PREPARED BY SNOHOMISH COUNTY
DEPARTMENT OF PUBLIC WORKS

GEOLOGIC INVESTIGATION
AND
GEOTECHNICAL ENGINEERING REPORT

Little Bear Creek Advance Mitigation Site

RC1730-115-37

SNOHOMISH COUNTY
DIRECTOR OF PUBLIC WORKS
STEVEN E. THOMSEN, P.E.

SUMMARY OF GEOTECHNICAL CONDITIONS

This is a summary of the geologic conditions and geotechnical recommendations for the construction of the Little Bear Creek Advance Mitigation Site located on the southwest corner of 58th Ave SE and 238th St SE in south central unincorporated Snohomish County, Washington. This summary should only be utilized in conjunction with and an understanding of the full *Geotechnical Report*.

Prior to its purchase by the County in 2017, the site had a long history of rural residential and agricultural use that involved channelization of run-off, streams and drainages; local draining of wetlands through the excavation of ditches; placement of fill within some of the wetlands; construction of interior access drives and outbuildings, fencing; and the grazing of cattle and other livestock. The practices altered the hydrology of the wetlands, reduced the quality and complexity of aquatic and terrestrial habitats, affected in-stream conditions, and contributed to water quality problems in the immediate are of the Little Bear Creek watershed. The County intends to restore the site and improve the functions and values of the wetlands and streams in a way that generates mitigation credits that can be used to offset unavoidable impacts from future County road projects within the Little Bear Creek drainage subbasin.

To support the design, permitting and construction of this project as proposed, a geologic investigation was performed by an Engineering Geologist from the **Snohomish County Public Works Geotechnical Group**. This investigation included: a review of readily available technical maps, geologic maps, seismic maps, Lidar maps and soil maps relevant to the project site; a review of readily available hydrogeological, geologic and/or geotechnical reports relevant to the project site and project area; a geologic and hydrogeologic reconnaissance of the project and surrounding area; a geologic investigation of the project site including the excavation of 29 test pits to delineate fill depths and fill types, the drilling of four-(*4*) test borings and the installation of observation wells at each test boring location to monitor ground water elevations, and the preparation of this report summarizing the process and necessary recommendations to successfully complete this project as proposed.

Test Boring and Test Pit Logs were developed based on observed soil conditions and an interpretation by the Engineering Geologist of the soils encountered at the sampled intervals. Depths shown on the site exploration logs are from the ground surface at each location. Soil conditions varied with depth but were mostly consistent with the mapped geology of the area as shown on the published **USGS** *Geologic Maps*. Some variations in soil types, densities, unit thicknesses and moisture content from that shown on the **Test Boring and Test Pit Logs** should be expected at the time of construction. The projects **Test Boring and Test Pit Logs** are presented here-in in good faith and are meant to be utilized as a general guidance for soil types, depths and thicknesses that may be encountered during construction of the proposed project.

Review of **Lidar Maps** covering the project site indicate a high probability of moderate to large scale soil movement and slides along the western slopes sometime in the last 10,000 years (*since the retreat of Vashon aged glaciers out of the area*). Colluvium (*soils moved and/or disturbed by slides*) may cover a significant area of southwestern portion of the site. Delineation of colluvium was not attempted during the site investigations. There were no indications of recent movements or instabilities along or immediately adjacent to the western slope noted or observed during the site reconnaissance's. There were some indications of soil creep or movement along the probably soil colluvium slopes within the project site. There are no mapped landslides shown on the **Geologic Map** in the immediate vicinity of the project site. However, determination of the existing overall stability of the western slopes and the colluvium slopes on site was outside of the current scope of services for this project at this time.

Review of the **South Whidbey Island Fault Zone (*SWIFZ*) Maps** covering the project area indicates a mapped splay crossing the project site in the immediate vicinity of the slide scarps shown on the **Lidar Maps**. In many areas of the County the locations of the **SWIFZ** splays have been delineated based on surficial topographic features such as those seen on the projects **Lidar Maps**. Movement along the splay could account for the surficial topographic features along the western slope noted on the **Lidar Maps**. The actual presence of the splay has not been verified by any other site data.

A high ground water table was observed within the area of the project limits. This ground water table may fluctuate seasonally, but it should be anticipated that ground water will be encountered somewhere between one and one-half (*1-1/2*) and six-(*6*) feet of the ground surface within the

project limits. This high ground water table will support a robust wetland habitat on this project site. Ground water conditions are described in detail in the projects **Hydrogeologic Report**.

Outwatering in the form of several ground water springs, both intermittent and constant, was noted in several locations along the base of the western slope. The majority of the water from these spring areas has been caught and channeled through man made ditches. It is the intent of this project to re-establish the natural sheetflow of this water across the ground surface in as many areas as possible in such a manner so as not to impact the existing western slope stability while supporting a renewed robust wetland habitat. Outwatering is concentrated in three-(3) locations along the western slope – southern, central and northern. Currently some of the water from the southern spring sheet flows across the slope and follows naturally established drainage pathways. This will not be disturbed. We believe that it is possible to disperse the captured portion water from the southern spring along the lower parts of the site slopes without any potential impacts to the adjacent western slope stability. The man made ditch that currently carries a small portion of this water should be filled in and graded to match existing adjacent topography. Year round water has been observed flowing out of the central spring area. Due to the proximity of this spring area and its drainage way to the adjacent steep slope, we recommend that this drainage way be maintained and improved as necessary to meet the project goals. Spring water for the northern outwatering area is collected and directed into a ditch that runs along the western side of the access road. Once this access road and its related fill has been removed, it is possible to allow the spring water in this area to re-establish its own natural sheet flow and flow pathways across the ground surface, supporting the wetland areas, without impacting the stability of the adjacent western slope.

Existing site improvements and related uncontrolled fill will be removed from the site after which the wetland habitat will be re-established. The construction recommendations contained in this report are given for dry weather construction. Control of surface water run-off and drainage ways to limit siltation and erosional impacts to Little Bear Creek will require careful and prudent construction methods. It is the contractor's responsibility utilize those careful and prudent construction methods to limit siltation and erosion within the construction limits and to provide safe working conditions at the project site and ensure that working areas are dewatered as necessary based on the encountered ground water and surface run-off volumes at the time of construction.

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APPENDICES

1.0 INTRODUCTION

This report contains the results of our geologic site investigation and geotechnical engineering recommendations for the design and construction of an approximate 17 acre wetland mitigation site in the Little Bear Creek drainage subbasin. The project site is located within unincorporated Snohomish County at the southwest corner of the intersection of 58th Ave SE and 238th St SE. A **Vicinity Map** showing the location of the project site relative to existing municipal improvements is contained in *Appendix A* of this report. Prior to its purchase by the County in 2017, the site had a long history of rural residential and agricultural use that involved channelization of run-off, streams and drainages; local draining of wetlands through the excavation of ditches; placement of fill within some of the wetlands; construction of interior access roads and outbuildings, fencing; and the grazing of cattle and other livestock. The practices altered the hydrology of the wetlands, reduced the quality and complexity of aquatic and terrestrial habitats, affected in-stream conditions, and contributed to water quality problems in the immediate area of the Little Bear Creek watershed. The County intends to restore the site and improve the functions and values of the wetlands and streams in a way that generates mitigation credits that can be used to offset unavoidable impacts from future County road projects within the Little Bear Creek drainage subbasin.

The purpose of this investigation was to review and evaluate existing soil and geological information in the project area, and based on this information provide geologic and geotechnical recommendations to be utilized during the design, permitting and construction phases of the project. There were no new subsurface field investigations performed for this report. Work performed during this investigation and for the preparation of this report has included: a review of readily available hydrogeological, geologic and seismic maps and/or reports relevant to the project site; the review and interpretation of aerial photos, lidar maps, office memorandums, consultant reports and soil information in our office files; a review of the project Geologic Conditions and Fill Assessment Report; a review of the project Hydrogeologic Report; a review of the project 60% plan set prepared by **ESA**; a geologic and hydrogeologic reconnaissance of the project site and surrounding area; and the preparation of this report summarizing the process and geotechnical engineering recommendations necessary to complete the project as proposed and outlined by the 60% plan set referenced above. This report has been completed in general

accordance with professional geologic and geotechnical standards currently utilized in the Puget Sound region for a project of this size and scope. The conclusions and recommendations contained in this report are based on our understanding of the project and its' geologic and geotechnical requirements at the time of writing.

2.0 PROJECT DESCRIPTION

The County intends to restore the project site and improve the functions and values of the wetlands and streams on the site in a way that generates mitigation credits that can be used to offset unavoidable impacts from future County road projects within the drainage subbasins. The proposed mitigation actions include:

- Remove invasive vegetation throughout the site
- Remove structures, conduit, culverts, piping and internal fencing
- Excavate fill and re-grade selected locations to appropriate elevations for wetland rehabilitation or creation
- Enhance site hydrology by filling drainage channels created by the prior land owner
- Create complex micro topography to encourage habitat diversity and retain water on the site
- Retain and/or install habitat features such as brush piles, nurse logs, stumps and standing snags
- Plant a diverse assemblage of native plants to establish forested and scrub-shrub wetland communities
- Reconnect Little Bear Creek with its floodplain
- Enhance in-stream habitat through placement of large wood, creation of a flood bench, and enhancement of the riparian corridor
- Enhance buffers and upland areas by removing invasive vegetation and planting native species
- Retain and enhance perimeter fencing to restrict unauthorized access

Project designs are at the 60% plan design stage. Based on our understanding of the project as proposed, the major geologic, hydrogeologic and/or geotechnical concerns include:

1. General geology of the project site and surrounding area
2. Hydrogeologic conditions of the project site and surrounding area
3. Stability of the adjacent slopes
4. Characteristics and quantity of existing fill
5. Grading
6. Seasonal working conditions, erosion and best management practices

These items are discussed in more detail below and were considered while developing the recommendations contained in *section 4.0* of this report.

3.0 DATA COMPILATION AND REVIEW

3.1 Site Description

The project site is located on the southwest corner of 238th St SE and 58th Ave SE, just north of the City of Woodinville, in the southwestern portion of unincorporated Snohomish County, Wa. The site currently acts as a transitional boundary between commercial and heavy industrial zoned property to the east and residential development to the west, south and north. Current zoning is Rural 5 (*R5*) acres or 910 undeveloped property. A **Vicinity Map** showing the location of the project site relative to existing municipal improvements is included in *Appendix A* of this report.

The property is comprised of four-(*4*) parcels with a combined total acreage of approximately 17 acres according to the property title reports. The site consists of a fairly high upland area along the north and western property boundaries that slopes moderately to steeply downward in a southern and eastern direction to a somewhat flat, gently sloping central portion of the property that boarders the floodway fringe of Little Bear Creek. Little Bear Creek bisects the southeastern portion of the site. A **Site Map** with aerial photo overlay showing existing improvements, drainage ways and access roads is included in *Appendix B* of this report. Topography, which slopes from the south to southeast, ranges from approximately el. 190 along the north and western sides of the property down to approximately el. 110 in the immediate vicinity of Little Bear Creek. For reference purposes a **Topographic Map** is included in *Appendix C* of this report.

Existing improvements to the property include a mobile home with associated outbuildings located on the northern, upland (*high*) portion of the site. Access to the mobile home is off of 238th St SE and has a given address of 5714 – 238th St SE. Dropping down a fairly steep slope along an access road from the mobile home, a small pump house and water well (***DOE** Unique Well #ALJ-148, unregistered*) are located at the base of the slope (***Site Map**, Appendix B*). Following the access road to the south, several farm related outbuildings are located in a meadow along the base of an eastern facing tree and heavy brush covered slope. The meadow area has been cleared and fenced. The farm related outbuildings include two-(*2*) rectangular metal buildings, several wooden coop

like structures and a newer partially sided barn. Several small drainages capture ground water discharging onto the property through springs located along the base of the western slope. The main drainages include: the northern drainage (*referenced as stream 5 on plan sheet G04*) captures ground water discharging out of the western slope in the immediate vicinity of the water well/pump house. The northern drainage area is channeled into a manmade ditch (*stream 5*) located along the western side of the access road, crosses below the access road through a pipe and then thru the adjacent wetland/pasture area where it joins with steam 4, eventually flowing into Little Bear Creek. The central stream (*referenced as stream 1 on plan sheet G04*) flows downslope in a southeasterly direction year round and discharges significant amounts of water through man made ditches into Little Bear Creek. The southern drainage (*referenced as stream 3 on plan sheet G04*) captures a portion of the ground water that is discharging out of the slope above the pasture/meadow area west of the farm related outbuildings. Steam 3 flows downslope in an easterly direction intermittently through a manmade ditch system along the southwestern corner of the project site where it also eventually flows down into Little Bear Creek. A final drainage ditch (*referenced as stream 4 on plan sheet G04*) picks up run-off coming onto the property from 58th Ave SE. This run-off is captured and drains through a manmade ditch across the wetlands/pasture area along the eastern side of the site, where it is joined by the north drainage discharge (*stream 5*). The combined drainages flow in a southerly direction and discharge into Little Bear Creek. The man made drainages described above have not been maintained for many years.

3.2 Geologic Setting

The project site is located within the Puget Sound Lowland Physiographic Province (*Puget Lowland*). The Puget Lowland is a north-south trending structural and topographic depression. Most of Snohomish County is located within the Puget Lowland, including all areas west of the Cascade Mountain foothills to the Puget Sound and the river basins/river valleys that extend up into the foothills. In general, the Puget Lowland is bounded by the Olympic Mountains to the west and the Cascade Mountains to the east. Less pronounced uplands define the southern boundary, and to the north it extends into southern British Columbia to merge with the Fraser Lowland and the Strait of Georgia. The Puget Lowland is underlain by Tertiary aged volcanic and sedimentary

bedrock and has been filled to the present day land surface with Pleistocene aged glacial and non-glacial sediments.

The low undulating plains that are characteristic of the Puget Lowland are the result of repeated advances (*stades*) and retreats (*interstades*) of the Puget Lobe of the cordilleran (*continental*) ice sheets that flowed into and out of this area from the north during the Pleistocene Epoch (*a geologic time period dating from approximately 1 million years ago to the present*). Within the river valleys that extend into the foothills, these repeated cordilleran ice sheet advances and retreats were supplemented by localized alpine glacier advances and retreats resulting in a more complex and longer lasting ice contact depositional history. Current land surfaces in the vicinity of the project site reflect surficial topographic changes directly related to the most recent glacial advance and retreat through Snohomish County – the Vashon Stade of the Fraser Glaciation. The Vashon Stade of the Fraser Glaciation covered the low lying areas of Snohomish County with thousands of feet of glacial ice between 20,000 and 13,000 years ago and achieved a maximum thickness in the vicinity of the project site between 18,000 to 16,000 years ago. The geologically mapped units of Vashon Advance Outwash (*Qva*), Vashon Glacial Till (*Qvt*), and Vashon Recessional Outwash (*Qvr*) were all deposited in this area as a result of the latest glacial advance and retreat during this time period. Since the last retreat of glacial ice out of the Snohomish County area approximately 13,000 years ago, existing topography in the area of the project site has been altered through erosional processes related to weathering. In the vicinity of the project site, processes related to weathering have deposited Younger Alluvium or Recent Alluvium (*Qal, Qyal*) in and along local drainages, creeks and in topographic low areas around the project site.

Surficial geology of the project area has been mapped by the **USGS** and is shown on the "Geologic Map of the Bothell 7.5-minute Quadrangle, King and Snohomish Counties, Wa." by J.P. Minard dated 1985, MF-1747. *Mapped* surficial geology of the site consists of Vashon Advanced Outwash (*Qva*) located along most of the western and northern slopes and Vashon Recessional Outwash (*Qvr*) through the central area. Recent Alluvium (*Qyal*) is found within the floodway fringe and along Little Bear Creek through the lower (*southeastern 1/4*) portion of the site. For reference purposes, a copy of a portion of the **Geologic Map** that includes the project site and surrounding area has been included in *Appendix D* of this report.

The primary mapped **NRCS** soils classifications varied on the site. Based on the **NRCS** maps of Snohomish County (*WA661*), soils on the project site consists of: Alderwood Gravelly Sandy Loam (*unit 2*) on the majority of the site; Everett Very Gravelly Sandy Loam (*unit 17*) on the central and southern part of the site; and Norma Loam (*unit 39*) along the southern side of Little Bear Creek.

3.3 Site Geology

A significant area of the site has been disturbed and filled for site improvements and farming activities over the last several decades. These disturbed areas were investigated to determine fill depth, fill composition and ground water seepage depths through the excavation of 29 test pits (*TP-01, TP-02, TP-04 thru TP-20, TP-23 thru TP-27, TP-42 thru TP-44, TP-47 and TP-48*). Further subsurface soil types and existing ground water elevations around the site were investigated through the drilling of four-(*4*) test borings and the installation of observation wells in each test boring upon completion (*PW-01 thru PW-04*). The test pits were excavated with a rubber tracked minihoe to depths between five-(*5*) and seven-(*7*) feet below ground surface (*bgs*). The borings were all advanced with a track mounted CME 850 drill rig to a depth of 20.5 feet below the ground surface (*bgs*). Ground water observation wells were placed within each test boring upon completion. Soils removed at each exploration location were visually observed upon removal from the ground and classified by a Geologist from *SCPW-Engineering Services* following the **Unified Soil Classification System** (*U.S.C.S*) in general accordance with **ASTM D2488**, Standard Recommended Practice for the Description of Soil *(Visual-Manual Procedures)*. Test pit and test boring locations are shown on the **Site Map** included in *Appendix B* of this report. **Test Pit and Test Boring Logs** are contained in *Appendix E* of this report. For reference purposes, a copy of the **Unified Soil Classification System** is contained in *Appendix F* of this report.

Site stratigraphy has been interpreted from the test pit and test boring logs and correlated with the mapped geology of the area as described on the **Geologic Map** in *Appendix D*. In general, a moderate correlation was observed between the mapped geology and the soil types found in the test pits and test borings locations on this site. Shallow surficial soil types encountered at the exploration locations included uncontrolled fill, gravelly sand, silty sand, sand, silts and peat. These soils have been interpreted as uncontrolled fill (*fill*), Recent or Younger Alluvium (*Qyal, Qal, Qa*), Recessional Outwash (*Qvr*), and Advance Outwash (*Qva*). Ground water was

encountered at the exploration locations approximately two-(*2*) to over six-(*6*) feet below the existing ground surface (*bgs*). Detailed soil descriptions and interpretations are included on the projects Geologic Conditions and Fill Assessment Report dated October 2018.

The purpose of the site explorations was to identify and quantify fill placement around the site through the excavation of shallow test pits with a rubber tracked minihoe. Test pit excavations took place March 5th thru March 9th, 2018. In addition, hydrogeologic conditions at the site were investigated through the drilling of four-(*4*) test borings and the installation of observation wells (*PW-01, PW-02, PW-03 and PW-04*) at each of the test boring locations on April 23rd thru 24th, 2018. These observations wells were developed in the following months and ground water elevations are being measured at each location on a monthly basis. Hydrogeologic conditions throughout the site are discussed in detail in the projects Hydrogeologic Report dated October 2018. Geotechnical recommendations discussed in this report were developed based on these site investigations and the work outlined on the projects 60% design plan set.

Fill locations around the property were initially delineated by the Snohomish County Public Work's *TES Division – Environmental Section*. A total of 48 test pit locations were proposed and staked by the *Geotech Group* based on the initial *TES Division – Environmental Section* delineations. These test pits were all located within proposed fill areas and took into consideration existing wetland flagging and equipment access needs. On-site test pit numbering and staking was based on this initial coverage assessment. Of the initial recommended 48 test pits, 19 were eliminated at the time of the field exploration by the *TES Division – Environmental Section*, primarily due to access (*wetland disturbance*) concerns. These test pits were all located within the southern half of the site, significantly reducing the test pit coverage of the mapped fill locations in that area of the site. One-(*1*) test pit location was eliminated in the northern half of the site (*TP-03*) due to underground utility conflict concerns.

The **Geologic Map** (*Appendix D*) indicates that the soil units present at the site were deposited during and/or following the last (*Vashon aged*) glacial advance. Geologic units at the project site, from youngest to oldest, includes: Holocene Recent or Younger Alluvium (*Qyal, Qal, Qa*), Vashon Recessional Outwash (*Qvr*), and Vashon Advanced Outwash (*Qva*). Uncontrolled fill

(fill) is specific to this site and is not shown on the **Geologic Map** (*Appendix D*). Generalized soil descriptions for each geologic unit found on this site are as follows:

- *Uncontrolled Fill (fill)*: specific to this site, consisting primarily of silty sand to gravelly sand with varying amounts of cobbles, silt, organics and deleterious materials. Some of the fill appears to be imported from off-site sources and some of the fill appears to be re-worked from other locations on-site. (*Not shown on the Geologic Map*).

- *Recent or Younger Alluvium (Qyal, Qal, Qa):* This unit lies in and along present streams near the water table, and is subject to seasonal flooding. This unit consists of loose, stratified clay, silt, and sand with varying amounts of organics. Brown to dark brown layers of organic silt and/or peat was found in all 29 test pits excavated as part of this site investigation. In most test pit locations sand and gravel was found underlying the surficial fill and fine-grained sediments.

- *Recessional Outwash (Qvr):* The recessional outwash typically consists of loose to medium dense, clean to silty sand. On this site, the Recessional Outwash (*Qvr*) is interlayered with thin clay and silt layers which grades downward to an underlying thicker lacustrine (*blue gray clay*) layer. Where thick enough, the recessional outwash (*Qvr*) sand deposits may form a local unconfined aquifer that is perched on top of the underlying lacustrine clays.

- *Advance Outwash (Qva):* These deposits are mostly clean, gray, stratified, pebbly sand with increasing amounts of gravel higher in the section. Fine-grained sands and silts are common in the lower part of the Advance Outwash (*Qva*) unit. Advance Outwash (*Qva*) sands were deposited by melt water flowing out of the front of the advancing Vashon aged glacier. As such, it can be locally silty and often oxidized where exposed to ground water fluctuations.

Soils encountered at the test pit locations correlated moderately well with the mapped geology of the area as shown on the attached **Geologic Map** (*Appendix D*) - with small differences in the contact location between the Recent Alluvium (*Qyal, Qal, Qa*), Recessional Outwash (*Qvr*) and Advance Outwash (*Qva*) through the middle to southern end of the site. Uncontrolled fill (*fill*) is not shown on the **Geologic Map** (*Appendix D*). The locations of the uncontrolled fill (*fill*) on the project site are shown on the **Fill Map** contained in *Appendix G* of this report. Interpretation of the encountered natural soils on this site indicates that the geology specific to LBCAMS is typical of flood plain environments along creeks in southern Snohomish County and indicates current and past flood plain elevations of historic Little Bear Creek.

Not investigated or delineated as part of this investigation was the possibility that some of the soils identified as "uncontrolled fill" in the vicinity of the barn/farm related structures, are instead colluvium that was deposited as the result of landslides off of the adjacent steep slopes located along the west side of the property. A review of Lidar imagery of the slopes above the farm related site structures shows possible slide scarp semi-circular shapes along with hummocky topography at the base – indicating possible moderate to large soil movements in this area. These slides would have occurred within the last approximate 10,000 years, after the Vashon aged glaciers receded out of this area. Further discussion concerning these features are contained in *section 3.6*, **Geologic Hazards**, below.

No environmental concerns were detected in any of the test pit or test boring locations during this site investigation. The 60% design plan set for the project was developed utilizing information on the **Test Pit Logs** and **Test Boring Logs** (*Appendix E*) and the **Fill Map** (*Appendix G*).

3.4 Ground Water

Regional ground water studies have been undertaken for **Snohomish County** by **Economic and Engineering Services, Inc./Sweet-Edwards/EMCON, Inc**. dated 1991; **Golder Associates** dated 1996 and the **USGS** dated 1997. Hydrogeologic units within the County have been identified and defined by these studies. In general, ground water throughout the County occurs in a few different aquifers that are in most areas separated from each other by confining beds. Depending upon topography and location, ground water occurs in both confined and unconfined conditions within the County's aquifers. The most extensive aquifers are found below the plateau areas of the County. Aquifers may also be found below the larger river systems within the County such as along the Stillaguamish River in north County and the Skykomish/Snohomish River that flows through the central portion of the County. According to these studies, the most productive aquifer throughout the County is the Advance Outwash (*Qva*) aquifer found below the plateau areas around the County, such as the Intercity Plateau upon which the project site is situated. The Intercity Plateau is a topographic upland area that extends from Everett southward to Lake Washington and is bounded on the east by the Snohomish and Snoqualmie Rivers and on the west by the Puget Sound.

Two-(*2*) sole source aquifers have been designated in the County by the **EPA**. Sole source aquifers are designated by the **EPA** in areas where the ground water resource is the only reliable water source for public consumption. One-(*1*) of these aquifers, the Cross Valley Sole Source Aquifer, is located on the Intercity Plateau just north and east of the project site.

According to the above referenced studies, unconsolidated geologic units permeable enough to transmit significant quantities of ground water (*aquifers*) throughout the County are Recent Alluvium or Younger Alluvium (*Qyal, Qal, Qa)*, Recessional Outwash (*Qvr*), Advance Outwash (*Qva*) and Olympia Gravels (*Qog*).

Confining beds are geologic units that are generally fine-grained and do not transmit significant quantities of water. According to the 1997 **USGS** report, confining beds or aquitards found throughout the County include Glacial Till (*Qvt*), Transitional Beds (*Qtb*), Older Till (*Qtu*), and portions of the Olympia Gravel (*Qog)*, Possession Drift (*Qpd*) and Tertiary Bedrock (*Tb*).

As shown on the **Geologic Map** (*Appendix D*), some of the geologic units described above are found in the immediate vicinity of and/or on the project site.

Ground water was encountered at all but a couple of the exploration locations on the project site between approximately two-(*2*) to six-(*6*) feet below the ground surface. Ground water was also observed outwatering from the base of the slopes along the western side of the project site in several locations. This ground water discharge supports the wetland habitats along the higher elevation areas of the project site. Ground water was found in an unconfined condition and is topographically controlled - sheet flowing across the site, discharging to manmade drainage ditches, into wetlands or directly into Little Bear Creek. The ground water gradient of the underlying aquifer in the vicinity of the project site is controlled by the gradient of Little Bear Creek. However, based on the observation well data, the site specific ground water gradient is to the south-southeast. Detailed discussions on the project sites hydrogeologic conditions may be found in the Hydrogeologic Report.

3.5 Public Water Supply, Private Wells, Critical Aquifer Recharge Areas, Wellhead Protection Areas, Sole Source Aquifer Areas

Public water in the immediate vicinity of the project site is supplied by the Alderwood Water and Wastewater District. A search of **DOE's** data base resulted in one-(*1*) registered water well within a one-(*1*) mile radius of the project site. The status of this well, located up-gradient of the project site within an industrial area, is unknown. However, we believe that it is possible that this well was decommissioned in 2001. The project site is located within a critical aquifer recharge area of moderate sensitivity according to the Snohomish County "Critical Aquifer Recharge Area Map" dated Feb. 2016. The project site is not located within a Wellhead Protection Area or Sole Source Aquifer Area. Please refer to the project Hydrogeologic Report for more specific details concerning these issues.

3.6 Geologic Hazards

Volcanic Hazard Area: The project site is not located within 200 feet of a mapped Volcanic Hazard Area.

Tsunami Hazards Zone: The project site is not located within 200 feet of a mapped Tsunami Hazard Zone.

Mine Hazards Area: The project site is not located within 200 feet of a historic mapped or known mine or mine hazard area.

Channel Migration Zone (CMZ): The project site is not located within 200 feet of a mapped Channel Migration Zone.

Flood Hazard Zone: Portions of the project site are located within the flood plain for Little Bear Creek. We understand flooding of the portion of the site immediately adjacent to Little Bear Creek occurs on an occasional basis.

Erosion Hazard Area: The project site is located within a mapped surficial soil erosion hazard area. This designation is based upon geologic depositional processes and mapped soil types and not on any existing site conditions. For reference purposes an **Erosion Hazard Area Map** covering the vicinity of the project site is included in *Appendix H* of this report.

Landslide Hazard Area: Based on the County's **Landslide Hazard Areas Map** included in *Appendix I* of this report, the slopes along the western side of the site are shown as a potential landslide hazard area – or slopes that are steeper than 33%. Although the soils that make up this slope have not been investigated, the slopes have been mapped as Glacial Till (*Qvt*) over Advance Outwash (*Qva*) on the **Geologic Map** (*Appendix D*). Lidar imagery of the slopes along the western side of the site shows semi-circular shaped features with sloping hummocky topography at the

base. These features may indicate historic slope movements along portions of the higher over-steepened western slopes immediately adjacent too and on portions of the project site. The Lidar imagery also shows signs of possible on-going soil creep along the lower sloping hummocky topography above the barn and outbuildings. For reference purposes a **Lidar Map** covering the project site is also included in *Appendix I* of this report.

Fault Hazards: It is probable that the site will experience the effects of a design level earthquake (*m >7.0*) during its design life. The Puget Lowland is located in a seismically active region where the effects of large-magnitude subduction zone earthquakes have been felt and a history of other seismicity has been recorded. In the last 20 years, several different fault systems have been identified that are the result of tectonic activity that has taken place between the late Pleistocene (*< 1 million years*) and recent time (*Holocene, < 12,000*). On-going investigations by the **USGS** and others have postulated late Pleistocene to Holocene movements on the **Olympic Fault** (*Thurston County*), the **Tacoma Fault** (*Pierce County*) and the **Seattle Fault** (*King County*). Across Snohomish County major tectonic activity resulted in the **Darrington-Devils Mountain Fault Zone** (*DDMFZ, 20 miles north*) and the **Straight Creek Fault Zone** (*SCFZ, 30 miles northeast*), the **Strawberry Point Fault** (*20 to 25 miles northwest*), the **Utsalady Point Fault** (*UPF, approximately 20 to 25 miles northwest*), the **South Whidbey Island Fault Zone** (*SWIFZ, projected splay crosses the project site*), the **Monroe Fault Zone** (*MFZ, 15 miles northeast*) and the **Cherry Creek Fault Zone** (*CCFZ, 12 miles northeast*) being identified as active by the **USGS**. Offsets along some of these fault zones are significant. Estimated movements and slip rates along these faults range from 0.2 to 0.6 mm/year according to the **USGS**. Geologic and geophysical information concerning these faults and other postulated fault-related lineation's throughout Snohomish County are the subject of on-going studies and interpretation by the **USGS** and others at this time. For reference purposes, a **Major Fault Structures in Western Washington State Map** is included in *Appendix J* at the end of this report. This map includes only major fault structures in western Washington, not all of the fault zones discussed above are included on this map.

Seismic Hazards: Seismic hazards can be divided into primary, secondary and tertiary hazards. Primary seismic hazards originate directly from stresses in the earth's crust resulting from earthquakes and consist of strong shaking, surface-fault rupture and tectonic deformation. Secondary hazards are caused by primary hazards where strong shaking results in landslides and/or soil liquefaction. Tertiary hazards are caused by secondary hazards such as surface displacement that have impacted man-made improvements within rupture zones and landslide areas.

A branch of a fault from the **SWIFZ**, commonly referred to as a splay, is mapped as crossing the project site. For reference purposes, the proposed location of the splay relative to the project site is shown on the **SWIFZ Splay Map** included in *Appendix K* of this report. While the exact location of the splay is unknown, its approximate location has been proposed based on subsurface geologic features and surficial topographic features observed in the vicinity of the project site. According to the **USGS**, the **SWIFZ** is an active fault zone. As such, it is possible that the project site could experience primary seismic hazards such as strong shaking and/or surface-fault rupture (*along the splay*) during its design lifespan. Based on the steep slopes along the western side of the site, the mapped geology of the site and the observed high ground water table and loose sandy

soil conditions around much of the site, secondary seismic hazards such as landslides and soil liquefaction could also be experienced on or immediately adjacent to the project site during a seismic event. These types of movements could affect the proposed improvements (*tertiary impacts*), although the type of impact would most likely not be detrimental to the proposed function of the site improvements.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Assumptions

The recommendations contained in this report are based on the following assumptions:

1. The recommendations contained in this report are based on the 60% plan set dated October, 2018.
2. Flood, Erosion, Landslide, Fault and Seismic Hazards have all been mapped on or immediately adjacent to this project site.
3. The design and construction of the proposed project will follow a zero tolerance policy for short term and/or long term erosion and/or ground water impacts.
4. The geology and hydrogeology present on this site are favorable for wetland creation and/or re-establishment without significant augmentation.

4.2 Seasonal Working Conditions

In order to limit any potential surface water quality impacts to either Little Bear Creek or to the drainages running through the site and into Little Bear Creek, we recommend that construction elements of the project that require any type of excavation or grading within or close to the ground water table be completed only during extended periods of dry weather or during the summer months of the year when the flow rates in Little Bear Creek and in the drainages running through the site are at their lowest. In general, due to the variable nature of the surficial fills placed around the site and the very high ground water table observed, seasonal weather and wet weather construction may encounter slightly higher than normal ground water elevations and alter the engineering characteristics of any moisture sensitive and moisture disturbed soils. If construction and/or site improvement work is attempted during periods of extended wet weather, contingencies should be provided for additional costs and expense that may be incurred.

4.3 Site Work

All site work should be completed in general accordance with the recommendations contained in *section 4.5* **Erosion Control** of this report. In addition, due to the location of the project site within in an area of unconfined aquifers, we recommend that special provisions be included in the project

contract documents requiring the contractor to have a County approved project specific *Spill Prevention, Control and Countermeasures Plan* in place prior to the start of work. We also recommend that any potential hazardous materials and/or hydrocarbon based products be stored in special containers while on-site that will provide containment of the materials if a release or leak were to occur during storage. We also recommend that if at all possible heavy equipment used on site utilize non-petroleum based hydraulic products.

4.3.1 *Site Preparation:* Initial clearing, grubbing and any overexcavation procedures should be performed in accordance with applicable section of **WSDOT Standard Specification section 2-01**, *Clearing, Grubbing and Roadside Cleanup*. Care should be taken to ensure minimal to no impact is made to the sensitive areas along the base of the western slopes or outside of the immediate area of the improvements shown on the site plans. Removal of any of the structures on the site should be done in accordance with applicable sections of **WSDOT Standard Specification section 2-02**, *Removal of Structures and Obstructions*. Disposal of unsuitable materials and debris generated by the site preparation work should be done in accordance with **WSDOT Standard Specification section 2-03.3**(*7*), *Disposal of Surplus Materials* and in accordance with the guidelines and specifications of **Snohomish County's GSP140**, *Disposal of Surplus Materials.* In compliance with **Snohomish County's GSP140**, all sites used for the disposal of surplus materials will have to be pre-approved by **Engineering Services** *Geotechnical Group* prior to use by the contractor.

Four-(*4*) **DOE** registered observation wells (*PW-01 thru PW-04*) have been installed on this property to monitor the shallow ground water elevations. These wells are all located within the proposed work areas for the project. We recommend that a minimum 15 foot non-disturbance protection radius be established around each of these well locations prior to the start of construction. If it is not possible to maintain a disturbance free radius around a well location due to proposed project improvements, the well will have to be decommissioned and removed by a licensed well driller per **Washington State WAC Chapter 173-160,** *Minimum Standards for Construction and Maintenance of Wells* – **section 460**, *Decommissioning Process for Resource Protection Wells* prior to the start of construction.

4.3.2 *Site Grading*: The majority of the site work for this project is comprised of grading. Uncontrolled fill will be removed from all areas of the site, drainages will be removed and/or improved, and topographic alterations will be constructed to help facilitate the re-establishment of wetlands as shown on the 60% plan set. As discussed in section 3.6 Geologic Hazards – *Landslide Hazard Areas* above, a small portion of the grading work shown on the 60% plans set is going to occur adjacent to possible historic landslide areas. Because of this, we recommend that a survey monitoring network be set up along the base of the western slope prior to the start of any grading work in that area. The purpose of this survey network will be to monitor the stability of the adjacent slope, the base of the slope, and along the graded slope before, during and for a season after the project grading starts and is completed. In addition, slopes regraded in the areas discussed above should have finished grades no steeper than 2H:1V slopes.

As indicated on the projects **Geologic Conditions and Fill Assessment Report** dated Oct. 2018, the composition of the uncontrolled fill material is variable. County personnel will review the materials as it is being removed by the contractor and direct him as to how the materials will be utilized. Organic rich materials will be re-used on site for the redevelopment of wetland topography. Granular materials may be re-used on site where appropriate to support the new topography, used to fill in drainage ways to be removed, or they could be placed in engineered stockpiles located off of 238th St SE. Materials deemed unusable by County personnel at the time of excavation will be removed from the site and treated as Surplus Materials. Materials placed in the engineered stockpile should be back bladed and track compacted to a non-yielding condition utilizing a maximum lift thickness not exceeding 8 to 12 inches. Saturated soils should not be placed in the engineered stockpile without amendment or without being windrowed until dry and approved by a representative of the **Geotech Group** prior to placement. Side slopes for the engineered stockpile may be graded to a maximum 1H:1V slope where protected from weather by visqueen until other methods of erosion control can be established. If this is not possible, side slope grades should not exceed 2V:1H.

Maintaining safe access roadways and safe excavations during construction is the responsibility of the contractor. Temporary cuts and excavations will stand in near vertical side walls/slopes of up to four-(*4*) feet in total depth/height for short periods of time if protected from weather and not

effected by ground water or surface water seepage. Extra care will need to be exercised by the contractor if seepage is encountered within a cut or excavation and when working within any area designated as part of the geologic hazards area on the site. Sloughing of side walls may occur where moderate to heavy ground water or surface water seepage is encountered. All temporary cuts and excavations over four-(*4*) feet in total depth/height should be retained by suitably designed retaining systems or digging boxes unless the side slopes are laid back to a minimum 1H:1V slope. Permanently exposed side slopes should be laid back to slopes no steeper than 2H:1V unless otherwise approved by the **Geotech Group**. Soil sloughs associated with persistent ground water out-watering may need to be armored with 2" to 4" crushed rock for stabilization and erosion protection.

4.3.3 *Structural Fill*: While it is not clear at this time whether or not structural fill will be necessary for this project, we recommend that any imported fill materials for structural use consist of well-graded, free-draining, granular soil free of organic and deleterious materials. The material for gravel borrow spelled out in **WSDOT Standard Specification section 9-03.14(1)**, *Gravel Borrow*, will meet the requirements for structural fill on this project except the fines portion of the gradation should not exceed 5% passing the #200 sieve. On-site materials should only be used in a structural fill application upon approval by a representative of the **Geotech Group**.

4.3.4 *Storm Water and Drainage Placement Considerations*: Ditch and/or drainage excavation should be performed in accordance with applicable sections of **WSDOT Standard Specification section 2-09**, *Structure Excavation*. The depth of excavation, removal of unsuitable base materials, disposal and replacement of those materials should be performed in accordance with applicable sections of this report and as shown on the 60% Plan Sheets. All ditches should be shaped with a 3H:1V or flatter sidewall slope and should be hydroseeded soon after completion to prevent erosion. Hydroseeding should comply with applicable sections of **WSDOT Standard Specification section 8-01.3(2)B**, *Seeding and Fertilizing*. For water quality and erosion control purposes we recommend that the base of all site ditches be lined with a minimum thickness of 0.5' of materials meeting **WSDOT Standard Specification section 9-03.11(1)**, *Streambed Sediment*. To prevent base and side slope erosion, we recommend that ditches going down slopes steeper than 2H:1V and ditches or drainages that show signs of down-cutting or erosion be armored with

a mixture of *Streambed Sediment* and slightly coarser materials meeting **WSDOT Standard Specification section 9-03.11(2)**, *Streambed Cobbles*.

4.3.5 *Habitat Rocks and Rock Piles*: Imported habitat rocks shall be rounded to sub-angular, hard, sound and durable rock free of seams and cracks. Habitat rocks shall meet **WSDOT Standard Specification section 9-03.11(4)**, *Habitat Boulders*. Existing on-site materials may be used for habitat rocks in rock piles provided they are clean, round to sub-angular, sound and durable rock greater than 4" in minimum dimension.

4.3.6 *Well Decommission*: A private well is located on the project site. Although the well has been tagged with a **DOE** unique well number (*ALJ-148*), it has not been registered on the **DOE** well log data base or on the **DOH Group B** water system data base. This will be considered an unregistered water well with unknown construction details. The well will need to be decommissioned by a licensed well driller following Washington State **WAC 173-160-381,** *Standards for Decommissioning a Well* and appropriate sections of **Chapter 18.104RCW.**

4.4 Geologic Hazards Considerations

Several geologic hazards were identified on this site and discussed in *section 3.6*, **Geologic Hazards** above. Flood, erosion, landslide, fault and seismic hazards have all been identified for this site. Of these hazards, the landslide and fault hazards have the highest potential of impact to the site and to the properties immediately adjacent to the site. Removal of the existing structures on the property will reduce the potential risks to the site from seismic related hazards. Based on our review of the data developed and presented in this report and the 60% design plans, it is our opinion that the project as proposed will either not be impacted by flood and erosion hazards in a preventable or detrimental manor, or will not increase the impact of the hazard in the immediate vicinity of the project site over its design lifespan. Additional mitigations beyond the proposed site improvements as outlined in the 60% design plan set and/or previously discussed in this report are not recommended or required given the presence of the flood and erosion hazard areas on this site.

The landslide hazard potentials for this site are associated with the over-steepened slopes along the western side of the site. As discussed in *section 3.6,*Geologic Hazards above, landslides have occurred along this slope in the past. The landslide hazard cannot be quantified without further site investigations which are outside the current scope of work. Based on our review of the 60% design plan set and the site improvements as proposed on the plan set, it is our opinion that the work and improvements as shown will not increase the existing landslide hazard.

4.5 Erosion Controls

As discussed above and in the other project geologic reports (*Geologic Conditions and Fill Assessment Report*, *Hydrogeologic Report*), the project site is underlain by an unconfined groundwater aquifer. This unconfined groundwater aquifer provides hydraulic conditions and supports the wetlands present on the project site as well as providing base flow support to Little Bear Creek. Because of the sensitive nature of the project sites surficial wetland soils and shallow unconfined aquifer, the following recommendations are presented:

1) A site specific *Spill Prevention, Control and Countermeasures Plan* should be prepared by the contractor as part of the project documents. This plan should be approved by the County as part of the contract documents. The *Spill Prevention, Control and Countermeasures Plan* should be implemented prior to site mobilization by the contractor.
2) A site specific *Health and Safety Plan* should be prepared by the contractor and approved by the County as part of the project documents. The *Health and Safety Plan* should be implemented prior to the start of any work on the site.
3) Tracking of heavy equipment, construction equipment, trucks and even personnel on foot will change the hydraulic properties of the exposed surficial soil. Due to this, we recommend that access of all construction equipment, trucks and personnel be limited to only those areas to be re-worked as part of the design plan, in accordance with the 60% project plan set. We recommend that final grading and surficial earthwork be done using "at arms-length" methodology. Once work in an area has been completed, the area should be closed to all access until such a time that the area has been re-vegetated and stabilized. Even then, we recommend that access be limited to foot traffic and only along chosen and identified trails that have been laid out in a purposeful and thoughtful way in advance.
4) We recommend that adequate erosion control measures be installed prior to the start of any earthwork to ensure minimal construction and siltation impacts to Little Bear Creek, adjacent wetlands, un-worked areas of the site, adjacent roadways or to adjacent properties. Designed and implemented erosion control measures should comply with all applicable sections of **WSDOT Standard Specification section 8-01**, *Erosion Control and Water Pollution Control* and all appropriate sections of **WSDOT Standard Specification section 9-14**, *Erosion Control and Roadside Planting*. Best

Management Practices (*BMP's*) should be established in accordance with **Snohomish County code 30.63A.110**, *Snohomish County Drainage Manual,* **Snohomish County code 30.63A.140**, *Washington State Department of Transportation Highway Runoff Manual* and **Snohomish County code 30.63A.445**, *Stormwater Pollution Prevention Plan* (*SWPPP*). To insure proper installation and maintenance of all erosion control measures and BMP's throughout the duration of the project we recommend that the contractor designate a responsible person that is a Certified Erosion and Sediment Control Lead (*CESCL*). We further recommend that inspection and documentation of these elements be completed on a daily basis by the CESCL and that the results of these inspections be included in the contractors' daily construction reports.

5) Site improvements and work should be performed in such a way so as not to impede existing surface drainage or encountered ground water flow through the area being worked. Impeding these flows could result in the destabilization of adjacent slopes. Shallow surficial soils are readily erodible. To prevent erosion and potential destabilization of slopes, run-off should not be allowed to flow uncontrolled over an exposed or unstabilized re-worked site slope at any time. If such conditions develop, we recommend that work be stopped in the immediate vicinity, the area be flagged off, and the Geotech Group be contacted to observe the area and provide appropriate recommendations to address the situation prior to allowing work to resume in the flagged area.

5.0 SPECIAL NOTES

The following special notes are recommended to be included in the projects documents relative to this geotechnical report:

1. The observed soil conditions presented on the subsurface test pit and test boring logs are as interpreted and recorded at the time and placement of exploration. Subsurface soil conditions may vary considerably between exploration locations and with time according to the prevailing climate, rainfall or other factors and are otherwise dependent on the duration of and methods used in the exploration program. Actual soil conditions encountered at the time of construction may vary from those found and presented in this report.
2. Sound engineering judgment was exercised in preparing the subsurface information presented herein. This information was prepared and is intended for use by the County design team and their consultants. It presentation on plans or elsewhere is for the purpose of providing intended users with access to the same information available to the County. This subsurface information interpretation is presented in good faith, and is not intended as a substitute for personal investigation, independent interpretations or judgment by the County, independent design consultants or by the Contractor.

This report is presented in accordance with accepted geologic and geotechnical engineering practices in this area.

5.1 Signatures

Kirk R. Bailey, LEG, LHG
Senior Geologist

Dale E. Topham, PG, PE
Geotechnical Engineer

March 2019
RC1730-115-37
Appendices

SELECTED REFERENCES

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2) **Freeze, R.A. and Cheney, J.A.**; Groundwater, Prentice and Hall, 1979
3) **Golder and Associates, Inc.**; Geohydrology Memorandum - Snohomish County Groundwater Management Program, 1996
4) **Golder and Associates, Inc.**; Little Bear Creek Hydrogeologic Overview, 2005
5) **National Resource Conservation Service**; Soil Survey of Snohomish County, 1983
6) **Snohomish County**; Critical Area Regulation 30.62C, 2016
7) **Snohomish County Public Works**; Aquifer Recharge/Wellhead Protection Map, 2001
8) **Snohomish County Public Works**; Geologic Conditions and Fill Assessment Report, October 2018
9) **Snohomish County Public Works**; Hydrogeologic Report, Little Bear Creek Advance Mitigation Site, October 2018
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12) **United States Geologic Survey**; "Geologic Map of the Bothell 7.5-Minute Quadrangle, King and Snohomish Counties, Wa." by J. P. Minard, 1985
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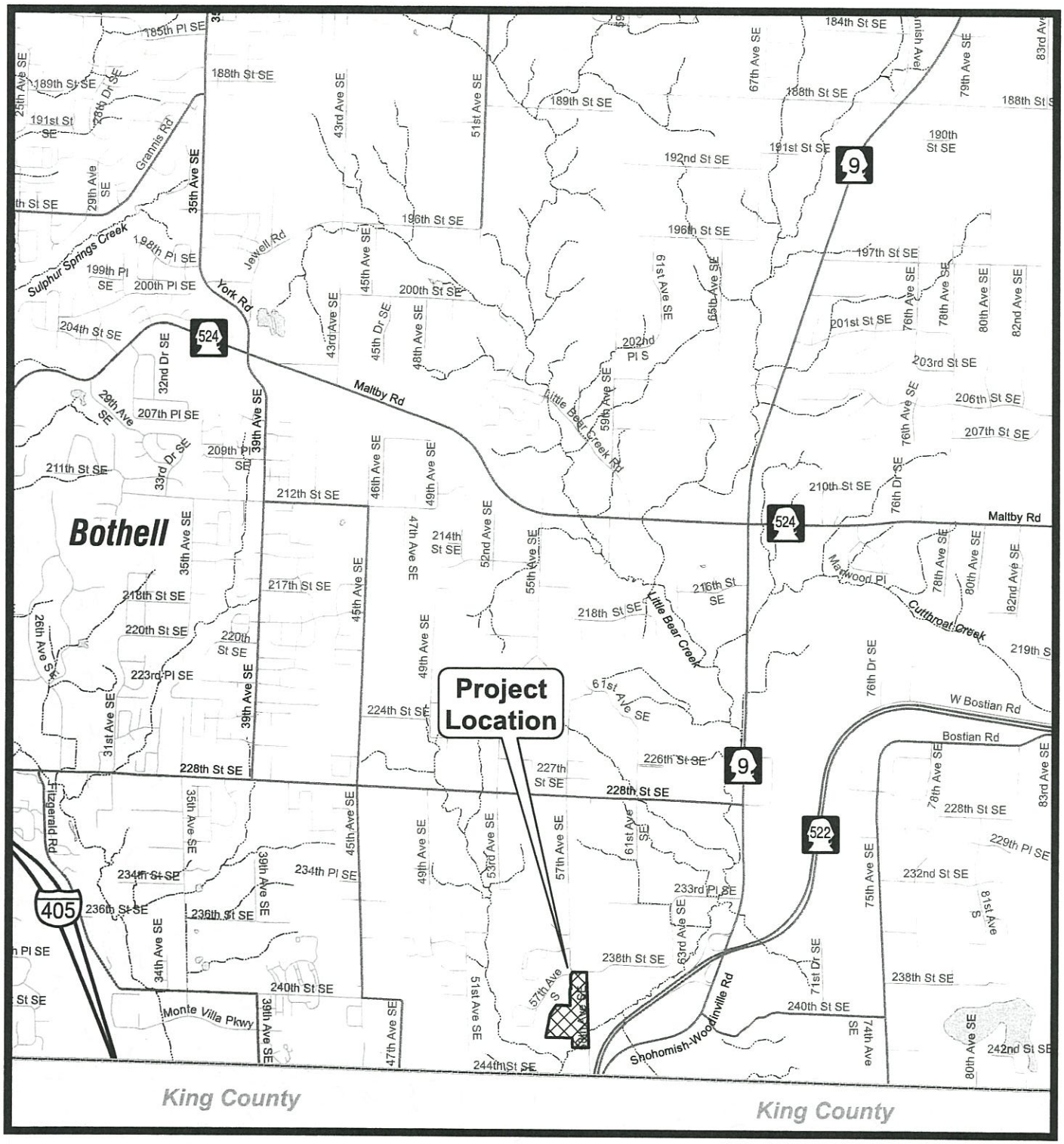
14) **United States Geologic Survey**; Numerical Model Analysis of the Effects of Ground Water Withdrawals on Discharge to Streams and Springs in Small Basins Typical of the Puget Sound Lowland, Wa., Water Supply Paper 2492, D.S. Morgan et al, 1999
15) **United States Geologic Survey**; "Topographic Map of the Bothell 7.5-Minute Quadrangle, King and Snohomish Counties, WA." 1953
16) **Washington State Department of Ecology**; Little Bear Creek Fecal Coliform Bacteria Total Maximum Daily Load (*Water Cleanup Plan*), May 2005
17) **Washington State Department of Ecology**; Well Logs, https://fortress.wa.gov/ecy/waterresources/map/WCLSWebMap/Default.aspx, 2018
18) **Washington State Department of Health**; Water Well Systems, https://doh.wa.gov/dataandstatisticalreports, Environmental Health, 2018
19) **Washington State Department of Transportation,** Standard Specifications M41-10 for Road, Bridge, and Municipal Construction, 2018

APPENDIX A

Vicinity Map



Key to Features:

- Project Location
- Arterial Roads
- Waterbodies
- Local Roads
- Streams
- County Boundary

0 0.25 Miles

Snohomish County

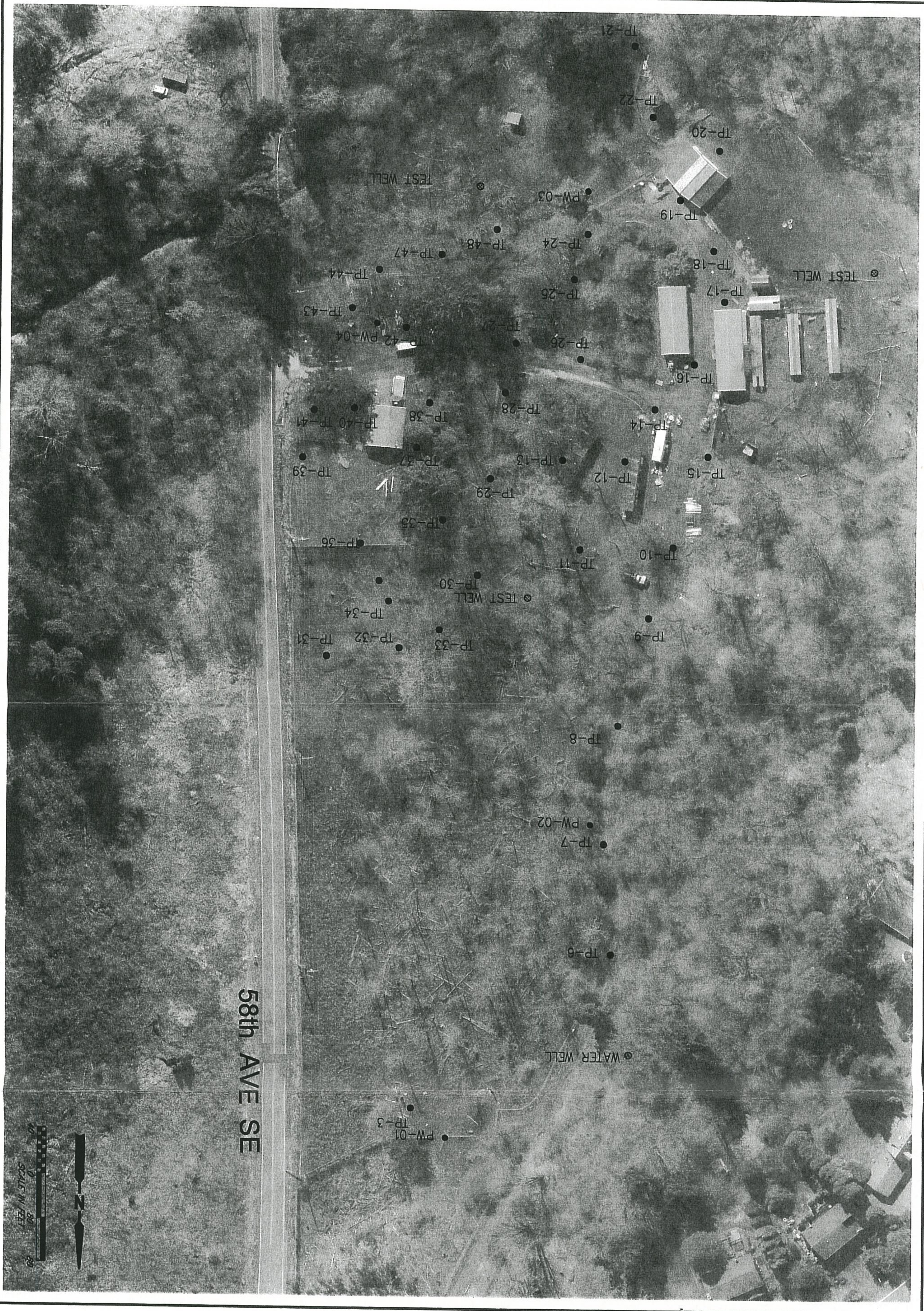
☆ Area Detailed

Figure 1. Colbeck Advanced Mitigation Site Vicinity Map

Snohomish County

APPENDIX B

Site Map



SITE MAP

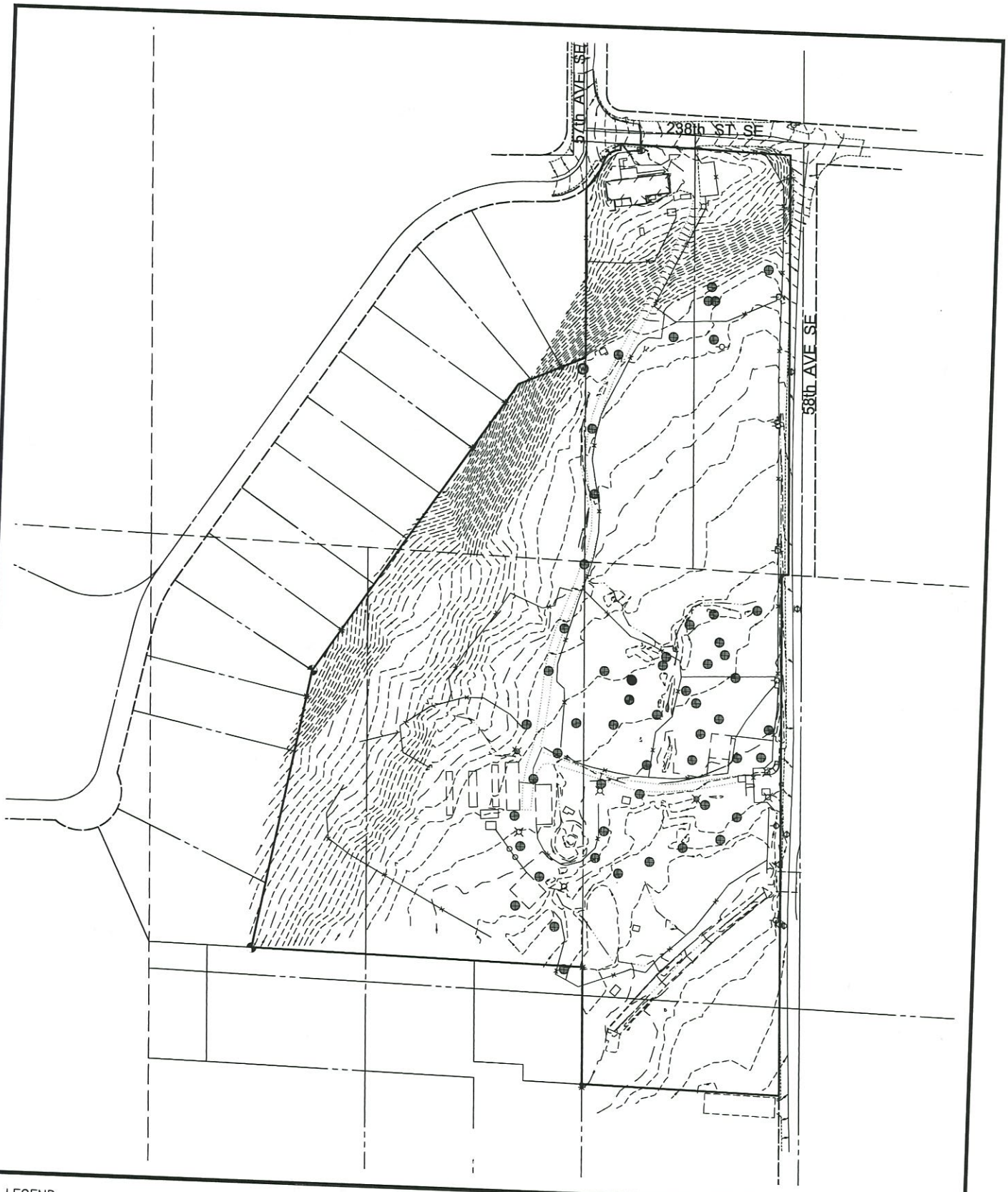
LITTLE BEAR CREEK
ADVANCED MITIGATION SITE
ROAD PROJECT NO. RC1730

LEGEND
- TEST PIT
- WELL
- TEST BORING

Figure 2

APPENDIX C

Topographic Map



LEGEND

- TEST PIT/TEST BORING
- WELL

Topographic Map

LITTLE BEAR CREEK
ADVANCED MITIGATION SITE
ROAD PROJECT NO. RC1730

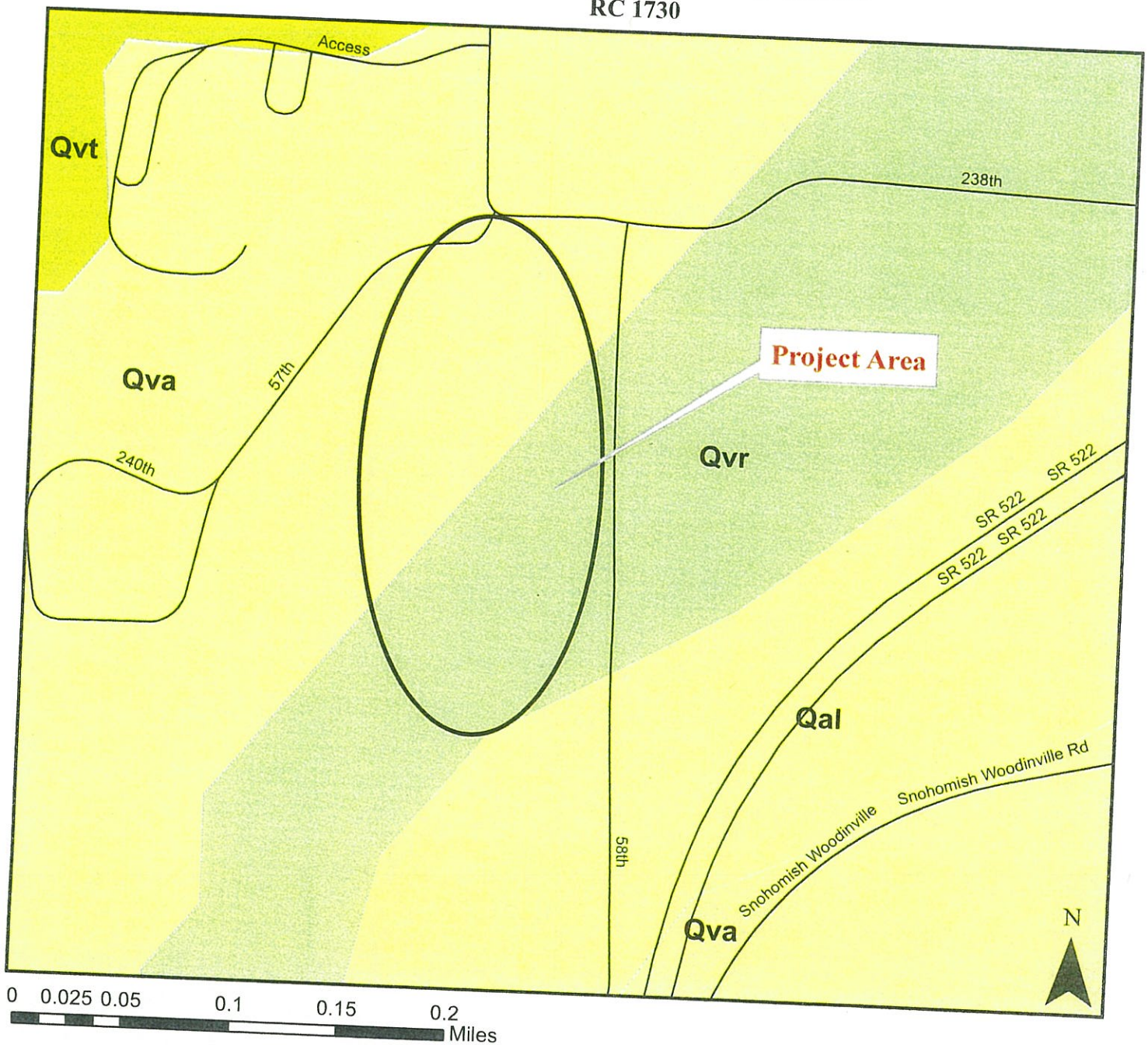
100 0 100 200
SCALE IN FEET

N

APPENDIX D

Geologic Map

GEOLOGIC MAP
Little Bear Creek Advanced Mitigation Site
RC 1730



Legend

- ice
- Fill — Manmade deposit
- Lahars — Volcanic Mudflow
- Qal — Alluvium
- Qmw — Mass wasting deposit
- Qgd — Glacial drift, undivided
- Qp — Peat
- Qvr — Vashon Recessioinal Outwash
- Qvrl — Vashon Recessional Lacustrine
- Qvt — Vashon Till
- Qvtm — Vashon Till - Marine
- Qva — Vashon Advance Outwash
- Qpf — Pre-Fraser deposits
- Qpfg — Pre Fraser - glacial
- Qtb — Pre-Fraser Transitional beds
- Ti — Tertiary Intrusive
- Ts — Tertiary Sandstone
- Tv — Tertiary Volcanic
- Ptm — Pre-Teriary bedrock
- water

Figure 3

APPENDIX E

Test Pit and Test Boring Logs

TEST PIT LOGS

TEST PIT LOG TP-01

Notes	Depth (feet)	Description
	0	0.0'-0.2' **Topsoil:** Grass, dead and down timber litter *(topsoil)*
		0.2'-2.5' **Silty Sand:** Brown, fine- to medium-grained, some silt, trace coarse-grained, trace gravel, medium dense, wet *(sm, fill)*
	2	Heavy seepage at 1.8'
		Caving below seepage to bottom of test pit
		2.5'-3.5' **Silt:** Dark brown, non-fibrous, loose, wet *(ol, alluvium)*
	4	3.5'-6.5' **Sand:** Brown/gray, fine- to coarse-grained and gravel up to 3", trace silt, loose, wet *(swg-spg, alluvium)*
	6	
		T.D. = 6.5'

TEST PIT LOG TP-02

Notes	Depth (feet)	Description
	0	0.0'-0.4' **Topsoil:** Grass *(topsoil)*
		0.4'-1.4' **Silty Sand:** Reddish-brown, fine- to medium-grained, some silt, trace gravel, trace organics, subround-subangular, iron staining throughout, medium dense, moist *(sm, fill)*
	2	1.4'-4.3' **Silty Sand:** Gray/brown, fine- to medium-grained, some silt, little gravel, subround, band of larger gravel in upper horizon, medium dense, moist *(sm, alluvium)*
	4	
		T.D. = 4.3'

Snohomish County Public Works

PROJECT: Little Bear Creek Advanced Mitigation Site

NUMBER: RC 1730
DATE: 2/27/18

Figure 4

TEST PIT LOGS

TEST PIT LOG TP-04

Notes	Depth (feet)	Description
		0.0'-0.4' **Topsoil:** Grass *(topsoil)*
	2	0.4'-2.6' **Gravelly Sand:** Dark brown, fine- to coarse-grained with gravel, trace silt, trace cobble up to 4", trace deliterius, buried asphalt, uncontrolled fill, areas of intermittent crushed, medium dense, moist *(gw-sw, fill)*
		Light seepage along southeast and east faces at 1.6'
	4	2.6'-4.2' **Peat:** Dark brown, fibrous, buried logs, irregular basal contact, contact pinches out to the east, medium dense, moist *(pt, alluvial)*
		Seepage along southwest face at 4.2'
		4.2'-5.6' **Silty Sand:** Gray blue, fine- to medium-grained, some silt laminae, trace coarse-grained, trace gravel, iron staining layer, medium dense, moist *(sm, alluvial)*
		T.D. = 5.6'

TEST PIT LOG TP-05

Notes	Depth (feet)	Description
		0.0'-0.5' **Crushed Rock:** Grass and roadbed *(gm, fill)*
	2	0.5'-1.4' **Gravelly Sand:** Brown gray, fine- to coarse-grained and gravel up to 2.5", dense, moist *(swg, fill)*
		Slight seepage at 1.3'
		1.4'-3.8' **Silt:** Dark brown, slightly fibrous, medium dense, wet *(ol, alluvial)*
	4	3.8'-4.4' **Silty Sand:** Gray blue, fine- to medium-grained, some silt laminae, trace coarse-grained, trace gravel, iron stained layer, medium dense, moist *(sm, alluvial)*
		Seepage at 3.8'
		Heavy seepage and piping on west face at 4.2'. Piping exceeds infiltration. Test pit filling with water
		T.D. = 4.4'

Snohomish County Public Works

PROJECT: Little Bear Creek Advanced Mitigation Site

NUMBER: RC 1730
DATE: 2/27/18

Figure 5

TEST PIT LOGS

TEST PIT LOG TP-06

Notes	Depth (feet)	Description
		0.0'-0.5' **Crushed Rock:** Grass and roadbed *(gm, fill)*
		0.5'-0.7' **Silty Sand:** Brown, fine- to coarse-grained with silt, trace gravel, trace cobble, subround, loose, moist *(sm,fill)*
	2	0.7'-2.0' **Cordoroy Road:** Brown, buried logs, organic, loose, moist to wet *(pt,fill)*
		2.0'-4.0' **Peat:** Dark brown, fibrous, buried wood debris, loose, moist, irregular basal contact *(pt, alluvial)*
	4	4.0'-4.8' **Sand:** Reddish brown, fine- to medium-grained with silt, michaceous, loose, wet *(sw-sm, alluvium)*
		Seepage throughout contact of sand and peat 4.0'
	6	4.8'-5.0' **Gravel:** Gray, gravel band within sand *(gp, alluvium)*
		5.0'-6.0' **Gravelly Sand:** Reddish brown, medium- to coarse-grained with gravel, trace silt, loose, saturated *(swg, alluvium)*
		Heavy seepage and piping at 5.7', piping exceeds infiltration
		T.D. = 6.0'

TEST PIT LOG TP-07

Notes	Depth (feet)	Description
		0.0'-0.3' **Crushed Rock:** Grass and roadbed *(gw, fill)*
		0.3'-0.7' **Gravelly Sand:** Dark gray, medium- to coarse-grained and gravel up to 2", some silt, uncontrolled fill, areas of
	2	intermittent crushed, subangular to angular, medium dense, moist *(gw-sw, fill)*
		0.7'-2.1' **Peat:** Dark brown, fibrous, medium dense, wet *(pt, alluvial)*
	4	Heavy root zone at 0.8'
		2.1'-6.0' **Gravelly Sand:** Light gray to gray, medium- to coarse-grained, little to some gravel up to 3", trace silt,
	6	subround, loose, wet to saturated *(sw-gw, alluvial)*
		Caving from 2.1' to bottom of test pit
		Piping at 5.8', piping exceeds infiltration, test pit filling with water
		T.D. = 6.0'

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Figure 6

TEST PIT LOGS

TEST PIT LOG TP-08

Notes	Depth (feet)	Description
		0.0'-0.6' **Crushed Rock:** Grass and roadbed *(gw, fill)*
	2	0.6'-2.3' **Gravelly Sand:** Dark gray, medium- to coarse-grained with gravel up to 2", some silt, uncontrolled fill, areas of intermittent crushed, subangular to angular, medium dense, moist *(gw-sw, fill)*
	4	2.3-7.0' **Peat:** Dark brown, fibrous, little to some laminated fine- to medium-grained sand layers, medium dense, moist *(pt, alluvium)*
	6	Seepage throughout peat layer
	8	7.0'-8.0' **Sand:** Light gray to gray, medium- to coarse-grained, little to some gravel up to 3", trace silt, subround, loose, wet *(sw-gw, alluvial)*
		T.D. = 8.0'

TEST PIT LOG TP-09

Notes	Depth (feet)	Description
		0.0'-0.4' **Crushed Rock:** Grass and roadbed *(gw, fill)*
	2	0.4'-1.0' **Gravelly Sand:** Brown, medium- to coarse-grained with gravel up to 2", some silt, uncontrolled fill, areas of intermittent crushed, subangular to angular, medium dense, moist *(gw-sw, fill)*
	4	1.0'-3.8' **Gravelly Sand:** Blue gray, medium- to coarse-grained with gravel up to 2", silt, uncontrolled fill, areas of intermittent crushed, subangular to angular, medium dense, moist *(gw-sw, fill)*
	6	3.8'-5.6' **Peat:** Dark brown, very fibrous, medium dense, moist *(pt, alluvium)* Seepage at 5.6'
		5.6'-7.4' **Sand:** Light gray to gray, medium- to coarse-grained, little to some gravel up to 3", trace silt, subround, loose, wet *(sw-gw, alluvial)*
		T.D. = 7.4'

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Figure 7

TEST PIT LOGS

TEST PIT LOG TP-10

Notes	Depth (feet)	Description
		0.0'-0.5 **Crushed Rock:** Grass and roadbed *(gw, fill)*
		0.5'-2.3' **Gravely Sand:** Brown gray, fine- to coarse-grained, trace silt, uncontrolled fill, areas of intermittent crushed, subangular to angular, medium dense, moist*(gp-gm, fill)*
	2	
		2.3'-3.4' **Peat:** Dark brown, fibrous, medium dense, wet *(pt, alluvial)*
		Heavy seepage at 3.4'
	4	
		3.4'-5.0' **Silty Sand:** Blue gray, fine- to medium-grained, little silt, trace gravel, subround, loose, moist *(sp-sm, alluvium)*
		Caving from 4.0' to base of test pit
		Piping, piping exceeds infiltration
		T.D. = 5.0'

TEST PIT LOG TP-11

Notes	Depth (feet)	Description
		0.0'-0.5' **Topsoil:** Grass *(topsoil)*
		0.5'-1.5' **Gravelly Sand:** Brown, fine- to coarse-grained, some silt, some gravel, subangular to subround, medium dense, moist *(spg, fill)*
	2	
		1.5'-2.7' **Silt:** Dark brown, non-fibrous, medium dense, wet *(ol, alluvium)*
	4	2.7'-4.4' **Sand:** Gray blue, fine- to coarse-grained, little to some gravel, little silt, trace cobble, subround, loose *(sw, alluvium)*
		Seepage at 2.7'
		Caving from 3.5' to base of test pit
		T.D. = 4.4'

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Figure 8

TEST PIT LOGS

TEST PIT LOG TP-12

Notes	Depth (feet)	Description
		0.0'-0.5' **Topsoil:** Grass *(topsoil)*
	2	0.5'-1.0' **Gravelly Sand:** Brown, fine- to coarse-grained, some silt, some gravel, subangular to subround, medium dense, moist *(spg, fill)*
		1.0'-2.0' **Silt:** Dark brown, non-fibrous, medium dense, wet *(ol, alluvium)*
	4	2.0'-3.4' **Sand:** Gray blue, fine- to coarse-grained, little to some silt, trace cobble, trace boulder, subround, moist, loose *(sw-sm, alluvium)*
		3.4'-5.5' **Clayey Silt:** Gray blue, clayey silt, some sand lenses/seams, little organics, slight plasticity, dense, wet *(ml, lacustrine)*
		Seepage at 4.5'
		T.D. = 5.5'

TEST PIT LOG TP-13

Notes	Depth (feet)	Description
		0.0'-0.2' **Topsoil:** Grass *(topsoil)*
	2	0.2'-1.0' **Silty Sand:** Gray brown, fine- to coarse-grained, some silt, trace gravel, trace boulders up to 7", subround to subangular, iron staining throughout, medium dense, moist *(sm, sandy fill)*
		1.0'-2.4' **Silt:** Black brown, non-fibrous, root zone in upper 12", medium dense, moist *(ol, alluvium)*
	4	2.4'-3.3' **Silty Sand:** Brown blue, fine- to medium-grained, some silt, trace coarse-grained, trace gravel, medium dense to loose, wet *(sm, alluvium)*
		Seepage at 2.4-2.8'
		3.3'-5.3' **Clayey Silt:** Gray blue, clayey silt, little to some sand lenses/seams, little organics, slight plasticity, dense, wet *(ml, lacustrine)*
		T.D. = 5.3'

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Figure 9

TEST PIT LOGS

TEST PIT LOG TP-14

Notes	Depth (feet)	Description
		0.0'-1.0' **Topsoil:** Grass, irregular basal contact *(topsoil)*
		Power utilities buried roughly 1.5' down, peagravel in utility trench.
	2	1.0'-2.5' **Silty Sand:** Gray brown, fine- to coarse-grained, some silt, trace gravel, trace boulders up to 7", subround to subangular, iron staining throughout, medium dense, moist *(sm, sandy fill)*
	4	Seepage at 1.2'-1.5'
		2.5'-4.6' **Silty Sand:** Blue gray, fine- to coarse-grained, some silt laminae, trace gravel, medium dense, moist *(sm, alluvium)*
		T.D. = 4.6'

TEST PIT LOG TP-15

Notes	Depth (feet)	Description
		0.0'-0.8' **Topsoil:** Grass *(topsoil)*
	2	0.8'-4.4' **Silty Sand:** Gray brown, fine- to coarse-grained, some silt, trace gravel and boulders up to 7", subround to subangular, iron staining throughout, medium dense, moist *(sm, sandy fill)*
	4	Seepage at 3.8'
		4.4'-5.8' **Peat:** Dark brown, fibrous, slightly mucky, trace sand and gravel, loose, wet *(pt, alluvium)*
	6	Seepage at 4.4'
		5.8'-6.9' **Sand:** Gray blue, fine- to coarse-grained, some gravel, trace silt, trace cobble, subround, loose, wet *(sw, alluvium)*
		Piping at 5.9'
		T.D. = 6.9'

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Figure 10

TEST PIT LOGS

TEST PIT LOG TP-16

Notes	Depth (feet)	Description
	2	0.0'-0.3' **Tosoil:** Grass, gravel roadbed *(topsoil)*
		0.3'-0.9' **Sandy Gravel:** Gray, reddish-brown, uncontrolled fill, iron staining throughout, medium dense, moist *(gm, fill)*
		0.9'-1.3' **Silt:** Dark brown, trace fine- to medium-grained, medium dense, moist *(ol, alluvium)*
	4	1.3'-2.2' **Silty Sand:** Gray blue, fine- to coarse-grained with silt, trace cobble, trace boulder, subround, moist, loose *(sm, alluvium)*
		2.2'-2.9' **Silt:** Dark brown, trace fine- to medium-grained, medium dense, moist *(ol, alluvium)*
		2.9'-4.0' **Silty Sand:** Gray blue, fine- to coarse-grained with silt, trace cobble, trace boulder, subround, moist, loose *(sm, alluvium)* Seepage at 4.0'
		4.0'-5.7' **Clayey Silt:** Gray blue, clayey silt, sand lenses/seams, little organics, slight plasticity, dense, wet *(ml, lacustrine)*
		T.D. = 5.7'

TEST PIT LOG TP-17

Notes	Depth (feet)	Description
		0.0'-0.5' **Topsoil:** Grass *(topsoil)*
	2	0.5'-2.1' **Silty Sand:** Brown, fine- to medium-grained with silt, trace gravel, medium dense, moist *(sm, fill)*
		2.1'-3.1' **Silt:** Dark brown, silty topsoil, high organics, medium dense, moist to wet *(ol, alluvium)*
	4	3.1'-4.0' **Sand:** Gray, fine- to coarse-grained, trace silt, trace gravel, trace cobble, medium dense, wet *(sw, alluvium)* Seepage encountered at 3.1'
		4.0'-5.8' **Clayey Silt:** Gray blue, clayey silt, sand lenses/seams, little organics, slight plasticity, dense, wet *(ml, lacustrine)*
		T.D. = 5.8'

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Figure 11

TEST PIT LOGS

TEST PIT LOG TP-18

Notes	Depth (feet)	Description
		0.0'-0.4' **Topsoil:** Grass *(topsoil)*
	2	0.4'-2.2' **Organic Gravelly Silt:** Black brown, fine- to medium-grained, trace gravel, trace boulder up to 6", subround to round, medium dense, very moist *(mlg, alluvium)*
	4	2.2'-3.3' **Gravel with Silt:** Brown gray, silt, fine- to coarse-grained sand, gravel, cobbles, trace boulders, round, loose, wet to saturated*(gw-gm, alluvium)* Heavy caving from 2.2' to base of test pit Heavy seepage at 2.5'
	6	3.3'-6.4' **Silty Sand:** Blue gray, fine- to medium-grained with silt, trace gravel, subround, loose, wet to saturated*(sm, alluvium)* Heavy seepage at 4.2' Heavy seepage and piping at 6.0' Test pit rapidly filled with 3.5' of water
		T.D. = 6.4'

TEST PIT LOG TP-19

Notes	Depth (feet)	Description
		0.0'-0.5' **Topsoil:** Grass *(topsoil)* Slight seepage at 0.4'
	2	0.5'-1.2' **Gravelly Sand:** Dark brown, fine- to coarse-grained with gravel, silt, subround, medium dense, moist *(gw-gm, fill)*
		1.2'-2.2' **Silt:** Dark brown, fine- to medium-grained sand, medium dense, moist *(ol, alluvium)*
	4	2.2'-4.8' **Silty Sand:** Gray blue, fine- to medium-grained with silt, trace gravel, loose, moist *(sm, alluvium)* Moderate seepage at 4.0'
		T.D. = 4.8'

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Figure 12

TEST PIT LOGS

TEST PIT LOG TP-20

Notes	Depth (feet)	Description
		0.0'-0.2' **Topsoil:** Grass and gravel *(topsoil)*
	2	0.2'-1.2' **Gravelly Sand:** Dark brown, fine- to coarse-grained with gravel, trace silt, subround, medium dense, moist *(gw-gm, fill)*
		1.2'-3.2' **Silt:** Dark brown, trace fine- to medium-grained, compressed, unit dipping east, medium dense, moist *(ol, alluvium)*
	4	Caving from 2.4' to base of test pit Seepage along the western face at 2.4'
		3.2'-5.0' **Sand:** Gray blue, fine- to coarse-grained with silt, trace gravel, trace cobble, unit dipping east, loose, moist *(sp-sm, alluvium)* Seepage along the eastern face at 3.4'
		T.D. = 5.0'

TEST PIT LOG TP-23

Notes	Depth (feet)	Description
		0.0'-0.35' **Topsoil:** Grass *(topsoil)*
		0.35'-1.8' **Sand:** Brown gray, fine- to coarse-grained with silt, with gravel, loose, saturated *(spg, fill)*
	2	1.8'-5.8' **Silt:** Dark brown, slightly fibrous, medium dense, wet *(ol, alluvial)* Seepage at 2.4' Root horizon from 2.8'-3.3'
	4	
		Seepage at 5.0'
	6	5.8'-6.0' **Sand:** Gray, fine- to medium-grained, trace coarse-grained, trace gravel, loose, wet *(sp-sm, alluvium)*
		T.D. = 6.0'

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Figure 13

TEST PIT LOGS

TEST PIT LOG TP-24

Notes	Depth (feet)	Description
	0	0.0'-0.4' **Topsoil:** Grass *(topsoil)*
		0.4'-0.8' **Gravelly Sand:** Dark brown, fine- to coarse-grained, some gravel, trace silt, little cobble up to 4", uncontrolled fill, areas of intermittent crushed, medium dense, moist *(gw-sw, fill)*
	2	0.8'-1.3' **Silt:** Roots, slightly fibrous, medium dense, moist *(ol, alluvium)*
		1.3'-2.6' **Silty Sand:** Blue gray, fine- to medium-grained, some silt, trace coarse-grained, trace gravel, iron staining throughout, loose, moist *(sm, weathered alluvium)*
	4	2.6'-6.5' **Sand:** Gray, fine- to medium-grained, trace silt, trace coarse-grained, trace gravel, loose, moist *(sp-sm, alluvium)*
		Piping at 5.0'
	6	T.D. = 6.5'

TEST PIT LOG TP-25

Notes	Depth (feet)	Description
	0	0.0'-0.4' **Topsoil:** Grass, leaves, roadbed *(topsoil)*
		0.4'-2.0' **Gravelly Sand:** Dark brown, fine- to coarse-grained, some gravel, trace silt, trace cobble up to 4", uncontrolled fill, areas of intermittent crushed, medium dense, moist *(gw-sw, fill)*
	2	Seepage at 1.5'
		2.0'-2.2' **Silt:** Roots, slightly fibrous, loose, moist *(ol, alluvium)*
	4	2.2'-6.5' **Sand:** Gray blue, fine- to medium-grained, trace silt, trace coarse-grained, little gravel, gravel band 4" below OL contact, loose, moist *(sp-sm, alluvium)*
		Seepage at 3.6'
	6	Seepage exceeds infiltration
		T.D. = 6.5'

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Figure 14

TEST PIT LOGS

TEST PIT LOG TP-26

Notes	Depth (feet)	Description
		0.0'-0.6' **Topsoil:** Grass *(topsoil)*
	2	0.6'-2.0' **Gravelly Sand:** Dark to light brown, gravel up to 3", some fine- to coarse-grained sand, little silt, little cobbles up to 6", little deliterius, buried concrete up to 3', subround to angular, loose, moist *(gw-gm, fill)*
	4	2.0'-2.3' **Silt:** Dark brown, with coarse- grained sand and gravel, unit pinches out to the east, medium dense, moist *(ol, alluvium)* Seepage at 2.0'
		2.3'-4.7' **Silty Sand:** Gray blue, fine- to medium-grained, some silt, trace coarse-grained, trace gravel, medium dense, moist *(sm, alluvial)*
		T.D. = 4.7'

TEST PIT LOG TP-27

Notes	Depth (feet)	Description
		0.0'-0.5' **Topsoil:** Dark brown, grass and roadbed, medium dense, moist *(topsoil)*
	2	0.5'-2.4' **Gravelly Sand:** Dark brown, fine- to coarse-grained and gravel, trace silt, little cobble up to 4", uncontrolled fill, areas of intermittent crushed, medium dense, moist *(gw-sw, fill)* Seepage at 1.5' on northern face 2.0'-2.4' **Asphalt:** Buried asphalt pad 0.4' thick
	4	2.4'-5.2' **Silty Sand:** Gray blue, fine- to medium-grained, some silt, trace coarse-grained, trace gravel, medium dense, moist *(sm, alluvial)* Seepage at 4.9' on northern face
		T.D. = 5.2'

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Figure 15

TEST PIT LOGS

TEST PIT LOG TP-42

Notes	Depth (feet)	Description
		0.0'-0.4' **Topsoil:** Grass, leaves, trace deliterius *(topsoil)*
	2	0.4'-3.0' **Silty Sand:** Gray brown, fine- to coarse-grained with silt, trace gravel, trace cobble, subround to subangular, loose, moist *(sm, sandy fill)*
	4	3.0'-4.0' **Silt:** Dark brown, abundant organic, buried wood and roots, fibrous, loose, moist to wet, *(ol, alluvial)*
		4.0'-4.5' **Silty Sand:** Reddish-brown, fine- to medium-grained with silt, trace coarse-grained, gravel and cobble up to 5", moist, loose *(sm, alluvium)*
	6	4.5'-6.6' **Silty Sand:** Blue gray, fine- to medium-grained with silt, trace coarse-grained, gravel and cobble up to 4", moist, loose *(sm, alluvium)*
		T.D. = 6.6'

TEST PIT LOG TP-43

Notes	Depth (feet)	Description
		0.0'-0.6' **Topsoil:** Grass, trace deliterius *(topsoil)*
	2	0.6'-3.3' **Silty Sand:** Tan, fine- to medium-grained with silt, trace gravel, trace cobble, trace boulder up to 8", trace deliterius, loose, moist *(sm, fill)*
	4	3.3'-6.0' **Peat:** Dark brown, highly organic, buried logs, roots and stumps, medium dense, very moist to wet *(pt, alluvial)*
	6	
	8	8.0'-8.7' **Sand:** Blue gray, fine- to medium-grained, trace silt laminae, trace coarse-grained and gravel, subround, micaceous, medium dense, wet *(sw, alluvial)*
		T.D. = 8.7'

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Figure 16

TEST PIT LOGS

TEST PIT LOG TP-44

Notes	Depth (feet)	Description
		0.0'-0.5' **Topsoil:** Grass and leaves *(topsoil)*
	2	0.5'-3.0' **Silty sand:** Tan, silt, fine- to medium-grained, trace gravel, trace cobble up to 8", trace deliterius, loose, moist *(sm, fill)*
	4	3.0'-5.8' **Peat:** Dark brown, highly organic, buried logs, roots and stumps, fibrous, medium dense, very moist to wet *(pt, alluvial)*
	6	5.8'-6.6' **Sand:** Blue gray, fine- to medium-grained, trace silt, trace coarse-grained, trace gravel, subround, micaceous, loose, saturated *(sw, alluvial)*
		T.D. = 6.6'

TEST PIT LOG TP-47

Notes	Depth (feet)	Description
		0.0'-0.6' **Topsoil:** Brown, grass and timber litter *(topsoil)*
	2	0.6'-2.8' **Sand:** Brown, fine- to coarse-grained, silt, gravel, trace cobble up to 6", abundant organics throughout, subangular to subround, dense, wet *(sw-sm, fill)* Cordoroy log road within fill. Large logs oriented NE-SW. Interpreted as being intentionally placed to damn up wetlands creek Seepage at 2.6'
		Excavation stopped due to logs
		T.D. = 2.8'

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Figure 17

TEST PIT LOGS

TEST PIT LOG TP-48

Notes	Depth (feet)	Description
		0.0'-0.8' **Topsoil:** Grass and roots *(topsoil)*
	2	0.8'-2.8' **Silty Sand:** Gray brown, fine- to medium-grained with silt, trace gravel, iron stained layers throughout, subangular to round, loose, very moist to wet *(sm, fill)*
	4	2.8'-6.0' **Peat:** Dark brown, abundant organics, wood, roots, fibrous, medium dense, wet *(pt, alluvium)*
		Seepage at 2.9'
	6	6.0'-7.3' **Silty Sand:** Gray, fine- to coarse grained with silt, trace gravel, loose, wet *(sm, alluvium)*
		Piping at 7.0', piping exceeds infiltration
		T.D. = 7.3'

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Figure 18

PROJECT:	**Little Bear Creek Advance Mitigation Site 24110-58th St SE**	BORING NO.:	**PW-01**
		DRILLER:	**WSDOT**
		DRILL TYPE:	**CME 850**
C.R.P.#:	**RC1730-115-37** DATE: **4/23/18**	AUGER TYPE:	**6" casing advancer**
LOCATION:		FLUID:	**water**
GEO./ENGR.:	**Kirk R. Bailey** ELEV.:	TOTAL DEPTH:	**20.50**

SAMPLE INTERVAL	SAMPLE #	SPT BLOWS/FT	STRATA	DEPTH	SOIL DESCRIPTION	WELL DETAIL
				0	0.0 - 1.5' **Silty Sand**; Brown, fine- to medium-grained. trace gravel, trace organic, iron staining, medium dense, moist (*sm, fill*)	SPT soil samples taken on 5 ft intervals. Representative soil samples were collected and sealed in glass jars for later correlation and testing.
					1.5 - 6.5' **Sand to Silty Sand**; Gray to gray brown, fine- to medium-grained, trace coarse-grained sand, medium dense, wet to saturated (*sp-sm, alluvium*).	
X	1	5/6/7		5		
					6.5 - 14.0' **Gravelly Sand to Sand and Gravel**; Brown, fine- to coarse-grained, angular to subangular, medium dense, saturated (*spg, Alluvium*).	
X	2	6/7/9		10		
X	3	5/12/19		15	14.0 - 20.5' **Sand**; Gray green, fine- to medium-grained, medium dense, saturated (*sp, alluvium*)	Observation well was installed upon completion of drilling.
X	4	10/16/24		20		
					Total Depth = 20.5 feet bgs	

NOTES: **Soil samples taken in accordance with ASTM D1586-84 standards and specifications. Soil descriptions developed in the field in general accordance with ASTM D2488 and following the Unified Soil Classification Format.**

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TEST BORING LOG PW-01

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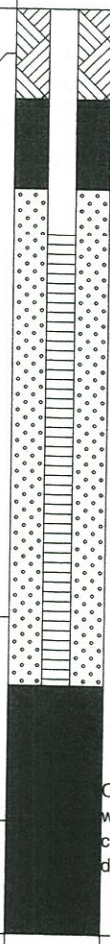
Figure 19

PROJECT:	**Little Bear Creek Advance Mitigation Site 24110-58th St SE**	BORING NO.:	**PW-02**
		DRILLER:	**WSDOT**
		DRILL TYPE:	**CME 850**
C.R.P.#:	**RC1730-115-37** DATE: **4/23/18**	AUGER TYPE:	**6" casing advancer**
LOCATION:		FLUID:	**water**
GEO./ENGR.:	**Kirk R. Bailey** ELEV.:	TOTAL DEPTH:	**20.50**

SAMPLE INTERVAL	SAMPLE #	SPT BLOWS/FT	STRATA	DEPTH	SOIL DESCRIPTION
				0	0.0 - 1.0' **Gravelly Sand to Silty Sand**; Brown, fine- to coarse-grained, loose, wet (*gps, fill).*
					1.0 - 13.5' **Sand**; Gray brown, fine- to coarse-grained, trace to little coarse-grained sand, trace gravels with depth, few thin laminations of silt, medium dense, saturated (*sp, alluvium*).
X	1	6/7/8		5	
X	2	6/5/10		10	
X	3	7/9/12		15	13.5 - 18.0' **Silt**; Blue gray, very fine- to fine-grained, trace fine-grained sand, trace organics, medium dense, damp (*ml, alluvium*).
X	4	9/14/16		20	18.0 - 20.5' **Sand**; Gray, very fine- to fine-grained, trace to little silt, medium dense, wet (*sp-sm, alluvium*).
					Total Depth = 20.5 ft bgs.

WELL DETAIL



SPT soil samples taken on 5 ft intervals. Representative soil samples were collected and sealed in glass jars for later correlation and testing.

Observation well was installed upon completion of drilling.

NOTES: **Soil samples taken in accordance with ASTM D1586-84 standards and specifications. Soil descriptions developed in the field in general accordance with ASTM D2488 and following the Unified Soil Classification Format.**

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TEST BORING LOG PW-02

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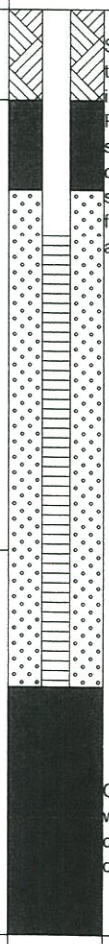
Figure 20

PROJECT:	**Little Bear Creek Advance Mitigation Site 24110-58th St SE**	BORING NO.:	**PW-03**
		DRILLER:	**WSDOT**
		DRILL TYPE:	**CME 850**
C.R.P.#:	**RC1730-115-37** DATE: **4/23/18**	AUGER TYPE:	**6" casing advancer**
LOCATION:		FLUID:	**water**
GEO./ENGR.:	**Kirk R. Bailey** ELEV.:	TOTAL DEPTH:	**20.50**

SAMPLE INTERVAL	SAMPLE #	SPT BLOWS/FT	STRATA	DEPTH	SOIL DESCRIPTION
				0	0.0 - 2.0' **Sand**; Gray brown, fine- to coarse-grained, trace to little silt, little gravels, loose, wet (*sp, fill*).
					2.0 - 12.0' **Sand**; Gray brown to gray, fine- to medium grained, trace coarse-grained sand, trace silt, trace gravel, dense, saturated (*sp, alluvium*).
X	1	1/2/9		5	
X	2	5/10/15		10	
					12.0 - 20.5' **Sand**; Gray, fine- to coarse-grained, little to some gravels, dense, saturated (*sp, alluvium*).
X	3	5/14/18		15	
X	4	16/20/21		20	
					Total Depth = 20.5 ft bgs.

WELL DETAIL



SPT soil samples taken on 5 ft intervals. Representative soil samples were collected and sealed in glass jars for later correlation and testing.

Observation well was installed upon completion of drilling.

NOTES: **Soil samples taken in accordance with ASTM D1586-84 standards and specifications. Soil descriptions developed in the field in general accordance with ASTM D2488 and following the Unified Soil Classification Format.**

Snohomish County Public Works

TEST BORING LOG PW-03

PAGE 1 OF 1

Figure 21

PROJECT:	**Little Bear Creek Advance Mitigation Site** **24110-58th St SE**	BORING NO.:	**PW-04**
		DRILLER:	**WSDOT**
		DRILL TYPE:	**CME 850**
C.R.P.#:	**RC1730-115-37** DATE: **4/24/18**	AUGER TYPE:	**6" casing advancer**
LOCATION:		FLUID:	**water**
GEO./ENGR.:	**Kirk R. Bailey** ELEV.:	TOTAL DEPTH:	**20.50**

SAMPLE INTERVAL	SAMPLE #	SPT BLOWS/FT	STRATA	DEPTH	SOIL DESCRIPTION	WELL DETAIL
					0.0 - 9.5' **Sandy Gravel**; Brown, fine- to coarse-grained, trace silt, loose, damp to wet (*gp, fill*).	
X	1	5/4/4		5		SPT soil samples taken on 5 ft intervals. Representative soil samples were collected and sealed in glass jars for later correlation and testing.
X	2	5/10/12		10	9.5 - 20.5' **Sand**; Gray green, fine- to coarse-grained, trace gravel, trace silt, locally iron stained, dense to very dense, saturated (*sp, alluvium*).	
X	3	11/20/19		15		
X	4	11/20/31		20		Observation well was installed upon completion of drilling.
					Total Depth = 20.5 ft. bgs.	

NOTES: **Soil samples taken in accordance with ASTM D1586-84 standards and specifications. Soil descriptions developed in the field in general accordance with ASTM D2488 and following the Unified Soil Classification Format.**

Snohomish County Public Works

TEST BORING LOG PW-04

PAGE 1 OF 1

Figure 22

APPENDIX F

Unified Soil Classification System

Geotechnical Report

Little Bear Creek Advance Mitigation Site

RC1730-115-37

UNIFIED SOILS CLASSIFICATION SYSTEM

MAJOR DIVISIONS			SYMBOL	LETTER	DESCRIPTION
COARSE GRAINED SOILS	GRAVEL & GRAVELLY SOILS	CLEAN GRAVELS		GW	WELL-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
				GP	POORLY GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GRAVELS W/FINES		GM	SILTY GRAVELS OR GRAVEL-SAND SILT MIXTURES.
				GC	CLAYEY GRAVELS OR GRAVEL-SAND-CLAY MIXTURES.
	SAND & SANDY SOILS	CLEAN SANDS		SW	WELL-GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES.
				SP	POORLY GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES.
		SANDS W/FINES		SM	SILTY SANDS OR SAND-SILT MIXTURES.
				SC	CLAYEY SANDS OR SAND-CLAY MIXTURES.
FINE GRAINED SOILS	SILTS AND CLAYS Liquid Limit Less Than 50			ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS, OR CLAYEY SILTS W/SLIGHT PLASTICITY.
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, OR 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 FINE SANDY OR SILTY SOILS, ELASTIC SILTS.
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS.
				OH	ORGANIC CLAYS OR MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS.
HIGHLY ORGANIC SOILS				PT	PEAT OR OTHER HIGHLY ORGANIC SOILS.

TOPSOIL	Humus and duff layer
FILL	Uncontrolled, with highly variable constituents.

SYMBOL	DATUM	NOTE	SYMBOL	DATUM	NOTE
I	2"O.D. SPLIT SPOON SAMPLER	SAMPLE INTERVAL	▽	WATER LEVEL	DATE RECORDED
II	SHELBY SAMPLE	SAMPLE INTERVAL	Ts	TORVANE READING	
*	CUTTING SAMPLE	SAMPLE INTERVAL	Vs	VANE READING	
LL	LIQUID LIMIT			WATER OBSERVATION WELL	TIP ELEVATION
PI	PLASTICITY INDEX		MC	MOISTURE CONTENT	

SNOHOMISH COUNTY
DEPARTMENT OF PUBLIC WORKS

KEY CHART

Figure 23

APPENDIX G

Fill Map

Geotechnical Report
Little Bear Creek Advance Mitigation Site

RC1730-115-37

Fill Depth Topographic Map

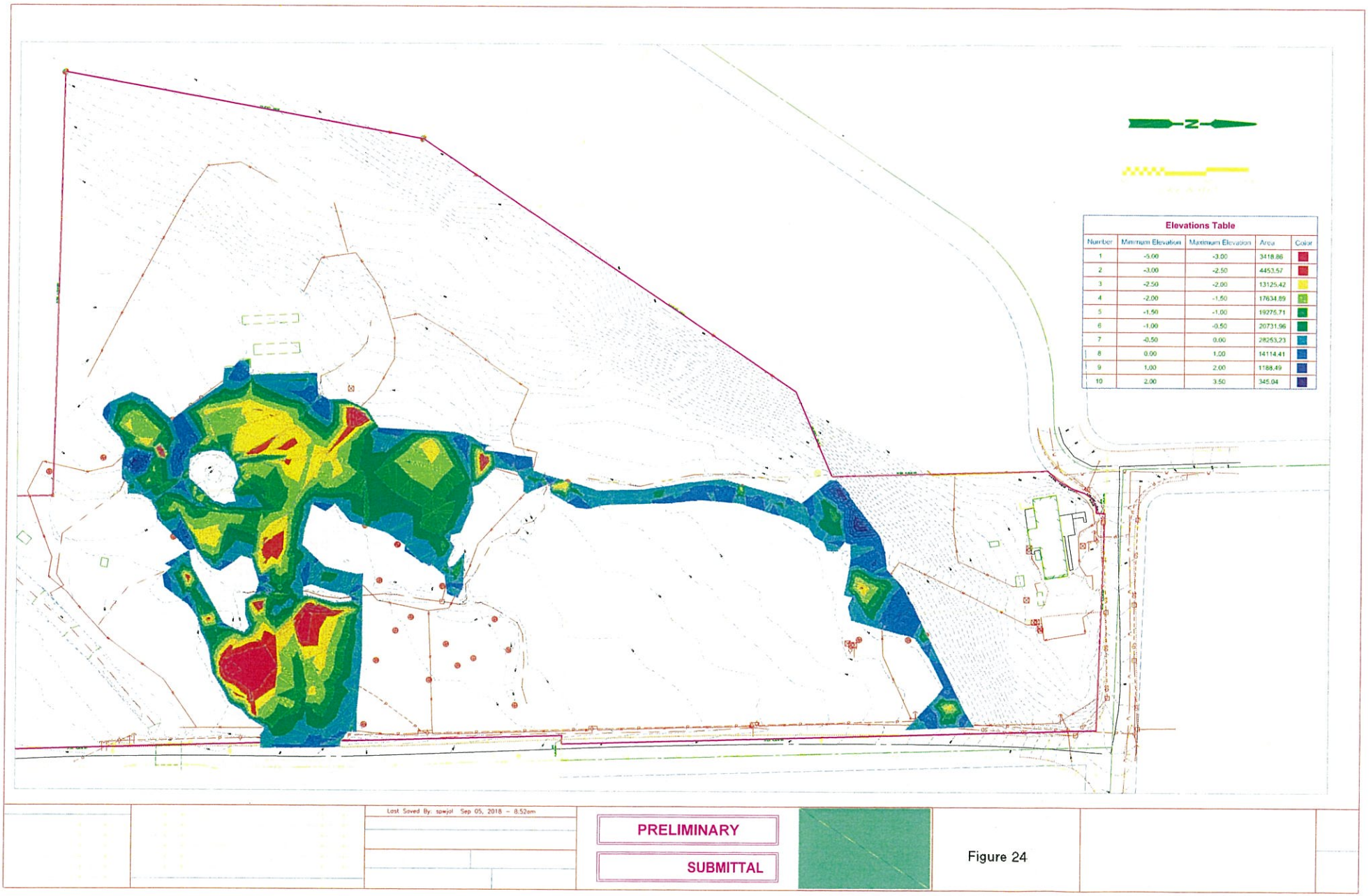


Figure 24

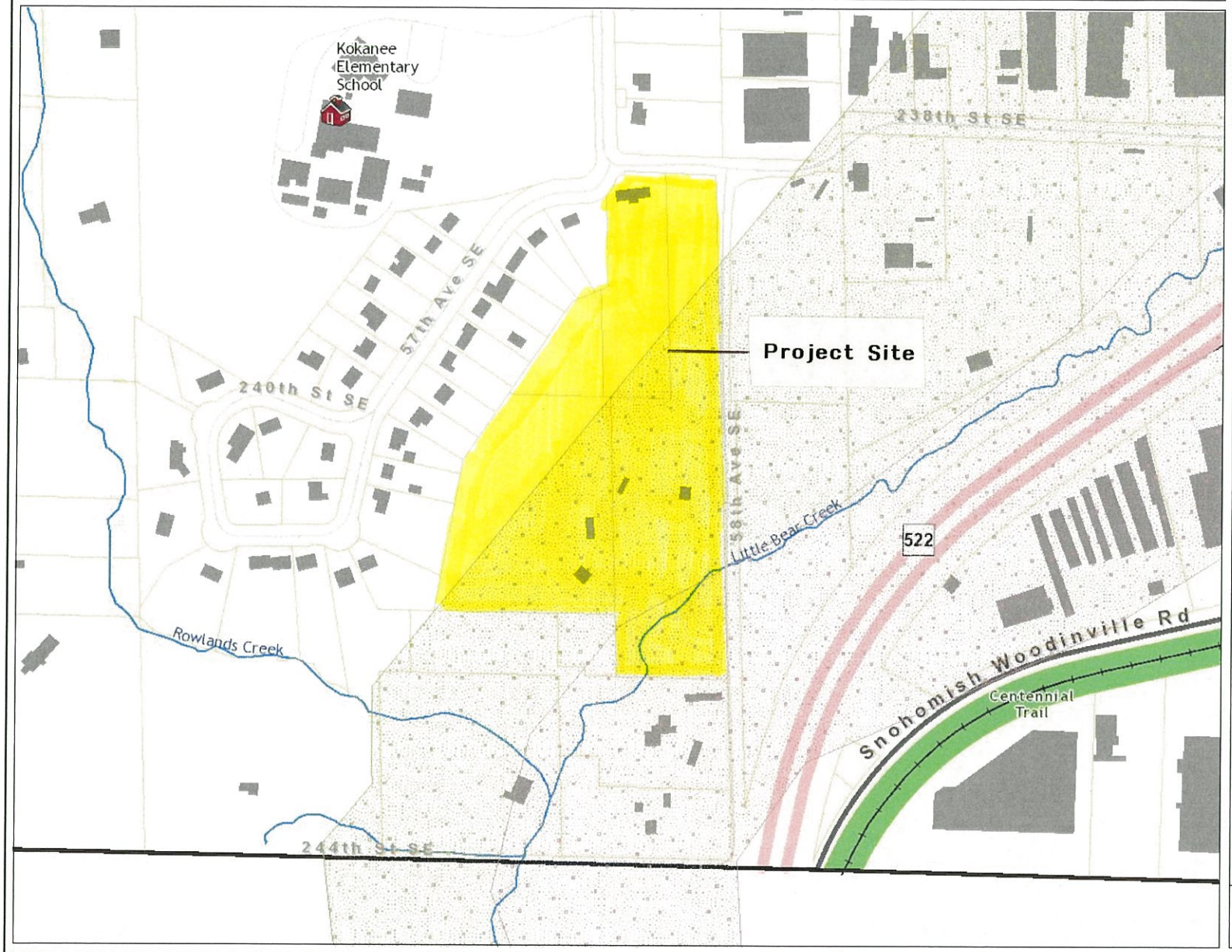
APPENDIX H

Erosion Hazard Area Map

Snohomish County, Washington
PDS MAP PORTAL

LBCAMS Erosion Hazards Map

12/3/2018



Legend

- Snohomish County Tax Parcels

Littoral Drift

- Zone of Divergence
- Left to Right
- No Appreciable Net Shore Drift
- Right to Left
- Undefined

Erodible Surficial Geology

- Alluvium
- Mass Wasting
- Vashon Recessional Outwash
- Vashon Recessional Lacustrine

Soil Erosion Hazard Areas

- ALDERWOOD-EVERETT GRAVELLY SANDY LOAMS, 25 TO 70 PERCENT SLOPES
- CATHCART LOAM, 25 TO 50 PERCENT SLOPES
- ELWELL-OLOMOUNT COMPLEX, 15 TO 30 PERCENT SLOPES
- ELWELL-OLOMOUNT-ROCK OUTCROP COMPLEX, 30 TO 60 PERCENT SLOPES
- KITSAP SILT LOAM, 25 TO 50 PERCENT SLOPES
- NARGAR-LYNNWOOD COMPLEX, 30 TO 65 PERCENT SLOPES
- OGARTY-TOKUL ROCK

1: 4,800

800.0 0 400.00 800.0 Feet

Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Planning and Development Services, Snohomish County

Notes

This map was automatically generated using Geocortex Essentials.

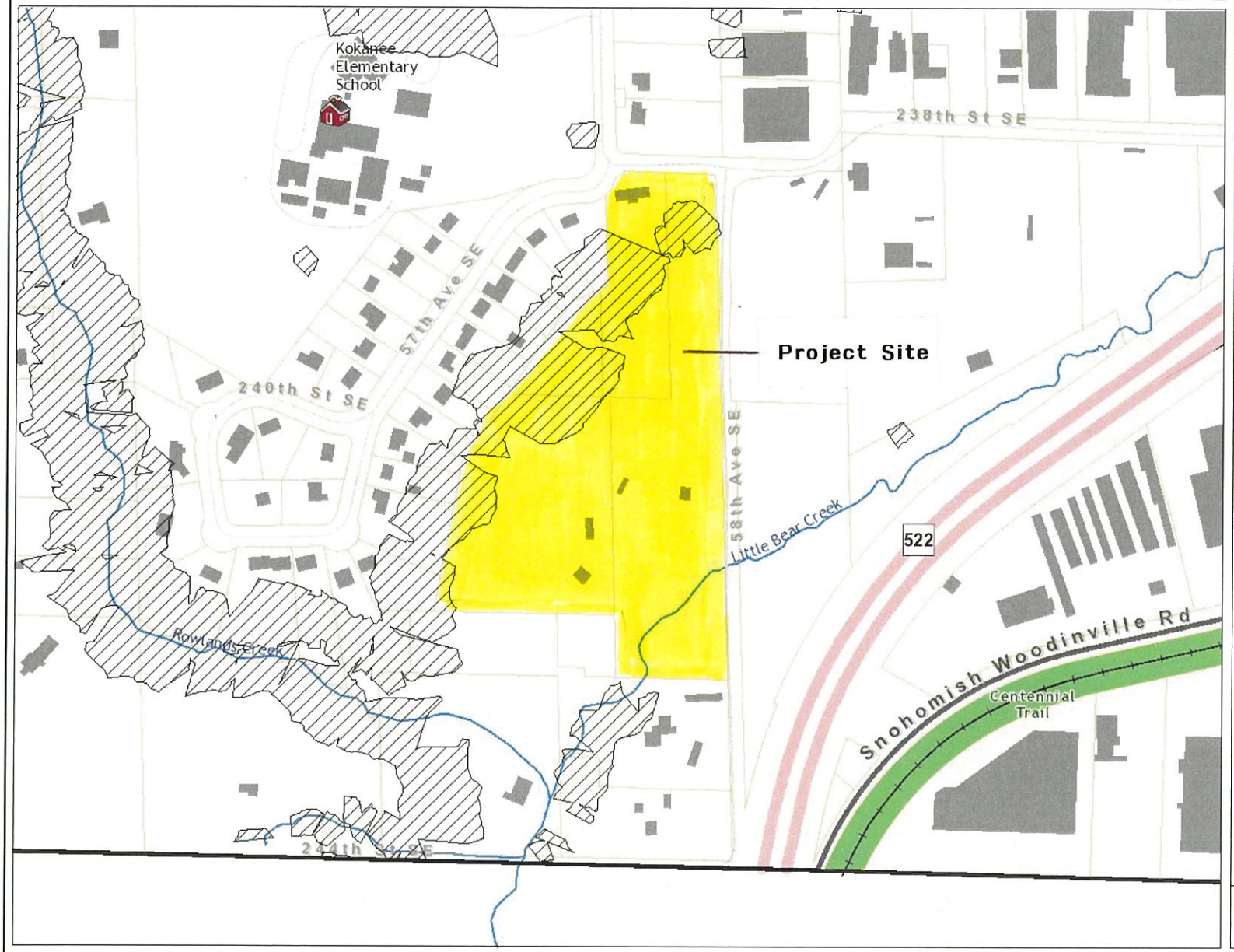
APPENDIX I

Landslide Hazard Area Map

Snohomish County, Washington
PDS MAP PORTAL

LBCAMS Landslide Hazards Map

12/3/2018



Legend

- Landslide Hazard Areas (as defined in SCC 30.91L.040)
- Snohomish County Tax Parcels

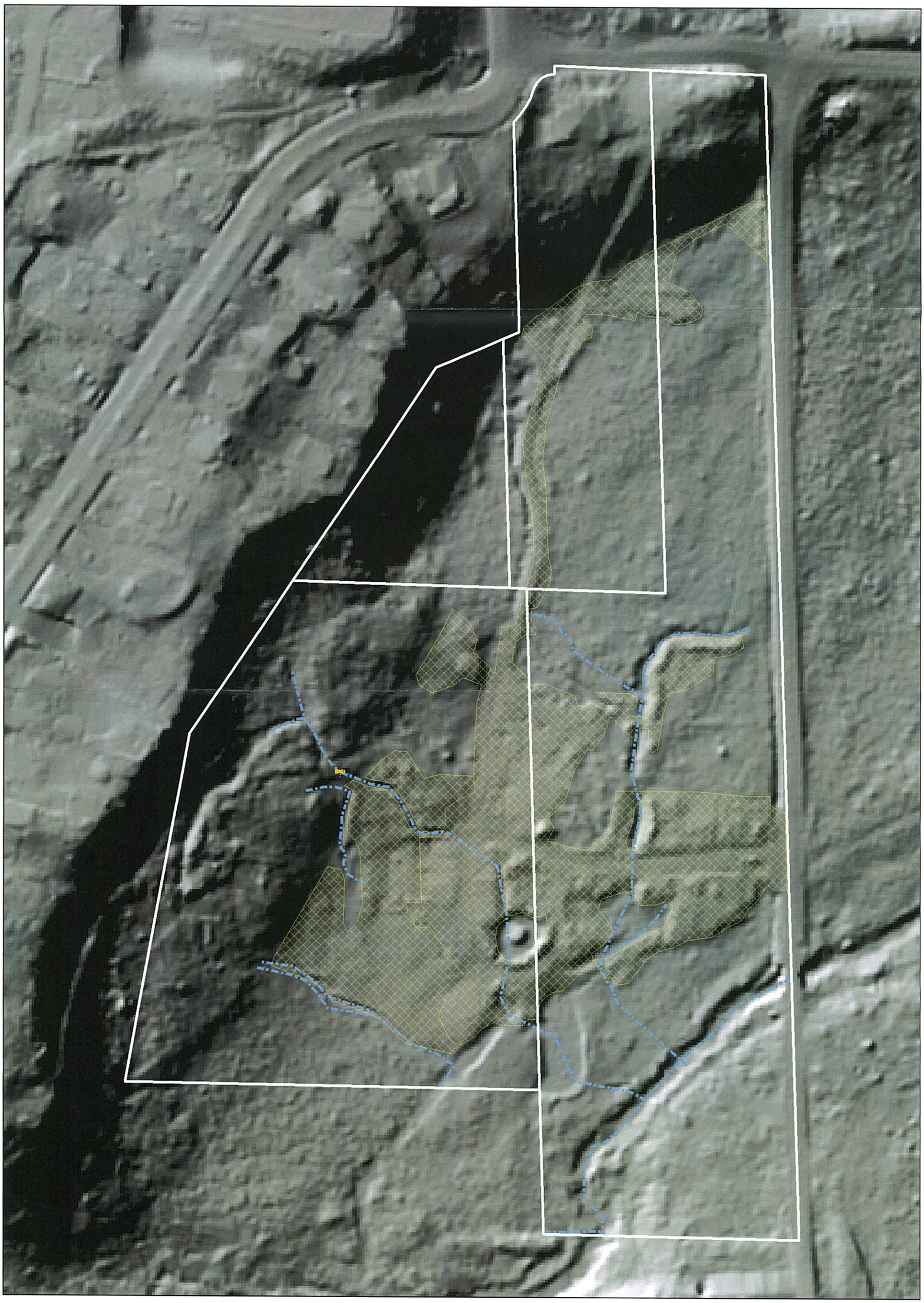
1: 4,800

800.0 0 400.00 800.0 Feet

Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Planning and Development Services, Snohomish County

Notes

This map was automatically generated using Geocortex Essentials.



LBCAM Hillshade (LiDAR)

DB 11/27/18

0 50 100 200 Feet

N

APPENDIX J

Major Fault Structures in Western Washington State Map

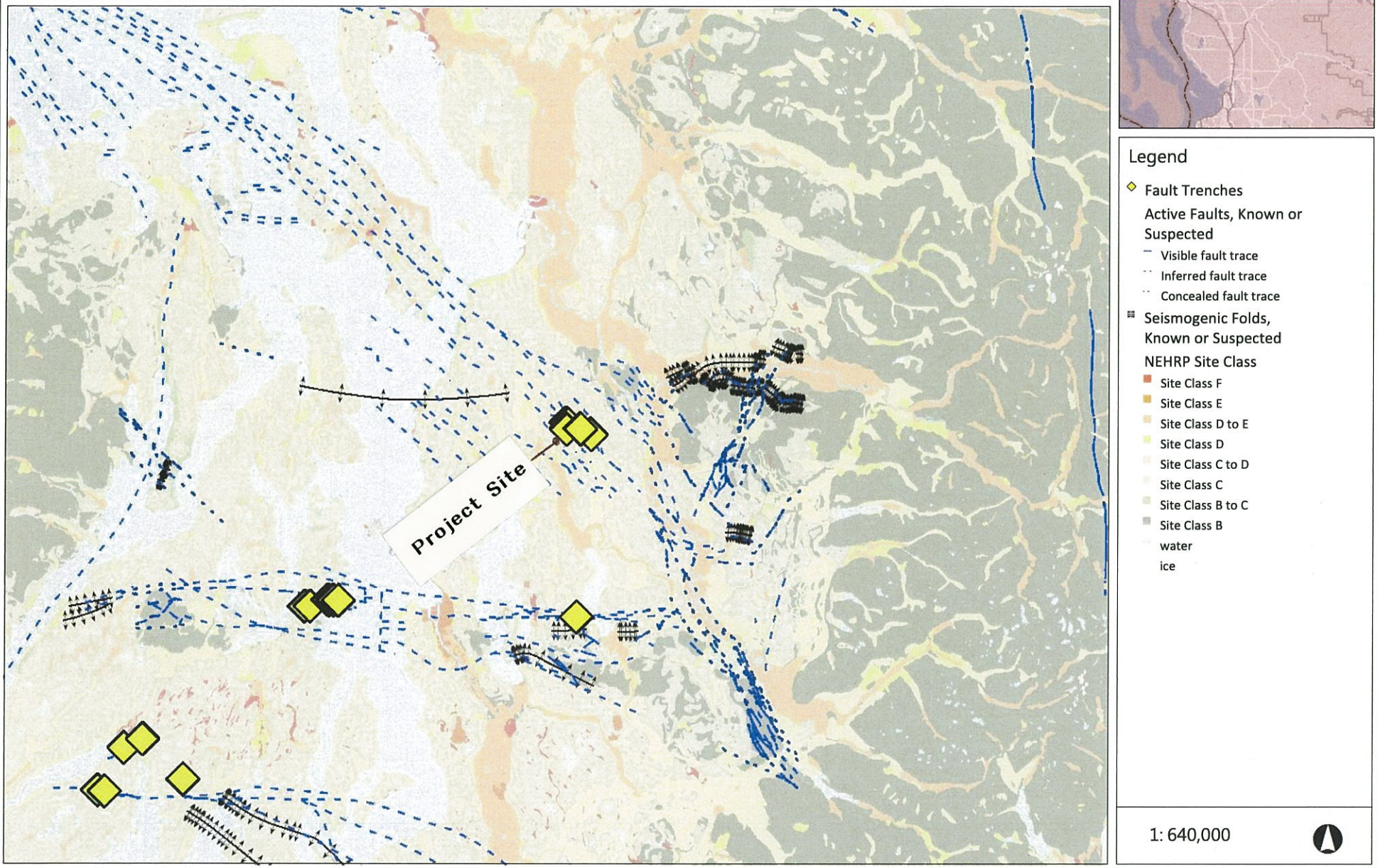
Geotechnical Report
Little Bear Creek Advance Mitigation Site

RC1730-115-37

Snohomish County, Washington
PDS MAP PORTAL

Major Fault Structures

12/3/2018



Legend

- Fault Trenches
- Active Faults, Known or Suspected
  - Visible fault trace
  - Inferred fault trace
  - Concealed fault trace
- Seismogenic Folds, Known or Suspected
- NEHRP Site Class
  - Site Class F
  - Site Class E
  - Site Class D to E
  - Site Class D
  - Site Class C to D
  - Site Class C
  - Site Class B to C
  - Site Class B
  - water
  - ice

1: 640,000

106,666.7 0 53,333.33 106,666.7 Feet

Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Planning and Development Services, Snohomish County

Notes

North Western Washington

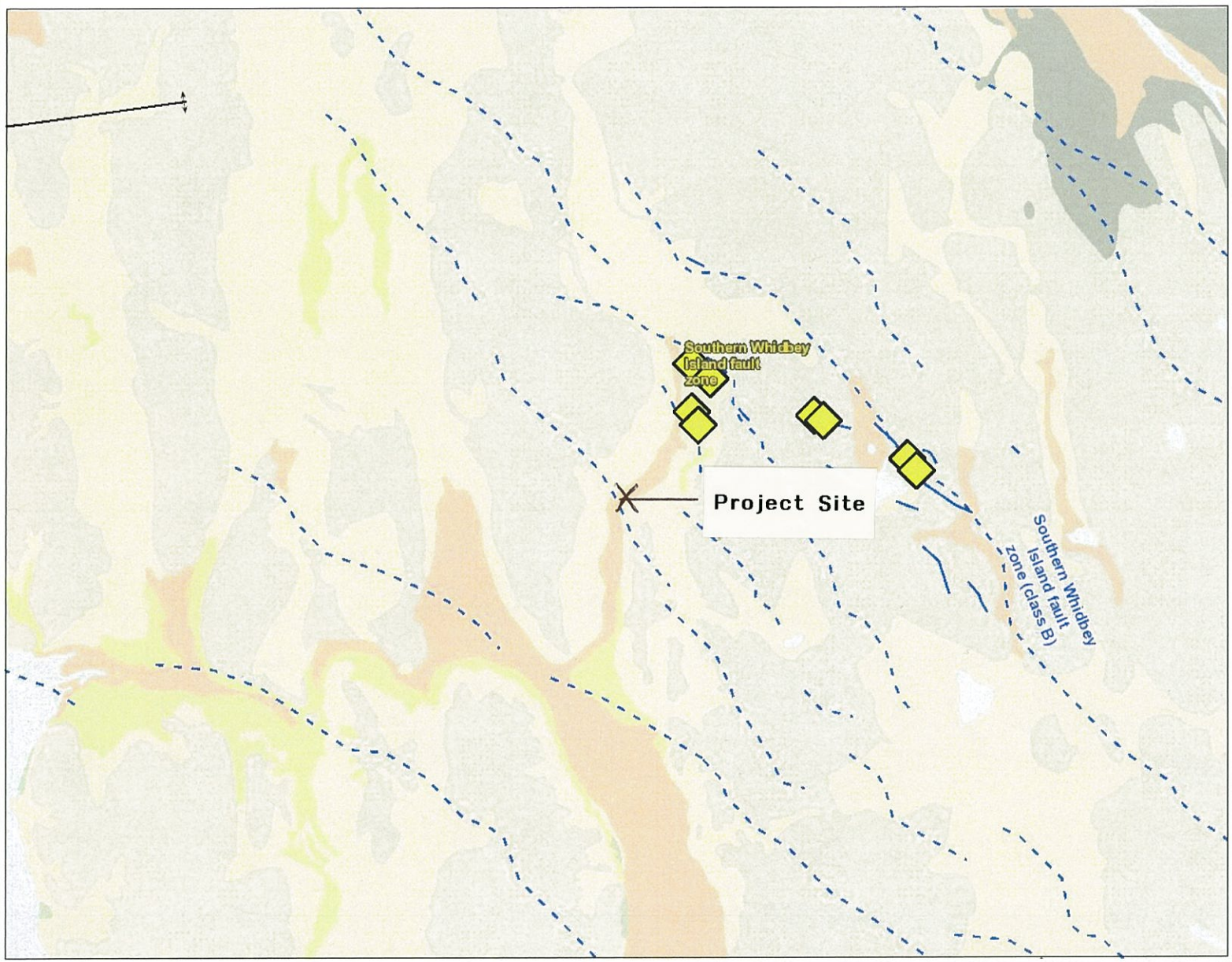
APPENDIX K

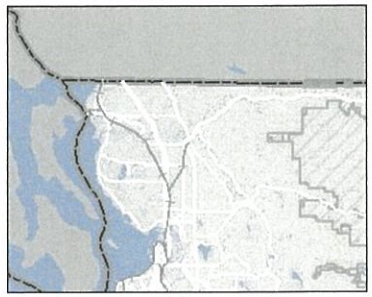
SWIFZ Splay Map

Snohomish County, Washington
PDS MAP PORTAL

SWIFZ Splay Map

12/3/2018





Legend

- Fault Trenches
- Active Faults, Known or Suspected
  - Visible fault trace
  - Inferred fault trace
  - Concealed fault trace
- Seismogenic Folds, Known or Suspected
- NEHRP Site Class
  - Site Class F
  - Site Class E
  - Site Class D to E
  - Site Class D
  - Site Class C to D
  - Site Class C
  - Site Class B to C
  - Site Class B
  - water
  - ice

1: 80,000

13,333.3 0 6,666.67 13,333.3 Feet

Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Planning and Development Services, Snohomish County

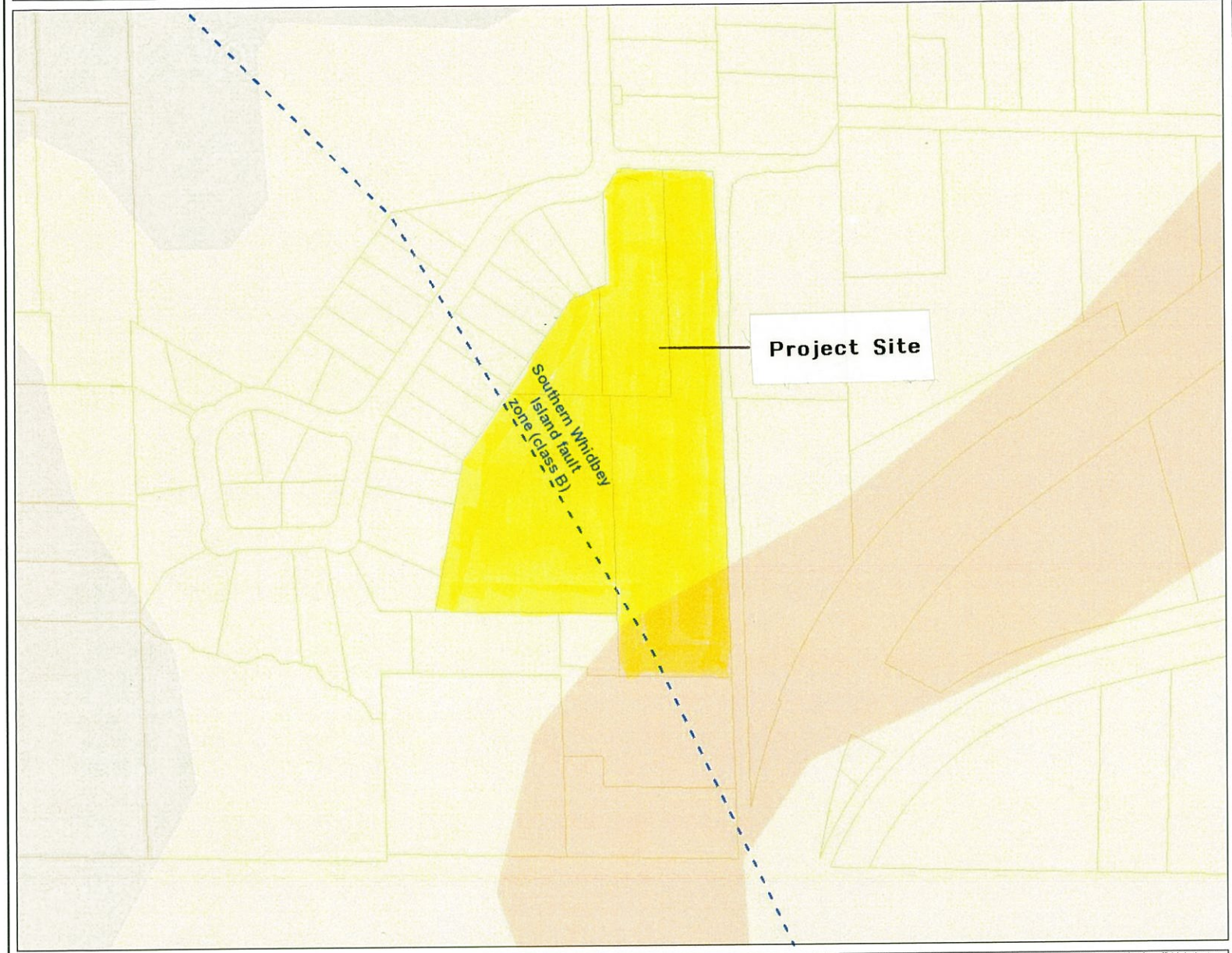
Notes

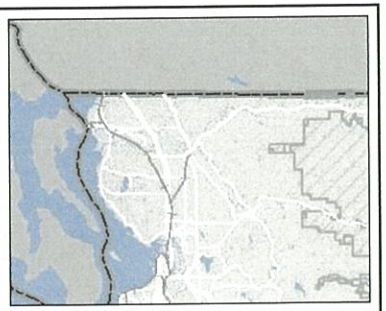
This map was automatically generated using Geocortex Essentials.

Snohomish County, Washington
PDS MAP PORTAL

LBCAMS Seismic Hazards Map

12/3/2018





Legend

- Snohomish County Tax Parcels
- Fault Trenches
- Active Faults, Known or Suspected
  - Visible fault trace
  - Inferred fault trace
  - Concealed fault trace
- Seismogenic Folds, Known or Suspected
- NEHRP Site Class
  - Site Class F
  - Site Class E
  - Site Class D to E
  - Site Class D
  - Site Class C to D
  - Site Class C
  - Site Class B to C
  - Site Class B
  - water
  - ice

1: 4,800

800.0 0 400.00 800.0 Feet

Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Planning and Development Services, Snohomish County

Notes

This map was automatically generated using Geocortex Essentials.