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June 19, 2017

Bruce Lorig, Building Committee Chair
Mercer Island Center for the Arts
P.O. Box 1702
Mercer Island, WA 98040

Re: **Mercer Island Center for the Arts**
**Slope Stability Study - Revision 01**
19120-01

Dear Bruce:

This report is the first revision to our original report dated November 22, 2016 and is submitted to address comments by Perrone Consulting, Inc., P.S.

We previously conducted a site visit and further analyses to assess the landslide risks for the proposed development site. We developed a cross section through the site and the adjacent hillside. It is presented as Figure 1 attached to this letter. Figure 1 also demonstrates the changing steepness of the slopes, from near flat at the building site, to 15% - 30% directly behind the building, to average slopes steeper than 40% up the rest of the hill.

## General Geologic Conditions

Based on our borings, other borings in the vicinity, geologic mapping, and published sources, we prepared a subsurface cross section as shown in Figu The soil layering is approximate, both in depth and thickness. As noted, the soils are generally glacial in origin and very dense or hard, except for surficial deposits.

During our recent site reconnaissance at the end of October 2016 we did not observe groundwater seepage on the slope, even though this past October has been the wettest on record. Groundwater levels and/or seepage rates are not static and we expect that groundwater conditions will vary depending on local subsurface conditions, season, precipitation, changes in land use both on and off site, and other factors.

## Geologic Hazards

### Steep Slope

The City of Mercer Island Municipal Code establishes that any ground with a grade of 40 percent or more is considered a "steep slope". However, the code also establishes that classification as a Landslide

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Hazard Area requires slopes steeper than 15 percent, a hillside that intersects geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock, and the presence of springs or groundwater seepage. Therefore, it is possible to have a site that contains steep slopes, but is not considered a Landslide Hazard Area, and vice versa.

Based on our surface and subsurface investigation, it is our opinion that a Landslide Hazard Area does not exist on the development property because of the absence of seepage and the expected and mapped layering of the soil units. Nor is the property a steep slope, since the average slopes are near flat.

Much of the near surface soils in the 15-40% upslope area are assumed to consist of landslide debris from much older landslides probably occurring approximately 650 to 800 ft. upslope from the proposed building location. The presence of these soils raises the risk of reactivation of slide debris, or soil creep, and suggests past instability. However, we noted that an existing rockery wall near the base of the slope behind the existing structure has shown no signs of movement or displacement due to soil creep or landslide reactivation.

## Slope Stability Analysis

To further analyze the slope stability, Hart Crowser conducted slope stability analysis using the computer program Slope/W to calculate safety factors on presumed critical slip surfaces.

### *Soil Conditions*

We did not conduct soil borings on the soil slope; therefore, for slope stability analysis, we defined the soil stratigraphy based on existing geologic mapping (Troost et al. 2006). The geologic mapping for the site is presented on Figure 2 and our interpretation of the mapped geology is shown on the slope stability model sections in Figures 3 through 5.

Much of the near surface soils in the 15-40% upslope area are assumed to consist of landslide colluvium from much older landslides probably occurring approximately 650 to 800 feet upslope from the proposed building location (or from previous disturbance, such as logging). Because we did not conduct borings on the slope, the depth of potential colluvium can only be assumed based on judgement.

The effective stress strength parameters for the mapped soils were referenced from the USGS Open-File Report, Shallow-Landslide Hazard Map of Seattle, Washington (Harp et al. 2006). These values are presented on the slope stability results figures.

For the seismic case, we performed analysis using both effective stress strength parameters and total stress, or undrained strength, parameters. The undrained strength parameters are provided on the slope stability results figures. While the effective stress strength parameters are based on published data from regional landslide studies, the undrained strength parameters are assumed based on local data from the Seattle region and judgment of likely slope failure modes; however, the potential range of undrained strengths can be very large, so uncertainty is inevitable in the analysis results.

### *Groundwater Conditions*

Groundwater conditions are assumed based on borings at the bottom of slope, observations of the slope face, and our judgment.

Observations of the slope face did not reveal seepage zones, so we have not included a perched water table at the modeled stratigraphic interfaces except for where the topmost advance outwash overlies the Lawton clay, as this is a typical seepage zone within local slopes and bluffs.

### *Analysis and Results*

We have assumed that likely landslide hazards are those that exit on the slope, or near the toe of the slope (consistent with existing surficial colluvium deposits). Therefore, we have performed the analysis without consideration of very deep failure surfaces that would encompass the entire hillside and valley. As shown on Figures 3 to 5, to discourage the slope stability analysis software from searching for very deep failure surfaces, we have assigned an "impenetrable / bedrock" soil model. This does not mean that bedrock exists at that depth, it is simply used to facilitate the model results.

The first analysis is shown in Figure 3, and assumes effective stress strength parameters and no seismic force. The critical failure surface is expected to occur near the top of the slope, across the intersection of the advance outwash and underlying Lawton clay deposits. Such a failure surface would result in soil slumping on the slope, but would not be catastrophic. The calculated factor of safety (ratio of the resisting forces to the driving forces along the potential failure surface) for this surface and static load conditions is about 2.3, indicating that a slope stability failure is unlikely to occur. Other, deeper failure surfaces presented by the analysis have factors of safety greater than 2.3, and so are also unlikely to occur.

We also estimated the safety factor for potential failure surfaces under seismic loading by applying forces to the slope that would only occur during a major event. We conducted pseudo-static analysis with a seismic coefficient of 0.29g. This value represents the imparted forces from an earthquake with a return period of 2, 475 years, referred to as the maximum considered earthquake. This is the most severe earthquake typically used in the design of new structures. The value of 0.29g is one-half the maximum credible peak ground acceleration. This is a catastrophic seismic event. For buildings, the code is roughly based on "collapse prevention" performance under the 2,475-year return period earthquake and "life safety" performance under 2/3 of this earthquake. Although not directly comparable, an earthquake with a magnitude of 7.5 to 9 could cause such accelerations, depending on the depth and location of the epicenter. If such an earthquake would hit the region many buildings and infrastructure would be severely damaged or could collapse.

Figure 4 presents the results assuming the same effective stress soil strength parameters that were used for the static case. Figure 5 presents the results assuming undrained strength parameters for the Lawton clay, pre-Olympia fine-grain, and recessional lacustrine deposits. The results present slip surfaces likely to exit near the middle or toe of the slope with a factor of safety of about 1.0.

Even during this extreme seismic event the factor of safety for the slope above the MICA development area on this deep potential failure surface is near 1, as shown on Figure

### *Conclusions*

Our conclusion is that this is a relatively stable, low risk slope under static conditions. Although a major earthquake would increase the risk of a slope failure, the safety factor is still above 1.0 (and thus the slope is still stable) based on our assumptions of stratigraphy and soil properties. The stability of the slope is enhanced or maintained if the slope remains vegetated and relatively undisturbed.

## Erosion

According to the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) website, soil within the property is mapped as Bellingham Silt Loam and Kitsap Silt Loam. The steepest portions of the property are sloped greater than 40 percent, but a large majority of the site is sloped between 0 and 20 percent.

The Bellingham Silt Loam has an erosion K factor (susceptibility of a soil to sheet and rill erosion by water) of 0.28. Values of K range from 0.02 to 0.69, and, the higher the value, the more susceptible the soil is to water erosion based on the mapped K factor. Therefore, Bellingham Silt Loam has an average susceptible to erosion. Kitsap Silt Loam does not have a mapped erosion K factor per the NRCS website. It should be noted, however, that the portions of the site mapped as Kitsap Silt Loam is low sloped (KpB 2-8% slope) and moderately sloped (KpD 15-30%) are estimated to be less than 10 percent of the proposed disturbed area of the site. Our opinion is that the Kitsap Silt Loam is unlikely to have substantial contributions to off-site erosion due to the small percentage that will be disturbed during construction based on the NRCS mapping and the soil types observed during our on-site explorations.

Site development is anticipated to include a Washington State Department of Ecology Construction Storm Water General Permit to mitigate the erosion potential of soils exposed during construction or site grading activities. In order to meet the criteria established by the Department of Ecology, an erosion control plan consistent with the governing municipal standards and best management practices will be required for this project. The contractor will be responsible for implementing the erosion control plan as established in the plans and specifications approved by the governing municipality for the project.

## References

Harp, Edwin L., Michael, John A., and Laprade, William T., 2006, Shallow-Landslide Hazard Map of Seattle, Washington: U.S. Geological Survey Open-File Report 2006-1139.

Troost et al., 2006. Geologic Map of Mercer Island, Washington [map]. 1:12,000. Mercer Island, 2006.

Troost et al., 2009a. Mercer Island Landslide Hazard Assessment [map]. 1:12,000. Mercer Island, 2009.

Troost et al., 2009b. Mercer Island Erosion Hazard Assessment [map]. 1:12,000. Mercer Island, 2009.

King County 2016. LiDAR data. Accessed from http://www5.kingcounty.gov/gisdataportal.

The City of Mercer Island Municipal Code. http://www.codepublishing.com/WA/MercerIsland.

## Closing

This report is for the exclusive use of Mercer Island Center for the Arts and their design consultants for specific application to this project and site. We completed this work in accordance with generally accepted geotechnical engineering practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. We make no other warranty, express or implied.

Please contact me directly if you have any questions, or if you would like additional information or review. We are available to meet with the team if needed to work through these issues on your behalf.

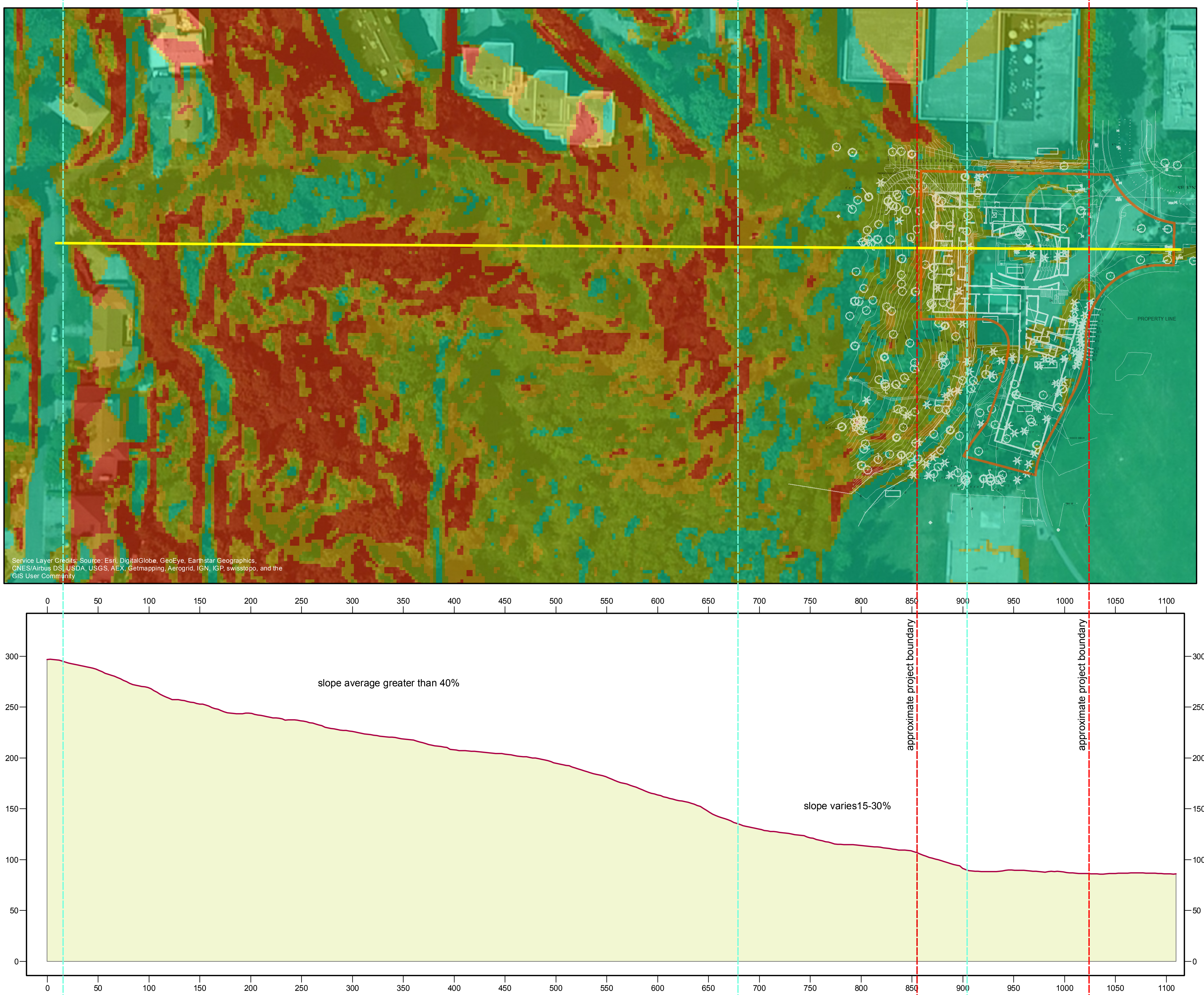
Sincerely,

**HART CROWSER, INC.**

**DAVID G. WINTER, PE, LEED AP**
Chief Executive Officer

Attached: Figures 1 – 5

L:\Notebooks\1912001_Mercer Island Center for the Arts Report Update\Deliverables\Letters\Slope Stability Review 6-19-17\MICA Slope Stability Review 6-19-17.docx




**Slope**

- 0-14%
- 15%-29%
- 30%-39%
- >40%
- profile

0 100 200 Feet

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Mercer Island Center for the Arts Geotechnical Report
Mercer Island, Washington

**Slope and Profile**

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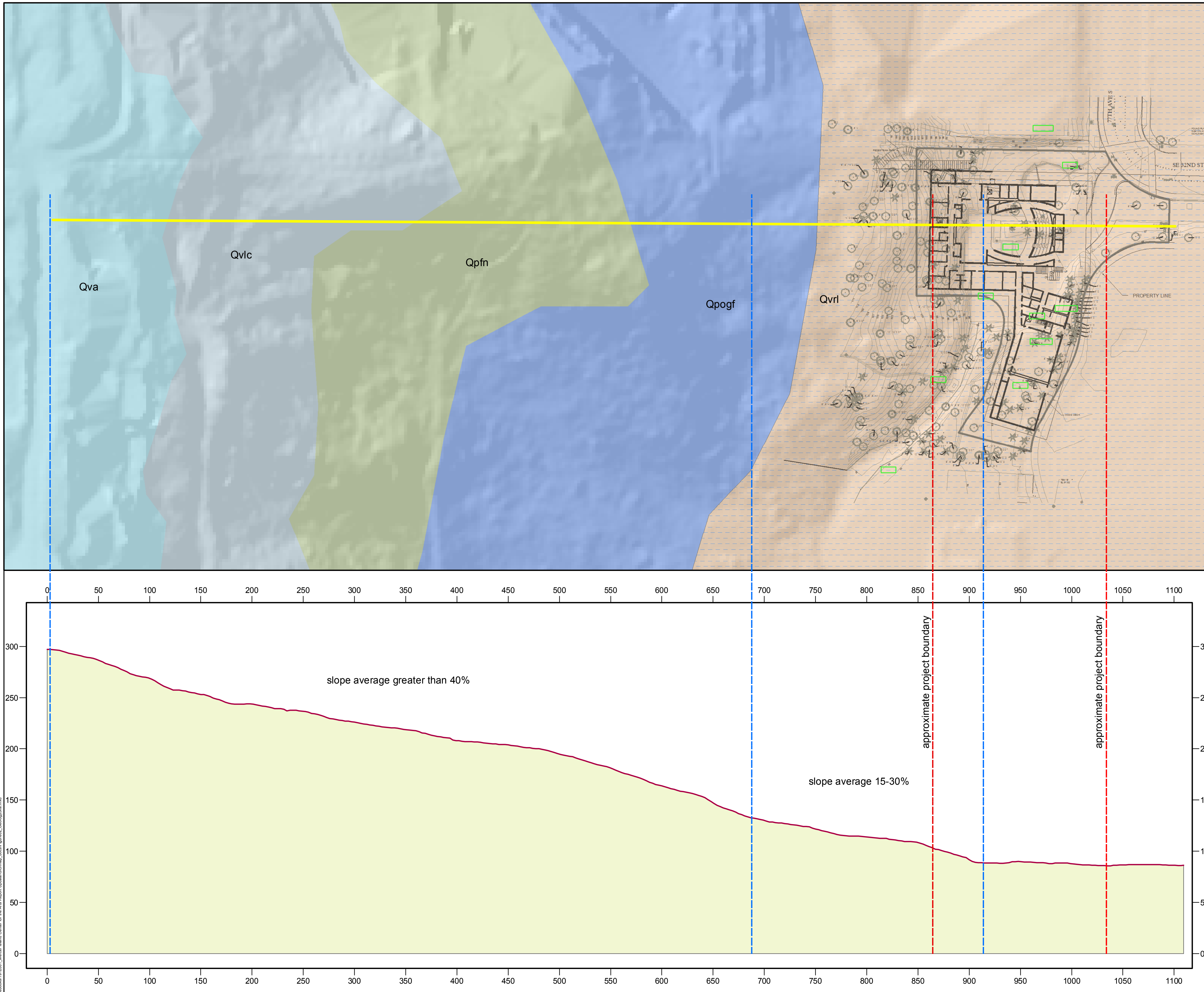
Figure
**1**




**Geologic Units**

- Qpfn - Pre-Fraser age nonglacial deposits
- Qpogf - Olympia glaciation age fine-grained glacial deposits
- Qva - Vashon glaciation age advanced outwash deposits
- Qvlc - Vashon glaciation age Lawton clay deposits
- Qvrl - Vashon glaciation age recessional lacustrine deposits
- profiles

0 100 200 Feet

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Mercer Island Center for the Arts Geotechnical Report
Mercer Island, Washington

**Surface Geology**

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Figure **2**

MWV 06/18/2017

Name: Qls, Landslide and Fill Deposits Model: Mohr-Coulomb Unit Weight: 120 Cohesion': 400 Phi': 32 Piezometric Line: 3
Name: Qva, Vashon Advance Outwash Model: Mohr-Coulomb Unit Weight: 120 Cohesion': 200 Phi': 38 Piezometric Line: 1
Name: Qvlc, Vashon Lawton Clay Model: Mohr-Coulomb Unit Weight: 115 Cohesion': 300 Phi': 26
Name: Qpfn, Pre-Fraser Non-glacial Model: Mohr-Coulomb Unit Weight: 125 Cohesion': 400 Phi': 36
Name: Qpogf, Pre-olympia Fine-grain Model: Mohr-Coulomb Unit Weight: 120 Cohesion': 600 Phi': 26
Name: Qvrl, Vashon Recessional Lacustrine Model: Mohr-Coulomb Unit Weight: 115 Cohesion': 400 Phi': 24 Piezometric Line: 2
Name: Impenetrable Model: Bedrock (Impenetrable)

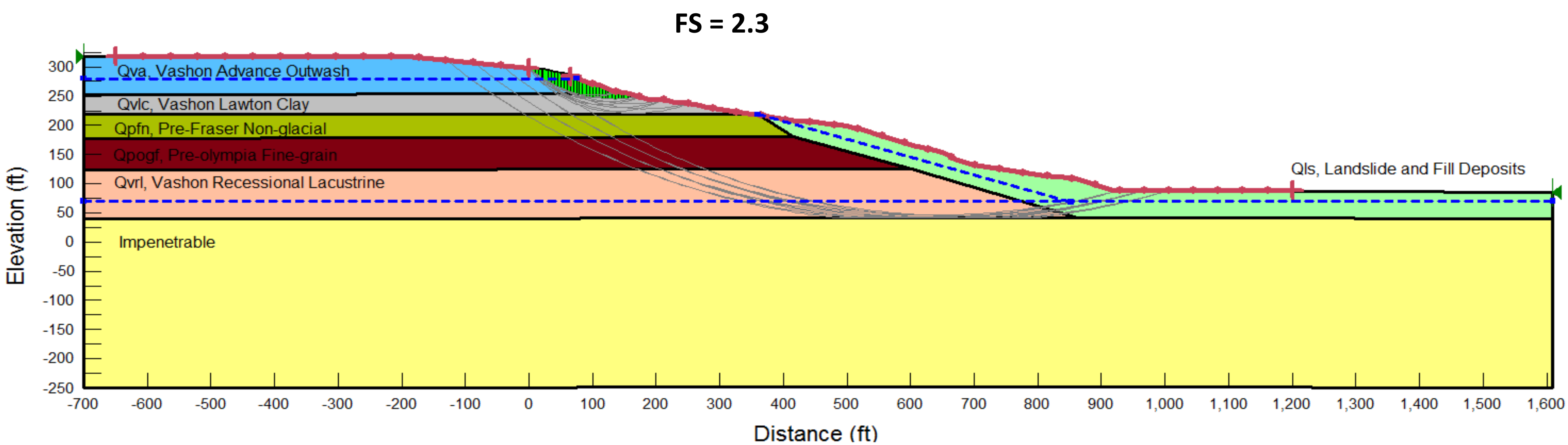


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Figure 3

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**Limit Equilibrirum Slope Stability Analysis**
**Results: Static, Effective Stress Strength**

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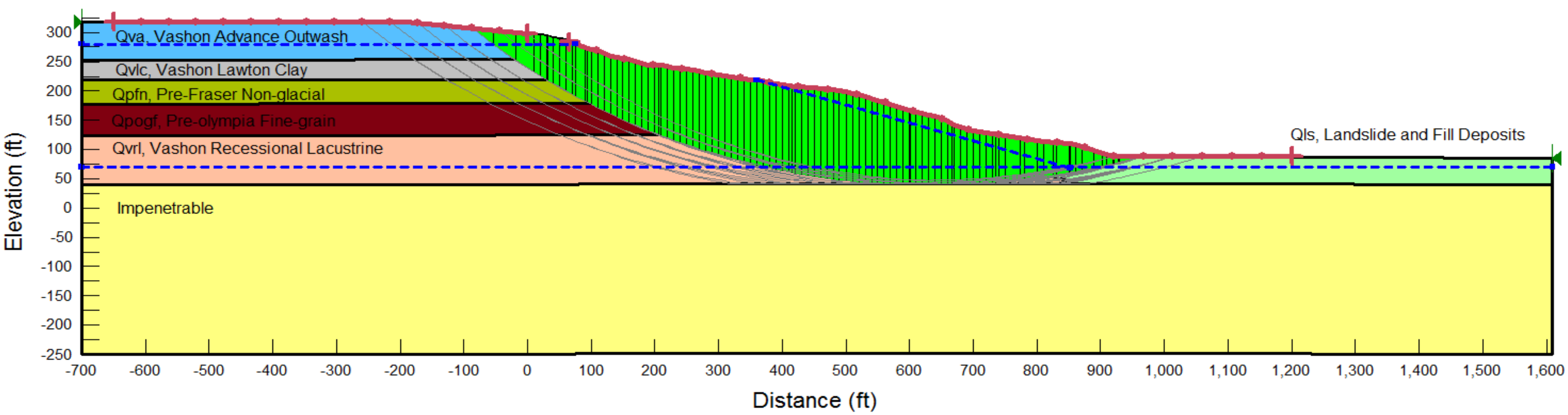
MWV 06/18/2017

Name: Qls, Landslide and Fill Deposits  Model: Mohr-Coulomb  Unit Weight: 120  Cohesion': 400  Phi': 32  Piezometric Line: 3
Name: Qva, Vashon Advance Outwash  Model: Mohr-Coulomb  Unit Weight: 120  Cohesion': 200  Phi': 38  Piezometric Line: 1
Name: Qvlc, Vashon Lawton Clay  Model: Mohr-Coulomb  Unit Weight: 115  Cohesion': 300  Phi': 26
Name: Qpfn, Pre-Fraser Non-glacial  Model: Mohr-Coulomb  Unit Weight: 125  Cohesion': 400  Phi': 36
Name: Qpogf, Pre-olympia Fine-grain  Model: Mohr-Coulomb  Unit Weight: 120  Cohesion': 600  Phi': 26
Name: Qvrl, Vashon Recessional Lacustrine  Model: Mohr-Coulomb  Unit Weight: 115  Cohesion': 400  Phi': 24  Piezometric Line: 2
Name: Impenetrable  Model: Bedrock (Impenetrable)  Piezometric Line: 1

**FS = 1.0**

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06/18/17

**Limit Equilibrirum Slope Stability Analysis**
**Results: Seismic, Effective Stress Strength**

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Seattle, WA

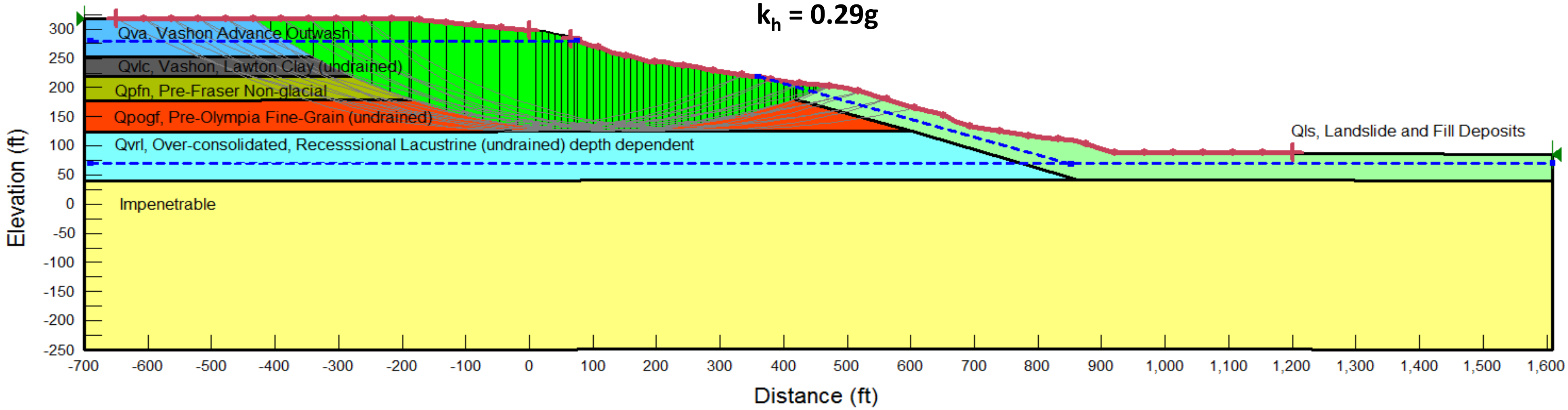
Figure

**4**

MWV 06/18/2017

Name: Qls, Landslide and Fill Deposits Model: Mohr-Coulomb Unit Weight: 120 Cohesion': 400 Phi': 32 Piezometric Line: 3
Name: Qva, Vashon Advance Outwash Model: Mohr-Coulomb Unit Weight: 120 Cohesion': 200 Phi': 38 Piezometric Line: 1
Name: Qpfn, Pre-Fraser Non-glacial Model: Mohr-Coulomb Unit Weight: 125 Cohesion': 400 Phi': 36
Name: Qvlc, Vashon, Lawton Clay (undrained) Model: Undrained (Phi=0) Unit Weight: 115 Cohesion': 5,000
Name: Qpogf, Pre-Olympia Fine-Grain (undrained) Model: Undrained (Phi=0) Unit Weight: 120 Cohesion': 5,000
Name: Qvrl, Over-consolidated, Recesssional Lacustrine (undrained) depth dependent Model: S=f(overburden) Unit Weight: 115 Tau/Sigma Ratio: 0.6 Minimum Strength: 400 Piezometric Line: 2
Name: Impenetrable Model: Bedrock (Impenetrable) Piezometric Line: 1

**FS = 1.0**
**$k_h$ = 0.29g**

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**Limit Equilibrirum Slope Stability Analysis**
**Results: Seismic, Undrained Strength**

19120-01 06/18/17

Figure
**3**