COBALT GEOSCIENCES

Cobalt Geosciences, LLC
P.O. Box 82243
Kenmore, Washington 98028

July 27, 2022

James McGillis
oldtrollers@centurylink.net

**RE: Geotechnical Investigation (DRAFT)**
Existing Roadway Distress
Hidden Springs Drive
Hood Canal/Port Ludlow, Washington

In accordance with your authorization, Cobalt Geosciences, LLC has prepared this report to discuss the results of our geotechnical evaluation at the referenced site.

The purpose of our evaluation was to provide determine the soil and groundwater conditions in the affected portion of roadway and provide preliminary recommendations for roadway repair and soil creep mitigation.

## Site Description

The site is located along the east side a small portion of Hidden Springs Drive south of Paradise Bay Road (Figure 1). Specifically, the area affected by settlement and soil movements is approximately 6 to 7.5 feet wide and about 40 feet long as indicated by the most recent asphalt patch. Within this patch, there are relatively recent tension cracks forming with some set down on the east side. The cracks form a typical arcuate shape, indicative of soil movements.

We understand that the roadway was created in the mid 1980's and paved in or about 2005. The last patch was placed about 8 years ago. We also understand that slope subsidence through erosion and/or soil creep has been noted over this time period. This has resulted in slope steepening near the roadway.

The affected area consists of an overall east facing slope system with natural magnitudes of mostly 20 to 40 percent. The slope adjacent to the affected area has slope magnitudes of about 50 to 80 percent and local relief of about 20 feet. There are local short cut slopes along the uphill side of the road with magnitudes of 50 to 100 percent and local relief of less than 6 feet. Based on our observations, it appears that there was a ravine with shallow side slopes in this area.

Site and area vegetated includes ferns, grasses, ivy, understory, blackberry vines, and variable diameter trees.

The project may include mitigation of the affected areas to reduce the rate of settlement and soil creep, or potentially, continued monitoring and/or road relocation to the west. We can update this report with more specific recommendations once a type of work has been selected by the homeowner's association.

## Area Geology

The Geologic Map of the Port Ludlow Quadrangle, indicates that the site is near the contacts between Vashon Advance Outwash and Pre-Vashon Alluvium of the Olympia Non-Glacial period.

Vashon Advance Outwash includes fine to medium grained sand with local interbeds of silt and clay, particularly near the base of the unit. These deposits typically become denser with depth below a weathered zone.

Pre-Vashon deposits include sands and lesser layers and amounts of silt, minor clay, and lesser wood debris. These deposits underlie the outwash sands and would be expected to be mostly dense due to consolidation during the Vashon-era glaciation.

## Soil & Groundwater Conditions

The geotechnical field investigation program was completed on July 11, 2022 and included drilling and sampling one hollow stem auger boring and two hand borings within and near the affected area for subsurface analysis.

Disturbed soil samples were obtained during drilling by using the Standard Penetration Test (SPT) as described in ASTM D-1586. The Standard Penetration Test and sampling method consists of driving a standard 2-inch outside-diameter, split barrel sampler into the subsoil with a 140-pound hammer free falling a vertical distance of 30 inches. The summation of hammer-blows required to drive the sampler the final 12-inches of an 18-inch sample interval is defined as the Standard Penetration Resistance, or N-value. The blow count is presented graphically on the boring logs in this appendix. The resistance, or "N" value, provides a measure of the relative density of granular soils or of the relative consistency of cohesive soils.

The soils encountered were logged in the field and are described in accordance with the Unified Soil Classification System (USCS).

A Cobalt Geosciences field representative conducted the exploration, collected disturbed soil samples, classified the encountered soils, kept a detailed log of the explorations, and observed and recorded pertinent site features.

The boring encountered approximately 6 inches of gravel underlain by approximately 15 feet of very loose, silty-fine to fine grained sand with local areas of poorly graded sand and woody debris (Likely Fill). These materials included larger logs at about 11 to 15 feet below grade, likely representing the original forest floor in this area. These deposits were underlain by stiff to very stiff, silt with fine grained sand trace clay (Pre-Vashon Deposits?), which continued to the termination depth of the boring.

Hand Boring HB-1 encountered about 4 feet of loose to medium dense, fine to medium grained sand (Advance Outwash) underlain by stiff silt trace to with fine sand (Pre-Vashon Deposits?). Hand Boring HB-2 encountered approximately 4 feet of loose, fine to medium grained sand trace gravel underlain by medium dense, silty-fine to fine grained sand (Outwash or Pre-Vashon Deposits?).

Groundwater was observed at 14.5 feet below grade in the boring during drilling. Groundwater likely follows the original topographic ravine feature in this area, perched on the finer grained silts below the fill and looser sands. We note that there was no surface water in the vicinity of the affected areas; however, there could be springs (emergent groundwater) downslope to the east.

Water table elevations often fluctuate over time. The groundwater level will depend on a variety of factors that may include seasonal precipitation, irrigation, land use, climatic conditions and soil permeability. Water levels at the time of the field investigation may be different from those encountered during the construction phase of the project.

## Steep Slope Hazards

Critical area ordinances designate slopes with magnitudes greater than about 40 percent and vertical relief of at least 10 feet as potentially geologically hazardous (steep slope/landslide hazards). Additional criteria include areas where landslide activity has taken place historically or where there is evidence of slope movements. Slope areas underlain by permeable soils overlying impermeable soils often exhibit landslide activity.

The steep road embankment is consistent with a steep slope hazard area. This area appears to include a former shallow ravine that was subsequently filled with soils. We anticipate that the fill used to fill the ravine was excavated from nearby road cuts to the west and south of the area.

It is our opinion that the risk of landslide activity in natural occurring slope areas near the site is low to very low. The risk of soil movements is moderate to high for the affected oversteepened fill slope at the affected location. Specifically, there is a moderate rate of soil creep and subsidence of the very loose fills within the eastern portion of the roadway at the affected area. Soil creep is ongoing at a low to moderate rate and will continue. Along with soil creep, there is likely vertical consolidation occurring of the very loose fills. The combination of soil creep and subsidence of fill will result in continued downward and lateral movements of at least the east side of the roadway in this area. We cannot rule out that the movements will not extend further west, north and south within the roadway areas.

Our boring encountered sandy soils overlying intact silts with groundwater at or near the contact between these units. This is a common geologic condition that results in landslide activity when coupled with a moderately steep to steep slope. There were buried logs and forest debris below the fill.

The risk of soil movements is highest for this condition during the winter months when groundwater is at higher levels, and during/after certain seismic events. While larger landslides do not appear to have taken place in this area to date, there is a risk of larger soil and slope movements due to the soil and groundwater conditions at this location.

## Erosion Hazard

The Natural Resources Conservation Services (NRCS) maps for Jefferson County indicate that the site is underlain by Kitsap silt loam (0 to 15 and 15 to 30 percent slopes). These soils would have a low to severe erosion potential in a disturbed state depending on the slope magnitude.

It is our opinion that soil erosion potential at this project site can be reduced through landscaping and surface water runoff control. Typically, erosion of exposed soils will be most noticeable during periods of rainfall and may be controlled by the use of normal temporary erosion control measures, such as silt fences, hay bales, mulching, control ditches and diversion trenches. The typical wet weather season, with regard to site grading, is from October 31$^{st}$ to April 1$^{st}$. Erosion control measures should be in place before the onset of wet weather.

## Seismic Hazard

The overall subsurface profile corresponds to a Site Class *D* as defined by Table 1613.5.2 of the International Building Code (IBC). A Site Class *D* applies to an overall profile consisting of medium dense to dense soils within the upper 100 feet.

We referenced the U.S. Geological Survey (USGS) Earthquake Hazards Program Website to obtain values for $S_S$, $S_1$, $F_a$, and $F_v$. The USGS website includes the most updated published data on seismic conditions. The following tables provide seismic parameters from the USGS web site with referenced parameters from ASCE 7-16.

Seismic Design Parameters (ASCE 7-16)

| Site Class | Spectral Acceleration at 0.2 sec. (g) | Spectral Acceleration at 1.0 sec. (g) | Site Coefficients | | Design Spectral Response Parameters | | Design PGA |
|---|---|---|---|---|---|---|---|
| | | | $F_a$ | $F_v$ | $S_{DS}$ | $S_{D1}$ | |
| D | 1.312 | 0.468 | 1.0 | Null | 0.875 | Null | 0.505 |

Additional seismic considerations include liquefaction potential and amplification of ground motions by soft/loose soil deposits. The liquefaction potential is highest for loose sand with a high groundwater table. The site has a relatively low likelihood of liquefaction. For items listed as "Null" see Section 11.4.8 of the ASCE.

## Slope Stability Analyses

We performed slope stability analyses through a representational cross section through the affected area and adjacent areas. Analyses were performed using data from the boring and hand borings. the estimated feature locations and elevations, and topography from County GIS maps/observations.

The commercially available slope stability computer program Slope/W was used to evaluate the global stability. The slope stability was analyzed under static and seismic (pseudo-static method) conditions for the existing topography.

The computer program calculates factors of safety for potential slope failures and generates the potential failure planes. This software calculates the slope stability under seismic conditions using pseudo-static methods. The stability of the described configuration was analyzed by comparing observed factors of safety to minimum values as set by standard geotechnical practice.

A factor of safety of 1.0 is considered equilibrium and less than 1.0 is considered failure. The required factor of safety for global stability is 1.5 for static conditions and 1.1 for seismic conditions. In accordance with typical engineering standards, we used a seismic acceleration equal to one half of the horizontal peak ground acceleration. At this location, the site modified PGA is 0.505g with one half equal to 0.253g. We initially conducted back analyses with varying soil parameters to achieve a factor of safety of about 1.0 for the area of the settlement/distress.

The following estimated soil parameters were used in our analyses:

| Soil Description | Unit Weight (pcf) | Cohesion (psf) | Friction (degrees) |
|---|---|---|---|
| Fill | 105 | 25 | 32 |
| Weathered Outwash (Upslope) | 110 | 0 | 34 |
| Silty-Sands | 115 | 50 | 36 |
| Silts | 115 | 150 | 30 |

**Slope Stability Results**

| Cross Section | Static Factor of Safety | 0.253g Seismic Factor of Safety |
|---|---|---|
| Current Global Stability (Back Analyses) | 1.093 | - |
| Proposed Stability with Soldier Pile Wall | 4.625 | 1.696 |

Our analyses show that a suitably strong soldier pile wall could be used to increase factors of safety to typical required values. We simulated a pile wall with 4 foot on center spacing and a pile length/depth of 30 feet. There are many options to reduce/mitigate the risk of vertical and lateral soil movements in this area. We provide an overview of these in subsequent sections of this report.

# Conclusions and Recommendations

## General

The affected portion of roadway (patched area) is underlain by likely fill that is very loose to a depth of about 15 feet. Groundwater was present above the native silts that underlie the area.

It is our opinion that soil creep, subsidence, and lateral soil movements will continue in this area without significant mitigation. This mitigation could include fill and loose soil removal with drainage improvements coupled with walls or reinforced fill slopes, soldier pile walls and local overexcavation to reduce the rate of vertical settlement; or re-locating the roadway to the west with ongoing monitoring of the affected area.

We provide general information in this report for discussion by the homeowner’s association. We can elaborate on specific mitigation options upon request.

## Site Preparation

The following section applies if fill removal is proposed.

The fill soils consist of fine to medium grained sand with gravel and local silty-sand with gravel. Most of the native soils may be used as structural fill provided they achieve compaction requirements and are within 3 percent of the optimum moisture. Some of these soils may only be suitable for use as fill during the summer months, as they will be above the optimum moisture levels in their current state. These soils are variably moisture sensitive and may degrade during periods of wet weather and under equipment traffic. Woody debris should be removed prior to use as structural fill.

Imported structural fill should consist of a sand and gravel mixture with a maximum grain size of 3 inches and less than 5 percent fines (material passing the U.S. Standard No. 200 Sieve). Structural fill should be placed in maximum lift thicknesses of 12 inches and should be compacted to a minimum of 95 percent of the modified proctor maximum dry density, as determined by the ASTM D 1557 test method.

## Temporary Excavations

If fill removal is performed, the following recommendations apply:

Temporary excavations should be sloped no steeper than 1.5H:1V (Horizontal:Vertical) in loose native soils and 1H:1V in medium dense native soils. If an excavation is subject to heavy vibration or surcharge loads, we recommend that the excavations be sloped no steeper than 2H:1V, where room permits.

Overall, we would anticipate that fill removal would include a series of near vertical cuts and level benches extending into medium dense native soils. Vertical cuts may be 2 to 4 feet tall with lateral benches of 4 feet or more. We recommend that 12 inches of 2-4 inch quarry rock be placed over the benches and along the vertical cuts to allow groundwater to migrate freely from the filled slope. Mirafi 140N should be placed on the rock. We can provide additional input if this is proposed.

Temporary cuts should be in accordance with the Washington Administrative Code (WAC) Part N, Excavation, Trenching, and Shoring. Temporary slopes should be visually inspected daily by a qualified person during construction activities and the inspections should be documented in daily reports. The contractor is responsible for maintaining the stability of the temporary cut slopes and reducing slope erosion during construction.

Temporary cut slopes should be covered with visqueen to help reduce erosion during wet weather, and the slopes should be closely monitored until the permanent retaining systems or slope configurations are complete. Materials should not be stored or equipment operated within 10 feet of the top of any temporary cut slope.

Soil conditions may not be completely known from the geotechnical investigation. In the case of temporary cuts, the existing soil conditions may not be completely revealed until the excavation work exposes the soil. Typically, as excavation work progresses the maximum inclination of temporary slopes will need to be re-evaluated by the geotechnical engineer so that supplemental recommendations can be made. Soil and groundwater conditions can be highly variable. Scheduling for soil work will need to be adjustable, to deal with unanticipated conditions, so that the project can proceed and required deadlines can be met.

If any variations or undesirable conditions are encountered during construction, we should be notified so that supplemental recommendations can be made. If room constraints or groundwater conditions do not permit temporary slopes to be cut to the maximum angles allowed by the WAC, temporary shoring systems may be required. The contractor should be responsible for developing temporary shoring systems, if needed. We recommend that Cobalt Geosciences and the project structural engineer review temporary shoring designs prior to installation, to verify the suitability of the proposed systems.

## Mitigation, Roadway Re-location, and Monitoring Options

There are numerous options to mitigate against the current fill consolidation and soil creep. Some options only provide lateral support and do not mitigate against vertical settlement while others fully or partially mitigate the combination of settlement and creep. These include but are not limited to:

- Soldier pile walls
- Replaced fill with geogrid reinforced wall or slope
- Limited near-surface mitigation

Soldier pile walls embedded into denser native soils below the fill zones could be used to provide lateral support of the roadway. While this system will not mitigate vertical settlement, it could be placed in conjunction with near-surface soil removal and replacement to help reduce the rate of settlement. Our slope stability analyses indicate that 30 feet long piles spaced at 4 feet on center could be used to support the roadway embankment in the affected area.

The entire loose fill zones could be removed and replaced with structural fill, geogrid reinforcement, and permanent facing with modular blocks or a permanent fill slope. This would involve benching and keying into medium dense native soils below the fill areas, replacing the removed soils with properly compacted structural fill. We anticipate that the lowest level of fill would have to consist of clean angular rock to facilitate drainage. Geogrid reinforced fill slopes could be created up to a 1H:1V permanent magnitude.

Limited near-surface soil removal could be performed to decrease the rate of soil creep and settlement. This would include overexcavation of approximately 5 or more feet of existing fill from the affected areas followed by replacement with geotextile/geogrids and structural fill up to subgrade. We note that this will not fully mitigate against settlement and soil creep.

The affected section of roadway could be re-located to the west of the current alignment approximately 15 feet or more. This would still likely require some fill and buried forest duff removal and reconstruction with structural fills and drainage; however, it may be more cost-effective than deep fill removal or pile wall construction.

Depending on the final grades and roadway location, local rockery or other walls could be necessary west of the roadway.

It is also feasible to install monitoring points to allow ongoing monitoring of the soil movements in the affected area to determine the rate and magnitude of the movements. Based on our observations, it appears that the rate of subsidence and soil creep is more than several inches a year and that the area will continue to erode and subside over time. In general, it is our opinion that monitoring is not very useful since the movements are easily observed by changes in the slope location and presence of cracks in the asphalt patches.

## Cantilever Soldier Pile Walls

A soldier pile wall with pressure treated timber (wood) or concrete lagging would be suitable to replace the failed and failing rockery system along the west and southwest portions of the property.

Soldier piles typically consist of steel W or H-beams inserted into oversized drilled shafts, which are backfilled with structural concrete, lean mix {Controlled Density Fill (CDF)}, or a combination of lean mix to the base of the excavation and structural concrete below the excavation to anchor the soldier piles.

Due to the potential for local caving during drilling operations for the soldier pile holes due to soft soil conditions and shallow groundwater, consideration should be given to using slurry or drilling fluid to reduce the risk of caving of the pile holes during installation. If water is present within the pile hole at the time of soldier pile concrete placement, the concrete should be placed starting at the bottom of the hole with a tremie pipe and the column of concrete should be raised slowly to displace the water.

We recommend that soldier piles have a maximum spacing of eight feet on center. To account for arching effects, lateral loading on the lagging can be reduced by 50 percent. Unlagged excavation heights should not exceed three feet. No portion of the excavation should remain unsupported overnight. Lagging sections may be up to 6 feet in height depending on stability.

Cantilever soldier pile walls for this site may be designed based on an active lateral earth pressure of 50 pcf for a level backslope, provided the wall is unrestrained (not fixed; permitted to move at least 0.2 percent of the wall height). The pressure will act on the soldier pile width below the base of the excavation as well. All applicable surcharge pressures should be included. A lateral uniform seismic pressure of 7H is recommended for seismic conditions (active).

In front of the soldier piles, resistive pressure can be estimated using an allowable passive earth pressure of 250 pcf acting over 2 times the soldier pile diameter, neglecting the upper 2 feet below the base of the excavation (or loose fill). A factor of safety of 1.5 has been incorporated into the passive pressure value. A lateral pressure reduction of 50 percent may be used for design of the lagging for a pile spacing of three diameters. Lagging should be backfilled with 5/8 inch clean angular rock to minimize void spaces.

Since the wall is permanent, we recommend either coating the piles to prevent oxidation or upsizing the beams slightly to account for oxidation. We can provide additional recommendations upon request.

## Erosion and Sediment Control

Erosion and sediment control (ESC) is used to reduce the transportation of eroded sediment to wetlands, streams, lakes, drainage systems, and adjacent properties. Erosion and sediment control measures should be implemented, and these measures should be in general accordance with local regulations. At a minimum, the following basic recommendations should be incorporated into the design of the erosion and sediment control features for the site:

- Schedule the soil, foundation, utility, and other work requiring excavation or the disturbance of the site soils, to take place during the dry season (generally May through September). However, provided precautions are taken using Best Management Practices (BMP's), grading activities can be completed during the wet season (generally October through April).
- All site work should be completed and stabilized as quickly as possible.

- Additional perimeter erosion and sediment control features may be required to reduce the possibility of sediment entering the surface water. This may include additional silt fences, silt fences with a higher Apparent Opening Size (AOS), construction of a berm, or other filtration systems.
- Any runoff generated by dewatering discharge should be treated through construction of a sediment trap if there is sufficient space. If space is limited other filtration methods will need to be incorporated.

## CONSTRUCTION FIELD REVIEWS

Cobalt Geosciences should be retained to provide part time field review during construction in order to verify that the soil conditions encountered are consistent with our design assumptions and that the intent of our recommendations is being met. This will require field and engineering review to:

- Monitor and test structural fill placement and soil compaction
- Verify drainage improvements
- Observe pile placement
- Verify overexcavation work
- Observe excavation stability

Geotechnical design services should also be anticipated during the subsequent final design phase to support the structural design and address specific issues arising during this phase. Field and engineering review services will also be required during the construction phase in order to provide a Final Letter for the project.

## CLOSURE

This report was prepared for the exclusive use of James McGillis and his appointed consultants. Any use of this report or the material contained herein by third parties, or for other than the intended purpose, should first be approved in writing by Cobalt Geosciences, LLC.

The recommendations contained in this report are based on assumed continuity of soils with those of our test holes and assumed structural loads. Cobalt Geosciences should be provided with final architectural and civil drawings when they become available in order that we may review our design recommendations and advise of any revisions, if necessary.

Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of James McGillis who is identified as “the Client” within the Statement of General Conditions, and its agents to review the conditions and to notify Cobalt Geosciences should any of these not be satisfied.

Sincerely,

**Cobalt Geosciences, LLC**

DRAFT

Phil Haberman, PE, LG, LEG
Principal

## Statement of General Conditions

**USE OF THIS REPORT:** This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Cobalt Geosciences and the Client. Any use which a third party makes of this report is the responsibility of such third party.

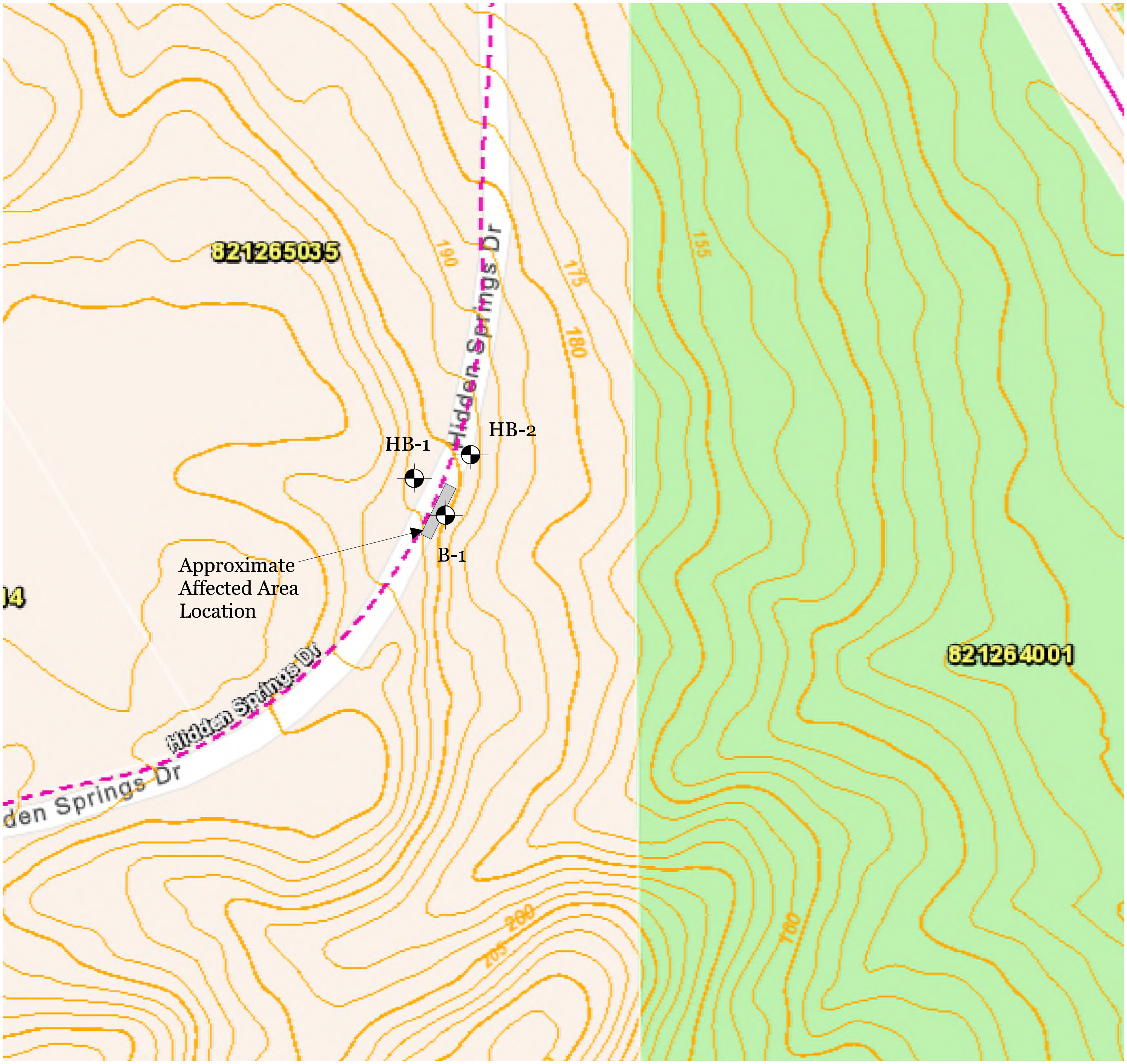
**BASIS OF THE REPORT:** The information, opinions, and/or recommendations made in this report are in accordance with Cobalt Geosciences present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Cobalt Geosciences is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

**STANDARD OF CARE:** Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state of execution for the specific professional service provided to the Client. No other warranty is made.

**INTERPRETATION OF SITE CONDITIONS:** Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Cobalt Geosciences at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

**VARYING OR UNEXPECTED CONDITIONS:** Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Cobalt Geosciences must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Cobalt Geosciences will not be responsible to any party for damages incurred as a result of failing to notify Cobalt Geosciences that differing site or sub-surface conditions are present upon becoming aware of such conditions.

**PLANNING, DESIGN, OR CONSTRUCTION:** Development or design plans and specifications should be reviewed by Cobalt Geosciences, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Cobalt Geosciences cannot be responsible for site work carried out without being present.




**B-1**
**HB-1**

Approximate Boring and
Hand Boring Location

Jefferson County GIS Map

Approximate Scale 1"= 100'

N

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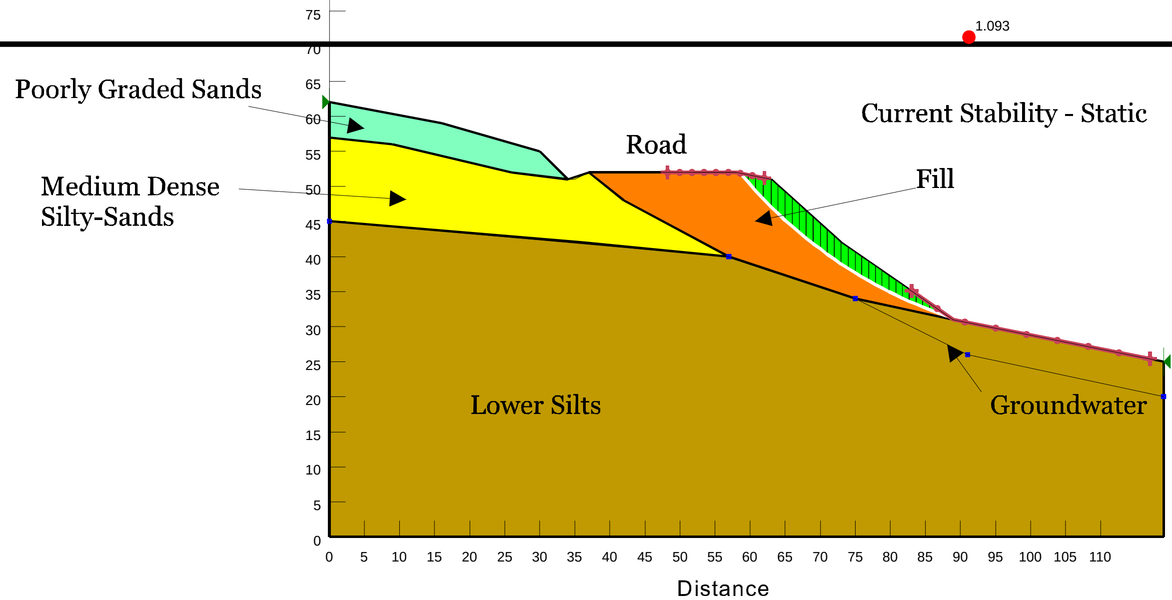
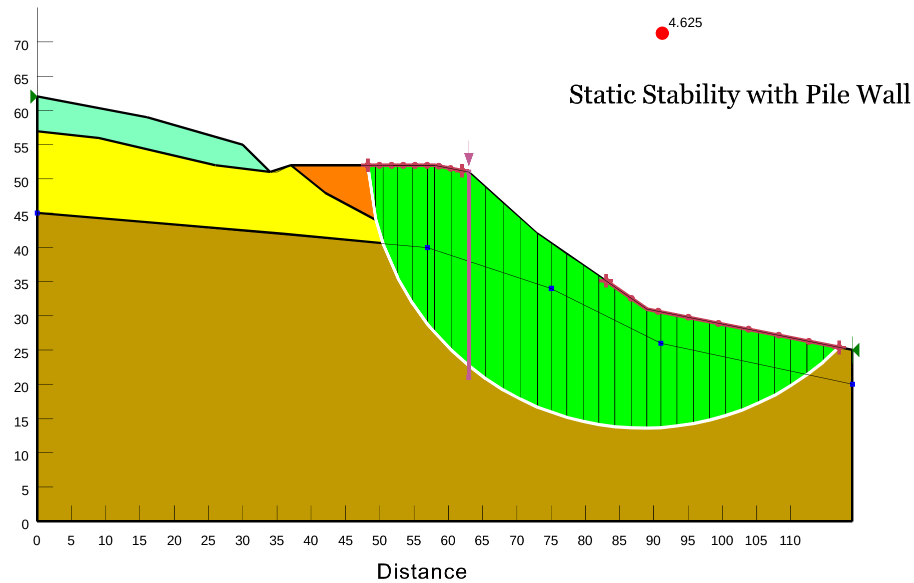
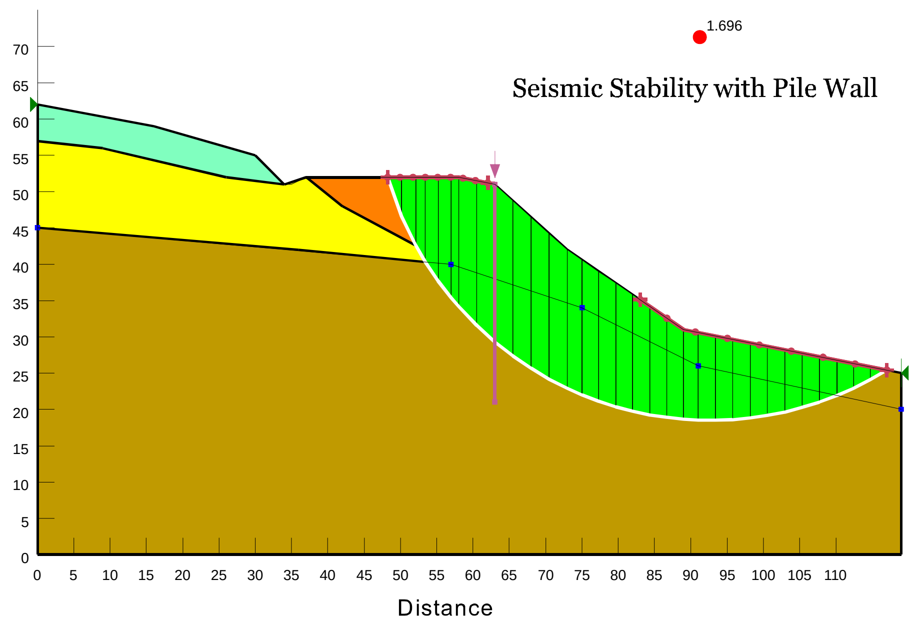
|---|---|---|---|
| COBALT GEOSCIENCES | Geotechnical Evaluation<br>Hidden Springs Drive<br>Jefferson County, Washington | **Area Plan**<br>**Figure 1** | Cobalt Geosciences, LLC<br>P.O. Box 82243<br>Kenmore, WA 98028<br>(206) 331-1097<br>www.cobaltgeo.com<br>cobaltgeo@gmail.com |

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| COBALT GEOSCIENCES | Geotechnical Evaluation<br>Hidden Springs Drive<br>Jefferson County, Washington | **Existing Slope Stability** | Cobalt Geosciences, LLC<br>P.O. Box 82243<br>Kenmore, WA 98028<br>(206) 331-1097<br>www.cobaltgeo.com<br>cobaltgeo@gmail.com |

# Unified Soil Classification System (USCS)

| MAJOR DIVISIONS | | | SYMBOL | TYPICAL DESCRIPTION |
|---|---|---|---|---|
| COARSE GRAINED SOILS (more than 50% retained on No. 200 sieve) | Gravels (more than 50% of coarse fraction retained on No. 4 sieve) | Clean Gravels (less than 5% fines) | GW | Well-graded gravels, gravels, gravel-sand mixtures, little or no fines |
| | | | GP | Poorly graded gravels, gravel-sand mixtures, little or no fines |
| | | Gravels with Fines (more than 12% fines) | GM | Silty gravels, gravel-sand-silt mixtures |
| | | | GC | Clayey gravels, gravel-sand-clay mixtures |
| | Sands (50% or more of coarse fraction passes the No. 4 sieve) | Clean Sands (less than 5% fines) | SW | Well-graded sands, gravelly sands, little or no fines |
| | | | SP | Poorly graded sand, gravelly sands, little or no fines |
| | | Sands with Fines (more than 12% fines) | SM | Silty sands, sand-silt mixtures |
| | | | SC | Clayey sands, sand-clay mixtures |
| FINE GRAINED SOILS (50% or more passes the No. 200 sieve) | Silts and Clays (liquid limit less than 50) | Inorganic | ML | Inorganic silts of low to medium plasticity, sandy silts, gravelly silts, or clayey silts with slight plasticity |
| | | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays silty clays, lean clays |
| | | Organic | OL | Organic silts and organic silty clays of low plasticity |
| | Silts and Clays (liquid limit 50 or more) | Inorganic | MH | Inorganic silts, micaceous or diatomaceous fine sands or silty soils, elastic silt |
| | | | CH | Inorganic clays of medium to high plasticity, sandy fat clay, or gravelly fat clay |
| | | Organic | OH | Organic clays of medium to high plasticity, organic silts |
| HIGHLY ORGANIC SOILS | Primarily organic matter, dark in color, and organic odor | | PT | Peat, humus, swamp soils with high organic content (ASTM D4427) |

### Classification of Soil Constituents

MAJOR constituents compose more than 50 percent, by weight, of the soil. Major constituents are capitalized (i.e., SAND).

Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (i.e., silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (i.e., slightly silty SAND).

Trace constituents compose 0 to 5 percent of the soil (i.e., slightly silty SAND, trace gravel).

### Relative Density (Coarse Grained Soils)

| N, SPT, Blows/FT | Relative Density |
|---|---|
| 0 - 4 | Very loose |
| 4 - 10 | Loose |
| 10 - 30 | Medium dense |
| 30 - 50 | Dense |
| Over 50 | Very dense |

### Consistency (Fine Grained Soils)

| N, SPT, Blows/FT | Relative Consistency |
|---|---|
| Under 2 | Very soft |
| 2 - 4 | Soft |
| 4 - 8 | Medium stiff |
| 8 - 15 | Stiff |
| 15 - 30 | Very stiff |
| Over 30 | Hard |

### Grain Size Definitions

| Description | Sieve Number and/or Size |
|---|---|
| Fines | <#200 (0.08 mm) |
| Sand | |
| -Fine | #200 to #40 (0.08 to 0.4 mm) |
| -Medium | #40 to #10 (0.4 to 2 mm) |
| -Coarse | #10 to #4 (2 to 5 mm) |
| Gravel | |
| -Fine | #4 to 3/4 inch (5 to 19 mm) |
| -Coarse | 3/4 to 3 inches (19 to 76 mm) |
| Cobbles | 3 to 12 inches (75 to 305 mm) |
| Boulders | >12 inches (305 mm) |

### Moisture Content Definitions

| | |
|---|---|
| Dry | Absence of moisture, dusty, dry to the touch |
| Moist | Damp but no visible water |
| Wet | Visible free water, from below water table |

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Cobalt Geosciences, LLC
P.O. Box 82243
Kenmore, WA 98028
(206) 331-1097
www.cobaltgeo.com
cobaltgeo@gmail.com

Soil Classification Chart

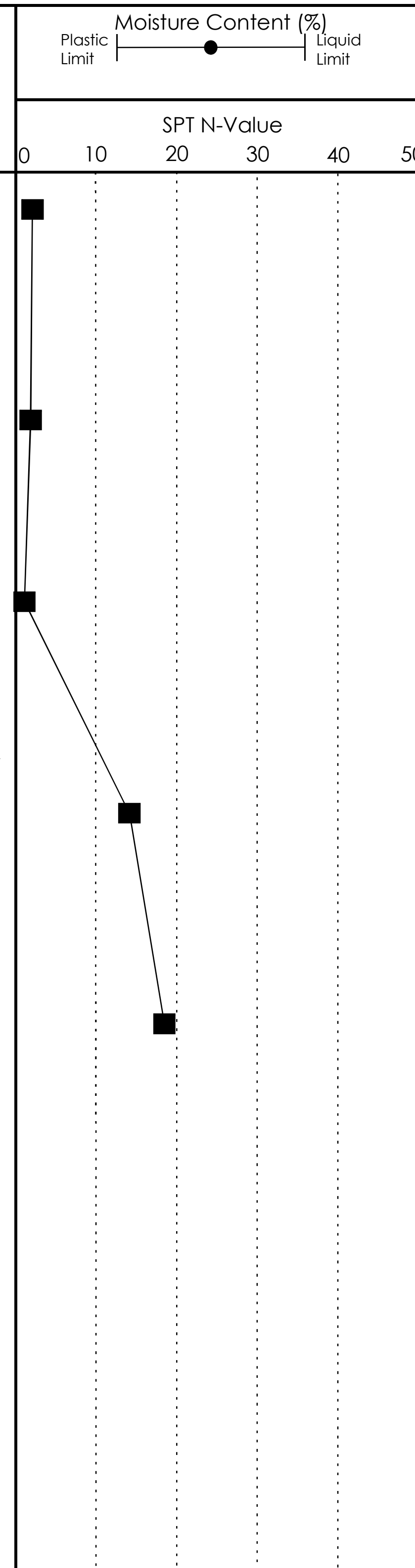
**Figure C1**

# Log of Boring B-1

| | | |
|---|---|---|
| Date: July 11, 2022 | Depth: 21.5' | Initial Groundwater: 14.5' |
| Contractor: CN | Elevation: N/A | Sample Type: Split Spoon |
| Method: Hollow Stem Auger | Logged By: PH Checked By: SC | Final Groundwater: N/A |

| Depth (Feet) | Blows/6" | USCS Symbol | Material Description |
|---|---|---|---|
| 0 | 1 | | Gravel |
| 0.5–15.5 | 1, 1 (0.5–2 ft); 1, 1, 1 (5–6.5 ft); 1, 0, 1 (10–11.5 ft) | SM | Very loose, silty-fine to fine grained sand trace to with gravel, local poorly graded sand and organics, dark yellowish brown to grayish brown, moist to wet. (Fill)<br>Local layers of SP-SM<br>Buried cedar logs and other forest duff at 11.25 to 15.5 feet. |
| 15.5–21.5 | 1, 5, 8 (15–16.5 ft); 5, 8, 11 (20–21.5 ft) | ML | Stiff to very stiff, silt trace to with sand, mottled olive gray to grayish brown, moist. (Pre-Vashon Deposits)<br>Local fine layered deposits with trace clay. |
| 21.5 | | | End of Boring 21.5' |

Groundwater: ▼ at 14.5'





COBALT GEOSCIENCES
Cobalt Geosciences, LLC
P.O. Box 82243
Kenmore, WA 98028
(206) 331-1097
www.cobaltgeo.com
cobaltgeo@gmail.com


Roadway Subsidence
Hidden Springs Drive
Jefferson County, Washington

**Boring Log**