquefaction, lateral spreading, seismically induced landsliding and surface fault rupture. Our evaluation indicates that the site soils have a low potential for liquefaction. Because there is a low risk of liquefaction, the site has a low risk of liquefaction-induced ground disturbance. There is also a low potential for seismically induced landsliding and/or lateral spreading resulting from liquefaction. Based on USGS maps of active faults in the Puget Sound region, the site is located approximately 4.8 miles north of the Seattle Fault Zone. Because of the distance to the nearest mapped fault and the lack of fault displacement evidence in the area, potential for surface fault rupture is considered very remote.

## Pavement Design

### Subgrade Preparation

We recommend that the subgrade soils in new pavement areas be prepared and evaluated as described in the "Earthwork" section of this report. We recommend that the subgrade be compacted to at least 95 percent of the MDD per ASTM D 1557 prior to placing pavement section materials. If the subgrade soils are loose or soft, it may be necessary to excavate the soils and replace them with structural fill. A layer of suitable woven geotextile fabric may be placed over soft subgrade areas to limit the thickness of structural fill required to bridge soft, yielding areas.

### New Hot Mix Asphalt Pavements

We recommend that new pavement sections be designed in accordance with City of Redmond minimum surfacing requirements, as presented in the City of Redmond Standard Specifications and Details, 2012. We recommend that the pavement section for parking areas with automobile and light truck parking only be consistent with the Parking Lot section given in Redmond Standard Detail SD301. We recommend that

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the pavement section for access driveways and for truck parking areas be consistent with the Commercial/Industrial section given in Redmond SD301. These pavement sections are presented in Table 3 below.

**TABLE 3. RECOMMENDED MINIMUM PAVEMENT SECTION**

| Type | Section Material | Section Thickness (inches) | |
|---|---|---|---|
| | | Automobile and Light Truck Parking | Access drives and Truck Parking |
| HMA | HMA Class ½-inch pg 64-22 | 3 | 7 |
| | HMA Class 1-inch pg 64-22 | 0 | 5 |
| Crushed Surfacing Base Course (WSDOT 9-03.9(3)) | | 4 | 0 |

Notes:
HMA – hot mix asphalt

Consideration can be given to an alternative pavement section for the access drives and truck parking areas consisting of 4 inches of hot mix asphalt (HMA) Class ½-inch pg 64-22 over 6 inches of Crushed Surfacing Base Course (WSDOT 9-03.9(3)).

## LIMITATIONS

We have prepared this report for the use of the City of Redmond, HDR Engineering, Inc. and other project team members for the 159th Avenue NE Vault project in Redmond, Washington. The data should be provided to prospective contractors for their bidding or estimating purposes, but our report and interpretations should not be construed as a warranty of the subsurface conditions.

Within the limitations of scope, schedule, and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers and will serve as the official document of record.

Please refer to Appendix C titled "Report Limitations and Guidelines for Use" for additional information pertaining to use of this report.

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N
W E
S

2,000 0 2,000

Feet

## Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Mapbox Open Street Map, 2015

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

**Vicinity Map**

159th Avenue NE Vault
Tosh Creek Watershed Restoration
Redmond, Washington

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**Figure 1**

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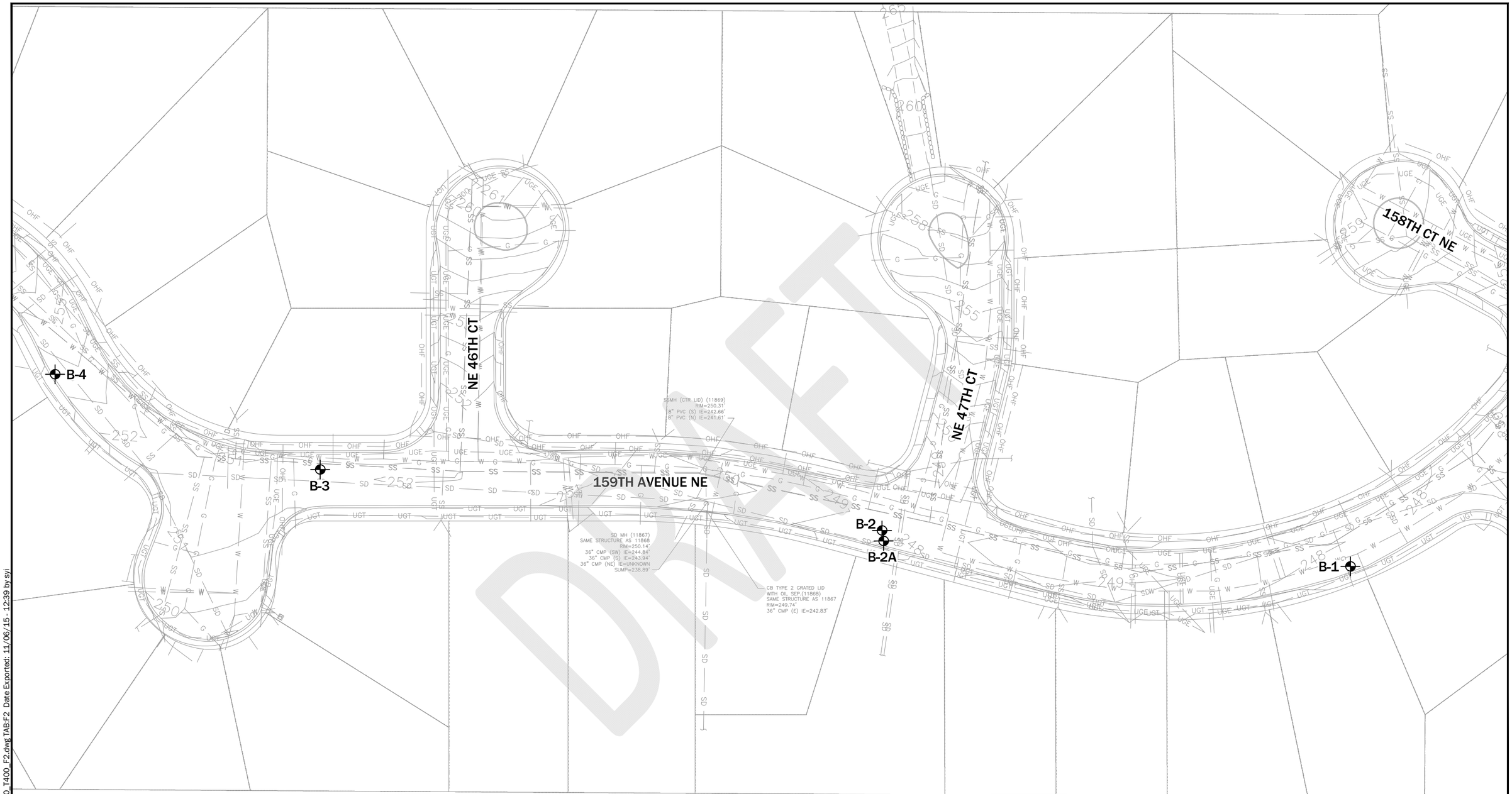


Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Base drawing provided by HDR Engineering, Inc.

Projection: NAD83 Washington State Planes, North Zone, US Foot.

Legend

B-1 Boring completed by GeoEngineers Inc., 2015

W N E S

60 0 60

Feet

**Site Plan**

159th Avenue NE Vault
Tosh Creek Watershed Restoration
Redmond, Washington

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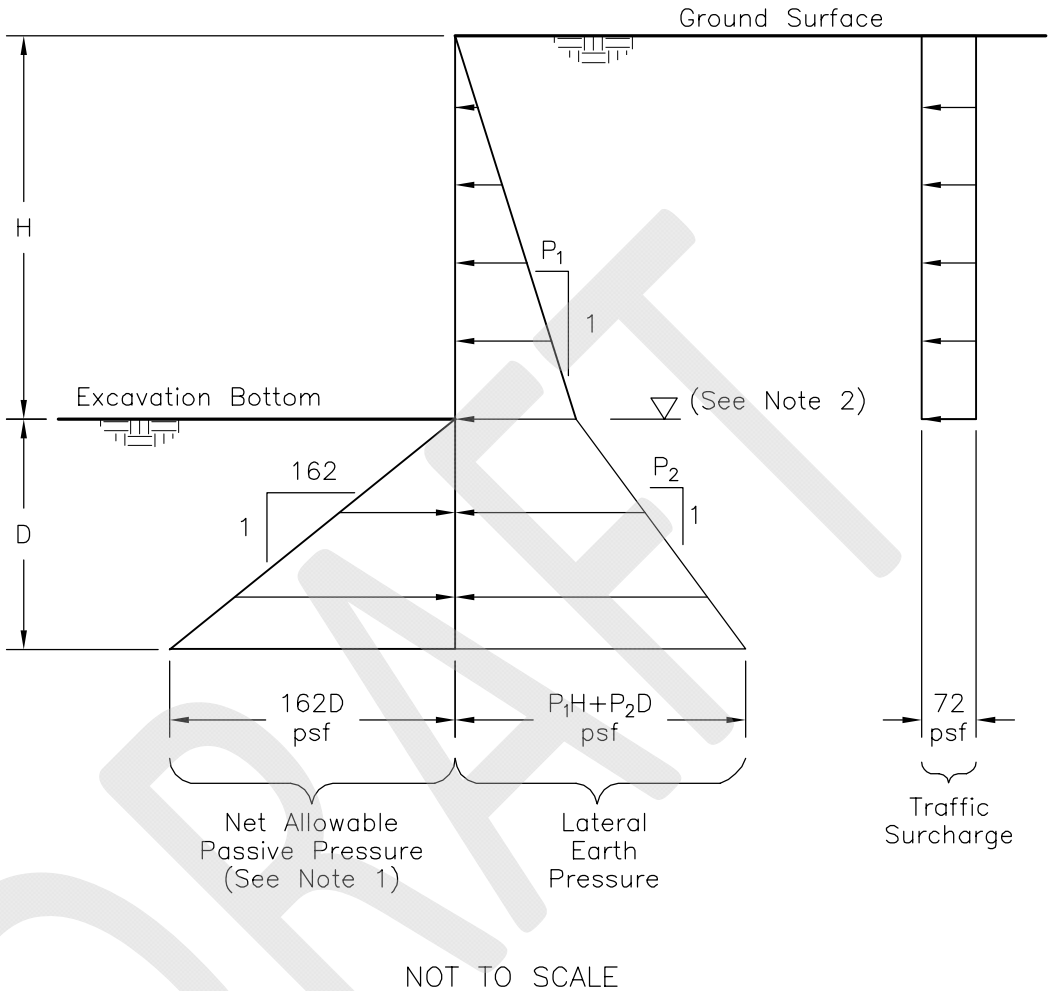
**Figure 2**

W:\Projects\0\0500204\00\CAD\050020400_T400_F2.dwg TAB:F2 Date Exported: 11/06/15 - 12:39 by syi

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Legend

H = Depth Below Finished Ground Surface, Feet

D = Foundation Embedment, Feet

P = Equivalent Fluid Density (pcf)

| P (pcf) | $P_1$ | $P_2$ |
|---|---|---|
| Active | 36 | 80 |
| At-Rest | 59 | 91 |

Notes:

1. Net allowable passive pressure includes a factor of safety of 1.5 and acts over 2.5 times the shaft diameter, but no more than the pile spacing.
2. Earth pressure diagram assumes drained conditions above the excavation bottom and submerged conditions below the excavation bottom.
3. If additional surcharge (such as from soil stockpiles, excavators, dumptrucks, cranes, or concrete trucks) loading is anticipated, GeoEngineers should be consulted to provide revised surcharge pressures.

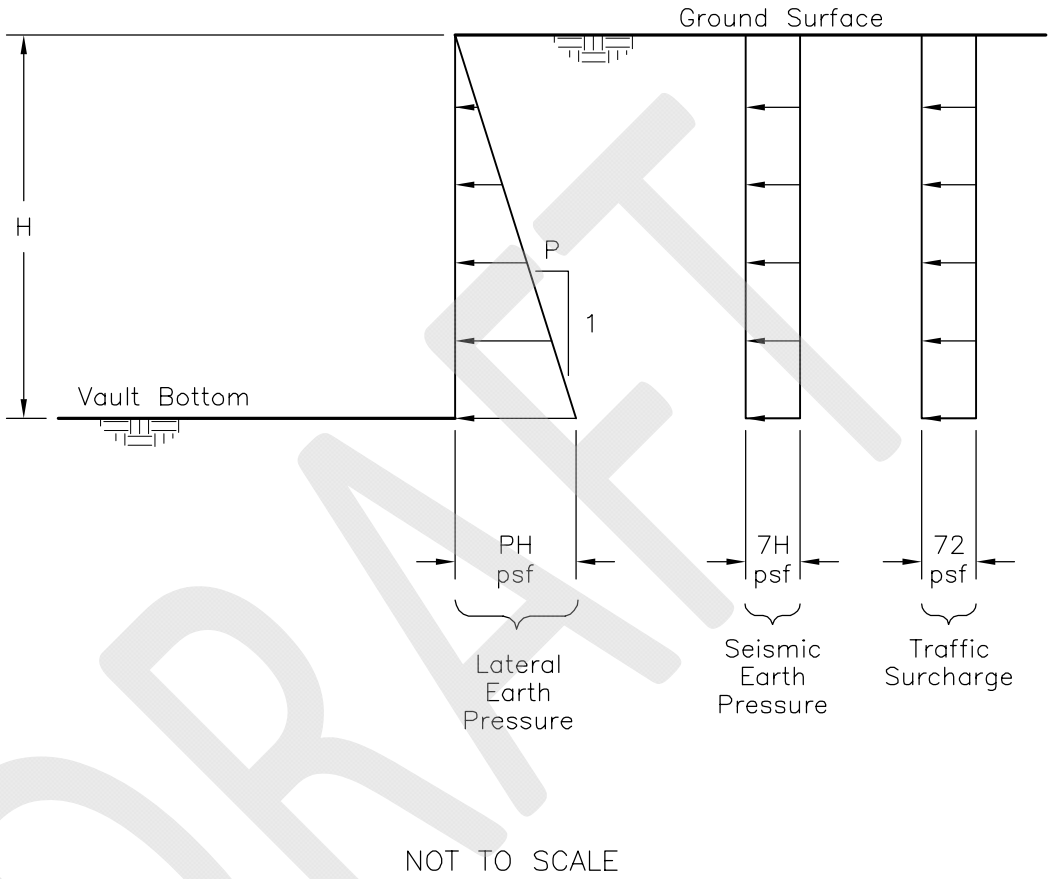
Temporary Shoring
Earth Pressure Diagram

159th Avenue NE Vault
Tosh Creek Watershed Restoration
Redmond, Washington

GeoEngineers

Figure 3

P:\0\0500204\CAD\0500204-00 FIGURE 3 & 4 EPD.DWG\TAB:FIG 3 MODIFIED BY HMARA ON DEC 02, 2015 - 16:01

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Legend

H = Depth Below Finished Ground Surface, Feet

P = Equivalent Fluid Density (pcf)

| P (pcf) | Active | At-Rest |
|---|---|---|
| Drained | 36 | 59 |
| Submerged | 80 | 91 |

(See Note 1)

Notes:

1. For vaults constructed without wall drainage use submerged values.
2. If additional surcharge (such as from soil stockpiles, excavators, dumptrucks, cranes, or concrete trucks) loading is anticipated, GeoEngineers should be consulted to provide revised surcharge pressures.

**Permanent Vault**
**Earth Pressure Diagram**

159th Avenue NE Vault
Tosh Creek Watershed Restoration
Redmond, Washington

GeoEngineers

**Figure 4**

P:\0\0500204\CAD\0500204-00 FIGURE 3 & 4 EPD.DWG\TAB:FIG 4 MODIFIED BY CSTICKEL ON DEC 04, 2015 - 11:17

# APPENDIX A
## Field Explorations

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## APPENDIX A
## FIELD EXPLORATIONS

Subsurface conditions at the site were explored by drilling five borings (B-1, B-2, B-2a, B-3, and B-4). The borings were completed to depths ranging from 7½ to 95 feet below the existing ground surface. The drilling was performed by Holocene Drilling, Inc. under subcontract to GeoEngineers on September 14, 15, and 21, 2015.

The locations of the explorations were estimated by taping/pacing from existing site features. The exploration locations are shown on the Site Plan, Figure 2.

### Drilling Methodologies

Borings B-1, B-2, B-2a, and B-4 were completed using track-mounted, continuous-flight, hollow-stem auger drilling equipment. Boring B-3 was completed using a track-mounted rotary sonic drilling equipment. The borings were continuously monitored by an engineer or geologist from our firm who examined and classified the soils encountered, obtained representative soil samples, observed groundwater conditions, and prepared a detailed log of the explorations.

#### Hollow Stem Auger

The soils encountered in the borings completed with the hollow-stem auger equipment were sampled at 2½- or 5-foot vertical intervals with a 2-inch outside diameter split-barrel standard penetration test (SPT) sampler. The samples were obtained by driving the sampler 18 inches into the soil with a 140-pound hammer free-falling 30 inches. The number of blows required for each 6 inches of penetration was recorded. The blow count ("N value") of the soil was calculated as the number of blows required for the final 12 inches of penetration. This resistance, or N value, provides a measure of the relative density of granular soils and the relative consistency of cohesive soils. Where very dense soil conditions precluded driving the full 18 inches, the penetration resistance for the partial penetration was entered on the logs. The blow counts are shown on the boring logs at the respective sample depths.

#### Sonic

Continuous soil cores were obtained in 5-foot intervals from the boring advanced using sonic drilling equipment. A representative from our staff collected representative samples from the cores for laboratory testing. An SPT sample was conducted in the upper part of the boring using the same procedure described above. The relative density of the soils cannot be determined using sonic drilling methods.

### Soils

Soils encountered in the borings were visually classified in general accordance with the classification system described in Figure A-1. A key to the boring log symbols is also presented in Figure A-1. The logs of the borings are presented in Figures A-2 through A-6. The boring logs are based on our interpretation of the field and laboratory data and indicate the various types of soils and groundwater conditions encountered. The logs also indicate the depths at which these soils or their characteristics change, although the change may actually be gradual. If the change occurred between samples, it was interpreted. The densities noted on the boring logs are based on the blow count data obtained in the borings and judgment based on the conditions encountered.

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## Groundwater

Observations of groundwater conditions were made during drilling and are included on the boring logs. These observations represent a short-term condition and may or may not be representative of the long-term groundwater conditions at the site. Groundwater conditions observed during drilling should be considered approximate.

In addition, piezometers (monitoring wells) were installed in borings B-1, B-3, and B-4. Installation details of the monitoring well and measured groundwater levels in the monitoring wells are included in Figures A-2, A-5, and A-6.

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## SOIL CLASSIFICATION CHART

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

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

## ADDITIONAL MATERIAL SYMBOLS

| SYMBOLS GRAPH | SYMBOLS LETTER | TYPICAL DESCRIPTIONS |
|---|---|---|
| | AC | Asphalt Concrete |
| | CC | Cement Concrete |
| | CR | Crushed Rock/ Quarry Spalls |
| | TS | Topsoil/ Forest Duff/Sod |

### Groundwater Contact

**Measured groundwater level in exploration, well, or piezometer**

**Measured free product in well or piezometer**

### Graphic Log Contact

**Distinct contact between soil strata or geologic units**

**Approximate location of soil strata change within a geologic soil unit**

### Material Description Contact

**Distinct contact between soil strata or geologic units**

**Approximate location of soil strata change within a geologic soil unit**

### Sampler Symbol Descriptions

- **2.4-inch I.D. split barrel**
- **Standard Penetration Test (SPT)**
- **Shelby tube**
- **Piston**
- **Direct-Push**
- **Bulk or grab**
- **Continuous Coring**

**Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.**

**A "P" indicates sampler pushed using the weight of the drill rig.**

### Laboratory / Field Tests

| | |
|---|---|
| %F | Percent fines |
| AL | Atterberg limits |
| CA | Chemical analysis |
| CP | Laboratory compaction test |
| CS | Consolidation test |
| DS | Direct shear |
| HA | Hydrometer analysis |
| MC | Moisture content |
| MD | Moisture content and dry density |
| OC | Organic content |
| PM | Permeability or hydraulic conductivity |
| PI | Plasticity index |
| PP | Pocket penetrometer |
| PPM | Parts per million |
| SA | Sieve analysis |
| TX | Triaxial compression |
| UC | Unconfined compression |
| VS | Vane shear |

### Sheen Classification

| | |
|---|---|
| NS | No Visible Sheen |
| SS | Slight Sheen |
| MS | Moderate Sheen |
| HS | Heavy Sheen |
| NT | Not Tested |

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

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**KEY TO EXPLORATION LOGS**

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**FIGURE A-1**

| Drilled Start 9/14/2015 | End 9/15/2015 | Total Depth (ft) 36.5 | Logged By EJC / Checked By CMK | Driller Holocene Drilling, Inc. | Drilling Method Hollow-Stem Auger |
|---|---|---|---|---|---|

| | | | |
|---|---|---|---|
| Hammer Data | Automatic<br>140 (lbs) / 30 (in) Drop | Drilling Equipment | Mobile B-59 Truck-Mounted |
| Surface Elevation (ft)<br>Vertical Datum | 247.61<br>NAVD88 | Top of Casing Elevation (ft) | 247.25 |
| Easting (X)<br>Northing (Y) | 1321424.7<br>240681.7 | Horizontal Datum | NAD83/91 |

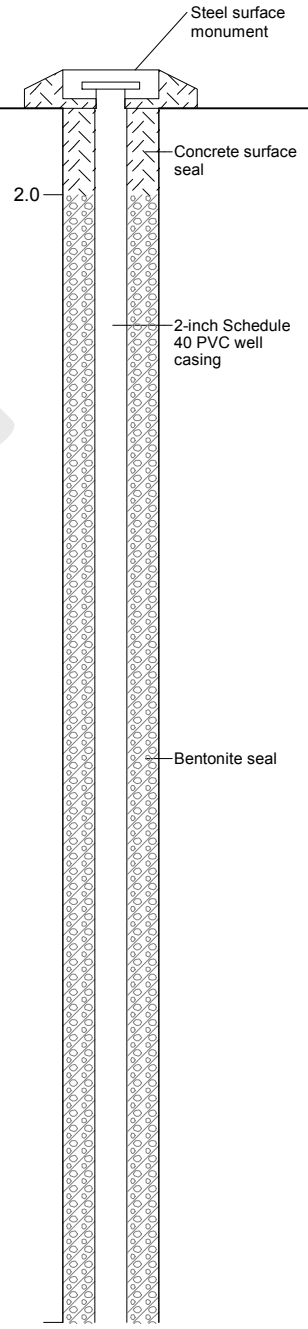
DOE Well I.D.: BJF-991
A 2 (in) well was installed on 9/15/2015 to a depth of 34.5 (ft).

| Groundwater Date Measured | Depth to Water (ft) | Elevation (ft) |
|---|---|---|
| 10/22/2015 | 17.5 | 230.2 |

Notes: Auger Data: 4-inch I.D.; 8½-inch O.D.

| Elevation (feet) | Depth (feet) | Interval | Recovered (in) | Blows/foot | Collected Sample | Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | AC | 3 inches asphalt concrete | | |
| | | | | | | | | | CR | 3 to 4 inches base course | | |
| | | | | | | | | | ML | Gray sandy silt (stiff, moist) (fill) | | |
| 245 | | | 8 | 10 | | 1 | | | | | 14 | 52 |
| | 5 | | 4 | 59 | | 2 | | | GM | Silty fine to coarse gravel with sand (very dense, moist) | 4 | 18 |
| 240 | | | 15 | 83 | | 3 | | | SM | Brown silty fine to medium sand with occasional gravel (very dense, moist) (glacially consolidated soils) | 11 | 48 |
| | | | | | | | | | CL | Gray to brownish gray sandy lean clay (stiff to hard, moist) | | |
| | 10 | | 17 | 68 | | 4 | | | | | | |
| 235 | | | 18 | 23 | | 5 AL | | | | | 21 | |
| | 15 | | 13.5 | 29 | | 6 | ▼ | | | | | |
| 230 | | | | | | | | | | | | |
| | 20 | | 18 | 16 | | 7 | | | | | | |
| 225 | | | | | | | | | CL-ML | Gray silty clay with sand (very stiff, moist to wet) | 21 | |
| | 25 | | 15 | 30 | | 8 AL | | | | | | |
| 220 | | | | | | | | | | | | |

WELL LOG




Note: See Figure A-1 for explanation of symbols.

DRAFT

## Log of Monitoring Well B-1

GeoEngineers

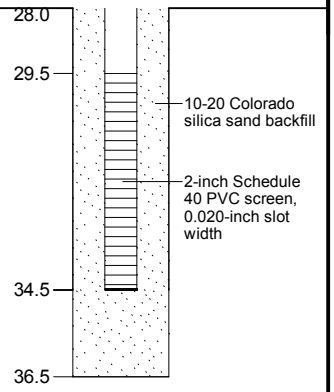
Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-2
Sheet 1 of 2

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate\GEOENGINEERS8.GDT/GE8_GEOTECH_WELL

| Elevation (feet) | Depth (feet) | FIELD DATA: Interval Recovered (in) | Blows/foot | Collected Sample: Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 215 | 30 | 18 | 27 | 9 | | | | Becomes wet<br>Perched groundwater encountered at 31.7 during drilling | | |
| | 35 | 18 | 31 | 10 | | | | Becomes moist | | |

WELL LOG




Note: See Figure A-1 for explanation of symbols.

DRAFT

## Log of Monitoring Well B-1 (continued)

GeoEngineers

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-2
Sheet 2 of 2

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE8_GEOTECH_WELL

| Drilled Start 9/21/2015 End 9/21/2015 | Total Depth (ft) 36.5 | Logged By EJC Checked By CMK | Driller Holocene Drilling, Inc. | Drilling Method Hollow-Stem Auger |
|---|---|---|---|---|
| Surface Elevation (ft) 248.26 Vertical Datum NAVD88 | | Hammer Data Automatic 140 (lbs) / 30 (in) Drop | | Drilling Equipment Mobile B-59 Truck-Mounted |
| Easting (X) 1321402 Northing (Y) 240386.8 | | System Datum NAD83/91 | | Groundwater Date Measured / Depth to Water (ft) / Elevation (ft) |

Notes: Auger Data: 4-inch I.D.; 8½-inch O.D.

| Elevation (feet) | Depth (feet) | Interval | Recovered (in) | Blows/foot | Collected Sample | Sample Name Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | AC | 4 inches asphalt concrete | | | |
| | | | | | | | | | CR | 3 inches base course | | | |
| | | | | | | | | | SM | Brown silty fine to coarse sand with gravel (medium dense, moist) (fill) | | | Rough drilling at 1 to 2 feet |
| 245 | | | 9 | 13 | | 1 SA | | | | | 8 | 19 | |
| | 5 | | 9 | 6 | | 2 SA | | | GM | Brown silty coarse gravel with sand (loose, moist) | 12 | 34 | |
| 240 | | | 8 | 29 | | 3 SA | | | SM | Gray silty fine to medium sand with gravel (medium dense, moist) (glacially consolidated soils) | 13 | 22 | |
| | | | | | | | | | ML | Gray silt with sand (very stiff, moist) | | | |
| | 10 | | 18 | 35 | | 4 AL | | | | | 24 | | |
| 235 | | | 18 | 46 | | 5 | | | CL | Gray lean clay with sand (stiff to hard, moist) | | | |
| | 15 | | 18 | 56 | | 6 | | | | | | | |
| 230 | | | | | | | | | | | | | |
| | 20 | | 18 | 44 | | 7 AL | | | | | 29 | | |
| 225 | | | | | | | | | | | | | |
| | 25 | | 18 | 20 | | 8 | | | | | | | |

Note: See Figure A-1 for explanation of symbols.

DRAFT

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE8_GEOTECH_STANDARD

## Log of Boring B-2

GEOENGINEERS

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-3
Sheet 1 of 2

| Elevation (feet) | Depth (feet) | FIELD DATA: Interval / Recovered (in) | Blows/foot | Collected Sample / Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 220 | | | | | | | | | | | |
| | 30 | | 27 | 9 | | | | | | | |
| 215 | | | | | | | | | | | |
| | 35 | | 38 | 10 | | | | Becomes moist to wet | | | |

Note: See Figure A-1 for explanation of symbols.

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## Log of Boring B-2 (continued)

GeoEngineers

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-3
Sheet 2 of 2

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE8_GEOTECH_STANDARD

| Drilled | Start 9/14/2015 | End 9/14/2015 | Total Depth (ft) 7.5 | Logged By EJC / Checked By CMK | Driller Holocene Drilling, Inc. | Drilling Method Hollow-Stem Auger |
|---|---|---|---|---|---|---|
| Surface Elevation (ft) 248.1 / Vertical Datum NAVD88 | | | Hammer Data Automatic 140 (lbs) / 30 (in) Drop | | Drilling Equipment Mobile B-59 Truck-Mounted | |
| Easting (X) 1321408.8 / Northing (Y) 240387.8 | | | System Datum NAD83/91 | | Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft) | |

Notes: Auger Data: 4-inch I.D.; 8½-inch O.D.

| Elevation (feet) | Depth (feet) | FIELD DATA: Interval | Recovered (in) | Blows/foot | Collected Sample | Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | AC | 4 inches asphalt concrete | | | |
| | | | | | | | | | CR | 3 to 4 inches base course | | | |
| | | | | | | | | | SM | Gray silty sand with gravel (loose, moist) (fill) | | | |
| 245 | | | 9 | 8 | | 1 | | | | | | | |
| | | | | | | | | | SM | Brownish gray silty sand with gravel (loose, moist) | | | |
| | 5 | | 2 | 5 | | 2 | | | | | | | |

Boring terminated due to presence of storm drain

Note: See Figure A-1 for explanation of symbols.

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## Log of Boring B-2a

GeoEngineers

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-4
Sheet 1 of 1

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE18_GEOTECH_STANDARD

| Drilled Start 9/14/2015 | End 9/15/2015 | Total Depth (ft) 95 | Logged By ERH / Checked By CMK | Driller Holocene Drilling, Inc. | Drilling Method Sonic |
|---|---|---|---|---|---|

| | | | |
|---|---|---|---|
| Hammer Data | Automatic<br>300 (lbs) / 30 (in) Drop | Drilling Equipment | Geoprobe 8140LC |
| Surface Elevation (ft)<br>Vertical Datum | 251.58<br>NAVD88 | Top of Casing Elevation (ft) | 251.22 |
| Easting (X)<br>Northing (Y) | 1321363.6<br>240033.1 | Horizontal Datum | NAD83/91 |

DOE Well I.D.: BFJ-992
A 2 (in) well was installed on 9/16/2015 to a depth of 95 (ft).

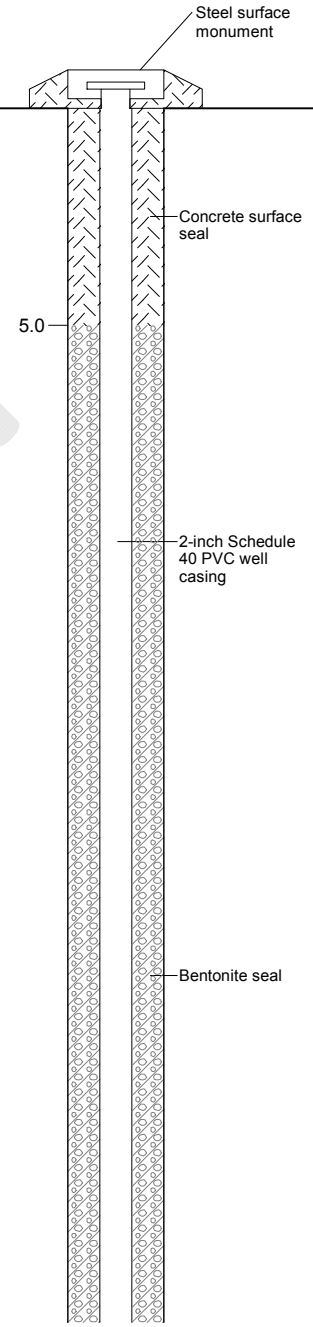
| Groundwater Date Measured | Depth to Water (ft) | Elevation (ft) |
|---|---|---|
| 10/22/2015 | 25.3 | 226.3 |

Notes: Sonic Drilling 5 3/8-inch I.D. Casing

FIELD DATA

| Elevation (feet) | Depth (feet) | Interval | Recovered (in) | Blows/foot | Collected Sample | Sample Name Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | AC | 9.3 inches asphalt concrete | | |
| | | | | | | | | | CR | 3 inches base course | | |
| 250 | | | | | | 1 | | | GM | Brown silty fine to coarse gravel with sand (medium dense, dry to moist) (fill) | | |
| | | | | 16 | | 2 SA 3 | | | | | 9 | 36 |
| | | | | | | | | | ML | Brown sandy silt (moist) (weathered glacially consolidated soils) | 16 | 50.3 |
| | 5 | | | | | | | | CL | Gray sandy lean clay (moist) (glacially consolidated soils) | | |
| 245 | | | | | | 4 AL | | | | | 17 | |
| | | | | | | 5 | | | | | | |
| | | | | | | 6 | | | | | | |
| | 10 | | | | | | | | | | | |
| 240 | | | | | | | | | ML | Gray sandy silt (moist) | | |
| | | | | | | 7 AL | | | | | 25 | |
| | 15 | | | | | | | | | | | |
| 235 | | | | | | | | | | | | |
| | | | | | | 8 AL | | | | | 24 | |
| | 20 | | | | | | | | | | | |
| 230 | | | | | | | | | | | | |
| | | | | | | 9 | | | | | | |
| | 25 | | | | | | | | | | | |
| 225 | | | | | | | | | | | | |
| | | | | | | 10 | | | | | | |

WELL LOG




Note: See Figure A-1 for explanation of symbols.

DRAFT

## Log of Monitoring Well B-3

GEOENGINEERS

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-5
Sheet 1 of 3

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate\GEOENGINEERS8.GDT/GE18_GEOTECH_WELL

| Elevation (feet) | Depth (feet) | Interval | Recovered (in) | Blows/foot | Collected Sample | Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) | WELL LOG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | | | | | 11 AL | | | CL | Gray lean clay (moist) | 26 | | |
| 220 | | | | | | | | | | | | | |
| | | | | | | 12 | | | | | | | |
| | 35 | | | | | | | | | | | | |
| 215 | | | | | | | | | | | | | |
| | | | | | | 13 | | | | | | | 2-inch Schedule 40 PVC well casing |
| | | | | | | 14 | | | | | | | |
| | | | | | | 15 | | | | | | | |
| | 40 | | | | | | | | SM | Gray silty fine sand (moist to wet) | | | |
| 210 | | | | | | | | | | | | | |
| | | | | | | 16 | | | | | | | |
| | 45 | | | | | | | | | | | | |
| 205 | | | | | | 17 AL | | | | | 22 | | |
| | | | | | | 18 | | | ML | Gray sandy silt (moist to wet) | | | |
| | 50 | | | | | | | | | | | | Bentonite seal |
| 200 | | | | | | | | | | | | | |
| | | | | | | 19 | | | | | | | |
| | 55 | | | | | | | | | | | | |
| 195 | | | | | | 20 | | | | | | | |
| | | | | | | 21 | | | | | | | |
| | 60 | | | | | | | | | | | | |
| | | | | | | 22 | | | | | | | |
| 190 | | | | | | | | | | | | | |
| | | | | | | 23 | | | | | | | |

Note: See Figure A-1 for explanation of symbols.

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## Log of Monitoring Well B-3 (continued)

GeoEngineers

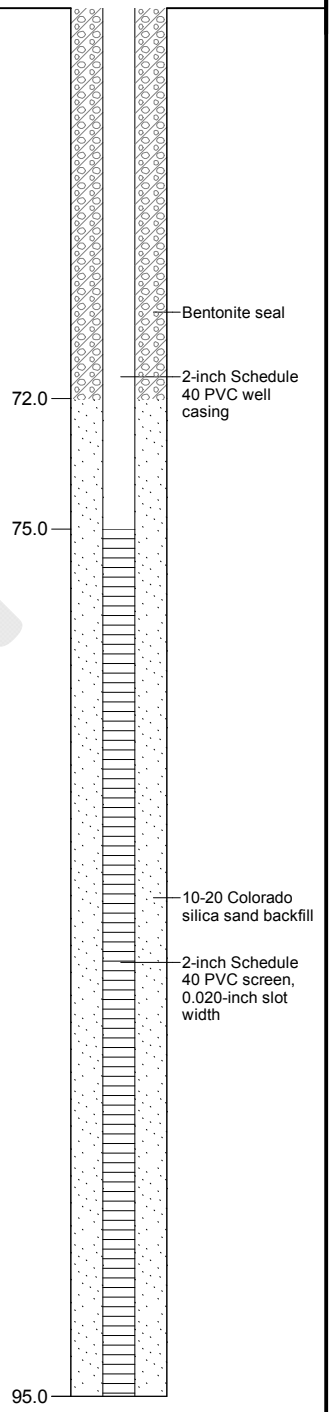
Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-5
Sheet 2 of 3

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate\GEOENGINEERS8.GDT/GE8_GEOTECH_WELL

| Elevation (feet) | Depth (feet) | FIELD DATA: Interval | Recovered (in) | Blows/foot | Collected Sample | Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 65 | | | | | | | | | | | |
| 185 | | | | | | 24 | | | | | | |
| | 70 | | | | | | | | | | | |
| 180 | | | | | | 25 / AL | | | | | 22 | |
| | 75 | | | | | | | | | | | |
| 175 | | | | | | 26 | | | | | | |
| | 80 | | | | | | | | | | | |
| 170 | | | | | | 27 | | | | | | |
| | 85 | | | | | | | | | | | |
| 165 | | | | | | 28 | | | | | | |
| | 90 | | | | | | | | | | | |
| 160 | | | | | | 29 | | | | | | |
| | 95 | | | | | | | | | | | |

WELL LOG




Note: See Figure A-1 for explanation of symbols.

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## Log of Monitoring Well B-3 (continued)

GeoEngineers

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-5
Sheet 3 of 3

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE8_GEOTECH_WELL

| Drilled | Start 9/14/2015 | End 9/14/2015 | Total Depth (ft) | 36.5 | Logged By / Checked By | EJC / CMK | Driller | Holocene Drilling, Inc. | Drilling Method | Hollow-Stem Auger |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | |
|---|---|---|---|
| Hammer Data | Automatic<br>140 (lbs) / 30 (in) Drop | Drilling Equipment | Mobile B-59 Truck-Mounted |
| Surface Elevation (ft)<br>Vertical Datum | 253.64<br>NAVD88 | Top of Casing Elevation (ft) | 253.29 |
| Easting (X)<br>Northing (Y) | 1321304<br>239866.2 | Horizontal Datum | NAD83/91 |

DOE Well I.D.: BJF-990
A 2 (in) well was installed on 9/14/2015 to a depth of 28 (ft).

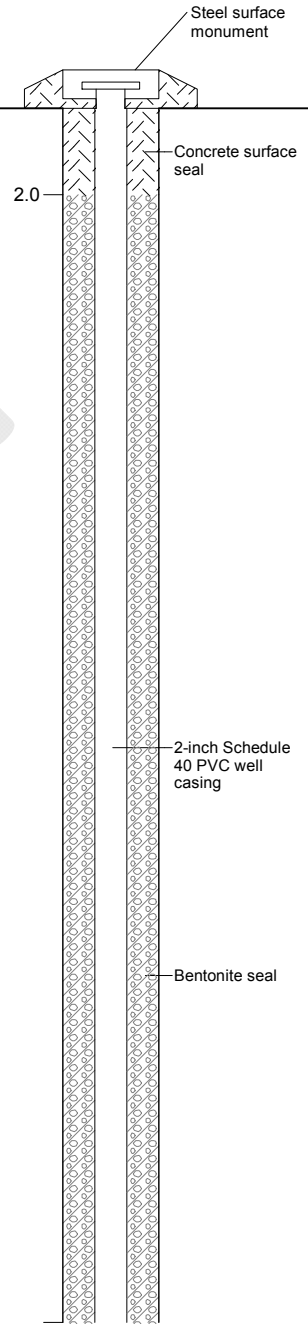
| Groundwater | | |
|---|---|---|
| Date Measured | Depth to Water (ft) | Elevation (ft) |
| 10/22/2015 | 17.2 | 236.5 |

Notes: Auger Data: 4-inch I.D.; 8½-inch O.D.

FIELD DATA

| Elevation (feet) | Depth (feet) | Interval Recovered (in) | Blows/foot | Collected Sample | Sample Name Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | AC | 3 inches asphalt concrete | | |
| | | | | | | | | CR | 3 to 4 inches base course | | |
| | | | | | | | | SM | Brown silty fine to medium sand with occasional gravel (medium dense, moist) (fill) | | |
| 250 | | 18 | 19 | | 1 SA | | | | | 12 | 20 |
| | | | | | | | | SM | Brownish gray silty fine to medium sand (medium dense, moist) | | |
| | 5 | 13 | 22 | | 2 %F | | | | | 13 | 36 |
| | | | | | | | | ML | Brownish gray silt with sand (medium stiff, moist) (glacially consolidated soils) | | |
| 245 | | 18 | 15 | | 3 AL | | | | | 26 | |
| | | | | | | | | CL | Gray lean clay (medium stiff to stiff, moist) | | |
| | 10 | 18 | 14 | | 4 AL | | | | | 24 | |
| 240 | | 18 | 19 | | 5 | | | | | | |
| | 15 | 18 | 16 | | 6 | | | | | | |
| | | | | | | | | ML | Gray silt (medium stiff to stiff, moist) | | |
| 235 | | | | | | | | | | | |
| | 20 | 15.5 | 19 | | 7 AL | | | | | 25 | |
| 230 | | | | | | | | | | | |
| | 25 | 13 | 13 | | 8 | | | | | | |

WELL LOG




Note: See Figure A-1 for explanation of symbols.

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Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE18_GEOTECH_WELL

## Log of Monitoring Well B-4

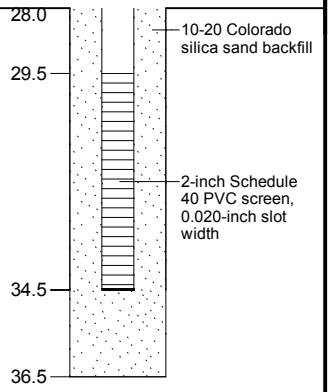
GEOENGINEERS

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-6
Sheet 1 of 2

| Elevation (feet) | Depth (feet) | FIELD DATA: Interval Recovered (in) | Blows/foot | Collected Sample: Sample Name / Testing | Water Level | Graphic Log | Group Classification | MATERIAL DESCRIPTION | Moisture Content (%) | Fines Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 225 | | | | | | | | | | |
| | 30 | 18 | 23 | 9 | | | | | | |
| 220 | | | | | | | | | | |
| | 35 | | 26 | 10 | | | | | | |

WELL LOG




Note: See Figure A-1 for explanation of symbols.

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## Log of Monitoring Well B-4 (continued)

GeoEngineers

Project: 159th Ave. NE Vault - Tosh Creek Watershed Restoration
Project Location: Redmond, Washington
Project Number: 0500-204-00

Figure A-6
Sheet 2 of 2

Redmond: Date:12/4/15 Path:P:\0050204\GINT\050020400.GPJ DBTemplate\LibTemplate:GEOENGINEERS8.GDT/GE8_GEOTECH_WELL

# APPENDIX B
## Laboratory Testing

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## APPENDIX B
## LABORATORY TESTING

Soil samples obtained from the explorations were transported to our laboratory and examined to confirm or modify field classifications, as well as to evaluate index properties of the soil samples. Representative samples were selected for laboratory testing consisting of moisture content, sieve analyses (grain size distribution), and Atterberg limits (plasticity characteristics). The tests were performed in general accordance with test methods of the American Society for Testing and Materials (ASTM) or other applicable procedures.

### Moisture Content Testing

Moisture content tests were completed in general accordance with ASTM D 2216 for representative samples obtained from the explorations. The results of these tests are presented on the exploration logs in Appendix A at the depths at which the samples were obtained.

### Percent Passing U.S. No. 200 Sieve (%F)

Selected samples were "washed" through the No. 200 mesh sieve to estimate the relative percentages of coarse and fine-grained particles in the soil. The percent passing value represents the percentage by weight of the sample finer than the U.S. No. 200 sieve. These tests were conducted to verify field descriptions and to estimate the fines content for analysis purposes. The tests were conducted in accordance with ASTM D 1140, and the results are shown on the exploration logs at the respective sample depths.

### Sieve Analyses

Sieve analyses were performed on selected samples in general accordance with ASTM D 422. The wet sieve analysis method was used to determine the percentage of soil greater than the U.S. No. 200 mesh sieve. The results of the sieve analyses were plotted, were classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figures B-1 and B-2.

### Atterberg Limits Testing

Atterberg limits testing was performed on selected fine-grained soil samples. The tests were used to classify the soil as well as to evaluate index properties. The liquid limit and the plastic limit were estimated through a procedure performed in general accordance with ASTM D 4318. The results of the Atterberg limits testing are summarized in Figures B-3 through B-5.

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| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

| Symbol | Boring Number | Depth (feet) | Moisture (%) | Soil Description |
|---|---|---|---|---|
| ◆ | B-2 | 2.5 | 8 | Silty fine to coarse sand with gravel (SM) |
| ■ | B-2 | 5 | 12 | Silty coarse gravel with sand (GM) |
| ▲ | B-2 | 7.5 | 13 | Silty fine to medium sand with gravel (SM) |
| ● | B-3 | 2 | 9 | Silty fine to coarse gravel with sand (GM) |

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The grain size analysis results were obtained in general accordance with ASTM D 6913.

**Sieve Analysis Results**

159th Avenue NE Vault – Tosh Creek Watershed, Redmond, Washington

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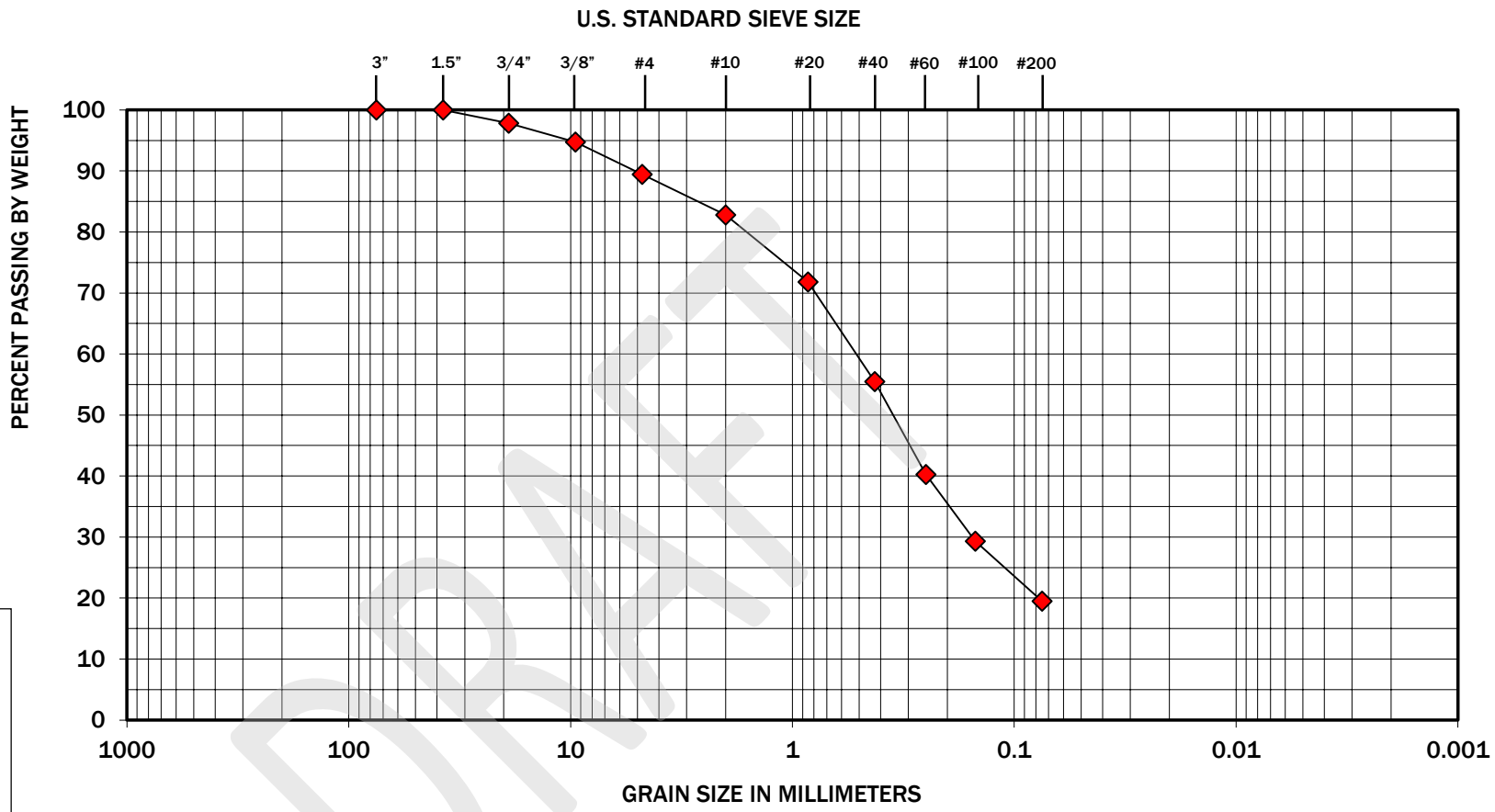
**Figure B-1**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

| Symbol | Boring Number | Depth (feet) | Moisture (%) | Soil Description |
|---|---|---|---|---|
| ◆ | B-4 | 2.5 | 12 | Silty fine to coarse sand with occasional gravel (SM) |

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The grain size analysis results were obtained in general accordance with ASTM D 6913.

**Sieve Analysis Results**

159th Avenue NE Vault – Tosh Creek Watershed, Redmond, Washington

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**Figure B-2**

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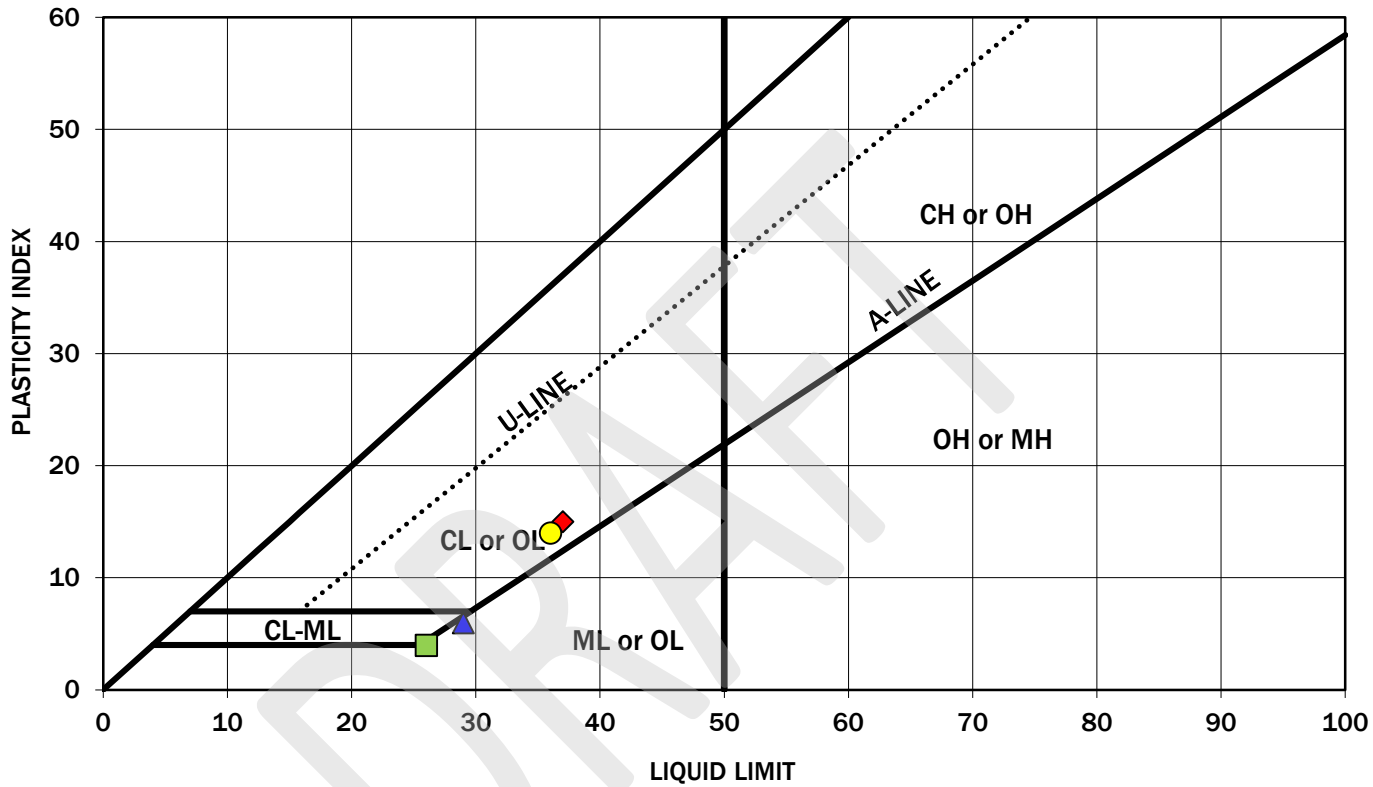
## PLASTICITY CHART




| Symbol | Boring Number | Depth (feet) | Moisture Content (%) | Liquid Limit (%) | Plasticity Index (%) | Soil Description |
|---|---|---|---|---|---|---|
| ◆ | B-1 | 12.5 | 21 | 37 | 15 | Sandy lean clay (CL) |
| ■ | B-1 | 25 | 21 | 26 | 4 | Silty clay with sand (CL-ML) |
| ▲ | B-2 | 10 | 24 | 29 | 6 | Silt with sand (ML) |
| ● | B-2 | 20 | 29 | 36 | 14 | Lean clay with sand (CL) |

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The liquid limit and plasticity index were obtained in general accordance with ASTM D 4318.

**Atterberg Limits Test Results**

159th Avenue NE Vault – Tosh Creek Watershed, Redmond, Washington

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**Figure B-3**

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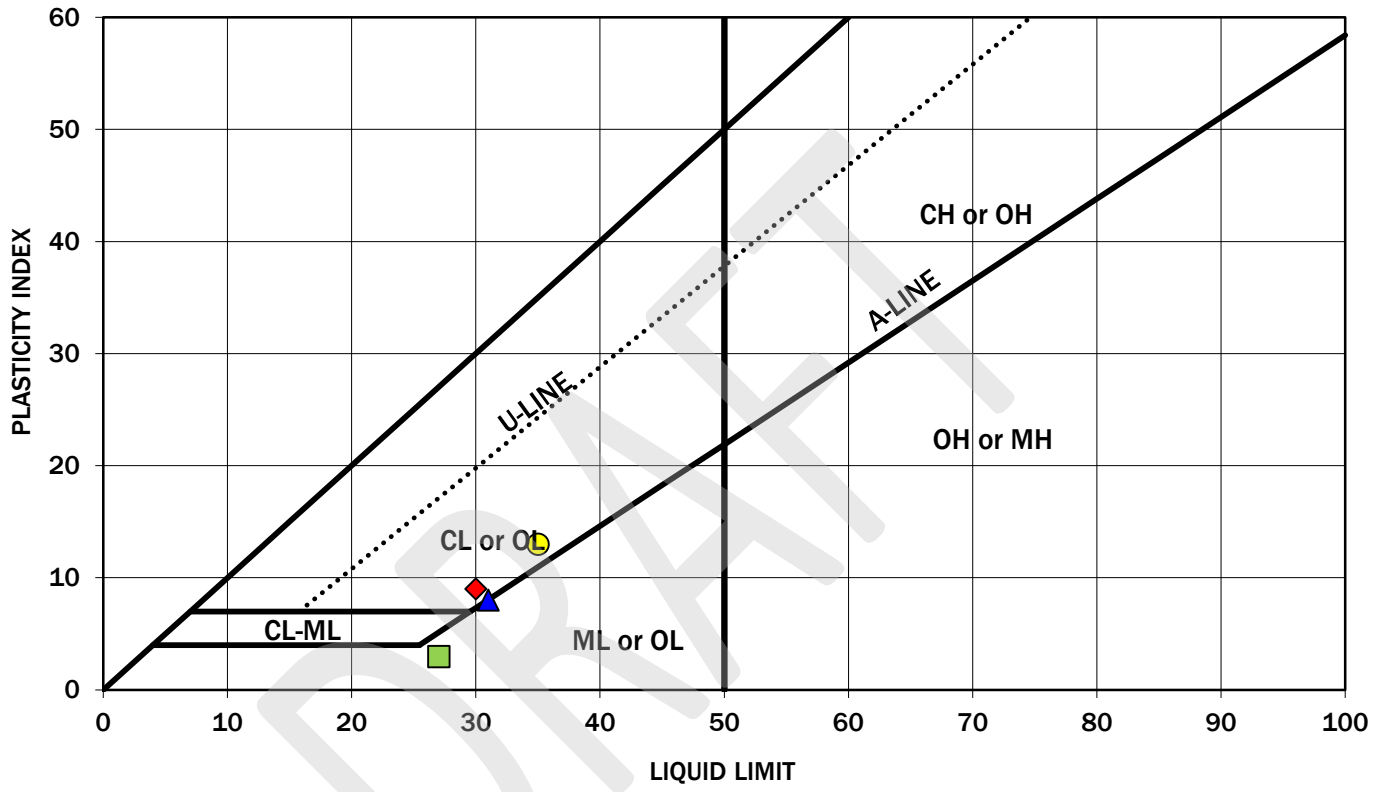
0500-204-00 Date Exported: 10/22/15

## PLASTICITY CHART




| Symbol | Boring Number | Depth (feet) | Moisture Content (%) | Liquid Limit (%) | Plasticity Index (%) | Soil Description |
|---|---|---|---|---|---|---|
| ◆ | B-3 | 6 | 17 | 30 | 9 | Sandy lean clay (CL) |
| ■ | B-3 | 12.5 | 25 | 27 | 3 | Sandy silt (ML) |
| ▲ | B-3 | 17.5 | 24 | 31 | 8 | Sandy silt (ML) |
| ● | B-3 | 30 | 26 | 35 | 13 | Lean clay (CL) |

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The liquid limit and plasticity index were obtained in general accordance with ASTM D 4318.

**Atterberg Limits Test Results**

159th Avenue NE Vault – Tosh Creek Watershed, Redmond, Washington

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**Figure B-4**

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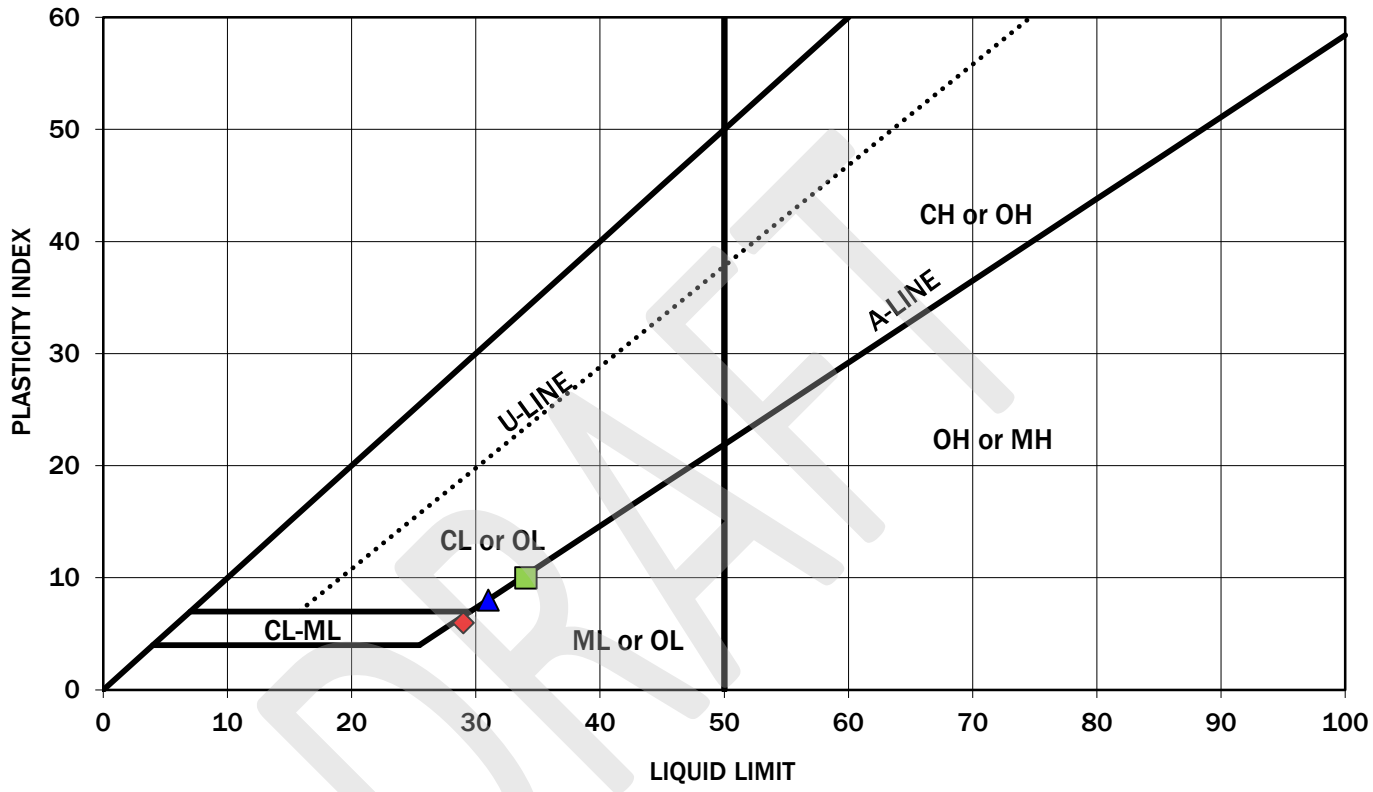
## PLASTICITY CHART




| Symbol | Boring Number | Depth (feet) | Moisture Content (%) | Liquid Limit (%) | Plasticity Index (%) | Soil Description |
|---|---|---|---|---|---|---|
| ◆ | B-4 | 7.5 | 26 | 29 | 6 | Silt with sand (ML) |
| ■ | B-4 | 10 | 24 | 34 | 10 | Lean clay (CL) |
| ▲ | B-4 | 20 | 25 | 31 | 8 | Silt (ML) |

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The liquid limit and plasticity index were obtained in general accordance with ASTM D 4318.

**Atterberg Limits Test Results**

159th Avenue NE Vault – Tosh Creek Watershed, Redmond, Washington

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**Figure B-5**

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# APPENDIX C
## Report Limitations and Guidelines for Use

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## APPENDIX C
## REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

### Geotechnical Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of the City of Redmond, HDR Engineering, Inc., and other project team members for the 159th Avenue NE Vault project in Redmond, Washington. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule, and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

### A Geotechnical Engineering or Geologic Report Is Based on a Unique Set of Project-specific Factors

This report has been prepared for 159th Avenue NE Vault project in Redmond, Washington. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you;
- not prepared for your project;
- not prepared for the specific site explored; or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;
- elevation, configuration, location, orientation or weight of the proposed structure;
- composition of the design team; or
- project ownership.

[1] Developed based on material provided by GBA, GeoProfessional Business Association; www.geoprofessional.org.



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If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

### Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability, or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

### Most Geotechnical and Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions, and interpretations should not be construed as a warranty of the subsurface conditions.

### Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

### A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

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### Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

### Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

### Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

### Read These Provisions Closely

Some clients, design professionals, and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims, and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

### Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques, and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

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## Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of Biological Pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of Biological Pollutants and no conclusions or inferences should be drawn regarding Biological Pollutants, as they may relate to this project. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.

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